RIVERS POLLUTION COMMISSION (1868).

SIXTH REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1868 TO INQUIRE INTO

THE BEST MEANS OF PREVENTING THE POLLUTION OF RIVERS.

DOMESTIC WATER SUPPLY OF GREAT BRITAIN.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1874.

[C.—1112.] *Price 16s.*

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CONTENTS.

COMMISSION (ENGLAND).

VICTORIA R.

VICTORIA, by the Grace of God of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith,—

To Our trusty and well-beloved Sir William Thomas Denison, Knight Commander of Our most Honourable Order of the Bath, Colonel in Our Corps of Royal Engineers; Our trusty and well-beloved Edward Frankland, Esquire; and Our trusty and well-beloved John Chalmers Morton, Esquire, Greeting.

Whereas We did by Warrant under Our Royal Sign Manual, bearing date the Eighteenth day of May, One thousand eight hundred and sixty-five, appoint Our trusty and well-beloved Robert Rawlinson, Esquire, John Thornhill Harrison, Esquire, and John Thomas Way, Esquire, to be our Commissioners for the purposes herein-after mentioned, which Warrant We were pleased to revoke and determine on the Fourteenth day of February last: and

Whereas We have deemed it expedient for divers good causes and considerations that a new Commission should forthwith issue for the purpose of inquiring how far the present use of rivers or running waters in England for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented without risk to the public health, or serious injury to such processes and manufactures, and how far such sewage and refuse can be utilized and got rid of otherwise than by discharge into rivers or running waters, or rendered harmless before reaching them; and also for the purpose of inquiring into the effect on the drainage of lands and inhabited places of obstructions to the natural flow of rivers or streams caused by mills, weirs, locks, and other navigation works, and into the best means of remedying any evils thence arising:

Now Know ye, that We, reposing great confidence in your zeal and ability, have authorised and appointed, and do by these Presents authorise and appoint you, the said Sir William Thomas Denison, Edward Frankland, and John Chalmers Morton, to be Our Commissioners for the purposes aforesaid.

And for the better enabling you to form a sound judgment on the premises, We do hereby authorise and empower you, or any two or more of you, to call before you, or any two or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, and experience, to afford you correct information on the subject of this Inquiry.

And it is Our further Will and Pleasure that you, or any two or more of you, do Report to us in writing, under your hands and seals, your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We Will and Command that this Our Commission shall continue in full force and virtue, and that you, Our Commissioners, or any two or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the due execution of this Our Commission, We do hereby authorise and empower you to appoint a Secretary to this Our Commission, whose services and assistance We require you to use, from time to time, as occasion may require.

Given at Our Court at St. James's the Sixth day of April 1868.

By Her Majesty's Command.

(Signed) GATHORNE HARDY.

Instructions to the Commissioners.

Rivers Pollution Commission,
2, Victoria Street, Westminster, S.W.
28th April 1868.

Sir,

I am directed by Her Majesty's Commissioners for inquiring into the Pollution of Rivers to state, for the information of Mr. Secretary Hardy, that they held their first meeting on Tuesday, 20th instant, and after consultation, assuming that the instructions issued to the late Commissioners are to be taken as instructions to the present Commissioners, it appeared desirable to take up the inquiry entrusted to them to investigate at the point where the former Commission left off, and they therefore propose (subject to the approval of Mr. Secretary Hardy) to commence with an investigation and inquiry into the condition of the basins of the rivers Mersey and Ribble.

I have, &c.
(Signed) S. J. Smith,
Secretary.

The Hon. A. F. O. Liddell, Q.C.,
&c., &c., &c.,
Home Office.

Sir,

Whitehall, 29th April 1868.

I am drected by Mr. Secretary Hardy to acknowledge the receipt of your letter of the 28th instant, and to acquaint you, for the information of the Commissioners appointed to inquire into the Pollution of Rivers, that he approves of their acting upon the instructions issued to their predecessors, and of their proceeding with the inquiry at the point where the former Commission left off, as proposed by the Commissioners.

I am, &c.
(Signed) A. F. O. Liddell.

S. J. Smith, Esq., Secretary,
Rivers Pollution Commission,
2, Victoria Street, Westminster, S.W.

INSTRUCTIONS to the COMMISSIONERS.

GENTLEMEN, Whitehall, 30th May 1865.

HER Majesty having been pleased to appoint you to be Commissioners for Inquiry into the Pollution of Rivers, I am directed by Secretary Sir George Grey to send you the following instructions for your guidance in the proposed inquiry.

Although it may be taken as proved generally that there is a wide spread and serious pollution of rivers, both from town sewage and the refuse of mines and manufactories, and that town sewage may be turned to profitable account as a manure, there is not sufficient evidence to show that any measure absolutely prohibiting the discharge of such refuse into rivers, or absolutely compelling town authorities to carry it on the lands, might not be remedying one evil at the cost of an evil still more serious, in the shape of injury to health and damage to manufacturers. It is, therefore, suggested that your inquiry should include selected river basins, illustrating different classes of employment and population; that these river basins might be:—

1st. The Thames Valley—both as an example of an agricultural river basin, with many navigation works, such as locks, and weirs, and mills affecting the flow of water, and many towns and some manufactories discharging their sewage and refuse into the stream from which is mainly derived the water supply of the metropolis.

2nd. The Mersey Valley—including its feeders, particularly the Irwell, as an example of the river basin most extensively polluted by all forms of manufacturing refuse, particularly that arising from the cotton manufacture and processes connected therewith.

3rd. The Aire and Calder Basin, as an additional example of the same class, more particularly in connexion with the woollen and iron manufactories.

4th. The Severn Basin, for the same reason, but in particular connexion with the great seats of the iron trade.

5th. The Taff Valley in connexion with mining and industry applied to metals.

6th. A river basin comprising a mining district in Cornwall.

Your special points of inquiry should, it is conceived, be in the Thames Valley, 1. The condition of the river as affected by mills, weirs, and locks, and as affecting the drainage of towns, villages, and adjacent lands; 2. The condition of the river, as affected by the discharge of sewage from towns and villages, and the refuse of manufactories, paper mills, &c., and the possibility of intercepting and rendering useful or innocuous these sources of pollution.

As to the other rivers mentioned, the main object of the inquiry should be how far the use or abuse of the rivers is, under present circumstances, essential to the carrying on the industry of these districts. How far by new arrangements the refuse arising from industrial processes in these districts can be kept out of the streams, or rendered harmless before it reaches them, or utilized or got rid of otherwise than by discharge into running waters. In the course of these investigations you will make inquiry into the effect on health and comfort of the existing system of sewage of towns and populous places in the districts examined, and into the best mode of protecting individual and public interests in the purity of running water.

Secondary questions will, no doubt, arise contingent on these leading points, in which case you will of course include them, so far as it is necessary, within the scope of your inquiry.

I am, &c.
(Signed) H. WADDINGTON.

The Commissioners appointed to inquire
into the Pollution of Rivers,
2, Victoria Street, Westminster, S.W.

INSTRUCTIONS to the COMMISSIONERS.

GENTLEMEN,   Whitehall, 7th July 1865.

I AM directed by Secretary Sir George Grey to transmit to you an extract of a letter from Mr. Charles Neate, and to state that it will be desirable to include in your inquiry into the pollution of rivers, the subject of the water supply suggested by Mr. Neate, provided such extension of your inquiry will not materially impede or delay the completion of the primary object of the Commission.

I am, &c.
(Signed) H. WADDINGTON.

The Commissioners appointed to inquire into the Pollution of Rivers,
2, Victoria Street, Westminster, S.W.

LETTER from CHARLES NEATE. Esq., M.P., to the Right Honourable Sir GEORGE GREY, Bart., G.C.B., M.P.

DEAR SIR,   House of Commons, 27th June 1865.

I BEG leave to submit to you, with reference to the Commission recently issued to inquire into the means of remedying the pollution of rivers, that as the scope of that Commission has already been enlarged beyond its original and professed object, so as to include an inquiry into the drainage of lands and inhabited places, it would be right to extend the inquiry still further as to include the great question of the water supply.

Even if the drainage referred to in the Commission is that only which is required for sanitary purposes, it may still be a question whether you might not subject the health of the country to far greater danger by wasting too rapidly the winter supply of water than it now is liable to from the temporary dampness of the soil in certain places.

The effect of drainage, even to the extent it has been already carried out for agricultural purposes, is a subject of serious alarm to many people, and I think it is matter of pressing interest to inquire how far the general level of springs in the country has been lowered, how far it depends upon the height at which the water is maintained in the neighbouring river, and what is the number of springs that have altogether failed, or at least that fail during the summer.

I believe it to be a matter of urgent necessity to provide reservoirs of water throughout the country, to be used for all purposes but drinking, and that the spring water should be habitually confined to that use.

If the Commission as it stands, is intended to apply to agricultural drainage, the reasons for extending the inquiry are more, still more cogent, for then it is no longer a conflict between one sanitary purpose and another, but between the health of the country and some increase in the productiveness of the soil.

I remain, &c.
(Signed) CHARLES NEATE.

The Right Honourable Sir George Grey,
Bart., G.C.B., M.P., &c., &c., &c.

P.S.—I think it would be a great point to inquire whether all the surface drainage of towns might not conveniently be kept out of the sewers and taken into the rivers.

COMMISSION (SCOTLAND).

VICTORIA, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith,—

To Our trusty and well-beloved Sir William Thomas Denison, Knight Commander of Our Most Honourable Order of the Bath, Major-General in Our Army; Our trusty and well-beloved Edward Frankland, Esquire; and Our trusty and well-beloved John Chalmers Morton, Esquire, Greeting:

Whereas We did by Warrant under Our Royal Sign Manual bearing date the sixth day of April, One thousand eight hundred and sixty-eight, appoint you Our Commissioners for the purpose of inquiring how far the present use of rivers or running waters in England for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented without risk to the public health, or serious injury to such processes and manufactures; and into the several other matters and things in such Warrant at large set forth;

And whereas We have deemed it expedient that such inquiry should be extended, and that you Our said Commissioners should be authorised to visit the River Tweed and its tributaries, and the River Clyde and its affluents, in that part of Our United Kingdom called Scotland, and also to visit such other rivers or parts of rivers in that part of Our said United Kingdom as We may from time to time be pleased to direct, by signifying Our Pleasure, under the hand of one of Our Principal Secretaries of State.

Now Know ye, that We, reposing great confidence in your zeal and ability, have authorised and appointed, and do by these Presents authorise and appoint you, the said Sir William Thomas Denison, Edward Frankland, and John Chalmers Morton, to be Our Commissioners to visit the River Tweed and its tributaries, and the River Clyde and its affluents, in that part of Our said United Kingdom called Scotland, and also to visit such other rivers or parts of rivers in that part of Our said United Kingdom as We may from time to time be pleased to direct, by signifying Our Pleasure, under the hand of one of Our Principal Secretaries of State;

And to inquire how far the present use of such rivers or running waters in Scotland for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, can be prevented without risk to the public health, or serious injury to such processes and manufactures, and how far such sewage and refuse can be utilized or got rid of otherwise than by discharge into rivers or running waters, or rendered harmless before reaching them; and also to inquire into the effect on the drainage of lands and inhabited places of obstructions to the natural flow of rivers or streams caused by mills, weirs, locks, and other navigation works, and into the best means of remedying any evils thence arising.

And for the better enabling you to form a sound judgment on the premises, We do hereby authorise and empower you, or any two or more of you, to call before you, or any two or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, and experience, to afford you correct information on the subject of this inquiry.

And it is Our further Will and Pleasure that you, or any two or more of you, do Report to us in writing, under your hands and seals, your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We Will and Command that this Our Commission shall continue in full force and virtue, and that you, Our Commissioners, or any two or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the due execution of this Our Commission, We do hereby authorise and empower you to appoint a Secretary to this Our Commission, whose services and assistance We require you to use as occasion may require.

In witness whereof We have ordered the Seal appointed by the Treaty of Union to be kept and made use of, in place of the Great Seal of Scotland, to be appended hereto.

Given at Our Court at Saint James's, the twenty-second day of November, in the year One thousand eight hundred and sixty-nine, and in the Thirty-third year of Our Reign.

Per Signaturam manu S. D. N. Reginæ supra scrip.
Written to the Seal and registered the third day of December 1869.

(Signed) JOHN M. LINDSAY,
Director of Chancery.

Sealed at Edinburgh, the third day of December, in the year One thousand eight hundred and sixty-nine.

(Signed) JOHN H. DUNN,
Substitute Keeper of the Seal.
80*l.* Scots.

Additional Instructions to the Commissioners.

Rivers Pollution Commission,
1, Park Prospect, Westminster, S.W.
1st March 1870.

Sir,

The First Report of the Rivers Pollution Commission (1868), on the Mersey and Ribble Basins, having been presented, I am directed by the Commissioners to state, for the information of Mr. Secretary Bruce, that they propose to investigate the condition of the rivers and streams in the valleys of the Lower Avon and Frome, the seat of the West of England Woollen Trade, to enable them to complete their Report on the Basins of the Aire and Calder, "most extensively polluted by the Woollen Manufacture and processes "connected therewith," a large amount of evidence on which has already been collected.

The Commissioners have on several occasions suggested an extension of the instructions issued for their guidance, and in the present instance they are of opinion that the Report upon the Pollution caused by the Woollen Manufacture in the Aire and Calder Basins will not be complete and satisfactory without an inquiry is made into the state of the streams in the West of England, and I am directed to submit that a modification should be made in that clause of the instruction which states "that the inquiry should "include selected River Basins illustrating different classes of employment and population," and that for the future the Commissioners should be directed to inquire into the specific pollution caused by any particular manufacture wherever located in England or Scotland.

The Commissioners are of opinion that their Reports will then be more generally useful; they will cease to have such a local designation as might lead to the supposition that their recommendations were intended to apply to a particular locality—and they will be free from a great deal of extraneous description which has but little to do with the subject of their inquiry.

The Commissioners also propose as soon as the second Report (Woollen Manufacture) is presented to take up that branch of the inquiry relating to pollution by the iron trade. This investigation will spread over a large area; for it by no means follows that the nuisance caused by a certain process in one locality is identical in character with that originating from an analogous process carried on in another place.

I am, &c.
(Signed) S. J. Smith,
Secretary.

The Under Secretary of State,
&c., &c., &c.,
Home Office.

Local Government Act Office,
8, Richmond Terrace, Whitehall, S.W.
8th March 1870.

Sir,

With reference to your letter of the 1st instant, I am directed by the Secretary of State for the Home Department to inform you, by way of supplement to the instructions already issued for the guidance of the Commissioners appointed to inquire into the pollutions of rivers, that the Commissioners are to consider themselves instructed to inquire into the specific pollution caused by any particular manufacture wherever located in England or Scotland.

I am, &c.
(Signed) T. Taylor.

S. J. Smith, Esq., Secretary,
Rivers Pollution Commission,
1, Park Prospect, Westminster, S.W.

SIXTH REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY.

INTRODUCTION.

WE, your Majesty's Commissioners appointed in 1868 to institute inquiries into the condition of polluted rivers in England and Scotland, and into the best means of remedying any evils arising out of the use or abuse of the waters passing down their channels, have also been directed to include in our inquiry the great question of the water supply of the country.

This branch of our work naturally falls into two divisions, viz., first, the water supply for manufacturing purposes; and, secondly, the water supply for domestic purposes. With regard to the first of these divisions, we have already given, in our previous reports, and especially in our first report (*Mersey* and *Ribble* basins, Vol. I., p. 104), the results of our investigations, but we have reserved for this special report the complete discussion of the second division of this subject, after having directed a large measure of our attention to it during the whole course of our inquiries into the waters of Great Britain, extending over a period of more than six years. During this long series of local investigations we have inspected the wells, springs, streams, and gathering grounds from which a large number of Corporations, Local Boards, and private Companies derive their water; in most instances we have personally examined the storage and service reservoirs, and in almost all cases we have collected and analysed samples of the water from the street mains, so as to ascertain the quality of the supply actually being delivered at the time to consumers. We have also analysed numerous specimens of spring, lake, and well waters, supplied to communities for domestic purposes; but we did not hesitate to include other samples of a typical character, even if not so employed,—such as the waters of the Cumberland, Westmoreland, and Lancashire lakes, the springs issuing from important geological formations, as the Chalk, Greensand, Carboniferous Limestone, Millstone Grit, Oolites, and Granite,—whenever the chemical examination of such samples promised to throw important light upon the effect on water, of storage in large lakes, or of percolation through particular strata.

An investigation as exhaustive as possible of this subject appeared to us of the greater importance, firstly, because the volume of water soiled by manufacturing refuse and sewage is every year becoming greater; and, secondly, because amongst the numerous processes for cleansing polluted water, with which we have become acquainted, there is not one which is sufficiently effective to warrant the use, for drinking, of water which has once been contaminated with sewage or other similar noxious animal matters. The observations and experiments described in our first report (*Mersey* and *Ribble* basins, Vol. I., p. 18) prove conclusively, that the so-called self-purifying power of streams contaminated with sewage is altogether untrustworthy, and indeed practically inoperative, the process being one of such extreme slowness that no river, in this country at least, is long enough to secure even an approach to such a purification as would render the use of the water as a beverage reasonably free from danger.

We have also devoted careful attention to the present water supply of the metropolis, and to the possibility of improving its quality. We have visited and inspected the works of the eight private companies who daily distribute upwards of 100,000,000 of gallons of water to the inhabitants of London; there never having been any previous inspection of these works by a Royal Commission. We have submitted to analysis numerous samples of this water, taken both at the works of the companies and from their distributing mains, and we have also chemically examined very numerous samples of water collected from various localities within the *Thames* basin, with the object of ascertaining how far water, better suited to the wants of the metropolis, could be substituted for the objectionable portion of the present supply.

INTRODUCTION.

These inspections and inquiries have been supplemented by the analysis of a larger number of samples of rain water, collected, for the most part, at considerable distances from towns, with the object of ascertaining how far water, which has undergone the natural process of distillation, becomes contaminated before it reaches the surface of the earth as rain.

The operations of agriculture tend more or less to contaminate water; and as the rapid progress of land drainage in this country is thus continually furnishing increasing volumes of water which has passed through cultivated or manured soil, it has become a matter of importance to ascertain whether such water is sufficiently pure to be available for the domestic supply of agricultural districts. We have therefore submitted to analytical investigation numerous samples of water collected from the outfall drains of cultivated and pasture land both unmanured and dressed with various descriptions of manure.

Lastly, we have extended our analyses to sea water, in illustration of the ultimate disposal of the impurities which the various forms of land water carry with them to the ocean.

Water has thus been followed through the complete cycle of its migrations; it has been caught as it descended from the clouds soon after its condensation from colourless and invisible vapour, collected as it flowed in streams after washing the surfaces upon which it fell, examined after it had penetrated to various depths through different geological strata, and finally it has been investigated after it had become part of the great mass of the ocean.

This, our sixth and final report, which we have now the honour humbly to present to Your Majesty, is arranged under four heads. The first part explains the mode of investigation which we have followed in the chemical examination of the various samples of water, and the meaning of the terms used in the analytical tables. The second part relates to the classification and chemical composition of drinking water. The third part discusses several considerations of special importance in connexion with the wholesomeness of certain kinds of water. The fourth part describes the condition of the water supplies to the metropolis, to a large number of cities, towns, villages, and rural districts of Great Britain, and to the residences of Your Majesty and of His Royal Highness the Prince of Wales.

PART I.

The Chemical Examination of Potable Waters.

PART I. CHEMICAL EXAMINATION.

Gas contents of water.

The *exhaustive* chemical examination of a sample of water is one of the most tedious and troublesome operations known to chemists. It requires weeks, sometimes even months, for its completion. This arises partly from the great multiplicity of separate substances which may be present in the water, both in solution and in suspension, partly from the very minute proportion in which these substances sometimes exist, and partly on account of the difficulties attending their exact determination when they are diffused through vast volumes of water. Such an exhaustive examination includes:—

1. The extraction and separate volumetric measurement of the dissolved gases.
2. The separate determination of the weight of each constituent of the saline matters in solution.
3. The determination of the two chief elements of the organic matters in solution.
4. The separation of the suspended matters, if any, and the determination of their total weight when dry.
5. The separation and determination of each mineral constituent of the suspended matters.
6. The separation and determination, as far as possible, of each organic constituent of the suspended matters.

Fortunately, many of the more tedious and laborious of these operations may be omitted, if the object of the analysis be only to ascertain the suitability or otherwise of the water for domestic or manufacturing purposes. Thus, the extraction and volumetric measurement of the gases may be safely dispensed with; since, in the present state of our knowledge, the gaseous constituents of water throw but little light upon its character. The existence of dissolved atmospheric gases in water doubtless adds to its palatability: recently boiled water, for instance, has a notoriously flat and vapid taste, but the solution of these gases by water is so rapid as almost to preclude the possibility of lack of aëration in natural waters. This is seen from the following comparison of the proportional volumes of atmospheric gases expelled on boiling 100 cubic inches of rain-water, Cumberland upland surface water, Loch Katrine water as delivered in Glasgow, *Thames* water as delivered in London, and water drawn from deep wells in the Chalk, respectively:—

VOLUME AND COMPOSITION OF THE GASES EVOLVED ON BOILING 100 CUBIC INCHES OF VARIOUS WATERS.

——	Rain Water.	Cumberland Mountain Water.	Loch Katrine Water.	Thames Water.	Deep Chalk-well Water.
	cubic inches.	cubic inches.	cubic inches.	cubic inches.	cubic inches.
Nitrogen - - - -	1·308	1·424	1·731	1·325	1·944
Oxygen - - - - -	·637	·726	·704	·588	·028
Carbonic acid - - - -	·128	·281	·113	4·021	5·520
	2·073	2·431	2·548	5·934	7·492

A comparison of the numbers in the foregoing table shows that the total volume of dissolved atmospheric gases differs but little, even in waters from the most widely different sources. It was at one time supposed that the proportion of oxygen in these gases was an important item in the history of the water, and it was believed to indicate, if small, the presence of putrescent organic matters; but the subsequent discovery that deep well waters (in which putrescent organic matter is certainly not present) contained little or no dissolved oxygen, deprived this analytical fact of much of its importance. The large proportion of carbonic acid which is present in *Thames* water and in deep chalk well water scarcely adds to the effective aëration of these waters, because nearly the whole of this carbonic acid is in chemical combination with lime, and not in the condition of dissolved gas.

The separate determination of the weight of each constituent of the saline matters in solution is also rarely required. These constituents have, with very few exceptions, no appreciable influence upon the wholesomeness of the water; hence, in the great majority

PART I. CHEMICAL EXAMINATION.

Various contents of water.

of cases, it is not necessary to determine the weight of each. Certain of them, however, —ammonia, nitrates, nitrites, and chlorides—are very useful in tracing the previous history of the water, and the separate determination of these must, therefore, on no account be omitted. Moreover, if the presence of lead, arsenic, or barium be suspected, these poisonous metals must be carefully sought for, and, if found, their respective quantities determined. The degree of hardness ought also to be ascertained in all cases.

The separation and determination of each mineral constituent of the suspended matters may be dispensed with, unless poisonous substances occur amongst them.

The separate determination of each organic constituent of the suspended matters is of comparatively little use in the present state of our knowledge, because it is impossible to distinguish, amongst the suspended matters in water, those which are injurious from those which are harmless. The really injurious organic suspended matters are probably not merely organic but organised matters—entozoic ova, or zymotic germs capable of reproduction in the human body with the simultaneous development of disease. Investigations of this class belong rather to microscopical than to chemical analysis, but even microscopic research is not yet competent to reveal any facts of direct importance in connexion with such organised suspended matters. The microscope has never yet discovered, even in the most polluted drinking water, any germ or organism which is known to be deleterious to human health: but, by showing the presence of living organisms in water, it proves, either that the water has not been so efficiently filtered as to remove these organisms, or that it has subsequently become polluted by them; and thus it is indirectly demonstrated that the water has not been treated, preserved, or stored under such conditions as would preclude the access of deleterious germs or organisms. A microscopic examination of the suspended matters in potable waters thus becomes indirectly of considerable value.

The analytical determinations, which we have deemed sufficiently important to warrant the expenditure upon them of the necessary time and labour, are the following; those which are of primary importance being printed in "**black type**":—

IN SOLUTION.

1. Total solid matters, or total solid impurity.
2. **Organic Carbon, or Carbon contained in the organic matter actually present.**
3. **Organic Nitrogen, or Nitrogen contained in the organic matter actually present.**
4. Ammonia.
5. Nitrogen as nitrates and nitrites.
6. Total combined nitrogen.
7. **Estimation of the previous sewage or animal contamination.**
8. Chlorine.
9. Temporary, permanent, and total hardness.

IN SUSPENSION.

10. Mineral matters in suspension.
11. **Organic matters in suspension.**

Every sample of water, the analysis of which is given in this report, has been submitted to all these determinations except the last two, which have only been employed in cases where the proportion of suspended matter was considerable. In all cases where these last-named determinations were not made, the samples of water were shaken up before analysis; and in these instances, therefore, the mere traces of suspended matter which were present are included amongst the soluble constituents.

A full description of the most important of these analytical determinations will be found in Appendix No. 12.

In order to render intelligible the analytical numbers given in this report, and the conclusions which we have based upon them, it is necessary that we should here offer some explanations of the object and significance of each of the before-mentioned determinations.

1. *Total solid matters in solution, or total solid impurity.*—When water is evaporated to dryness, there is left behind a solid residue containing the mineral and organic matters with which the water had become contaminated since its condensation from the atmosphere. Leaving out of consideration the quality of the ingredients contained in potable matters, the proportion of solid residue left on evaporation affords an approximate, though rough, indication of the comparative purity of such waters. On the one hand it may

PART I
CHEMICAL EXAMINATION.

Organic Carbon and Nitrogen.

be safely concluded, that waters leaving very large residues on evaporation are unfit for domestic use, whilst on the other, those containing very small residues are, on this account alone, well adapted for such purposes, and but very rarely contain, amongst their constituents, any which are seriously objectionable. Not only do waters leaving small residues on evaporation generally possess a superiority for domestic purposes, but they are also much more valuable than less pure waters for a large number of manufacturing purposes. Thus, in feeding steam boilers, their use precludes the formation of incrustations, which not only seriously interfere with the transmission of heat from the fuel to the water, but are probably a frequent cause of disastrous explosions.

We regard these solid matters constituting the residue left on evaporating a sample of potable water as impurities, firstly, because they are quite useless, and secondly, because they act injuriously in several of the processes to which such water is applied. It is true that some persons prefer waters which leave large solid residues, because the saline constituents, with which such waters abound, impart a piquant taste, but this preference cannot be accepted as a trustworthy guide, because it often leads those who are influenced by it to resort to shallow wells which are often fed by sewers and cesspools. It deserves also to be mentioned that a very large proportion of the potable water supplied to towns is employed for washing and for manufacturing purposes, and here the presence of a large amount of solid matter giving hardness to the water is undoubtedly injurious. We have therefore, in the following analytical tables, designated the total solid matter in solution as "total solid impurity."

2. **Organic Carbon.**—From a sanitary point of view, the most important constituent of the total solid impurity is organic matter, and various processes have from time to time been devised for the quantitative determination of this matter or of some of its constituents. The problem is surrounded with unusual difficulties, and hitherto no method, worthy of any degree of confidence, has been discovered by which the weight of organic matter dissolved in water can be even approximately determined. We have already alluded to grave errors which have arisen from reliance having been placed upon such determinations. (See First Report, *Mersey* and *Ribble* Basins, Vol. I., page 71.) Even of several analytical processes which do not pretend to the estimation of the total weight, and aim at the quantitative determination of only some of the elements of the organic matter, we have found, after practically testing them, that only one yielded results which were trustworthy. This process is both troublesome and tedious, and requires considerable manipulative skill; but, as it is the only method which throws any light whatever upon the actual pollution of water by organic matter, we have not been deterred from employing it, and every sample of water recorded in the following tables has been submitted to this operation. It consists in transforming, by combustion in close vessels, the carbon and nitrogen of the organic matter into carbonic acid and free nitrogen, and then measuring the respective volumes of these gases. By a simple calculation, the weights of carbon and nitrogen contained in the original organic matter present in the water can be arrived at, from these volumetric determinations, with great precision. The weight of organic carbon, or carbon contained in the organic matter found in different samples of water, indicates the amount of organic matter with which the water is contaminated, but it does not indicate the source, animal or vegetable, whence that organic matter was derived. *Cæteris paribus* the smaller the proportion of organic carbon, the better the quality of the water. Even if the source of the organic matter be altogether vegetal, experience has shown that a larger proportion of organic carbon than 0·2 part in 100,000 parts of water is undesirable, because it renders the water slightly bitter and unpalatable. A larger proportion of organic carbon, if it be contained in animal matter, does not interfere with the palatability of the water, but it exposes the consumer to the risk of infection; and we consider that potable water which contains organic matter, even only partially derived from animal sources, should not yield much more than 0·1 part of organic carbon from 100,000 parts of water.

3. **Organic Nitrogen.**—The character of the organic matter contained in potable water, that is to say, its animal or vegetable origin, may in most cases be judged of by the relative proportions in which the two elements, carbon and nitrogen, occur in the organic matters. Hence the necessity for determining the amount of organic nitrogen in waters used for domestic purposes. This has long been considered as the most important determination in water-analysis; thus in their report to the President of the General Board of Health, on the Metropolis Water Supply in 1856, Dr. A. W. Hofmann, F.R.S., and Mr. Blyth remark:—"It is now generally admitted that the substances "which constitute the organic matter of water act injuriously by no means in conse-

Part I. Chemical Examination.

Proportion of Carbon to Nitrogen in upland surface water.

" quence of being poisonous themselves, but by undergoing those great processes of " transformation called decay and putrefaction to which all vegetable and animal matter " is subject when no longer under the control of vitality, either in plants or animals. " These putrefactive processes either give rise to the formation of poisonous bodies, or " they act simply as ferments, generating similar processes of decomposition in the " substances composing the animal organism. Now with special reference to the last " mode of action, it is well established by general experience that *nitrogenous* substances " are infinitely more liable to undergo putrefaction than organic bodies from which " nitrogen is absent. And hence the very general and correct opinion that the deleterious " character of organic matter in water is proportionate to the amount of *nitrogen* " which it contains. Could this nitrogen be estimated with any degree of accuracy, " such an estimate would certainly afford the most satisfactory element in the exami- " nation of organic matters."

Eleven years elapsed after these remarks were made before a process was discovered by which this desirable object could be accomplished; and the method which was then devised, and which includes in addition, as already described, the determination of organic carbon, is the one which we have employed throughout the analyses recorded in this report.

The determination of organic nitrogen, taken in connexion with that of organic carbon, frequently affords information of great value as to whether the organic matter be of animal or vegetable origin; and this information acquires additional importance and trustworthiness when it is subsequently tested by a chemical investigation of the previous history of the water as revealed by the proportions of the chief products derived from sewage and animal matters, viz., ammonia, nitrates, nitrites, and chlorine. The smaller the absolute quantity of organic nitrogen, and the less the proportionate amount as compared with organic carbon, the better is the quality of the water as regards present or actual pollution, and the less likely is the water to contain any organic matters of animal origin. In connexion with this part of the analytical investigation, however, it must be borne in mind that vegetable organic matter is far from being destitute of nitrogen. We have found for instance, that peat, which is a form of vegetable matter least likely to contain nitrogen, yields to water organic substances in solution containing much nitrogen. Doubtless different samples of peat vary in the nitrogenous character of the soluble vegetable matter which they contain; in one sample which we examined the proportion of nitrogen to carbon was—N : C = 1 : 11·4; and we find that such peaty matters dissolved in water may, after prolonged exposure to oxidizing influences, lose carbon so much more rapidly than nitrogen, as to materially increase the proportion of the latter element to the former.

The following tables show the proportion of nitrogen to carbon in waters containing organic matter of peaty origin. The first table enumerates upland surface waters in which the peaty matter present could only have been exposed to slight oxidizing action. The second table contains examples of similar water after exposure to atmospheric oxidation in lakes. The third table contains samples of spring water, believed to have been originally contaminated almost exclusively with peaty matter, which had however been subsequently exposed to the powerful oxidizing action of the porous strata through which the water had filtered before its appearance at the spring.

Table I.

Proportion of Organic Carbon to Organic Nitrogen in unoxidised Peaty Matter contained in Upland Surface Water.

Source of Water.	Proportion of Carbon to 1 part of Nitrogen.
Stream at Gazelan Clay Works, Cornwall - -	9·1
Mountain stream above St. Neot's, Cornwall - -	18·4
The *Gelder Burn* at Balmoral - - -	10·3
Stirling water supply - - - - -	10·7
Greenock water supply - - -	13·5
The unpolluted *Rheidol*, Wales - - -	10·4
The *Burn of Mooran*, Forfar - - - -	9·0
The *Tay* above Dunkeld - - - -	21·1
An affluent of the *Tay* above Dunkeld - -	10·3
Bridge of Allan water supply - - - -	9·7

TABLE I.—*continued.*

Part I. Chemical Examination

Proportion of Carbon to Nitrogen in surface water and reservoirs.

Source of Water.	Proportion of Carbon to 1 part of Nitrogen.
The *Tweed* above Peebles	8·2
The *Meldon Burn* above Peebles	11·5
The *Megget* flowing into St. Mary's Loch	20·2
The *Leven* above Barrhead	10·2
The *Doon* at the Brig	12·4
Mountain stream above Kinder Printworks, Hayfield	10·7
Leeds water supply from the *Wharfe*	10·3
Mountain stream at Allenheads	13·5
One of the head waters of the *Wear*	8·5
Another „ „	12·3
One of the head waters of the *Tees*	14·8
Another „ „	13·2
The *South Esk* above Gladhouse Mill	13·1
The *Douglas* at Standish railway station	14·7
Water supply to Aldershot Camp	8·7
The *Nethan* near its junction with the *Clyde*	10·3
The *Calder* and *Brun* above Burnley	10·1
Alloa water supply	11·4
Stream from Malham Tarn	9·1
The *Wharfe* at the Strid, Bolton Abbey	15·8
The *Stonecroft Burn*, affluent of the *Tyne*	8·4
Average	11·916

TABLE II.

PROPORTION OF ORGANIC CARBON TO ORGANIC NITROGEN IN PEATY MATTER AFTER EXPOSURE TO ATMOSPHERIC OXIDATION IN NATURAL LAKES OR LARGE ARTIFICIAL RESERVOIRS.

Source of Water.	Proportion of Carbon to 1 part of Nitrogen.
Water supplied to Devonport from Dartmoor	4·3
Grassmere lake, at foot	4·7
Rydal lake, at foot	5·9
Windermere lake, one mile from head	3·9
Derwentwater lake, at foot	5·1
Bassenthwaite lake, at foot	4·2
Buttermere lake, at foot	3·2
Crummock lake, half a mile from head	3·3
The *Ness*, as it issues from Loch Ness	6·6
Loch Katrine, two miles from head	8·4
St. Mary's Loch, at the foot	11·4
Loch Lomond, at the foot	7·2
Water from lowest reservoir Rivington Pike	7·8
Water supplied to Manchester from Woodhead reservoirs	6·4
Water supplied to Sheffield from reservoirs	6·2
„ Preston „	7·6
„ Newcastle-on-Tyne from reservoirs	3·8
Water supplied to Edinburgh from Swanston	6·4
Water supplied to Edinburgh from Colinton	4·8
Water supplied to Merthyr Tydfil	7·2
Average	5·92

Part I. Chemical Examination.

Proportion of Carbon to Nitrogen in spring water.

TABLE III.

PROPORTION OF ORGANIC CARBON TO ORGANIC NITROGEN IN SPRING WATER CONTAINING PEATY MATTER.

Source of Water.	Proportion of Carbon to 1 part of Nitrogen.
Lower spring, Malvern waterworks - - -	3·4
Upper ,, ,, ,, - - -	4·1
Water supplied to Plymouth from Dartmoor - -	2·6
Water supplied to St. Austell - - - - -	2·2
Spring at Abergeldie Castle - - - - -	5·4
South spring on Llandabarn flat, near Aberystwith -	2·2
Spring near Burwarton Hall - - - -	3·7
Another spring ,, - - - - -	4·4
,, ,, - - - - -	3·9
Spring near Penrhyn Castle - - - -	1·4
Another spring ,, - - - - -	2·7
,, ,, - - - - -	3·0
Spring near Whitbeck, Cumberland - - -	1·9
Water supplied to Chepstow - - - - -	3·5
Intermittent spring at Giggleswick, Yorkshire - -	1·6
St. Winifred's Well, Holywell - - - - -	5·0
Spring at Wood Top, Hebden Bridge, near Halifax -	3·8
Penny Well Spring, Hexham, Northumberland -	2·6
Springs at Longwood, near Huddersfield - -	2·7
Spring in railway cutting near Barnard Castle -	3·4
Source of the *Windrush* at Taddington - -	3·4
The Wishing Well, St. Boniface Down, Isle of Wight -	4·9
The *Manor*, near its source - - - - -	3·9
The *Rochdale Road Calder*, near its source - -	2·7
Spring in Mother Ludlam's cave, Moor Park, near Farnham - - - - - - -	3·0
Average - - - - - -	3·26

An inspection of these tables shows clearly that the proportion of carbon to nitrogen in the peaty organic matter of water decreases rapidly as oxidation progresses. The average proportion in the unoxidized peaty matter contained in 31 samples of water was N : C = 1 : 11·93.

After the water had been stored for weeks or months in lakes, the slow progress of oxidation there effected decreased the proportion of carbon, on an average of 20 samples, to N : C = 1 : 5·92.

The anomaly, presented by the water of St. Mary's Loch in this series, disappears when it is known that this loch is fed chiefly by the *Megget*, in which the proportion of organic carbon to organic nitrogen is very high. This stream moreover, enters the loch, not at the head, but at a point about equidistant from the head and foot. The proportion of organic nitrogen to organic carbon in the *Megget* water was 1 : 20·2, and in that at the foot of the loch it was 1 : 11·4. There is consequently here also a decrease of the proportion of organic carbon about equal to that observed in other cases.

After the water containing the peaty matter has been subjected to the powerful oxidizing influences which accompany filtration through porous strata, it re-appears as spring water with a greatly augmented proportion of organic nitrogen, although the absolute quantity has been much diminished. In other words large quantities of both carbon and nitrogen have been oxidized and converted into mineral matter, but the carbon has undergone this transformation more rapidly than the nitrogen. The average of 25 samples of spring water from such sources exhibits the following proportions:— N : C = 1 : 3·26.

This concentration of nitrogen during oxidation assimilates oxidized vegetable, to unoxidized animal, organic matter in chemical composition, so far, at least, as the proportion between the chief elements nitrogen and carbon, is concerned. There is, however, still a considerable difference in this respect between these two kinds of organic matter; but even this disappears when the water containing animal organic matter is subjected to oxidizing influences; for whilst vegetable organic matter suffers a concentration of nitrogen during oxidation, animal organic matter exhibits, as a rule, a concentration of carbon, and a diminution in the proportion of nitrogen under the same influence. This is evident from an inspection of the following tables, in one of which the proportion is given of carbon to nitrogen in animal organic matter present in water which has been slightly or not at all exposed to oxidizing influences, whilst the other records the proportion in animal organic matter present in water which has been subjected to the oxidizing action attending slow percolation through porous strata in its passage to shallow wells.

PART I. CHEMICAL EXAMINATION

Proportion of Carbon to Nitrogen in polluted well waters.

TABLE IV.

PROPORTION OF CARBON TO NITROGEN IN ANIMAL ORGANIC MATTER DISSOLVED IN WATER.

DESCRIPTION.	Proportion of Carbon to one part of Nitrogen.
Fresh urine - - - - - - - -	·99
Average of fresh sewage from 16 watercloset towns -	2·1
Average of fresh sewage from 15 midden towns -	2·1
Urine preserved without oxidation for 24 days - -	1·6

TABLE V.

PROPORTION OF CARBON TO NITROGEN IN THE ANIMAL MATTER CONTAINED IN POLLUTED SHALLOW WELLS.

SOURCE OF WATER.	Proportion of Carbon to one part of Nitrogen.
Shallow well at Gainford, near Darlington - -	3·1
Shallow well at Horbury, near Wakefield - -	4·1
Another shallow well at Horbury, near Wakefield -	1·8
Shallow well in High street, Kilmarnock - -	2·6
Shallow well at Musselburgh - - - - -	2·8
Another ,, ,, - - - - -	2·9
Shallow well in Birmingham - - - - -	3·2
Another ,, ,, - - - - -	1·6
,, ,, ,, - - - - -	2·4
,, ,, ,, - - - - -	5·9
,, ,, ,, - - - - -	2·1
,, ,, ,, - - - - -	3·0
Shallow well at Darlington - - - - -	3·9
,, Greasely, Notts - - -	4·5
,, Hurworth, near Darlington - -	1·6
Another - - - - - - - -	1·6
Shallow well at Kidderminster - - -	1·8
,, Leamington - - - -	3·8
,, Newent, Gloucestershire - -	1·2
Another ,, ,, - - -	4·7
,, ,, ,, - - -	1·8
,, ,, ,, - - -	1·8
Shallow well at Newnham - - - - -	2·1
,, Retford, Notts - - -	3·9
,, Clarboro', near Retford - -	2·4
,, Stafford - - - -	3·3
,, Worksop, Notts - - -	4·1
Another ,, ,, - - -	3·6

PART I. CHEMICAL EXAMINATION.

Proportion of Carbon to Nitrogen in polluted well waters.

TABLE V.—*continued.*

Source of Water.	Proportion of Carbon to 1 part of Nitrogen.
Shallow well at Bitteswell, Leicestershire - -	2·9
„ Hillmorton, near Rugby - -	5·5
„ Somerby, Rutlandshire - -	2·5
Another „ „ - - -	·7
Shallow well at Somerton, Somerset - - -	5·6
„ Warkton, Northamptonshire - -	6·1
„ Oakham, Rutland - - -	2·6
„ Pepper Harrow, Surrey - -	1·2
„ Norwich - - - -	3·0
„ Sudbury, Suffolk - - -	1·8
„ Thetford, Norfolk - - -	2·7
„ Wokingham, Berks - - -	4·6
„ Christchurch, Hants - - -	4·4
„ Barking Sewage Farm - -	4·7
„ Leigh, Essex - - - -	3·2
Town pump, Peterborough - - - -	2·8
Pump in Gray's Inn Road, London - - -	4·6
Pump in Wellclose Square „ - - -	3·2
Pump in Idol Lane, London - - - -	3·2
„ Wandsworth Road, London - - -	3·4
„ Manor Street, Clapham, „ - - -	2·8
Average - - - - -	3·126

A large proportion of the soluble organic matter of sewage is of animal origin, and Table IV. shows that on the average of 31 samples of fresh sewage the proportion of nitrogen to carbon in the organic matter was—Nitrogen : Carbon = 1 : 2·1.

The water of highly polluted shallow wells consists chiefly of sewage and the drainage of cesspools, middens, or urinals which have percolated through a few feet of porous soil, and Table V. shows the following average proportion of nitrogen to carbon in the soluble organic matter remaining in the water after it has reached such wells:—Nitrogen: Carbon = 1 : 3·126.

It is thus evident that, unlike the effect of the analogous operation upon vegetable organic matter, there is here a marked diminution in the original proportion of the organic nitrogen to the organic carbon. But the conditions to which sewage is exposed on its way to a shallow well are not all of an oxidizing character. Such sewage is often retained for weeks in cesspools, where it is exposed to the condition of putrefaction,—a condition essentially different from, and quite opposed to that of oxidation. In the experiments upon the upward filtration of sewage through sand, described in our First Report (*Mersey* and *Ribble* Basins, Vol. I. page 63), we have a good illustration of the putrefactive treatment of sewage; and they prove that, under this condition, the proportion of nitrogen to carbon, though at first diminished, may again become considerably increased when the putrefactive process is in full activity.

CHANGES IN THE COMPOSITION OF THE ORGANIC MATTER OF SEWAGE DURING PUTREFACTION.

Sewage before filtration	- - - - -	Nitrogen : Carbon = 1 : 1·8
Sewage after filtration	Oct. 11, 1869 - -	„ : „ = 1 : 3·2
„ „ „	Oct. 19 „ - -	„ : „ = 1 : 3·7
„ „ „	Oct. 25 „ - -	„ : „ = 1 : 3·0
„ „ „	Nov. 1* „ - -	„ : „ = 1 : 2·1
„ „ „	Nov. 8 „ - -	„ : „ = 1 : 1·7
„ „ „	Nov. 15 „ - -	„ : „ = 1 : 1·9
„ „ „	Nov. 22 „ - -	„ : „ = 1 : 1·8

* At this date active putrefaction was established, and it continued until the close of the experiment.

PART I. CHEMICAL EXAMINATION

Proportion of Carbon to Nitrogen in polluted waters.

This behaviour of the soluble organic matter of sewage, when exposed to the putrefactive process, explains one or two anomalous numbers in Table V., and suggests that the average proportion of carbon in the organic matter of sewage after oxidation, as deduced from that table, is too low. This suggestion is confirmed by an appeal to the results of our experiments upon downward intermittent filtration described in our first report (vol. I., *Mersey* and *Ribble* Basins, pp. 63-68). These experiments show the following alterations in the composition of the soluble organic matter of sewage during the very powerful oxidation to which it was subjected as it slowly filtered through porous soils of various kinds:—

(i.) In the downward intermittent filtration of London sewage through quartz sand, the average composition of the sewage before filtration, and the average results of the analysis of 12 samples of the filtered sewage, afford the following comparison:—

Average sewage before oxidation	- -	Nitrogen : Carbon = 1 : 1·8
Average sewage after oxidation	- -	„ : „ = 1 : 7·7

(ii.) In the similar filtration of sewage through a mixture of sand and chalk, the average results of the analysis of 11 samples of the filtered sewage afford the following comparison with the sewage before filtration:—

Average sewage before oxidation	- -	Nitrogen : Carbon = 1 : 1·8
Average sewage after oxidation	- -	„ : „ 1 : 6·9

(iii.) After downward intermittent filtration through soil taken from the sewage farm at Beddington, near Croydon, 18 samples of effluent sewage water were analysed. The average results afford the following comparison with those yielded by the fresh sewage before filtration:—

Average sewage before oxidation	- -	Nitrogen : Carbon 1 : 1·8
Average sewage after oxidation	- -	„ : „ 1 : 6·5

(iv.) A similar series of experiments, in which Hambrook soil was the oxidizing medium, gave the following comparison:—

Average sewage before oxidation	- -	Nitrogen : Carbon = 1 : 1·8
Average sewage after oxidation	- -	„ : „ = 1 : 7·1

(v.) The average results yielded by 12 samples of sewage water filtered intermittently through soil taken from the Barking sewage-farm exhibit the following comparison with the original sewage:—

Average sewage before oxidation	- -	Nitrogen : Carbon = 1 : 1·8
Average sewage after oxidation	- -	„ : „ = 1 : 6·9

(vi.) Lastly, 16 samples of sewage similarly oxidized by intermittent filtration through Dursley soil show the following comparison with the raw or unoxidized sewage:—

Average sewage before oxidation	- -	Nitrogen : Carbon = 1 : 1·8
Average sewage after oxidation	- -	„ : „ = 1 : 4·9

It is thus evident that the proportions of nitrogen to carbon in soluble vegetable and animal organic matters vary in opposite directions during oxidation; a fact which renders more difficult the decision as to whether the organic matter present in any given sample of water is of animal or vegetable origin. This difficulty can, however, be greatly diminished or entirely overcome by an appeal to the previous history of the water as revealed partly by a knowledge of its source, and the kind of contamination to which it has been exposed, and partly through the information afforded by chemical analysis. In the first place, if the water is known by an inspection of its source to have been polluted by animal matters, and to have been subjected, after such pollution, only to the slight oxidation effected in rivers or streams, a portion at least of the organic matter which it contains must have been derived from animal matter, because we have proved (pages 134–138) that there is no river in Great Britain long enough to completely oxidise or destroy the soluble animal organic matter present in polluted water. In the second place, if the water is found, on analysis, to contain considerable quantities of one or more of the mineral compounds, ammonia, nitrates, and nitrites, into which animal organic matter is resolved during its decomposition or oxidation, the inference may be drawn that the soluble organic matter of such water has been derived from animal sources. But this inference must only be provisional; it must stand or fall by an investigation into the source of the water; for although the presence of the products of the decomposition of animal matter indubitably convicts the water of previous pollution, yet it is obviously possible, from the facts and considerations which we have just adduced, that the whole of the original organic matter may have been oxidised and converted into innocuous mineral compounds during the prolonged filtration of the water through a

PART I. CHEMICAL EXAMINATION.

Ammonia and nitrates in waters.

great thickness of porous strata, and that the water so purified may afterwards have become contaminated with vegetable matter only. In other words, water polluted by animal matters may become pure spring water, retaining only the innocuous evidence of its former pollution, and may then become polluted by the soluble matter of peat. Such water would be suspicious owing to the evidence of its previous pollution, which it still bears about with it, and it could only be cleared from this suspicion on proof of efficient purification after its pollution by animal matter. To render the water safe for domestic use the animal pollution must have occurred *before* it became spring water.

It is upon this part of the investigation of potable water that the next four determinations have a very important bearing.

4. *Ammonia.*—This mineral nitrogenous compound is rarely absent from potable waters, which derive it, sometimes from the atmosphere, but more usually from decomposing animal matters. An inspection of the analytical table at page 29 shows that rain water falling in London sometimes contains as much as ·21 part of ammonia in 100,000 parts of water, but this is exceptional, and the proportion rarely exceeds one third of that amount. The average quantity present in the 71 samples of rain water from Rothamsted, the analyses of which are given at page 27, was ·049 part in 100,000 parts of water. In river water the proportion rarely exceeds ·01 part; in unpolluted well water it is usually still less; whilst in spring water it is either absent altogether or present in only very minute proportion. On the other hand, it often abounds in the water of much polluted shallow-wells. The analytical results given at page 85 show that the proportion of ammonia in the London shallow-well waters sometimes rises as high as 2·75 parts in 100,000 parts of water. In contact with animal matter and under the operation of oxidising influences, ammonia is very rapidly converted into nitrites and nitrates, and its presence therefore in considerable proportion in shallow well waters indicates their very recent contamination with animal matters. Its occurrence in water from deep wells, however, does not permit of the same inference being drawn, because we find that in such water the decomposition of nitrates not unfrequently gives rise to ammonia. This is particularly the case in very deep wells, and in those which are sunk into the Chalk beneath the London Clay. The ammonia which occurs under such circumstances is obviously still more remote from the animal matter whence it originated, than the nitrates from which it was immediately derived, and which were themselves generated by the oxidation of animal matter.

The chief significance attaching to the determination of ammonia in potable water lies in the circumstance that this compound is derived almost exclusively from the decomposition of animal matter. It is obvious, however, from the considerations just mentioned, that all inferences to be drawn from its presence must be controlled by a study of the physical and chemical history of the water.

5. *Nitrogen as Nitrates and Nitrites.*—In the presence of oxygen, the nitrogen of animal matters is transformed, in great part, into nitric acid and nitrous acid; and these, by combining with the basic substances always present in polluted water, are in their turn converted into nitrates and nitrites. This transformation takes place most rapidly and completely when the polluted water soaks through aërated soil. Thus 97 per cent. of the combined nitrogen of London sewage is converted into nitrates during its slow percolation through a stratum of gravelly soil only 5 feet thick. In hot climates and in villages where the concentrated excrements of the population are allowed to soak away into a porous soil, large quantities of nitrate of potash (nitre) are often generated. It is thus that nitre is produced in India. Dr. W. J. Palmer, F.R.C.S., additional Chemical Examiner to the Government of India, thus describes the process (Journal of the Chemical Society, vol. xxi. page 318):—

"The *sorawallah* (collector of nitre) goes about the village, examining the small surface drains " which issue from holes in the mud-wall, usually found around native dwellings and their cow-" houses; when he detects a faint white veil-like patch of crystalline formation, on or near the " dark coloured borders of these little drains, he knows that a considerable quantity of nitre exists, " on or near the surface of all the surrounding earth; he accordingly proceeds to scrape off a very " thin layer of the surface soil, which he carries away to his place of manufacture. The nitre-" producing parts of India are more densely populated than England; the villages are large " and are made up for the most part of mud houses surrounded by a mud wall, which generally " encloses the dwellings of a whole family, including uncles and aunts and their families as well " as grandparents and grandchildren; every family will have at least one pair of plough oxen. " The only drains from these houses are the small surface ones before alluded to, and the only " fluids which pass by these drains are urine and the small quantity of refuse water brought to the " house for culinary or drinking purposes. These drains open on to a small open plot of ground, " where the drainage diffuses itself and is rapidly dried in the sun."

As further evidence that the production of nitrates in India is dependent essentially upon the presence of animal excrements, and especially of urine, Dr. Palmer states:— **Part I. Chemical Examination**

" Firstly, that no other known source of nitre exists; and secondly, that nitre is found only in " and near populous villages; that it continues to be found on the same spot of ground so long as " it is inhabited, and gradually ceases when a village is deserted." **Previous animal contamination.**

Whilst the oxidation of animal matters in solution in water yields abundance of nitrates and nitrites, vegetable matters furnish under like circumstances none, or mere traces, of these compounds. A reference to the analytical results at pages 33–47 shows that upland waters, which have been in contact only with mineral matters or with the vegetable matter of uncultivated soil, contain, if any, mere traces of nitrogen in the form of nitrates and nitrites; but the analyses at pages 47–53 show that as soon as the water comes into contact with cultivated land, or is polluted by the drainage from farmyards or human habitations, nitrates in abundance make their appearance. The presence of these salts in sufficient quantity is, therefore, trustworthy evidence of the previous pollution of the water with animal matters. It must be borne in mind, however, that nitric and nitrous acids are present, though in but minute quantity, in the atmosphere, and that rain washes them out of the air through which it falls. In 71 samples of rain water collected at Rothamsted, near St. Albans, the proportion of nitrogen as nitrates and nitrites varied from nil up to ·044 part in 100,000 parts of water. Even the highest proportion, which occured only once, is a very small one, and we have never met with one so large in unpolluted upland waters.

6. *Total combined Nitrogen.*—The element nitrogen may exist in water in four forms; viz.:—firstly as a constituent of organic matter, secondly as a constituent of ammonia, thirdly as a compound of nitrates and nitrites, and fourthly as a constituent of dissolved atmospheric air. In the last case, the nitrogen is in the free or elementary condition; and as it neither pollutes the water nor throws any light upon its previous pollution, it may be left out of consideration. In all the other three forms, the nitrogen is combined with other elements, constituting, either polluting matter, or the resultant of previously existing polluting matter. With a slight deduction for the minute amount of this element which is met with in combination in rain water, the determination of total combined nitrogen sums up, as it were, the evidence of the *past* and *present* pollution of each water by nitrogenous organic matter of either animal or vegetable origin. The evidence is unfortunately incomplete—*i.e.* the quantity of combined nitrogen which it indicates is generally less than what was originally present—especially in spring and summer, because some of the compounds containing nitrogen constitute an important part of the food of both animal and vegetable organisms. Combined nitrogen also suffers diminution whenever the organic matter in the water enters into putrefaction or undergoes oxidation in the absence of atmospheric oxygen and in the presence of nitrates and nitrites. The latter salts supply, under these circumstances, the oxygen required to transform the carbon and hydrogen of the organic matter into carbonic acid and water, whilst their nitrogen is converted only to a slight extent into ammonia, the rest being set free and consequently ceasing to exist as combined nitrogen. It is thus that the water of very deep wells frequently retains few or no traces of the nitrates and nitrites which it previously held in solution, whilst a comparatively small proportion of ammonia is found in their place. The artesian wells of London afford striking instances of this destruction of nitrates and consequently of combined nitrogen.

7. **Previous sewage or animal contamination.**—It has been established by very numerous chemical analyses, the results of which are given partly in our previous reports and partly in the following pages, that animal matters dissolved in water, such as those contained in sewage, the contents of privies and cesspools, or farmyard manure, undergo oxidation in lakes, rivers, and streams very slowly, but in the pores of an open soil very rapidly. When this oxidation is complete, they are resolved into mineral compounds; their carbon is converted into carbonic acid and their hydrogen into water,—products which can no longer be identified in the aërated waters of a river or spring; but their nitrogen is transformed partly into ammonia, chiefly however into nitrous and nitric acids, which, combining with the bases present in nearly all water that has been in contact with the earth, form nitrates and nitrites, and frequently remain dissolved in the water for a long time; there constituting a record of the sewage or other analogous contamination, to which it has been subjected since its descent to the earth as rain.

It is convenient to have a concrete expression for the amount of previous animal contamination revealed by this record of the past history of the water. Such an expression is obtained by taking as a standard of comparison the amount of total combined

PART I. CHEMICAL EXAMINATION.

Previous animal contamination.

nitrogen contained in solution in 100,000 parts of average London sewage. Although a considerable proportion of this nitrogen is found at the sewer outfall in the condition of ammonia, it is well known that in the perfectly fresh sewage, the nitrogen of this ammonia was present as a constituent of animal organic matter. The earlier analyses of London sewage made by Professor A. W. Hofmann, F.R.S., and Mr. H. M. Witt, F.C.S. (Appendix No. 1 to Report on Metropolitan Drainage, 1857) give the number 8·363 as the amount of total combined nitrogen contained in 100,000 parts of average London sewage. Our own more recent analyses (First Report, 1870, *Mersey* and *Ribble* Basins, Vol. I. page 63) show that 100,000 parts of average London sewage contained in 1868 and 1869 only 7·06 parts of total combined nitrogen. This difference is doubtless owing to the more abundant supply of water to the metropolis at the later period. For simplicity, however, a round number—10—was assumed as the amount of total combined nitrogen in solution in 100,000 parts of average London sewage. This number is considerably higher than that furnished by the earlier analyses, and is still less in accordance with that derived from the more recent ones; but as the standard thus adopted has now been in use for several years, and as it would obviously be, in any case, only a conventional one, it is not desirable to alter it merely for the sake of bringing it into closer harmony with the present strength of London sewage, more especially as that strength is liable to vary from time to time,—to be increased by a more efficient inspection of water-fittings, and to be diminished by a more abundant supply of water to the poorer districts of the metropolis.

In estimating, in terms of this standard, the previous animal contamination of water, from the proportion of nitrogen, in the form of ammonia and of nitrates and nitrites which it holds in solution, it is necessary to bear in mind that rain water itself contains these substances, although in minute quantities. The average composition of seventy-one different samples of rain water collected for us at Rothamsted by Dr. J. H. Gilbert, F.R.S. (*see* page 27) gives the amount of nitrogen in these forms as ·047 part in 100,000 parts of water. This differs rather widely from the number ·032 derived from a more limited number of previous analytical observations upon rain water, and always used by us as the constant to be deducted from the nitrogen in these forms found in potable waters. It is exceedingly difficult however to collect samples of rain water quite free from animal pollution. The rain collector used in obtaining the samples just alluded to was a wooden tray lined with lead — $\frac{1}{1000}$th of an acre in area. It was erected at a height of two feet above the ground in the middle of an arable field, and the rain water was delivered into a glass carboy placed beneath the tray. The water was liable to pollution, firstly from the dust of the highly manured field in which the collector stood, and secondly, from the excrements of birds, the collector forming an inviting perch near the middle of the field. To avoid these pollutions, the collector was sometimes watched during heavy rain, and a sample collected apart after the tray had been cleansed by the rain itself from all polluting materials. The samples mentioned in the analytical table at page 27 and described as having been collected at a particular hour as "3 to 4 p.m., May 18, 1869," were secured under these favourable circumstances. Fifteen samples of this kind were analysed, and the mean proportion of nitrogen found in them as a constituent of nitrates, nitrites, and ammonia was ·034 part in 100,000 parts of water, the maximum being ·125 part and the minimum ·004 part. The average does not therefore differ materially from the constant (·032) which we have adopted in our estimations of previous sewage or animal contamination.

After this number (·032) has been subtracted from the amount of nitrogen, in the forms of nitrates, nitrites, and ammonia, found in 100,000 parts of a potable water, the remainder, if any, represents the nitrogen derived from oxidized animal matters with which the water had been in contact. Thus a sample of water which contains, in the forms of nitrates, nitrites, and ammonia, ·326 part of nitrogen in 100,000 parts, has obtained ·326 − ·032 = ·294 part of that nitrogen from animal matters. Now this last amount of combined nitrogen is assumed to be contained in 2,940 parts of average London sewage, and hence such a sample of water is said to exhibit 2,940 parts of previous sewage or animal contamination in 100,000 parts; or in other words, 100,000 lbs. of the water contain the mineral residue of an amount of animal organic matter equal to that found in 2,900 lbs. of average London sewage.

We are, therefore, of opinion that this constant (·032), when deducted from the amount of nitrogen in these forms contained in any sample of potable water, very rarely indeed leaves a remainder, when the water has not actually been polluted by animal matter. For although the maximum amount of nitrogen in the form of nitrates, nitrites and ammonia, in rain water amounted on one occasion to ·125 part in 100,000 of water, yet these compounds are so rapidly appropriated by vegetation as to leave, in nearly

Part I. Chemical Examination.

Nitrates in water.

every case, a far smaller proportion of nitrogen in these forms, than that with which we have debited rain water. Thus out of 195 samples of upland surface water mentioned in the analytical tables at pages 33–47, there are only 20 which contain in 100,000 parts more than ·032 part of nitrogen in the form of nitrates, nitrites and ammonia, and of these there was not one collected under such circumstances as to preclude the possibility of animal pollution. Again, out of 21 samples of spring water from indisputably unpolluted sources, there were only two which contained in 100,000 parts more than ·032 part of nitrogen in the form of nitrates, nitrites and ammonia. These were both taken from a very small spring known as St. Boniface's Wishing Well. The spring issues from the steep slope on the south side of St. Boniface Down, Ventnor, Isle of Wight, about 100 feet below the summit of the down. The first sample was taken on November 16th, 1872, when the spring was scarcely running 2 gallons per hour: 100,000 parts of this sample contained ·083 part of nitrogen in the form of nitrates, nitrites and ammonia. The second sample was collected on March 8th, 1873, when the issue of water was at least twentyfold as great as on the former occasion. This sample contained ·061 part of nitrogen as nitrates, nitrites and ammonia, in 100,000 parts of water. Several explanations of this abnormal excess of nitrogen in the forms just specified offer themselves. In the first place, the upper part of Boniface Down is occasionally pastured by sheep and cattle; secondly, chalk naturally contains fossil animal remains in which all organic matter is probably not oxidised; and thirdly, the nitrogen compounds in the rain falling upon Boniface Down may undergo concentration by the evaporation of a considerable proportion of the water from the spongy surface of this chalk down. Considerable support is given to the last explanation by the fact, that the proportion of chlorine as chlorides (which are chiefly derived from sea spray), is very high, viz. 6·4 part in 100,000 parts of water in the autumn, and 7·4 in the spring sample, whilst the proportion in springs at the base of the down is only from 3 to 3·6 part in 100,000 parts of water. In summer and autumn the deposit of sea spray would be small and the evaporation great, whilst in winter and spring the deposition of sea spray would be copious, and the evaporation comparatively small. This would explain, on the one hand, the occurrence of a larger proportion of nitrates, nitrites, and ammonia, and a somewhat smaller proportion of chlorides in the autumn sample, and on the other, the presence of a smaller proportion of nitrates, nitrites, and ammonia, and a somewhat larger one of chlorides in the spring sample. Whatever be the true explanation, however, of the abnormally high proportion of nitrates, nitrites, and ammonia in the unpolluted water of the Wishing Well, the fact is one of but slight importance, because, as we shall presently show, the presence of a moderate excess of nitrates, nitrites, and ammonia in spring water very rarely throws suspicion upon the quality of the water.

The occurrence of nitrates in minute quantity in the earth of unmanured forest land observed by M. Boussingault, was probably due to the evaporation of rain water from the surface of the soil, and the concentration of nitrates in the upper layers. The term *unmanured* as applied to soils must also be accepted with some reserve, since it is evident from the analytical tables given at pages 60, 61, and 62, that the complete decomposition of animal manures in soils requires a very great length of time. During the past 29 years Mr. J. B. Lawes, F.R.S., and Dr. J. H. Gilbert, F.R.S., have been making an important series of experiments at Rothamsted on the continuous cultivation of wheat on the same land in some cases without manure, and in others with the continuous application of the same manure from year to year. We were furnished by these gentlemen with samples of drainage water from the plot of continuously unmanured land, as well as from those plots to which various manures had been annually applied. The composition of these waters revealed the fact that, occasionally at least, there was an admixture of water in the subsoil from neighbouring plots. The experimental plots constitute a single field about 352 yards long, the plots themselves are strips of this field running its whole length: some are eight yards wide, others only four yards, a separate drain pipe passes up the centre of each at a depth of between three and four feet from the surface. The field is gently undulating with a general inclination across the drains, but in opposite directions at the top and bottom of the field. The following table, which gives the proportions of chlorine in the drainage waters from the different plots, shows that the proportion of this element in the drainage water from a plot to which no chlorine has been added in the manure is occasionally increased by contiguity to a plot upon which manure containing chlorine has been put.

Thus, on December 8th, 1868, the water discharged from the drain pipe of plots 3 and 4 contained only 3·8 parts of chlorine in 100,000 parts, whilst 100,000 parts of that discharged from the drain of plot 9 contained no less than six parts of chlorine. As no chlorine had been applied to the latter plot during seventeen years this large proportion could only have been derived from the neighbouring plots, which had received large

PART I. CHEMICAL EXAMINATION.

Character of drainage waters.

yearly doses of chlorine. A similar comparison of the samples collected from the same plots on January 5th, 1872, May 18th, 1872, and October 26th, 1872, shows a like admixture of drainage water from neighbouring plots, although to a less extent.

PROPORTION OF CHLORINE IN 100,000 PARTS OF AGRICULTURAL DRAINAGE WATERS.

100,000 Parts of Drainage Water contained.	PLOT 2. Farmyard Manure.	PLOT 3. No Chlorine in Manure. / PLOT 4. Unmanured since 1852.	PLOT 5. No Chlorine supplied in Manure.	PLOT 6. Chlorine supplied in Manure.	PLOT 7. Chlorine supplied in Manure.	PLOT 8. Chlorine supplied in Manure.	PLOT 9. No Chlorine supplied in Manure.	PLOT 10. Chlorine supplied in Manure.	PLOT 11. Chlorine supplied in Manure.	PLOT 12. Chlorine supplied in Manure.	PLOT 13. Chlorine supplied in Manure.	PLOT 14. Chlorine supplied in Manure.	PLOT 15. Chlorine supplied in Manure.	PLOT 16. Unmanured since 1865.
Chlorine, Jan. 13, 1868 -	—	1·40	1·8	—	4·45	—	1·45	—	—	—	—	—	—	—
Do. Jan. 22, 1868 -	·90	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Nov. 23, 1868 -	—	1·6	2·4	—	—	—	—	—	—	—	—	—	—	—
Do. Dec. 8, 1868 -	—	3·8	2·0	—	7·0	—	6·0	—	—	—	—	—	—	—
Do. Dec. 15, 1869 -	—	—	1·42	—	3·9	—	—	—	—	—	—	—	—	—
Do. Dec. 16, 17, 1869	—	1·14	1·23	—	4·65	—	1·2	—	—	—	—	—	—	—
Do. Feb. 7, 1870 -	1·05	·90	·90	—	2·22	—	·81	—	—	—	—	—	—	—
Do. Feb. 8, 1870 -	·60	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Jan. 5, 1872 -	3·35	1·4	1·45	4·3	6·85	11·25	1·8	7·35	9·25	8·05	9·1	9·5	5·75	1·25
Do. Jan. 6, 1872 -	1·4	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. May 18, 1872 -	—	1·05	·75	1·1	1·95	1·6	1·25	2·0	2·3	2·1	2·1	2·15	·95	—
Do. June 11, 1872 -	—	1·20	·9	1·25	·80	—	—	1·2	1·2	1·3	1·4	—	—	—
Do. Oct. 26, 1872 -	2·8	·95	1·1	4·8	8·2	7·6	1·45	7·9	7·0	6·6	7·4	7·6	1·9	1·2
Do. Nov. 30, 1872 -	·9	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Dec. 9, 1872 -	1·05	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Dec. 17, 1872 -	1·4	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Jan. 3, 1873 -	1·1	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Jan. 10, 1873 -	1·0	—	—	—	—	—	—	—	—	—	—	—	—	—
Do. Jan. 19, 1873	·7	·8	·85	1·95	2·5	3·3	—	2·4	2·75	2·75	3·1	2·5	·95	—
Do. Feb. 26, 1873 -	·65	·85	1·0	1·0	1·35	1·35	·70	1·45	1·5	1·3	1·4	1·25	1·0	·8

But although it is thus evident that the drainage water of one plot is liable to, and sometimes does, travel into the adjoining plots, this does not take place to a sufficient extent to account for the excess of nitrates and nitrites (*see* pages 60, 61, and 62) above the proportion contained in rain water, sometimes found in the drainage waters of those plots which have received no nitrogenous manure. There can be no doubt that much of this excess of nitrates is due to the oxidation of animal manure still remaining in the soil of the plots, even although those plots have received no dressing since the year 1852; for the considerable proportion of nitrogenous organic matter present in the drainage water shows that there must still be a large quantity of such organic matter in the soil through which the water had percolated. That this is the case, and that the nitrates are not derived to any material extent from the crops grown upon the land is corroborated by the analysis of numerous samples of water draining from land which had not only been continuously unmanured, but also continuously uncropped for five years. A reference to the table at page 62 recording the results of these analyses shows that the soil contained considerable quantities of soluble and highly nitrogenised organic matter, and that very large amounts of this matter were, even after the lapse of many years, still undergoing oxidation, and yielding abundance of nitrates and nitrites.

The character of the organic matter dissolved in the drainage water of the unmanured plots does not materially differ from that found in solution in the drainage from a plot continuously receiving heavy annual dressings of animal manure; and it is therefore to be inferred that in both cases a portion of the organic matter in solution is of animal origin. Such old animal matter as this is doubtless less likely than that which is of more recent origin to render potable water unwholesome; and consequently the evidence of previous animal contamination afforded by the nitrates, nitrites, and ammonia, derived from its decay and oxidation might, from a hygienic point of view, cast more suspicion upon such drainage water than it really deserved. But it must be remembered, that the results we are now commenting upon were obtained from experimental plots of unmanured land, upon which annual crops of wheat had been grown without interruption for twenty years, a combination of circumstances which is not likely to occur upon any considerable scale on British farms. We are, therefore, of opinion that the presence of nitrogen in the form of nitrates, nitrites and ammonia, in water, in quantity above that which can be derived from rain (*see* p. 14), is reasonably safe and trustworthy evidence of the previous pollution of that water by animal matters.

On the other hand, it must not be forgotten that the absence of nitrogen in these forms is not absolutely conclusive evidence of immunity from this pollution. There are several agencies at work by which this testimony, as to the amount of animal matter previously in contact with the water, may be weakened or altogether destroyed. Thus we look in vain for the full evidence of previous animal pollution in the effluent water from fields irrigated with sewage; because the growing plants have removed a considerable proportion of ammonia, nitrates, and nitrites, from the liquid as it flows amongst their rootlets. In like manner the aquatic vegetation of rivers, lakes, and reservoirs, slowly removes these compounds from the water, and to that extent destroys the evidence of anterior animal contamination. Nitrates and nitrites are also rapidly destroyed when the organic matter in the water

Part I. Chemical Examination.

Classification of waters.

containing them enters into putrefaction,—a condition which often occurs in streams or reservoirs containing much polluting organic matter. It again not unfrequently takes place in water-bearing strata far removed from the surface, although the water in this case may contain but a comparatively small amount of organic matter; the latter, however, cut off from a supply of atmospheric oxygen—as in the Chalk beneath the London Clay for instance—accomplishes its oxidation at the expense of the nitrates or nitrites, and thus destroys them. Owing to this cause, the evidence of previous animal contamination is not met with in the water of some deep wells in which it might otherwise be expected to occur.

The previous animal contamination of water, as deduced from chemical analysis, must therefore always be regarded as a minimum quantity; it does not denote the *comparative* freedom of different samples of water from anterior pollution; but whenever analysis shows this excess of nitrogen in the shape of nitrates, nitrites and ammonia, the water stands convicted of previous contamination at least to the extent so indicated.

The importance of the history of water as regards its anterior pollution with organic matters of animal origin, does not arise from the presence of the inorganic residues (nitrates, nitrites, and ammonia) of the original polluting matters, for these are in themselves innocuous, but from the risk lest some portion (not detectable by chemical or microscopical analysis) of the noxious constituents of the original animal matters should have escaped that decomposition, which has resolved the remainder into innocuous mineral compounds. This evidence of previous contamination implies, however, much more risk when it occurs in water from rivers and shallow wells, than when it is met with in the water of deep wells or of deep-seated springs. In the case of river water, there is great probability that the morbific matter, sometimes present in animal excreta, will be carried rapidly down the stream, escape decomposition, and produce disease in those persons who drink the water; for the organic matter of sewage undergoes decomposition very slowly when it is present in running water. In the case of shallow-well water, the decomposition and oxidation of the organic matter are also very liable to be incomplete during the rapid passage of polluted surface water into shallow wells. In the case of deep-well and spring water, however, if the proportion of previous contamination do not exceed 10,000 parts in 100,000 parts of water, this risk is very inconsiderable, and may be regarded as *nil* if the direct access of water from the upper strata be rigidly excluded; because the prolonged filtration to which such water has been subjected in passing downward through so great a thickness of soil or rock, and the rapid oxidation of the organic matters contained in water, when the latter percolates through a porous and aerated soil, afford a considerable guarantee that all noxious constituents have been removed.

It follows from what has been already stated that chemical analysis cannot discover the noxious ingredient or ingredients in water polluted by infected sewage or animal excreta; and as it cannot thus distinguish between infected and non-infected sewage, the only perfectly safe course is to avoid altogether the use, for domestic purposes, of water which has been polluted with excrementitious matters.

Nevertheless, as it is very difficult in some localities to obtain water, which has not been more or less polluted by excrementitious matters, it is desirable to classify such previously contaminated drinking waters into:—

Reasonably safe water.
Suspicious or doubtful water.
Dangerous water.

Reasonably safe water.—We consider that water, although it exhibits previous sewage or animal contamination, may be regarded as reasonably safe when it is derived either from deep wells (say 100 feet deep), or from deep-seated springs; provided that all contaminated surface water has been rigidly excluded from the well or spring, and that the proportion of previous contamination do not exceed 10,000 parts in 100,000 parts of water.

Suspicious or doubtful water is, first, river or flowing water which exhibits any proportion, however small, of previous sewage or animal contamination; and, second, well or spring water containing from 10,000 to 20,000 parts of previous contamination in 100,000 parts of water.

Dangerous water is, first, river or flowing water which exhibits more than 20,000 parts of previous animal contamination in 100,000; second, river or flowing water containing less than 20,000 parts of previous contamination in 100,000 parts, but which is known, from an actual inspection of the river or stream, to receive sewage, either discharged into it directly or mingling with it as surface drainage; third, as the risk attending the use

Part I. Chemical Examination.

of all previously contaminated water increases in direct proportion to the amount of such contamination, well or deep-seated spring water exhibiting more than 20,000 parts of previous contamination in 100,000 must be regarded as dangerous.

Chlorine in waters.

River or running water, containing less than 10,000 parts of previous animal contamination, should only be provisionally placed in the class of suspicious waters, pending an inspection of the banks of the river and tributaries; which inspection will obviously transfer it either to the class of reasonably safe waters, if the previous contamination be derived exclusively from spring water, or to the class of dangerous waters, if any part of the previous contamination be traced to the direct admission of sewage or excrementitious matters.

8. *Chlorine.*—The chlorine found in potable waters is always in combination with other elements, and chiefly with sodium in the form of chloride of sodium or common salt. A knowledge of the proportion of chlorine in water often throws important light upon the history of the water as regards its previous contamination with the liquid, as distinguished from the solid, excrements of animals. Human urine contains about 500 parts of chlorine or 824 parts of common salt in 100,000 parts, whilst upland surface water free from previous or present pollution rarely contains more than one part of chlorine or 1·648 part of common salt in the same weight; and it is present in but comparatively minute proportion in the solid excrements of animals. Again, in the case of the metropolitan water supply, the proportion of chlorine has sometimes afforded evidence of the admixture of the brackish tidal waters of the polluted reaches of the *Thames* with the contents of the storage reservoirs, some of which reservoirs are situated on the banks of the river and below high water mark. By this means the admission of tidal water into the reservoirs of one of the London companies was detected on several occasions in the year 1868, and the culvert, through which this water was admitted, has since been removed. It is scarcely necessary to state that the determination becomes valueless, for the purpose of indicating previous sewage contamination, in the neighbourhood of the sea and of natural deposits of salt. The normal proportion of chlorine, as common salt, existing in British waters which have never been polluted by excrementitious matters is, as just stated, about 1 part in 100,000 parts of water; but it varies considerably in different parts of the country. Thus, at the Land's End with a strong wind from the S.W. even rain water contains as much as 21·8 parts of chlorine in 100,000 parts, while the *Gelder Burn* at Balmoral contained on March 9th, 1872, only ·35 part in 100,000 parts. Unpolluted rivers and lakes in inland countries contain still less. Thus the *Rhine* at Schaffhausen contains only ·2 part, and the lakes of Zug and Zurich ·27 and ·17 part respectively in 100,000 parts of water. The proportion of chlorine in rain water varies in like manner, and the variation is also here doubtless due to the varying distance from the sea at which the rain falls. Thus, whilst rain water at the Land's End was found to contain 21·8 parts, the average proportion in rain at Rothamsted was only ·33 part.

Dr. R. Angus Smith, F.R.S., Your Majesty's Inspector General of Alkali Works, has made numerous determinations of chlorine in rain water. We give an abstract of his results in the following table:—

Average Chlorine in Rain Water.

Expressed in Parts per 100,000.

Rain obtained from	Chlorine.
London, specimens for 1869	·12
Birkenhead, Liverpool	·31
Scotland, inland country places	·33
Near an alkali works	·33
England, inland country places	·39
Manchester, 1870	·56
„ average of 1869 and 1870	·57
Scotland, towns (Glasgow not included)	·57
Manchester, 1869	·57
Newcastle-on-Tyne	·79
England, towns	·85
Glasgow	·87
St. Helen's	·93
Liverpool	·99

Average Chlorine in Rain Water—*continued.*

Part I. Chemical Examination.

Chlorine in waters.

Rain obtained from	Chlorine.
Scotland—sea-coast country places, west	1·19
„ „ „ „ average of, east and west.	1·22
Scotland—sea-coast country-places, east	1·26
Runcorn	2·50
Waterloo, near Liverpool	3·55
Ireland, Valentia	4·73
England—sea-coast country place, west, only one	5·46

Samples of rain water collected and analysed for us by Mr. J. Broughton, B.Sc., the Government Chemist on the Cinchona plantations at Ootacamund in India, contained only ·04 part of chlorine in 100,000 parts of water during the S.W. monsoon in the spring of 1870, and ·03 part when the wind blew from the N.E. In different parts of Great Britain the proportion of chlorine in unpolluted upland surface waters varies between wide limits, being greatest in Cornwall and Devonshire where all winds, except the east, are liable to carry sea spray, less on the eastern side of the island which is sheltered from the westerly gales that bring rain and spray from the Atlantic, and least in the midland districts of England and the eastern side of Scotland. Of ten unpolluted samples of water from Cornwall and Devonshire the maximum, minimum, and average proportion of chlorine in 100,000 parts, were as follow :—

Maximum	2·10
Minimum	1·20
Average	1·53

In twenty-nine samples from the Midland districts of England the proportions were :—

Maximum	1·52
Minimum	·57
Average	·99

The proportions in forty-three samples collected on the west coast of England were :—

Maximum	2·00
Minimum	·52
Average	1·12

The proportions in thirteen samples collected on the north-east coast of England were :—

Maximum	1·59
Minimum	·65
Average	1·04

Twenty-three samples collected in the river basins on the western side of Scotland contained chlorine in the following proportions :—

Maximum	1·52
Minimum	·70
Average	1·114

Lastly forty samples taken in the eastern river basins of Scotland contained the following proportions of chlorine :—

Maximum	1·40
Minimum	·35
Average	·841

Besides the contributions of chlorine which water receives from the ocean and from inland saline deposits, many polluting agents furnish considerable quantities of this element. We have already mentioned that the liquid excrements of animals abound in chlorine in the shape of common salt. The drainage from sewers, middens and cesspools is consequently rich in chloride of sodium. Twenty samples of sewage from towns in which the midden system prevailed contained the following proportions of chlorine in 100,000 parts :—

Maximum	21·5 parts.
Minimum	6·5 „
Average	11·54 „

Part I. Chemical Examination.

Chlorine in waters.

In thirty-six samples of sewage from towns in which the watercloset system prevailed, the following proportions were observed:—

Maximum	- - - -	21·5 parts.
Minimum	- - - -	4·0 „
Average	- - - -	10·66 „

The pollution of water by the washings of the solid excrements of animals imparts comparatively little chlorine to water. Thus seventeen samples of drainage water from fields dressed with farmyard manure and night soil contained in 100,000 parts the following proportions of chlorine:—

Maximum	- - - -	3·35 parts.
Minimum	- - - -	·60 „
Average	- - - -	1·54 „

Of refuse liquids from manufactories seven samples of drainage water from works in which calico was printed, dyed and bleached, gave the following proportions of chlorine in 100,000 parts of the water:—

Maximum	- - - -	7·29 parts.
Minimum	- - - -	1·48 „
Average	- - - -	3·56 „

In fifteen samples of drainage water from factories in which wool was scoured, dyed and fulled, the following proportions of chlorine were observed:—

Maximum	- - - -	160·00 parts.
Minimum	- - - -	1·50 „
Average	- - - -	20·69 „

In seven samples of drainage water from mills in which linen, flax, and jute, were bleached, dyed and spun, contained the following proportions of chlorine:—

Maximum	- - - -	832·25 parts.
Minimum	- - - -	4·29 „
Average	- - - -	147·13 „

In a sample of refuse liquid from a tannery the proportion of chlorine was 430·8.

The proportions of chlorine in nine samples of drainage water from paper mills were as follow:—

Maximum	- - - -	58·00 parts.
Minimum	- - - -	3·00 „
Average	- - - -	19·12 „

The drainage from alkali works is necessarily rich in chlorine. Four samples exhibited the following proportions:—

Maximum	- - - -	717·50 parts.
Minimum	- - - -	99·28 „
Average	- - - -	538·49 „

Still larger contributions of chlorine are made to water by tinplate, galvanizing and other metal works. Fifteen samples of drainage from such works contained the following proportions:—

Maximum	- - - -	19,750·00 parts.
Minimum	- - - -	8·50 „
Average	- - - -	1,920·30 „

On the other hand, operations in connexion with metalliferous mines contribute comparatively little to the proportion of chlorine in river or spring water. Forty-four samples of effluent water from mines and dressing floors exhibited the following proportions, which are, on the average, not much higher than those contained in unpolluted water:—

Maximum	- - - -	12·40 parts.
Minimum	- - - -	·60 „
Average	- - - -	2·37 „

But the effluent water discharged from collieries and coal-washing establishments is frequently charged with a considerable proportion of chlorine, as is seen from the following proportions observed in twenty-seven samples of such water:—

Maximum	- - - -	71·73 parts.
Minimum	- - - -	1·20 „
Average	- - - -	8·11 „

It is thus evident that, besides the liquid excrements of man and animals, there are many other sources whence excessive proportions of chlorine in potable waters may be derived, and that it would, therefore, be unsafe to convict a water of animal contamination

Part I. Chemical Examination. — Hardness of water.

merely upon the evidence afforded by an excessive proportion of chlorine. Nevertheless, our experience has taught us that, in a vast majority of instances, excessive proportions of chlorine in potable waters are due to excremental pollution; and it would, therefore, only rarely lead to the rejection of good water if all samples, containing such an excessive proportion of chlorine as 5 parts in 100,000 parts of water, were condemned as unfit for domestic use. Of no less than 569 samples of water which our analyses have shown to be good and wholesome there are only 53 which contain more than 5 parts of chlorine in 100,000 parts.

9. *Hardness.*—Some of the mineral substances which occur in solution in potable waters communicate to the latter the quality of hardness. Hard water decomposes soap, and cannot be efficiently used for washing. The chief hardening ingredients met with in potable waters are the salts of lime and magnesia. In the decomposition of soap, these salts form curdy and insoluble compounds, containing the fatty acids of the soap, and the lime and magnesia of the salts. So long as this decomposition goes on the soap is useless as a detergent, and it is only after all the lime and magnesia salts have been decomposed at the expense of the soap, that the latter begins to exert a useful effect; as soon as this is the case, however, the slightest further addition of soap produces a lather when the water is agitated, but this lather is again destroyed by the addition of a further quantity of the hard water. Thus the addition of hard water to a solution of soap, or the converse of this operation, causes the production of the insoluble curdy matter above mentioned. These facts render intelligible the process of washing the skin with soap and hard water:—The skin is first wetted with the water and then soap is applied; the latter soon decomposes all the hardening salts contained in the small quantity of water with which the skin is covered, and there is then formed a strong solution of soap which penetrates into the pores. This is the process which goes on whilst a lather is being produced in personal ablution; and now the lather, and the impurities which it has imbibed, require to be removed from the skin—an operation which can be performed in one of two ways, viz., either by wiping the lather off with a towel, or by rinsing it away with water. In the former case, the pores of the skin are left filled with soap solution; in the latter they become clogged with the greasy, curdy matter which results from the action of the hard water upon the soap solution which had previously gained possession of the pores of the cuticle. As the latter process of removing the lather is the one universally adopted, the operation of washing with soap and hard water is analogous to that used by the dyer and calico-printer when he fixes his pigments in calico, woollen, or silk tissues. The pores of the skin are filled with insoluble, greasy, and curdy salts of the fatty acids contained in the soap, and it is only because the insoluble pigment produced is white, or nearly so, that such a repulsive operation is tolerated. To those, however, who have been accustomed to wash in soft water, the abnormal condition of the skin thus induced is, for a long time, extremely unpleasant.

Of the hardening salts present in potable water, carbonate of lime is the one most generally met with; and to obtain a numerical expression for this quality of hardness, a sample containing 1 lb. of carbonate of lime or its equivalent of other hardening salts in 100,000 lbs. is said to have one degree of hardness. Each degree of hardness indicates the destruction and waste of 12 lbs. of the best hard soap by 100,000 lbs., or 10,000 gallons of the water, when used for washing.

Hard water frequently becomes softer after it has been boiled for some time. When this is the case a portion, at least, of the original hardening effect is due to the bi-carbonates of lime and magnesia. These salts are decomposed in boiling water into free carbonic acid, which escapes as gas, and the carbonates of lime and magnesia. The latter, being nearly insoluble in water, cease to exert more than a very slight hardening effect. As the hardness resulting from the carbonates of lime and magnesia is thus removable by boiling the water, it is designated *temporary hardness*, whilst the hardening effect which is due chiefly to the sulphates of lime and magnesia, and cannot be got rid of by boiling, is termed *permanent* hardness. The *total* hardness of a water is therefore commonly made up partly of temporary and partly of permanent hardness.

Hard water not only acts injuriously when it is used for washing; but, when it is employed for the generation of steam, it forms troublesome and dangerous incrustations in the boiler. A constant supply of hot water has become almost a necessity in every household, but great difficulties are thrown in the way of its attainment by the supply of hard water to towns, owing to the formation of thick calcareous crusts in the heating apparatus. Waters which have much temporary hardness are most objectionable in this respect, and the evil is so great where the heating is effected in

PART I. CHEMICAL EXAMINATION.

Hardness of water.

a coil of pipe, as practically to prevent, in London for instance, the use of this most convenient mode of heating water.

We shall afterwards notice the advantages which a temporarily hard water has over that which is permanently of equal or even less hardness. The property of softening by boiling is, however, practically of not much domestic use, because household water is, even when used hot, either not heated to the boiling point, or is boiled for too short a time to remove more than a small proportion of its temporary hardness. Thus thirteen samples of water drawn on thirteen different days from the kitchen boiler of a dwelling-house and from that of the Athenæum Club were found to be usually nearly as hard as the cold water with which those boilers were supplied, as is seen from the following tabulated results:—

EFFECT OF HEAT UPON THE HARDNESS OF WATER.

Hours at which Sample was drawn.	Hardness of Cold Water.	Hardness of Hot Water.
	°	°
8 P.M.	14·6	13·6
8 P.M.	14·4	13·9
8 A.M.	14·4	13·4
9 P.M.	14·6	11·6
8 A.M.	14·6	7·6
8 P.M.	14·4	11·7
8 A.M.	14·4	12·1
8 P.M.	15·4	14·3
8 P.M.	15·9	11·9
8 A.M.	16·1	11·9
5 P.M.	18·7	18·4
5 P.M.	18·7	18·6
6 P.M.	18·7	18·4

The hardness of rain water as seen from the analytical table at pages 27–29 varies from 0° to 10°. The latter degree of hardness is, however, only attained near the seashore and in rough weather. At Rothamsted, in seventy-one samples, it never exceeded 1°·7 and averaged only 0°·49. The hardness of water which has once touched the earth depends obviously upon the character of the gathering ground or water-bearing stratum over or through which it passes, and also upon the length of time during which it has been in contact with the earth. Calcareous and magnesian soils or strata cause the water passing over or through them to be hard. If the calcareous or magnesian matter contain carbonate of lime or carbonate of magnesia, a portion at least of the hardness will be temporary. If, on the other hand, gypsum (sulphate of lime) be the calcareous material, the hardness will be permanent. Unpolluted water collected from Igneous rocks, either as surface drainage or springs, is the softest. Its hardness varies from 0°·8 to 5°·9, and averages 2°·4. Next to this in softness must be ranged the unpolluted waters from Metamorphic, Cambrian, Silurian, and Devonian rocks, the Millstone Grit, London Clay, and Bagshot Beds, which range from 0°·4 to 32°·5, and average 5°·6. The Lower Greensand also yields very soft water (about 4° of hardness) when the water does not previously percolate through calcareous strata, but this is so rarely the case as to prevent any reliance from being placed upon the softness of Greensand water. The hardness of unpolluted Greensand water sometimes ranges as high as 44°.

Amongst the slightly calcareous strata, the New Red Sandstone generally yields water of moderate hardness, a large proportion of the hardness is, however, frequently permanent. In 51 samples of unpolluted New Red Sandstone water, the temporary hardness ranged from 0° to 19°·8, and averaged 7°·7; whilst the total hardness varied from 5°·7 to 35°·7, and averaged 17°·9.

Of true calcareous strata, the Mountain Limestone yields water of least total hardness, whilst the permanent hardness is in general only a small proportion of the total. The analysis of nineteen samples of unpolluted limestone water showed a total hardness varying from 9°·8 to 27°·9, and averaging 15°·7. The permanent hardness ranged from 3°·3 to 12°·9, and averaged 7°·1.

The Dolomite or Magnesian Limestone generally imparts to water great hardness, a large proportion, and sometimes nearly the whole of which is permanent. This stratum occupies, however, a comparatively small area in this country, and the water from it is consequently but little used for domestic purposes; we have indeed only been able to obtain five samples for examination. These varied in total hardness from 14°·7 to 67°·3, and averaged 41°·2; whilst the permanent hardness varied from 8°·3 to 40°·8, averaging 24°·8, and the temporary hardness from 0°·8 to 26°·5, averaging 16°·4.

The Lias yields water of variable, but always of great hardness. The permanent hardness of water from this geological formation is also invariably high. In ten samples, the total hardness argued from 10°·3 to 50°, and averaged 29°; the permanent hardness varied from 1°·7 to 17°·4, averaging 8°·2; and the temporary hardness from 8°·6 to 35°·3, averaging 20°·9.

The Oolite and Chalk strata yield water of great, but chiefly of temporary hardness. In forty samples of unpolluted Oolitic water which we have examined, the total hardness ranged from 12°·4 to 38°, and averaged 23°·3; the permanent hardness varied from 3°·5 to 13°·5, averaging 6°·2, whilst the temporary hardness was from 6°·6 to 30°, and averaged 17°·1.

In ninety-six samples of unpolluted water from the Chalk, the total hardness ranged from 12°·4 to 50°, and averaged 26°·4; the permanent hardness ranged from 2°·7 to 13°·8, averaging 6°·2, whilst the temporary hardness varied from 6°·8 to 38°·6, and averaged 20°·2.

The Chalk beneath the London Clay yields water which is usually much softer than that obtained from Chalk which is not covered by an impervious stratum. In thirteen samples of water from this source the total hardness ranged from 0°·9 to 48°·5, the average being 18°·4; the permanent hardness varied from 0°·9 to 25°·4, but this extreme number and the extreme of total hardness occurred only in the water from a deep well at Harrow-on-the-Hill. Omitting this well, the extreme total hardness was 28°·2 and the extreme permanent hardness 9°·7; whilst, omitting the Harrow sample, the temporary hardness varied from 0° to 21°·2, and averaged 6°·2.

The Coal Measures yield water of very variable hardness owing to the variety in chemical composition presented by these rocks. The surface waters are generally very soft, but those derived from springs and deep wells are not unfrequently very hard. In sixty samples, the total hardness varied from 2°·3 to 75°, and averaged 14°·7; the permanent hardness ranged from 1°·2 to 48°·5, and averaged 9°·6: whilst the temporary hardness varied from 0° to 28°·2.

Water obtained from any stratum permeable to the foul liquids of sewers, middens, and cess-pits is always hard, and generally exhibits a large proportion of permanent hardness. The food of man and beast contains considerable quantities of lime, nearly the whole of which, in the adult, is discharged in the liquid and solid excrements. In 272 samples of shallow well water polluted by excrementitious matters to such an extent as to exhibit evidence of 10,000 parts and upwards of previous sewage or animal contamination (*see* pages 69–88), the total hardness ranged from 9°·9 to 191°, and averaged 50°·5. The permanent hardness varied from 3°·8 to 164°·3, and averaged 31°·5; whilst the temporary hardness ranged from 0° to 52°, and averaged 19°.

10. *Mineral matters in suspension.*—The mineral matters in suspension in potable water are almost invariably of an innocuous character, but they diminish or altogether destroy the transparency and brilliancy of the water, and impart a repulsive appearance, which often leads to the rejection of a wholesome water for a bright and sparkling though dangerous one. Slow filtration through sand is almost always effective for the removal of visible suspended matters, but the washings of clay soils are very difficult to render bright by sand filtration; and in all cases filtered water, if turbid previous to filtration, is always seen by suitable optical means, to be full of minute suspended particles, although to unassisted vision it is perfectly clear and transparent.

11. **Organic matters in suspension.**—The organic matters in suspension in potable water possess not only all the objectionable qualities of similar matters of mineral origin, but in addition they are sometimes actively injurious (*see* page 140), and they always promote the development of crowds of animalculæ. Their presence in drinking water is therefore much more objectionable than is the occurrence of mineral matters in suspension. Like the suspended mineral matters, the finely divided organic matters in suspension cannot be entirely removed by sand filtration.

In the performance of the analytical operations to which reference has now been made, and of the vast mass of computations involved in the following part of this report we have to acknowledge the valuable aid which we have received from Mr. W. Thorp, B. Sc., who has occupied the position of chief assistant in our laboratory during the whole course of this inquiry. We have also to thank Mr. J. J. Day, Mr. F. Clowes, B. Sc., Mr. J. W. Bell, and Mr. Walter Odling, who were employed during a portion only of the time, for the efficient help which they rendered in the execution of the necessary analytical work.

PART II.

Classification and Chemical Composition of the Potable Waters of Great Britain.

Part II. Classification of Waters.

The results of our investigations show, that as soon as water quits the vaporous condition, and assumes the form of clouds and rain, it becomes more or less contaminated by atmospheric impurities. When it reaches the earth it flows over surfaces, or percolates through strata, more or less soluble, and thus acquires further impurities in addition to, or sometimes in the place of, those which it had previously contracted from the atmosphere. It thus becomes, in some cases more, in others less, suitable for domestic use. The nature of the changes which water suffers from such influences must obviously depend to a great extent upon the character of the geological formations over or through which it passes; and in studying the vast mass of analytical facts which we have collected in reference to potable water it will, therefore, be instructive to classify the various samples, chiefly according to the geological positions of their sources, but also partly according to the condition of the land as to cultivation; the last-named basis of classification being obviously most important in the case of surface waters. It must be clearly understood, however, that in many cases the surface water drains not altogether from the solid rock formations, but also from the superficial deposits which lie upon them.

In making this geological classification we have received important aid from the Officers of the Geological Survey of Great Britain, more especially from Professor A. C. Ramsay, F.R.S., the Director-General of the Survey, and from Messrs. E. Best, W. Whitaker, B.A., William Topley, and C. E. De Rance, Geologists on the English Survey.

Geological, Hyetographical, and Hydrographical Maps of the United Kingdom are added to this report, facing page 24; also a Map of the polluted river basins of Great Britain.

CLASSIFICATION OF THE POTABLE WATERS OF GREAT BRITAIN.

The following is the scheme which we have adopted in the classification of the waters of Great Britain:—

CLASS I.—RAIN WATER.

CLASS II.—UPLAND SURFACE WATERS.

This class includes all those waters which drain chiefly from uncultivated land slightly or not at all manured. It naturally falls into the two following divisions:—

DIVISION I.—WATERS FROM NON-CALCAREOUS STRATA; OR STRATA WHICH CONTAIN NEITHER CARBONATE NOR SULPHATE OF LIME.

DIVISION II.—WATERS FROM CALCAREOUS STRATA.

The first division is sub-divided into the following four sections:—

Section I.—Surface Water from Igneous Rocks.

Section II.—Surface Water from Metamorphic, Cambrian, Silurian, and Devonian Rocks.

Section III.—Surface Water from the Yoredale and Millstone Grits and the Non-Calcareous portion of the Coal Measures.

Section IV.—Surface Water from Lower London Tertiaries and Bagshot Beds.

The second division is broken up into the following five sections:

Section I.—Surface Water from the Calcareous portions of Silurian and Devonian Rocks.

Section II.—Surface Water from Mountain Limestone.

Section III.—Surface Water from the Calcareous portion of the Coal Measures.

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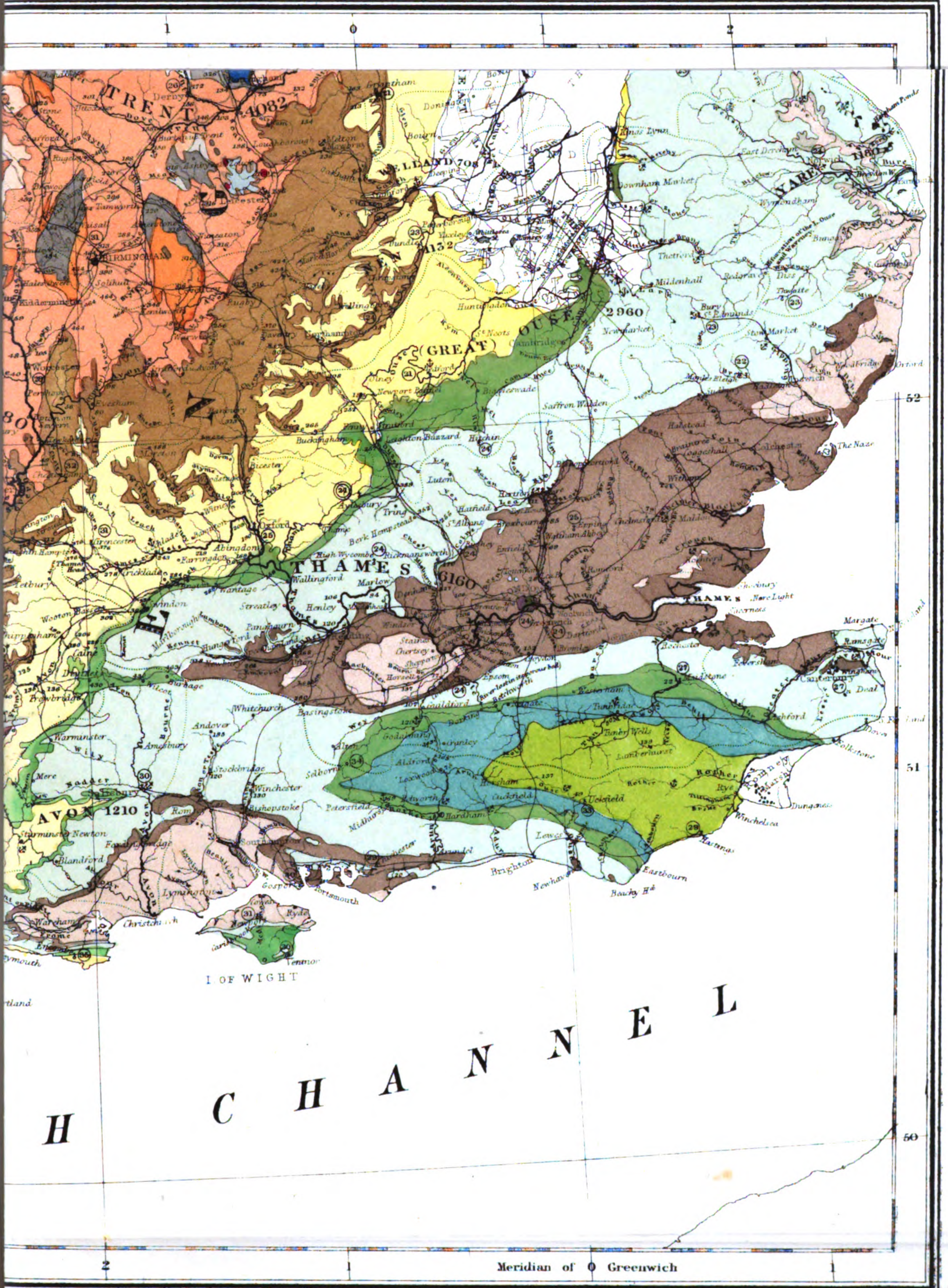
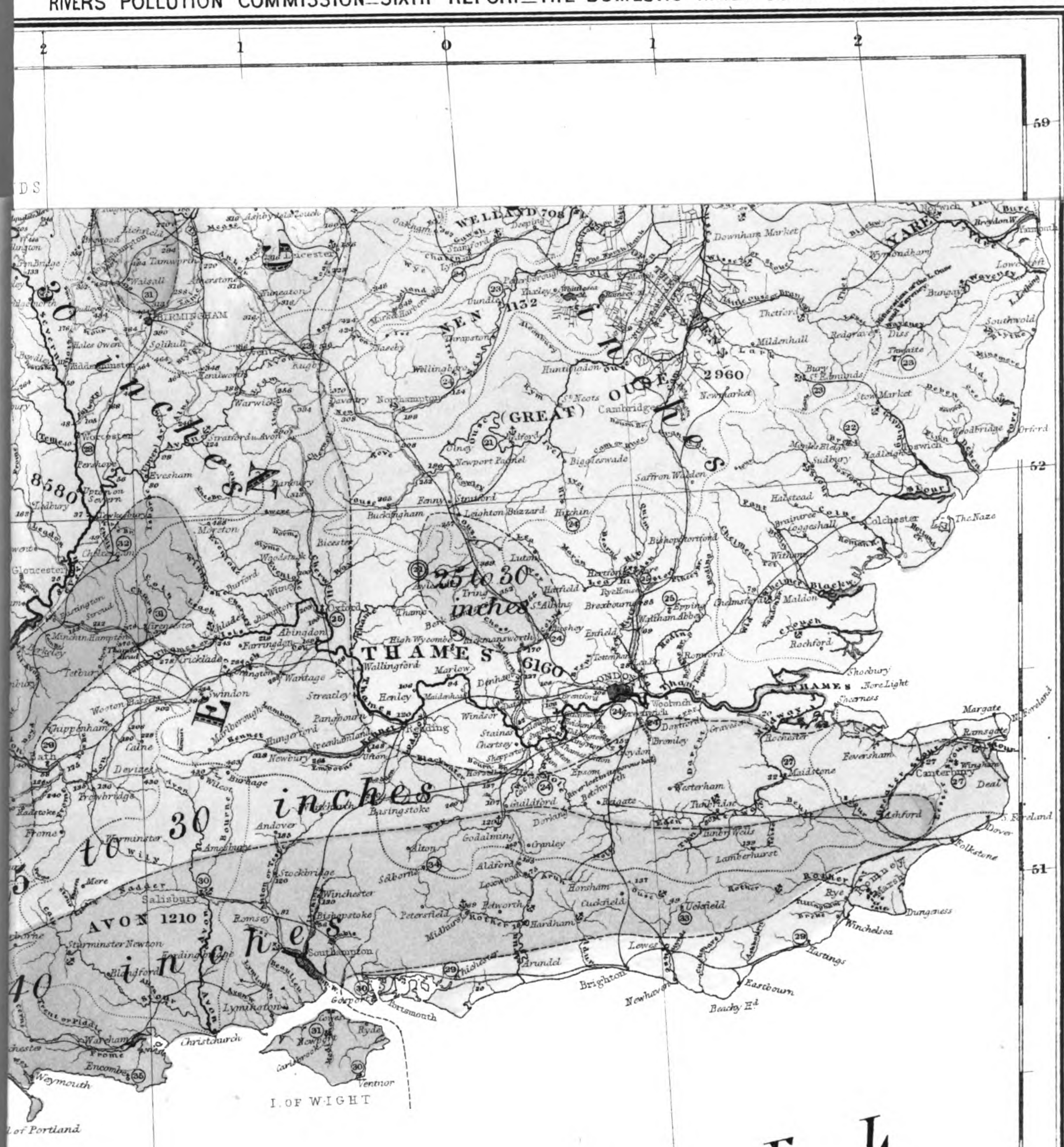


RIVERS POLLUTION COMMISSION – SIXTH REPORT – THE DOMESTIC WATER SUPPLY OF GREAT BRITAIN – 1874.

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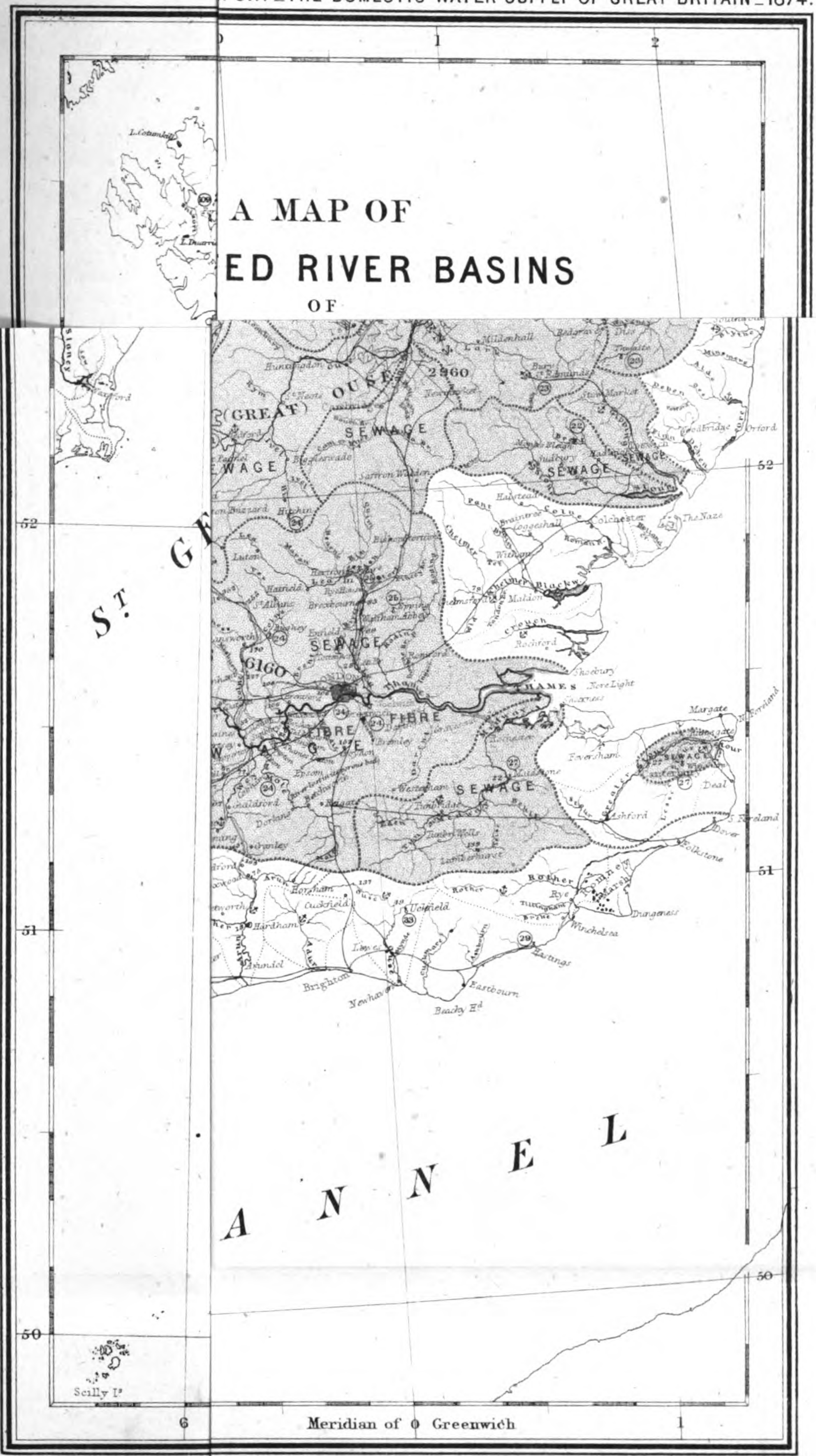

Stanford's Geogl Estabt Charing Cross, S.W.

SECTION IV.—SURFACE WATER FROM THE LIAS, NEW RED SANDSTONE, CONGLOMERATE SANDSTONE, AND MAGNESIAN LIMESTONE.

SECTION V.—SURFACE WATER FROM OOLITES.

CLASS III.—SURFACE WATERS FROM CULTIVATED LAND.

This class embraces all waters which drain from cultivated land, or from fields to which manure is applied. Like the first class it falls into the two following divisions :—

DIVISION I.—SURFACE WATERS FROM NON-CALCAREOUS STRATA.

DIVISION II.—SURFACE WATERS FROM CALCAREOUS STRATA.

The application of manure to land exercises such a dominant influence upon the surface water as to nearly mask geological differences other than those broad ones which distinguish calcareous from non-calcareous strata. It would therefore serve no useful purpose to classify surface waters from cultivated land more minutely by breaking up these divisions into sections.

CLASS IV.—SHALLOW WELL WATERS.

This great class comprehends all those waters which are drawn from wells not more than 50 feet deep and rarely exceeding half that depth. These wells are almost always sunk close to human habitations, and they are then exposed to excremental pollution, which imparts to the water salts of lime even when the well is sunk into an otherwise non-calcareous stratum. It is, therefore, not necessary to adopt the intermediate classification which has been employed in Classes II. and III. Hence Class IV. is immediately subdivided into the following fourteen sections :—

SECTION I.—WATERS FROM SHALLOW WELLS IN SILURIAN ROCKS AND GNEISS.

SECTION II.—WATERS FROM SHALLOW WELLS IN DEVONIAN ROCKS.

SECTION III.—WATERS FROM SHALLOW WELLS IN THE YOREDALE AND MILLSTONE GRITS.

SECTION IV.—WATERS FROM SHALLOW WELLS IN THE COAL MEASURES.

SECTION V.—WATERS FROM SHALLOW WELLS IN MOUNTAIN LIMESTONE AND MAGNESIAN LIMESTONE.

SECTION VI.—WATERS FROM SHALLOW WELLS IN THE NEW RED SANDSTONE.

SECTION VII.—WATERS FROM SHALLOW WELLS IN THE LIAS.

SECTION VIII.—WATERS FROM SHALLOW WELLS IN THE OOLITES.

SECTION IX.—WATERS FROM SHALLOW WELLS IN THE UPPER AND LOWER GREENSAND AND WEALDEN.

SECTION X.—WATERS FROM SHALLOW WELLS IN THE CHALK.

SECTION XI.—WATERS FROM SHALLOW WELLS IN THE GRAVEL ON LONDON CLAY.

SECTION XII.—WATERS FROM SHALLOW WELLS IN BAGSHOT BEDS.

SECTION XIII.—WATERS FROM SHALLOW WELLS IN FLUVIO MARINE SERIES.

SECTION XIV.—WATERS FROM SHALLOW WELLS IN ALLUVIUM AND GRAVEL.

CLASS V.—DEEP WELL WATERS.

These waters have been obtained from boreholes and from wells which are rarely less than 100 feet in depth, and sometimes penetrate as far as 1,285 feet from the surface. The water feeding many of these wells started from the surface in much the same condition as that which supplies shallow wells, but a deep well not only compels originally polluted water to filter through a great perpendicular thickness of strata, but also draws it from great distances in a more or less horizontal direction, and thus the water from deep wells has usually been exposed to an exhaustive process of purification by intermittent filtration. Such purified water is, however, occasionally polluted, either by foul drainage entering the shaft near the surface, or by polluted surface water gaining access to the well through open fissures in the rocks

Part II. (Classification. — Spring waters.)

in which it is sunk. Hence it is necessary to distinguish two divisions in this class of waters, viz. :—

DIVISION I.—UNPOLLUTED DEEP WELL WATERS.

DIVISION II.—POLLUTED DEEP WELL WATERS.

The first division is subdivided into the following eleven sections:—

Section I.—Unpolluted Water from Deep Wells in Devonian Rocks.

Section II.—Unpolluted Water from Deep Wells in Millstone Grit.

Section III.—Unpolluted Water from Deep Wells in the Coal Measures.

Section IV.—Unpolluted Water from Deep Wells in Magnesian Limestone.

Section V.—Unpolluted Water from Deep Wells in New Red Sandstone.

Section VI.—Unpolluted Water from Deep Wells in the Lias.

Section VII.—Unpolluted Water from Deep Wells in Oolites.

Section VIII.—Unpolluted Water from Deep Wells in Hastings Sand and in the Lower and Upper Greensand and Weald Clay.

Section IX.—Unpolluted Water from Deep Wells in the Chalk.

Section X.—Unpolluted Water from Deep Wells in Chalk below London Clay.

Section XI.—Unpolluted Water from Deep Wells in Thanet Sand and Drift.

The second division (Polluted Deep Well Waters) of this class is represented by but few samples, as the pollution of deep wells does not often occur. It is not, therefore, necessary to make any formal classification of this division into sections. We have, however, given in each case the name of the stratum into which the polluted well is sunk.

CLASS VI.—SPRING WATERS.

This large and important class consists of waters which closely resemble that obtained from deep wells in their general chemical character. Though rarely liable to pollution, we have found some examples in which contamination by actual organic matter has occurred, owing, no doubt, either to the shallow source of the spring, or to the admission of polluted surface water through open fissures. It is therefore necessary to subdivide spring, like deep well waters, into two divisions, viz. :—

DIVISION I.—UNPOLLUTED SPRING WATERS.

DIVISION II.—POLLUTED SPRING WATERS.

The first division is further classified into the following fourteen sections:—

Section I.—Unpolluted Spring Water from Granite and Gneiss.

Section II.—Unpolluted Spring Water from Silurian Rocks.

Section III.—Unpolluted Spring Water from Devonian Rocks, and Old Red Sandstone.

Section IV.—Unpolluted Spring Water from Mountain Limestone.

Section V.—Unpolluted Spring Water from the Yoredale and Millstone Grits.

Section VI.—Unpolluted Spring Water from the Coal Measures.

Section VII.—Unpolluted Spring Water from Magnesian Limestone.

Section VIII.—Unpolluted Spring Water from the New Red Sandstone.

Section IX.—Unpolluted Spring Water from the Lias.

Section X.—Unpolluted Spring Water from the Oolites.

Section XI.—Unpolluted Spring Water from the Lower Greensand and Hastings Sand.

Section XII.—Unpolluted Spring Water from the Upper Greensand.

Section XIII.—Unpolluted Spring Water from the Chalk.

Section XIV.—Unpolluted Spring Water from Fluvio-Marine, Drift, and Gravel.

Polluted spring waters are, like polluted deep-well waters, of comparatively rare occurrence, and it is, therefore, not necessary further to subdivide the second division of this class.

CHEMICAL COMPOSITION OF THE POTABLE WATERS OF GREAT BRITAIN.

CLASS I.—RAIN WATER.

In the investigation of the composition of rain water we have been indebted to the courtesy of Mr. J. B. Lawes, F.R.S., and Dr. J. H. Gilbert, F.R.S., for the collection of samples upon Mr. Lawes's experimental farm at Rothamsted, near St. Albans, 25 miles from London; where a leaden rain collector $\frac{1}{1000}$th of an acre area has been erected. This collector stands in the middle of an arable field, and is supported at a height of two feet above the ground, and about 420 feet above the sea-level. The rain is delivered by a spout into a glass carboy placed beneath the apparatus. We have also collected a sample in London, and one at the Land's End when a S.W. wind was blowing. The following table contains the results of our analyses of these samples:—

Composition of Rain Water.

Results of Analysis expressed in Parts per 100,000.

Description and Date of Collection.	Approximate direction of Wind.	Dissolved Matters.												Remarks.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
From Rothamsted Rain Collector. 1869.													
During thunderstorm, 9 a.m. to to 4.30 p.m. April 14.	S.W. to S.E.	5·04	**·143**	**·022**	·126	0	·126	720	·35	0	·6	·6	No arsenic. Trace of phosphoric acid.
From April 14, 4.30 p.m., to April 16, 9 a.m.	S.E. to S.W.	8·58	**·135**	**·024**	·070	0	·082	260	·46	·9	·7	1·6	Trace of phosphoric acid.
From 9 a.m. to 4.30 p.m., April 16.	S.W.	7·54	**·153**	**·024**	·040	0	·057	10	·59	·9	·3	1·2	Do.
From April 16, 4.30 p.m., to April 17, 9 a.m.	S.W.	7·00	**·133**	**·004**	·055	0	·049	130	·26	·6	·4	1·0	Do.
From 9 a.m. to 4.30 p.m., April 17.	S.W. to N.W.	5·92	**·155**	**·019**	·040	0	·052	10	·40	·3	1·1	1·4	Do.
From April 17, 4.30 p.m., to April 20, 4.30 p.m.	N.W. to S.W.	8·16	**·210**	**·006**	·155	0	·134	960	·93	·3	1·2	1·5	Do.
From April 20, 4.30 p.m., to April 21, 9 a.m.	S.W.	7·06	**·121**	**·015**	·040	0	·048	10	·43	0	·1	·1	
From 9 a.m. to 4.30 p.m. April 23, distant thunder.	S.W.	6·60	**·348**	**·019**	·060	0	·055	170	·35	—	—	·3	
From April 23, 4.30 p.m., to April 24, 9 a.m., continuous and copious fall.	S.W. to N.W.	2·30	**·166**	**·003**	·055	0	·048	130	·16	—	—	0	Metallic arsenic =·002.
From May 3, 4.30 p.m., to May 4, 9 a.m.	S.E. to N.E.	4·22	**·131**	**·026**	·040	0	·059	10	·19		—	·5	
From 9 a.m. to 4.30 p.m., May 4.	N.E.	2·50	**·117**	**·015**	·011	0	·024	0	·14	—	—	0	Metallic arsenic =·001.
From May 5, 4.30 p.m., to May 6, 9 a.m.	N.E. to S.E.	4·20	**·139**	**·031**	·055	0	·076	130	·23	—	—	·2	
From 4.30 p.m., May 17, to 9 a.m., May 18, 1869.	S.W.	3·44	**·109**	**·017**	·026	0	·038	0	·38	—	—	·3	Showery.
From 8 to 9 a.m., May 18	S.W.	5·20	**·105**	**·023**	·018	0	·038	0	·41	—	—	·1	Do.
From 9 a.m. to 4.30 p.m., May 18, 1869.	S.W.	4·14	**·122**	**·023**	·026	0	·044	0	·35	—	—	0	Heavy showers.
From 3 to 4 p.m., May 18, 1869	S.W.	4·20	**·104**	**·021**	·020	0	·037	0	·35	—	—	·1	Do.
From 9 a.m. to 4.30 p.m., May 19, 1869.	S.W.	3·24	**·128**	**·018**	·018	0	·033	0	·22	—	—	0	Heavy showers with thunder.
From 10 to 11 a.m., May 19, 1869.	S.W.	7·90	**·100**	**·009**	·005	0	·013	0	·16	...	.	0	Do.
From May 22, 9 a.m., to May 23, 9 a.m.	N.W. to S.W.	3·30	**·113**	**·009**	·075	0	·071	300	0	—	—	·5	No arsenic.

COMPOSITION OF RAIN WATER—*continued.*

DESCRIPTION AND DATE OF COLLECTION.	Approximate direction of Wind.	Dissolved Matters.											REMARKS.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
FROM ROTHAMSTED RAIN COLLECTOR.													
From May 27, 4.30 p.m., to May 28, 9 a.m.	N.E.	2·58	·	**·012**	·065	·004	·070	260	·60	—	—	·3	
May 28, from 9 a.m. to 10 a.m.	N.E.	2·70	**·027**	**·009**	·030	·015	·049	80	·55	—	—	·6	
From June 11, 9 a.m., to June 14, 9 a.m.	N.W.	2·28	**·051**	**·010**	·060	·040	·099	570	·80	—	—	·1	
June 14, at 6.30 a.m. - -	N.W.	·62	**·026**	**·008**	·041	·010	·052	120	·30	—	—	—	
From June 14, 9 a.m., to June 15, 9 a.m.	N.W. to S.W.	1·60	**·095**	**·016**	·025	·013	·050	20	·45	—	—	·1	Hailstorm.
From 9 a.m. to 4.30 p.m., June 15	N.W.	2·54	**·045**	**·005**	·065	·017	·076	390	·45	—	—	1·4	Do.
From 4.30 p.m., July 22 to July 28, 9 a.m.	S.W. to S.E.	2·84	**·127**	**·039**	·080	0	·105	340	·20	—	—	1·4	No arsenic.
July 28, at 9 a.m. - -	S.E.	1·80	**·056**	**·007**	·020	0	·023	0	0	—	—	·1	
At 4.30 p.m., August 3 -	S.W.	1·34	**·041**	**·010**	·010	0	·018	0	0	—	—	·1	
From 7.30 to 8 a.m., August 13	S.W.	2·16	**·062**	**·007**	·027	0	·029	0	·10	—	—	·8	
From September 1, 9 a.m., to September 6, 9 a.m.	N.E. to S.W.	4·52	**·096**	**·032**	·080	0	·098	340	·45	—		1·4	No arsenic.
From 6 to 7 a.m., September 10	S.E.	1·37	**·086**	**·030**	·056	0	·076	140	0	—	—	1·0	No arsenic; thunder rain. Collector washed previously.
From 9 a.m. to 4.30 p.m., September 10.	S.E. to S.W.	1·51	**·071**	**·020**	·028	0	·043	0	0	—	—	·1	
From 6 to 7 a.m., September 12	N.W.	1·87	**·071**	**·016**	·027	·003	·041	0	·25	—	—	·4	
From September 13, 4.30 p.m., to September 14, 9 a.m.	N.W. to S.W.	2·35	**·054**	**·014**	·020	0	·030	0	·40	—	—	·4	
From September 18, 4.30 p.m. to September 19, 9 a.m.	S.W.	1·88	**·040**	**·005**	·018	—	—	—	·12	—	—	0	
From September 30, 9 a.m., to October 1, 9 a.m.	S.E. to S.W.	1·32	**·025**	**·011**	·016	0	·024	0	0	—	—	0	
From October 12, 9 a.m., to October 13, 9 a.m.	S.W.	2·08	**·028**	**·006**	·030	0	·031	0	0	—	—	0	Collector washed.
From October 18, 4.30 p.m., to October 19, 9 a.m.	S.W. to N.W.	1·78	**·070**	**·012**	·025	0	·033	0	·15	—	—	0	Do.
From October 24, 9 a.m., to October 26, 9 a.m.	N.W.	3·02	**·053**	**·010**	·035	0	·039	0	·20	—	—	·4	Collector washed October 25.
From 9 a.m., to 4.30 p.m., November 22.	N.W.	1·80	**·041**	**·008**	·008	0	·015	0	0	—	—	·1	
From November 26, 9 a.m., to November 27, 4.30 p.m.	N.W. to S.W.	1·91	**·032**	**·007**	·011	0	·016	0	0	—	—	·7	Collector washed.
From November 30, 4.30 p.m., to December 4, 9 a.m.	N.E.	3·60	**·131**	**·043**	·075	0	·105	300	·80	—	—	·6	Snow.
1870.													
From January 24 to January 31, 9 a.m.	N.E. to S.E.	7·14	**·275**	**·121**	·150	·006	·250	970	1·35	—	—	1·7	Sample frozen.
From 12 noon to 4.30 p.m., January 31.	S.E.	3·46	**·188**	**·036**	·090	·013	·123	550	·35	—	—	·6	Collector washed at noon.
From 9 a.m. February 1, to 9 a.m. February 2.	S.E.	2·68	**·036**	**·017**	·042	·005	·057	80	·35	—	—	·3	
From 9 a.m. to 4.30 p.m., February 2.	S.E.	2·84	**·070**	**·016**	·048	·002	·058	100	·35	—	—	·3	
From 4.30 p.m., February 2, to 9 a.m., February 3.	S.E.	2·03	**·058**	**·034**	·040	·023	·090	240	·23	—	—	0	
From 9 a.m., February 4, to 9 a.m., February 5.	S.E.	1·98	**·056**	**·023**	·045	·003	·063	80	·17	—	—	0	
From 4.30 p.m., February 5, to 4.30 p.m., February 6.	S.E.	3·80	**·110**	**·033**	·045	·013	·083	180	·40	—	—	·4	
From 4.30 p.m., February 6, to 9 a.m., February 7.	S.E.	1·71	**·060**	**·017**	·014	·004	·033	0	·15	—	—	0	
From 4.30 p.m., February 7, to 9 a.m., February 8.	S.E.	2·85	**·137**	**·040**	·075	·036	·138	660	·45	—	—	0	
From 4.30 p.m., February 8, to 9 a.m., February 16.	S.E. to N.E.	2·96	**·128**	**·078**	·127	·026	·209	990	·65	—	—	·3	Snow water.
From 4.30 p.m., February 16, to 4.30 p.m., February 19.	N.E.	7·00	**·156**	**·056**	·140	·023	·194	1,060	1·65	—	—	1·5	Collector washed, Feb. 17, p.m.
From 4.30 p.m., February 19, to 9 a.m., February 21.	N.E. to N.W.	4·30	**·099**	**·016**	·077	·013	·092	440	·80	—	—	1·0	Collector washed, Feb. 21, p.m. and Feb. 26, a.m.
At 4.30 p.m., March 1 -	S.W.	3·64	**·034**	**·025**	·040	·004	·062	50	·50	—	—	·6	
From 4.30 p.m., March 1, to 9 a.m., March 2.	S.W.	1·50	**·027**	**·014**	·020	·011	·041	0	·12	—	—	0	
From 7 to 9 a.m., March 4 -	N.E.	1·94	**·089**	**·025**	·035	·005	·059	20	·50	—	—	1·0	Snow, hail, and rain.
From 9 a.m. to 3.30 p.m. March 4	N.E.	1·54	**·027**	**·019**	·025	·003	·043	0	·35	—	—	0	Do.
From 3.30 p.m., March 4, to 9 a.m., March 5.	N.E.	2·84	**·054**	**·026**	·045	·012	·075	170	·70	—	—	·5	Do.
From 9 a.m., March 12, to 9 a.m., March 13.	N.W.	3·64	**·037**	**·022**	·020	·004	·042	0	·30	—	—	·9	Snow water. Collector washed, Mar. 7, and Mar. 12, 7 a.m.
From 9 a.m., March 14, to 9 a.m., March 16.	N.W. to S.W.	3·66	**·043**	**·025**	·055	·009	·079	220	·35	—	—	·7	
From 9 a.m., March 16, to 9 a.m., March 17.	S.W.	2·78	**·037**	**·011**	·022	·001	·030	0	·10	—	—	·2	
From 7 to 8 p.m., April 26 -	N.W.	2·86	**·021**	**·010**	·025	·001	·032	0	·10	—	—	·2	Collector washed.
From 4.30 p.m., April 29, to 9 a.m., April 30.	S.W. to N.W.	3·20	**·034**	**·027**	·045	·044	·108	490	·08	—	—	·3	Do.
From 9 a.m., May 1, to 9 a.m., May 2.	N.W. to S.W.	3·22	**·099**	**·004**	·080	·021	·091	550	·22	—	—	·2	Thunder, rain.

COMPOSITION OF RAIN WATER—*continued.*

DESCRIPTION AND DATE OF COLLECTION.	Approximate direction of Wind.	Dissolved Matters.											REMARKS.
		Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
FROM ROTHAMSTED RAIN COLLECTOR.													
At 3 p.m., May 11	S.E.	4·08	**·093**	**·018**	·130	·018	·143	930	·10	—	—	1·4	Collector washed at 11.30 a.m.
At 4.30 p.m., May 11	S.E.	2·94	**·062**	**·019**	·045	·013	·069	180	·08	—	—	0	
From 4.30 p.m., May 11, to 9 a.m., May 12.	S.E.	2·10	**·026**	**·016**	·025	·012	·049	10	·10	—	—	0	
From 9 a.m. to 4.30 p.m., May 12	S.E. to S.W.	4·50	**·119**	**·020**	·033	·023	·070	180	·80	—	—	·4	
From 9 a.m. to 4.30 p.m., May 13	S.W.	3·26	**·080**	**·019**	·025	·017	·057	60	·25	—	—	·7	
1872.													
From 9.30 a.m. to 4.30 p.m., January 26. The greater part fell between 2 and 4 p.m.	S.E.	2·68	**·372**	**·066**	·095	·029	·173	750	·45	—	—	1·4	Collected during very unusual darkness.
1873.													
CORNWALL.													
Rainwater from landward roof of Land's End Hotel, January 2.	S.W.	42·80	**·131**	**·034**	0	·020	·054	0	21·80	0	10·0	10·0	Suspended matter; mineral = ·25; organic = ·39.
MIDDLESEX.													
Rainwater collected at Lancaster Gate, Hyde Park, November 8.	S.W.	2·76	**·383**	**·040**	·210	·008	·221	1,490	·50	0	1·1	1·1	
Average		3·95	**·099**	**·022**	·050	·007	·071	220	·63	·3	1·7	·62	

Note.—The numbers in this and the following analytical tables can be converted into grains per imperial gallon by multiplying them by 7 and then moving the decimal point one place to the left. The same operation transforms the hardness in the tables into degrees of hardness on Clark's scale.

These results of the analytical examination of samples of rain show that this kind of water, even when collected at a distance of twenty-five miles from any large town, is by no means so uniformly free from impurities as is commonly supposed, and we have every reason to believe that when rain water is collected from the roofs of houses and stored for domestic use in tanks, it generally contains, especially if the latter are underground, far more impurity than was found in the samples enumerated in the foregoing table. Indeed five out of eight samples of stored rain water which we have examined were, very badly polluted, as is seen from the following results which they yielded on analysis.

COMPOSITION OF RAIN WATER STORED FOR DOMESTIC USE.
RESULTS of ANALYSES expressed in parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Rain water collected in tank at Oakham, Rutland, May 30, 1870.	11·70	**·331**	**·090**	·005	·094	·188	**660**	1·10	·4	4·6	5·0	Small quantity of suspended matter.
Soft water pump, Morley's yard, Greaseley, Notts, June 1871.	10·80	**·127**	**·031**	·012	·261	·302	**2,390**	1·20	·7	5·1	5·8	Slightly turbid.
Briggs' soft water cistern, Brook Hill, Greaseley, Notts, June 1871.	126·60	**·672**	**·301**	·730	7·910	8·812	**84,790**	11·50	4·2	51·5	55·7	Do.
Rain water from tank supplying cottages at Epsom, August 1872.	8·10	**·167**	**·021**	·009	·301	·330	**2,770**	·90	0	3·9	3·9	Contained a few suspended particles.
Ditto, September 24, 1872	8·50	**·248**	**·058**	0	·228	·286	**1,960**	·70	0	3·9	3·9	Turbid.
Rain water from tank of four cottages at Shurville Hill, Goring, Nov. 20, 1873.	9·42	**·215**	**·061**	·032	·072	·159	**660**	·80	·4	7·5	7·9	Clear.
Water from Mr. Allen's rain water tank, Podehole, near Spalding (unfiltered), Nov. 24, 1873.	5·28	**·142**	**·029**	0	·031	·060	**0**	·90	0	3·8	3·8	Slightly turbid.
Rain water from N.E. tank in rear of North Cavalry Soldiers' Block, Sheffield Barracks, Dec. 8, 1873.	12·00	**·154**	**·053**	·130	·227	·387	**3,020**	1·60	0	5·0	5·0	Turbid.
Average	24·05	**·257**	**·080**	·115	1·140	1·315	**12,031**	2·34	·7	10·7	11·4	

Note.—For the translation of these numbers into grains per gallon, *see* note to preceding table.

PART II. CLASSIFICATION.

Rain water.

Only one of these samples was fit for domestic use, viz., that taken from Mr. Allen's rain water tank; the others were all polluted by animal matter. The so-called soft water collected in a cistern at Brook Hill, Greasley, consisted of sewage of even greater strength than average London sewage.

In the rain falling at Rothamsted the proportion of total solid impurity ranged from ·62 part to 8·58 part in 100,000 parts, the minimum occurred in a sample collected at 6.30 a.m. on the 14th June 1869 when the wind was blowing from the N.W., and the maximum in an average sample collected from 4.30 p.m. on April 14th, to 9 a.m. on April 16th, 1869, the wind having varied during the time from S.E. to S.W. The total solid impurity averaged in seventy-one samples 3·42 parts in 100,000 of water. It is very difficult to preserve average samples of rain water collected over a period of many hours from contamination by the excrements of birds and by other terrestrial polluting matters, but in the list of samples enumerated in the analytical table at pages 27–29 there are fifteen samples each collected during a brief period and under personal supervision. In these samples, however, the total solid impurity varied from ·62 part in one of the samples just mentioned to 7·9 parts per 100,000 which were extracted from a sample collected from 10 to 11 a.m. on the 19th of May 1869, when the wind was blowing from the S.W., the average being 2·97 parts in 100,000 of water.

The direction of the wind exercises great influence upon the proportion of solid impurities in the rain falling at Rothamsted. The S.W. wind brings the greatest, and the N.W. wind the least proportion of foreign matters, as is seen from the following table:—

TOTAL SOLID IMPURITY in 100,000 parts of RAIN WATER.

Wind.	N.E.	S.E.	S.W.	N.W.
Maximum - -	2·70	4·08	7·90	2·86
Minimum - -	1·94	1·37	1·34	·62
Average - -	2·32	2·55	4·07	1·78
No. of samples -	2	4	6	3

The organic elements contained in 100,000 parts of the rain water falling at Rothamsted varied from ·031 part in the rain which fell from 7 to 8 p.m. on the 26th April 1870, when the wind was blowing from the N.W., to ·438 part in the rain which fell chiefly between 2 and 4 p.m. on the 26th January 1872 during very unusual darkness, and when the wind was from the S.E.—the direction of London. The average proportion of organic elements in the seventy-one samples collected at Rothamsted was ·116 part in 100,000 parts of water. It is, as already stated, very difficult to preserve average samples of rain water collected over a period of several hours duration from contamination by the excrements of birds and by other terrestrial polluting matters, and it was found that samples collected under personal supervision were much less contaminated with organic matters. The organic elements in the latter samples varied from ·128 part in the rain which fell from 8 to 9 a.m on the 18th May, 1869, when the wind blew from the S.W., to ·031 part per 100,000 parts, in the rain collected from 7 to 8 p.m. on the 26th April 1870, when the wind came from the N.W., the average being ·081 part of organic elements in 100,000 parts of water. By comparison with the average of organic elements contained in spring and deep well waters given at pages 131 and 409 it will be seen that even specially collected rain water contains more organic polluting matter than that present in water which has undergone an exhaustive treatment by natural intermittent filtration, whilst the best rain water that could be collected from the roofs of houses is far less pure as regards organic pollution than water derived from deep wells or deep seated springs. This result is not surprising when we reflect that the atmosphere, in a densely peopled country like Great Britain, is the recipient of vast aggregate quantities of impurity, derived partly from the respiration of animals, partly from the combustion of enormous quantities of fuel, and partly from excremental dust, the fine particles of which, in dry windy weather, become suspended in the air to the extent, over the area of this country, of hundreds of tons, and remain there for weeks unless washed out by rain. The condensation of moisture in the form of clouds in such an atmosphere must of necessity include the imprisonment of these dispersed particles in the excessively minute globules of water which constitute cloud and fog. Thus rain is in reality water which has washed a more or less dirty atmosphere. It is laden with mineral and excrementitious dust, zymotic germs, and the products of animal and vegetable decay and putrefaction. A half-pint of rain water often condenses out of about 3,373 cubic feet of air; and thus, in drinking a tumbler of such water, impurities, which would only gain access to the lungs in about 8 days, are swallowed at once. In Great Britain, and more especially in England, we shall, therefore, look in vain to the atmosphere for a supply of water pure enough for dietetic purposes. Doubtless such water can be occasionally collected under favourable circumstances of wind and rainfall, but the average of water so collected, even in favoured localities, would probably always be found to be much below the standard of purity which is easily obtained from springs and deep wells.

Part II. Classification. — Rain water

The direction of the wind has less influence upon the proportion of organic impurity in the rain water collected at Rothamsted than might be expected; nevertheless, when the wind blows from quarters between S.E. and N.E. it delivers rain distinctly more highly charged with organic impurity than when coming from any other point. Thus in four samples, collected when the direction of the wind was between these points of the compass, the maximum proportion of organic elements was ·396 part, the minimum ·157 part, and the average ·232 part in 100,000 parts of water. When the wind blew from the S.E., the maximum proportion was ·438 part, the minimum ·042 part, and the average in fourteen samples ·127 part in 100,000 parts of water. Six samples, collected when the wind blew from points between S.W. and S.E., contained a maximum of ·166 part, a minimum of ·036 part, and an average of ·126 part of organic elements in 100,000 parts. Eighteen samples, collected when the wind blew from S.W., averaged ·114 part of organic elements in 100,000 parts of water, the maximum being ·39 part, and the minimum ·034 part. In eleven samples, collected when the wind blew from N.W. to S.W., the average proportion was ·110 part, the maximum being ·216 part and the minimum ·039 part in 100,000 parts of water. Rain from the N.E. contained a still smaller proportion of organic elements, the average of eight samples being ·109 part, the maximum ·212 part, and the minimum ·036 part in 100,000 parts of water. Of all winds, however, that blowing from the N.W. delivers rain at Rothamsted with by far the smallest proportion of organic elements. In eight samples the average was only ·054 part, the maximum being only ·087 part, and the minimum ·031 part in 100,000 parts of water. These results are nearly though not entirely in accord with those yielded by the fifteen samples of rain collected under personal supervision, as is seen from the following table, which shows on an average a maximum in rain from the S.E. and a minimum in that from the N.W.

ORGANIC ELEMENTS in 100,000 parts of RAIN WATER.

Wind.	N.E.	S.E.	S.W.	N.W.
Maximum	·114	·116	·128	·087
Minimum	·036	·063	·051	·031
Average	·075	·093	·090	·051
No. of samples	2	4	6	3

We have already remarked at page 14 upon the mineral combined nitrogen, or nitrogen in the form of nitrates, nitrites, and ammonia contained in rain water, and its importance in reference to the estimation of previous sewage or animal contamination in potable waters generally, and we have now only to add that, in the fifteen samples collected under personal supervision, the average proportion of mineral nitrogen was ·034 part in 100,000 parts of water, the maximum being ·125 part and the minimum ·004 part. The influence of the direction of the wind upon the proportion of mineral nitrogen is illustrated by the following table in which the fifteen specially collected samples are embodied :—

MINERAL COMBINED NITROGEN in 100,000 parts of RAIN WATER.

Wind.	N.E.	S.E.	S.W.	N.W.
Maximum	·040	·125	·037	·044
Minimum	·034	·016	·004	·022
Average	·037	·059	·017	·030
No. of samples	2	4	6	3

On the average, therefore, the S.E. wind, which is liable to blow over London before it reaches Rothamsted, delivers rain most highly charged with mineral nitrogen. The N.E. wind comes next, then the N.W., and lastly the S.W. wind deposits rain in which there is not one third as much mineral nitrogen as in the rain from the S.E.

PART II. CLASSIFICATION.

Dew and Hoar Frost.

Finally, the rain at Rothamsted which is most highly charged with chlorides is that which comes from the N.E., that being the direction in which wind that has travelled over a great extent of sea reaches Rothamsted over the shortest stretch of land. The next most intensely chlorinous winds are the S.W. and N.W. which are nearly equal, whilst the rain from the S.E., contains on the average only $\frac{1}{13}$th as much chlorine as that present in the rain from the N.E. The following table, which illustrates these points, is compiled from the results yielded by the fifteen samples of rain which were collected under personal supervision. The proportion of chlorine found in these samples varied from 0 to ·55 part in 100,000 parts of water.

CHLORINE in 100,000 parts of RAIN WATER.

Wind.	N.E.	S.E.	S.W.	N.W.
Maximum	·55	·10	·50	·30
Minimum	·50	0	0	·10
Average	·52	·04	·25	·22
No. of samples	2	4	6	3

A sample of rain water collected by us at a height of about 100 feet above the sea at the Land's End when a strong wind was blowing from the S.W., contained no less than 21·8 parts of chlorine in 100,000 parts of water.

The average proportion of chlorine contained in the fifteen samples was ·23 part in 100,000 parts of water.

We have already remarked on the hardness of these samples of rain water at page 22.

DEW AND HOAR FROST.

Closely connected with rain water, in character, are the deposits of dew and hoar frost, several samples of which, collected on the leaden gauge described on pp. 14 and 27, we have submitted to analysis with the results enumerated in the following table:—

COMPOSITION OF DEW AND HOAR FROST.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.
Collected from May 12 to June 7, 1869	5·42	**·214**	**·052**	·194	·049	·261	1,770	·60	1·4
Ditto from July 17 to August 24, 1869	6·20	**·317**	**·085**	·140	·050	·250	1,330	·55	2·5
Ditto from June 19 to September 28, 1869	8·00	**·268**	**·057**	·210	·032	·262	1,730	·80	2·4
Ditto from October 6 to October 7, 1869	3·20	**·197**	**·073**	·130	0	·180	750	·35	2·4
Ditto from October 10 to October 12, 1869	4·16	**·207**	**·046**	·260	0	·260	1,820	·35	1·6
Ditto from November 17 to November 18, 1869	4·50	**·195**	**·026**	·170	0	·166	1,080	·53	1·6
Ditto { April 2, 1870, 11 oz.; " 4, " 11 oz.; " 5, " 14½ oz.; " 6, " 2 oz.; " 14, " 18½ oz. }	2·64	**·450**	**·196**	·280	·028	·455	2,270	·55	1·3
Average	4·87	**·264**	**·076**	·198	·023	·262	1,536	·53	1·9

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results demonstrate that dew and hoar frost are even still less pure than rain water. They are condensed out of that stratum of atmospheric air which is nearest to the earth's surface, and which consequently contains, in a given volume, more impurities than are present in the higher regions of the air where rain condenses. These forms of water may therefore be regarded as the washings of the most impure portions of the atmosphere. The very large proportion of ammonia contained in all these samples is remarkable; but it need not excite surprise, as it is obviously due to the continuous evolution of ammonia from manured land, and from putrescent animal matter near the surface of the earth.

CLASS II.—UPLAND SURFACE WATERS.

DIVISION I.—WATERS FROM NON-CALCAREOUS STRATA.

SECTION I.—UPLAND SURFACE WATERS FROM IGNEOUS ROCKS.

PART II. CLASSIFICATION.

Upland surface waters.

The following Table contains the results of our analyses of potable waters derived from igneous rocks, or the uncultivated soil resting thereon. All the samples were collected by ourselves personally, except the two from the river *Erme*, near Ivy Bridge, which were forwarded to us through the Local Government Board :—

COMPOSITION OF UPLAND WATER FROM IGNEOUS ROCKS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
CORNWALL AND DEVONSHIRE.												
Brook at Vale Pleasant Clay Works, St. Austell, June 9, 1871.	5·10	**·074**	**·013**	·001	0	·014	**0**	2·10	0	1·2	1·2	Very slightly turbid.
Stream at Gazelan Clay Works, September 20, 1872.	4·28	**·237**	**·026**	·002	·029	·057	**0**	1·80	0	·8	·8	Clear. Yellowish.
Mountain stream above St. Neot's, September 20, 1872.	5·96	**·553**	**·030**	·002	0	·032	**0**	1·70	0	·9	·9	Very turbid.
The *Teign* above Old Wheal Exmouth, September 26, 1872.	6·08	**·582**	**·058**	·004	0	·061	**0**	1·40	·8	1·8	2·6	Turbid. Brownish.
The *South Teign* at Yeo Bridge, September 27, 1872.	3·62	**·166**	**·019**	·001	0	·020	**0**	1·25	0	1·1	1·1	Slightly turbid.
Water supplied to Devonport from Dartmoor, June 2, 1873.	3·50	**·104**	**·024**	0	0	·024	**0**	1·25	0	·8	·8	Very turbid.
The *Erme* above Harford Bridge, near Ivy Bridge, June, 1871.	3·38	**·125**	**·014**	·001	0	·015	**0**	1·20	0	1·1	1·1	Slightly turbid.
The *Erme*, two miles lower down, June, 1871.	3·70	**·112**	**·020**	0	0	·020	**0**	1·30	0	1·4	1·4	" "
SCOTLAND.												
BASINS OF THE DEE AND DON.												
The *Dee* above Balmoral, March 9, 1872.	1·52	**·132**	**·014**	0	0	·014	**0**	·50	0	1·5	1·5	Clear and colourless.
The *Gelder Burn*, at Balmoral, March 9, 1872.	1·98	**·196**	**·019**	0	0	·019	**0**	·35	0	·9	·9	Slightly turbid. Yellowish.
Kentore Den water, Abergeldie, March 9, 1872.	4·68	**·198**	**·036**	0	0	·036	**0**	1·40	·4	2·2	2·6	Turbid.
Water supplied to Aberdeen from the *Dee*, September 12, 1870.	4·36	**·399**	**·029**	0	0	·029	**0**	·56	·4	1·7	2·1	Slightly turbid. Yellowish.
The *Don*, at Alford, March 11, 1872.	5·66	**·112**	**·026**	·001	0	·027	**0**	1·20	·4	3·2	3·6	Very slightly turbid.
BASIN OF THE FORTH.												
The *Bannockburn*, above the village, August 23, 1872.	12·70	**·376**	**·060**	·001	0	·061	**0**	·95	·2	5·7	5·9	Turbid.
Stirling, water supply of, August 21, 1872.	6·44	**·481**	**·045**	·001	0	·046	**0**	·70	0	2·7	2·7	" light brown.
BASIN OF THE CLYDE.												
Dumbarton, water supply of, August 14, 1872.	7·26	**·386**	**·071**	·002	0	·073	**0**	·85	0	3·8	3·8	Clear. Yellowish.
Port Glasgow, water supply of, August 14, 1872.	7·10	**·273**	**·045**	·002	0	·047	**0**	·85	0	3·3	3·3	Very slightly turbid.
Greenock, water supply of, July 26, 1870.	5·42	**·501**	**·037**	·002	0	·039	**0**	1·00	0	1·9	1·9	Yellowish Slightly turbid.
Average - - -	5·15	**·278**	**·033**	·001	·002	·035	**0**	1·13	·1	2·0	2·1	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

Surface waters from Igneous Rocks.

These analytical results, together with the known history of the several samples, lead to the following conclusions:—

Total solid impurity.—Igneous rocks, undergoing as they do the process of weathering but very slowly, and containing but mere traces of matter soluble in water, constitute an excellent gathering ground for the rain falling upon them. Moreover, as these rocks are very slightly absorbent of moisture, a very large proportion of the rainfall flows off their surfaces. As a natural consequence of these qualities of the collecting ground, the water from igneous rocks always contains a very small proportion of total solid matter in solution (total solid impurity). The total quantity of lime and magnesia contained in waters belonging to this section is generally considerably less than one grain per gallon, and the total weight of solid impurity is seen from the above table to vary from 1·52 part in 100,000 parts, or 1·06 grain per gallon, in the *Dee* at Balmoral, to 12·7 parts in 100,000, or 8·89 grains per gallon, in the *Bannockburn*, and to average 5·15 parts in 100,000, or 3·6 grains per gallon.

Organic Elements.—Unfortunately for the purity of the water draining from it, a large proportion of igneous gathering ground in this country is covered with peat, which often communicates to the water falling upon it a yellowish or brownish colour and a slightly bitter taste, both of which are due to the vegetable matter of peat which is slightly soluble in water. A moderate proportion of this matter does not appear to have any deleterious effect upon persons drinking the water; but when it is present in large proportion, it has a tendency to produce diarrhœa, especially in the case of strangers to the locality who have been accustomed to the use of non-peaty water. Thus the medical officer of health at Inverness informed us, that the peaty water of the *Ness* supplied to that town frequently affected families in this manner, for a short time after the commencement of their residence in the town, (Fourth Report, Rivers of Scotland, Vol. II., page 53). A similar result is known to ensue in other places in Scotland, where water strongly impregnated with peat is used for domestic purposes. The non-absorbent character of the igneous rocks prevents that removal of much of the peaty matter from the water, in the process of percolation through an aërated material, which is so frequently observed upon gathering grounds of a more porous description.

In the eighteen samples of water, belonging to this section, enumerated in the foregoing table, the sum of the chief organic elements (organic carbon and organic nitrogen) varied from ·087 part in 100,000 parts, or ·061 grain per gallon, in the brook entering the Vale Pleasant Clay Works near St. Austell; to ·64 part in 100,000 parts, or ·448 grain per gallon, which was found in the *Teign* above Old Wheal Exmouth, in Devonshire. The latter proportion is much too high to permit of the use of the water for drinking, (*see* page 5). The average proportion of organic elements in the eighteen samples was ·311 part in 100,000 parts, or ·218 grain per gallon.

That the organic matter contained in these waters is of vegetable origin is proved, firstly, by the large proportion of carbon to nitrogen which it contains (*see* page 6), varying from N : C = 1 : 4·31 in the organic matter contained in the *Don* at Alford, March 11, 1872; to N : C = 1 : 18·43 in the organic matter found in the mountain stream above St. Neot's, Cornwall, September 20, 1872,—and secondly, from the entire absence of any evidence of previous sewage or animal contamination in all the samples.

Previous sewage or animal contamination.—All the samples having been derived from uncultivated gathering grounds, and not having been polluted by the drainage of inhabited places, are free from all evidence of previous sewage or animal contamination.

Hardness.—All the samples of upland water which we have examined from igneous gathering grounds are very soft, owing to the almost total absence from these formations, of soluble compounds of lime and magnesia. The above analytical table shows a variation in hardness from 0°·8 to 5°·9 and an average hardness of 2°·1.

General character.—These waters may be shortly described as soft and peaty. They are also generally turbid and of a yellowish or even brownish colour, and ought, therefore, as a rule to be filtered before being supplied for domestic use. Those samples which contain more than 0·2 part of organic carbon in 100,000 parts, equal to 0·14 grain per gallon, are not desirable for domestic use. The extreme softness of these waters makes them well adapted for washing and for manufacturing purposes. Their freedom from previous sewage or animal contamination is a considerable guarantee for their wholesomeness.

Section II.—Upland Surface Waters from Metamorphic, Cambrian, Silurian, and Devonian Rocks.

Part II. Classification.

Surface waters from Metamorphic and other rocks.

The following table exhibits the composition of eighty-one samples of upland surface waters from Metamorphic, Cambrian, Silurian, and Devonian rocks. The numbers attached to the samples marked with an asterisk are taken from the Appendix to the Report of the Royal Commission on Water Supply, pp. 17 and 18. Nearly all the remaining samples were collected by us, and all of them were analysed in our laboratory :—

Composition of Upland Surface Waters from Metamorphic, Cambrian, Silurian, and Devonian Rocks.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
Cornwall and Devonshire.												
Affluent of the *Camel* above Mulberry Tin Mine, Sept. 21, 1872.	11·24	·336	·060	·008	·032	·099	70	3·35	0	4·0	4·0	Very turbid.
Water supplied to Lynton and Lynmouth from the *West Lynn*, October 2, 1872.	6·36	·173	·024	0	·026	·050	0	1·25	0	2·5	2·5	Clear and colourless
Water supplied to Ilfracombe from Slade Valley, October 3, 1872.	12·48	·247	·032	0	·028	·060	0	2·05	0	6·9	6·9	Clear and colourless.
Wales.												
The *Rheidol*, above all mines, April 26, 1871.	3·38	·167	·016	·001	0	·017	0	·98	1·4	1·2	2·6	Very slightly turbid.
The *Ystwith*, at Pont Llanychaiarn, April 27, 1871.	5·90	·166	·025	·001	·011	·037	0	1·20	·3	2·3	2·6	Very turbid.
Severn Basin.												
The *Severn* above Cae-yn-y-coed, June 13, 1867.*	3·37	·200	·005	·003	·007	·014	0	·82	0	·9	0·9	Clear and colourless.
The *Tylwch* above Llanidloes, June 12, 1867.*	4·80	·335	·010	·003	·004	·016	0	—	—	—	1·2	Clear and colourless.
The *Tarannon*, June 12, 1867*	4·42	·282	·002	·008	·024	·033	0	·88	·2	1·7	1·9	Clear and colourless.
The *Ceryst* above the Van Mine, October 8, 1872.	6·10	·311	·041	·002	·015	·058	0	·95	0	1·5	1·5	Turbid.
The *Banw* in flood, June 6, 1867*	4·14	·894	·013	0	·006	·019	0	—	—	—	·7	Clear but very yellow.
The *Eira* in flood, June 6, 1867*	5·06	·995	·012	·001	0	·013	0	—	—	—	1·4	Clear and brownish yellow.
The *Banw* and *Eira* in flood after junction, June 6, 1867.*	4·90	1·040	·011	·003	·005	·018	0	—	—	—	1·1	Deep yellow. Slightly turbid.
The *Banw* and *Eira* after subsidence of flood, June 14, 1867.	4·86	·265	·004	·004	·023	·030	0	·86	0	2·0	2·0	Clear and colourless.
The *Vyrnwy*, June 14, 1867*	3·73	·218	·005	·003	·011	·018	0	·74	·3	1·1	1·4	Clear and colourless.
The *Vyrnwy* in flood, June 7, 1867.*	4·08	·963	·009	·003	0	·011	0	·57	0	·7	·7	Clear. Deep yellow.
The *Severn* above Newtown, April 27, 1870.	6·60	·123	·016	·003	·010	·028	0	1·35	0	3·1	3·1	Slightly turbid.
Stream entering the *Severn* near Newtown, March 1, 1872.	4·62	·104	·020	·003	·007	·029	0	·75	·3	3·2	3·5	" "
Dee Basin.												
Mixed waters from four feeders of Bala Lake, July 3, 1867.*	4·10	·311	·010	·003	·011	·023	0	—	—	—	1·1	Very slightly yellow.
Bala Lake, July 3, 1867*	2·79	·227	·001	·001	0	·002	0	·73	·1	·3	·4	Very slightly yellow.
Northern Counties of England.												
Windermere Basin.												
Stockgill Beck, above Ambleside, May 23, 1867.*	4·48	·128	·011	0	·029	·040	0	—	—	—	2·3	Clear and colourless.
Troutbeck, above bridge at Troutbeck, May 23, 1867.*	4·48	·125	·007	0	·018	·025	0	—	—	—	1·8	Clear and colourless.
The *Upper Rothay*, above Grassmere, May 22, 1867.*	3·06	·106	·010	·003	·002	·014	0	·13	0	1·3	1·3	Clear and colourless.
Grassmere Lake, Sept. 28, 1868	4·18	·235	·050	·001	0	·051	0	·79	0	2·7	2·7	Clear.
Rydal Lake, September 28, 1868	4·44	·254	·043	·002	0	·045	0	·69	·7	2·4	3·1	"
Windermere Lake, above Lowwood Hotel, September 28, 1868.	5·78	·299	·076	·002	·018	·096	0	·99	1·6	2·4	4·0	Slightly turbid.
Kent Basin.												
The *Sprint*, near the Sprint Corn Mill, May 24, 1867.*	5·83	·130	·007	0	·021	·028	0	—	—	—	2·9	Clear and colourless.

COMPOSITION OF UPLAND SURFACE WATERS FROM METAMORPHIC AND OTHER ROCKS—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
EDEN BASIN.												
Haweswater Lake, off the Earl of Lonsdale's Boat House, May 16, 1867.*	3·56	**·158**	**·004**	·004	0	·007	**0**	·54	0	1·3	1·3	Clear and colourless.
Measand Beck, just above Measand Hall, May 16, 1867.*	2·14	**·117**	**·003**	0	0	·003	**0**	—	—	—	2·0	Clear and colourless.
The Upper Lowther above Rossgill Bridge, May 16, 1867.*	5·10	**·263**	**·006**	·004	·002	·011	**0**	—	—	—	2·1	Clear and colourless.
Ullswater Lake near Pooley Bridge, May 21, 1867.*	3·63	**·067**	**·000**	·003	·005	·007	**0**	·60	·5	1·4	1·9	Clear and colourless.
Airy Beck just before junction with Ullswater, May 17, 1867.*	4·60	**·259**	**·009**	·004	0	·012	**0**	—	—	—	2·1	Clear and colourless.
Grisedale Beck above Patterdale Hall, May 18, 1867.*	3·77	**·157**	**·012**	·001	·012	·025	**0**	—	—	—	2·3	Clear, Slightly yellow.
Goldrill Beck just above Patterdale Hall, May 18, 1867.*	3·95	**·262**	**·001**	·002	0	·003	**0**	—	—	—	1·6	Clear and colourless.
BASIN OF THE DERWENT, CUMBERLAND.												
Thirlmore Lake at bridge in centre, May 13, 1867.*	2·66	**·194**	**·004**	·003	·002	·008	**0**	·52	0	·7	·7	Clear and colourless.
Main feeder to Thirlmere, May 13, 1867.*	2·75	**·298**	**·008**	·001	·003	·012	**0**	—	—	—	1·0	Clear. Slightly brown.
Naddle Beck above Keswick Road, May 13, 1867.*	4·05	**·366**	**·004**	·001	·010	·015	**0**	—	—	—	1·3	Clear and colourless.
Troutbeck (*Greta*) May 10, 1867*	6·00	**·536**	**·006**	·004	·001	·010	**0**	—	—	—	2·1	Clear. Yellow.
Troutbeck (*Greta*) in flood, May 11, 1867.*	5·91	**1·059**	**·068**	·006	·015	·088	**0**	—	—	—	2·9	Clear. Yellowish brown.
Mosedale Beck in flood, May 11, 1867.*	4·90	**·942**	**·042**	·005	·006	·052	**0**	—	—	—	2·0	Clear. Yellowish brown.
Helvellyn Gill just above Keswick Road, May 13, 1867.*	3·31	**·133**	**·001**	·004	·003	·007	**0**	—	—	—	1·6	Clear and colourless.
Watendlath Tarn at outlet, May 14, 1867.*	3·05	**·305**	**·011**	·002	·006	·019	**0**	—	—	—	1·0	Clear. Brownish.
Derwentwater Lake at foot, September 29, 1868.	6·56	**·218**	**·043**	·001	0	·044	**0**	1·29	0	1·7	1·7	Clear.
Keswick, water supply of, from Skiddaw, September 29, 1868.	4·34	**·132**	**·024**	·001	0	·025	**0**	1·09	1·3	2·1	3·4	Very slightly turbid.
Bassenthwaite Lake at foot, September 29, 1868.	4·64	**·154**	**·037**	0	0	·037	**0**	1·29	·8	2·0	2·8	Very slightly turbid.
The *Cocker* near its junction with the *Derwent*, September 28, 1868.	4·62	**·069**	**·022**	·001	0	·023	**0**	1·09	·1	2·0	2·1	Very slightly turbid.
Buttermere Lake at foot, September 29, 1868.	3·56	**·127**	**·040**	·004	0	·043	**0**	·89	0	1·0	1·0	Clear.
Crummock Lake half a mile from head, September 29, 1868.	4·06	**·183**	**·055**	·007	0	·061	**0**	·89	0	1·3	1·3	"
Water supplied to Maryport from the *Derwent*, September 28, 1868.	6·00	**·210**	**·041**	·004	0	·044	**0**	1·09	·4	3·0	3·4	Very slightly turbid.
EHEN BASIN.												
Ennerdale Lake as supplied to Whitehaven, September 28, 1868.	2·16	**·042**	**·017**	0	0	·017	**0**	·99	0	1·4	1·4	Clear.
SCOTLAND.												
BASIN OF THE NESS.												
The *Ness* as it issues from Loch Ness, March 8, 1872.	3·30	**·361**	**·055**	·002	0	·057	**0**	·85	·3	2·3	2·6	Slightly turbid. Yellow.
NORTH ESK BASIN. FORFAR.												
The *Burn of Mooran*, March 12, 1872.	3·04	**·224**	**·025**	0	0	·025	**0**	·65	·1	1·7	1·8	Slightly turbid.
TAY BASIN.												
The *Tay* above Dunkeld, September 15, 1870.	2·86	**·274**	**·013**	0	0	·013	**0**	·68	·4	·9	1·3	Slightly turbid. Yellow.
Water supplied to Dunkeld from an affluent of the *Tay*, March 7, 1872.	4·02	**·185**	**·018**	0	0	·018	**0**	·75	0	2·7	2·7	Clear and colourless.
Water supplied to Blairgowrie, August 20, 1872.	4·10	**·316**	**·021**	·001	0	·022	**0**	·85	0	2·1	2·1	Slightly turbid and yellow.
BASIN OF THE FORTH.												
Loch Katrine, August 3, 1870	2·40	**·185**	**·022**	·001	0	·023	**0**	·85	0	·9	·9	Slightly turbid.
Water supplied to the Bridge of Allan, August 24, 1872.	8·54	**·632**	**·065**	·001	0	·066	**0**	·80	0	4·9	4·9	Brown and turbid.
BASIN OF THE TWEED.												
The *Tala* near its source, September 24, 1870.	4·02	**·105**	**·017**	·002	0	·019	**0**	·63	·6	1·7	2·3	Clear and colourless.
The *Tala* near its source, April 3, 1871.	2·92	**·080**	**·008**	0	0	·008	**0**	·67	·4	1·7	2·1	Clear and colourless.
The *Tweed* above Peebles, April 5, 1870.	8·16	**·097**	**·010**	0	·043	·053	**110**	·98	·6	4·2	4·8	Clear and colourless.

COMPOSITION OF UPLAND SURFACE WATERS FROM METAMORPHIC AND OTHER ROCKS—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
The *Tweed* above Peebles, March 13, 1872.	5·50	·310	·038	0	0	·038	0	1·10	·4	3·8	4·2	Slightly turbid.
Water supplied to Peebles from *Meldon Burn*, April 5, 1870.	7·68	·218	·019	0	·008	·027	0	1·15	·6	3·4	4·0	" "
The *Megget* flowing into St. Mary's Loch, June 20, 1871.	4·22	·405	·020	·001	0	·021	0	·70	·3	2·2	2·5	Yellow and slightly turbid.
St. Mary's Loch at the head, April 3, 1871.	4·90	·310	·018	0	0	·018	0	·65	0	2·6	2·6	Slightly yellow and slightly turbid.
St. Mary's Loch, one mile from the head, September 24, 1870.	4·74	·293	·023	0	0	·023	0	·64	·3	2·3	2·6	Slightly yellow and turbid.
St. Mary's Loch at foot, September 24, 1870.	4·48	·254	·019	0	0	·019	0	·72	·1	2·0	2·1	Clear and colourless.
St. Mary's Loch at foot, April 3, 1871.	3·58	·284	·025	·001	0	·026	0	·69	·1	1·9	2·0	Slightly turbid.
The *Ettrick* above Selkirk, April 2, 1870.	6·20	·183	·015	0	·023	·038	0	·80	0	3·7	3·7	Clear and colourless.
The *Heriot* near its source, September 24, 1870.	8·12	·085	·010	0	0	·010	0	·85	1·8	4·3	6·1	Clear. Brownish.
The *Heriot* near its source, April 1, 1871.	7·30	·099	·015	0	0	·015	0	·89	1·1	4·6	5·7	Clear and colourless.
The *Manor* near its source, Feb. 22, 1873.	3·52	·043	·011	·001	0	·012	0	·65	0	1·5	1·5	Clear and colourless.
BASINS OF THE CLYDE AND DOON.												
The *Clyde* at Elvanfoot, July 19, 1870.	5·72	·254	·042	·001	0	·043	0	·70	0	2·7	2·7	Slightly turbid.
The *Elvan* above Leadhills Mines, July 22, 1870.	4·30	·091	·015	·001	0	·016	0	·75	·2	1·7	1·9	" "
The *North Calder* at head reservoir, March 14, 1872.	9·06	·661	·075	·006	·030	·110	30	1·10	0	4·2	4·2	Turbid.
Water supplied to Hamilton, July 28, 1870.	11·76	·474	·052	·004	0	·055	0	1·40	0	6·3	6·3	Slightly turbid. Brownish.
Water supplied to Glasgow from Gorbals, August 3, 1870.	8·80	·339	·049	·002	·018	·069	0	1·11	·1	4·3	4·4	Clear. Yellowish.
Water supplied to Paisley from Rowbank Reservoir, July 21, 1870.	11·68	·521	·068	·002	0	·070	0	1·20	0	5·9	5·9	Clear. Brownish.
Water supplied to Paisley from Stanley Reservoir, July 21, 1870.	9·14	·262	·034	·002	0	·036	0	1·12	·2	3·9	4·1	Clear and colourless.
The *Levern* above Barrhead, July 27, 1870.	6·62	·601	·059	·008	0	·066	0	·98	·6	1·7	2·3	Turbid.
The *Leven* flowing from Loch Lomond, July 23, 1870.	3·46	·194	·027	·003	0	·029	0	·90	·5	1·3	1·8	Clear and colourless.
The *Leven* flowing from Loch Lomond, March 14, 1872.	3·40	·245	·025	0	0	·025	0	1·20	·1	2·9	3·0	Slightly turbid. Colourless.
The *Doon* at the Brig, October 3, 1870.	6·60	·285	·023	·001	0	·024	0	·87	·6	2·6	3·2	Slightly turbid. Colourless.
Average - -	5·12	·293	·024	·002	·006	·031	3	·92	·3	2·5	2·5	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

A consideration of the results contained in this table leads to the following conclusions:—

Total solid impurity.—The area of exposed Metamorphic, Cambrian, Silurian, and Devonian rocks in Great Britain being comparatively large, the geological formations of this section constitute some of the most important gathering grounds for potable water supplied to towns, more especially in Scotland. These formations are nearly as insoluble in water as the igneous rocks, which they also resemble in being but slightly absorbent. Most of the rain which falls upon them neither evaporates nor disappears beneath the surface, but flows off rapidly as rivulets and streams, and has consequently but little time to take up soluble impurities. The total solid impurity in the water belonging to this section is, therefore, but little greater than that found in upland surface water collected from igneous rocks.

It varies from 2·14 parts in 100,000 parts or 1·5 grain per gallon, in the water of the *Measand Beck*, Cumberland, to 12·48 parts in 100,000 parts, or 8·74 grains per gallon in the water supplied to Ilfracombe from Slade Valley; the average of eighty-one samples being 5·12 parts in 100,000, or 3·58 grains per imperial gallon.

Organic elements.—A large area of the rocks constituting the gathering ground of this section of potable waters is covered with a layer of peat, which contaminates the

PART II. CLASSIFICATION.

Surface waters from Millstone Grit and non-calcareous beds of the Coal formations.

water with a brownish yellow organic substance, rendering it slightly bitter to the taste. (*See* page 6.)

The weight of the chief organic elements (organic carbon and organic nitrogen), entering into the composition of this peaty organic matter in the eighty-one samples contained in the foregoing table of analytical results, varied from ·054 part in 100,000 parts of water, or ·038 grain per gallon in the *Manor* (a tributary of the *Tweed*) near its source, to 1·127 part in 100,000 parts, or ·789 grain per gallon, in the *Trout Beck* a tributary of the *Greta* in Cumberland; the average amount being ·317 part in 100,000 parts, or ·222 grain in one imperial gallon.

The exclusively vegetable character of the organic matter in nearly all the samples in the foregoing table is testified, firstly, by the large proportion of carbon to nitrogen which the organic matter contains,—this proportion varying from N : C = 1 : ∞ in Ullswater Lake near Pooley Bridge, to N : C = 1 : 2·47 in Ennerdale Lake as supplied to Whitehaven, and averaging N : C = 1 : 29·78,—and secondly, from the absence of any evidence of previous sewage or animal contamination in all but the following three samples:—(1.) an affluent of the *Camel* in Cornwall which is slightly contaminated with the excrements of workmen who are employed in the tin-stone quarry above the mine; (2.) the *Tweed* above Peebles which is not quite exempt from occasional drainage from manured land; (3.) the *North Calder* in Scotland, which is also liable to receive drainage from cultivated land.

Previous sewage or animal contamination.—With the three exceptions just mentioned all these samples of water from upland gathering ground are free from evidence of previous pollution by animal matters. In the exceptional samples this evidence is very slight; it amounts to only 30 parts in 100,000 in the *North Calder*, 70 parts in the affluent of the *Camel*, and to 110 parts, on one occasion, in the *Tweed* above Peebles. These three streams ought, however, to be inspected before their waters are used for domestic purposes, and they ought to be avoided if it be found that unpurified sewage enters them. (*See* remarks on page 17.)

Hardness.—Nearly all the samples belonging to this section are very soft,—the Metamorphic, Cambrian, Silurian, and Devonian rocks containing, as a rule, but mere traces of soluble salts of lime and magnesia. The analytical table shows that the minimum hardness occurs in the water of the Bala Lake, which has a hardness of only 0°·4, and the maximum in the water supplied to Ilfracombe from the Slade Valley which has 6°·9 of hardness. The average hardness of the eighty-one samples is only 2°·5.

General character.—The general character of these waters closely resembles that of the upland surface waters from igneous rocks; both classes of waters are soft and, generally, peaty. The waters of Section II. are, however, less liable to turbidity than those from igneous rocks, and they are also, on the average, less contaminated with peat. Their general freedom from previous sewage or animal contamination is favourable testimony to their wholesomeness, whilst their extreme softness renders them very suitable for washing and for manufacturing purposes. Sand filtration will diminish the yellow tinge, and generally improve the quality of these waters for domestic use; but it is somewhat less imperatively required than in the case of upland surface waters from Igneous rocks. Those samples which contain more than 0·2 part of organic carbon in 100,000 parts of water, equal to 0·14 grain per imperial gallon, should not be supplied for domestic use if they can be dispensed with, as they are usually slightly coloured and unpalatable.

SECTION III.—UPLAND SURFACE WATERS FROM THE YOREDALE AND MILLSTONE GRITS AND THE NON-CALCAREOUS PORTION OF THE COAL MEASURES.

The following table contains the results furnished by forty-seven samples of upland surface water from the Yoredale and Millstone Grits and Coal Measures when submitted to chemical analysis. The head waters of the *Wear* and *Tees* drain a country in which there is a good deal of mountain limestone, but this is so covered up with peat as to prevent the hardness of the water from being thereby much affected. All the samples were analysed in our laboratory, and nearly all were collected by us personally :—

PART II. CLASSIFICATION.

Surface waters from Millstone Grit and Coal Measures.

COMPOSITION OF UPLAND SURFACE WATERS FROM THE YOREDALE AND MILLSTONE GRITS AND THE COAL MEASURES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
ENGLAND.												
BASIN OF THE WYRE, LANCASHIRE.												
Water supplied to Lancaster from Bleasdale Fells, October, 1868.	4·58	**·129**	**·022**	·001	0	·023	**0**	·99	0	·9	·9	Clear.
MERSEY AND RIBBLE BASINS.												
Water supplied to Bolton, Entwistle Reservoir, June 22, 1868.	9·37	**·297**	**·018**	·024	·010	·048	**0**	1·19	·1	5·0	5·1	Slightly turbid.
Water supplied to Liverpool from Rivington Pike, before filtration, June 4, 1869.	8·48	**·243**	**·031**	·004	0	·034	**0**	1·53	·1	3·6	3·7	Turbid.
Ditto after filtration through sand, June 4, 1869.	9·66	**·210**	**·029**	·002	0	·031	**0**	1·53	·3	3·7	4·0	Clear.
Source of the *Medlock*, supplied to Oldham, July 22, 1868.	12·80	**·166**	**·014**	·004	·011	·028	**0**	1·29	·9	6·0	6·9	Clear.
Padiham, water supply of, August 1871.	8·14	**·442**	**·059**	·002	0	·061	**0**	1·18	0	3·2	3·2	Slightly turbid.
The *Shelf Brook* above Glossop, July 28, 1868.	7·62	**·222**	**·000**	·002	·021	·023	**0**	·94	·7	4·6	5·3	Clear.
Brook above Kinder Printworks, Hayfield, March 15, 1869.	6·02	**·246**	**·023**	0	0	·023	**0**	1·10	2·6	2·8	5·4	Clear.
Water supplied to Preston, July 31, 1868.	12·44	**·236**	**·031**	·006	0	·036	**0**	1·59	3·7	5·3	9·0	Slightly turbid.
Water supplied to Chorley from Rivington Pike, March 9, 1869.	11·66	**·401**	**·019**	·001	0	·020	**0**	1·56	0	5·4	5·4	Clear.
Water supplied to Rochdale, June 26, 1868.	8·82	**·134**	**·000**	·014	0	·012	**0**	1·09	0	5·1	5·1	——
Water supplied to Blackburn, August 5, 1868.	11·80	**·249**	**·021**	0	·010	·031	**0**	1·14	·	5·8	5·9	Slightly turbid.
Water supplied to Over Darwen, August 10, 1868.	10·98	**·272**	**·068**	·001	·029	·098	**0**	1·39	0	6·2	6·2	——
Water supplied to Manchester, June 19, 1868.	6·20	**·183**	**·009**	·006	·025	·039	**0**	1·12	·1	3·6	3·7	Slightly turbid.
Water supplied to Manchester, January 29, 1870.	5·74	**·070**	**·007**	·001	0	·008	**0**	·80	·1	2·4	2·5	Slightly turbid.
Water supplied to Manchester, May 19, 1871.	6·68	**·136**	**·029**	·002	·033	·064	**30**	1·07	0	3·2	3·2	„ „
Water supplied to Manchester, October 9, 1871.	7·10	**·230**	**·036**	·001	·029	·066	**0**	·90	·6	4·0	4·6	Turbid.
Water supplied to Manchester, May 9, 1874.	7·00	**·132**	**·031**	·003	0	·033	**0**	·90	0	2·7	2·7	Turbid.
The *Irwell* near its source, June 12, 1869.	7·80	**·187**	**·025**	·004	·021	·049	**0**	1·15	0	3·7	3·7	Clear.
BASINS OF THE AIRE AND CALDER.												
The *Burnley Road Calder*, January 26, 1871.	7·80	**·053**	**·008**	·006	·040	·053	**130**	1·10	1·1	3·8	4·9	Very slightly turbid.
The *Rochdale Road Calder*, January 26, 1871.	7·30	**·033**	**·012**	·001	0	·013	**0**	1·20	·3	3·5	3·8	Very slightly turbid.
The *Ramsden Clough Calder*, January 26, 1871.	7·74	**·093**	**·013**	·003	·042	·057	**120**	1·10	·3	3·6	3·9	Very slightly turbid.
Water supplied to Batley, September 21, 1869.	7·60	**·364**	**·043**	·002	0	·045	**0**	·99	0	3·3	3·3	Yellow and very turbid.
Water supplied to Halifax, September 24, 1869.	8·16	**·133**	**·031**	·005	·029	·064	**10**	1·10	0	3·2	3·2	Very turbid.
Water supplied to Bradford, High Level Service, October 6, 1869.	10·10	**·582**	**·079**	·004	0	·082	**0**	1·02	·9	5·5	6·4	Yellowish. Very turbid.
Low Level supply to Bradford, Heaton reservoir, October 6, 1869.	13·20	**·396**	**·036**	·003	·026	·064	**0**	1·13	·8	6·3	7·1	Yellowish. Turbid.
Water supplied to Saltaire, Jan. 26, 1874.	12·36	**·189**	**·027**	0	0	·027	**0**	1·30	0	7·3	7·3	Slightly turbid.
Ramsden Clough (Riding Wood), February 18, 1871.	5·64	**·134**	**·019**	0	·030	·049	**0**	·95	·3	2·3	2·6	Slightly turbid.
BASIN OF THE OUSE.												
LEEDS, water supply of, September 29, 1869.	15·00	**·258**	**·025**	0	0	·025	**0**	1·30	1·8	6·5	8·3	Clear.
KNARESBOROUGH, the *Nidd* above the town, December, 1871.	11·72	**·206**	**·039**	0	·027	·066	**0**	1·07	·6	8·1	8·7	Slightly turbid.
RIPON, the *Laver*, 9½ miles from source, Jan. 27, 1874.	6·32	**·189**	**·013**	0	0	·013	**0**	1·20	0	4·0	4·0	Clear and palatable.
BASINS OF THE WEAR AND TEES.												
Mountain stream at Allenheads, September 29, 1871.	8·60	**1·025**	**·076**	0	·025	·101	**0**	·85	·5	3·5	4·0	Turbid.

Surface waters from Millstone Grit and Coal Measures.

COMPOSITION OF UPLAND SURFACE WATERS FROM THE YOREDALE GRITS, &c.—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
One of the head waters of the *Wear*, October 3 1871.	6·30	**·713**	**·084**	0	0	·084	**0**	·90	0	2·9	2·9	Slightly turbid.
Another of the head waters of the *Wear*, October 5, 1871.	10·20	**·666**	**·054**	·001	0	·055	**0**	·65	1·2	5·9	7·1	Turbid.
One of the head waters of the *Tees*, October 5, 1871.	7·60	**1·053**	**·071**	·001	0	·072	**0**	·75	·7	2·7	3·4	„
Another of the head waters of the *Tees*, October 4, 1871.	7·40	**·912**	**·069**	·001	0	·070	**0**	·70	·4	3·1	3·5	Very turbid.
BASIN OF THE DON.												
Water supplied to Sheffield, December 20, 1872.	8·36	**·356**	**·057**	·001	·032	·090	**10**	·85	0	4·4	4·4	Turbid.
BASIN OF THE DERWENT (DERBYSHIRE).												
Water supplied to Buxton from Burbridge reservoir, October 11, 1872.	10·28	**·623**	**·056**	·001	·016	·073	**0**	·70	0	5·7	5·7	Turbid. Brownish.
Water supplied to Buxton from Watford reservoir, October 11, 1872.	11·14	**·411**	**·103**	·001	·012	·116	**0**	·70	0	5·3	5·3	Very turbid. Slightly yellow.
Water supplied to Buxton from Lightwood reservoir, October 11, 1872.	5·54	**·509**	**·041**	·003	·014	·057	**0**	·70	0	2·2	2·2	Slightly turbid. Slightly yellow.
WALES.												
Swansea, water supply of, October 17, 1872.	4·84	**·205**	**·025**	0	·010	·035	**0**	1·10	·1	2·2	2·3	Turbid.
SCOTLAND.												
BASIN OF THE FORTH.												
Water supply to Edinburgh from *Crawley Burn*, September 22, 1868.	11·28	**·187**	**·031**	·001	0	·032	**0**	1·04	·7	5·4	6·1	Clear.
Ditto from Loganlee reservoir, Pentland Hills, June 13, 1871.	8·88	**·638**	**·034**	·005	0	·038	**0**	·95	0	4·7	4·7	Brown and slightly turbid.
Ditto from Harperrig reservoir, Pentland Hills, June 6, 1871.	7·16	**1·457**	**·061**	·012	0	·071	**0**	·77	·4	2·7	3·1	Very brown and turbid.
Water supplied to Stirling, August 21, 1872.	6·44	**·481**	**·045**	·001	0	·046	**0**	·70	0	2·7	2·7	Turbid and brown.
The *South Esk* at Gladhouse Mill, June 16, 1871.	9·86	**·682**	**·052**	·004	0	·055	**0**	·90	0	5·7	5·7	Brownish and very turbid.
BASIN OF THE CLYDE.												
The *Douglas* at Standish Railway Station, March 15, 1872.	11·48	**·777**	**·053**	·001	0	·054	**0**	·95	0	6·3	6·3	Turbid.
Average - - - -	8·75	**·377**	**·033**	·003	·010	·050	**6**	1·05	·4	4·3	4·7	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Upon the foregoing analytical results we have the following observations to offer :—

Total solid impurity.—The Millstone Grit and the non-calcareous portions of the Coal Measures contain somewhat larger quantities of constituents soluble in water than are met with in the Igneous, Metamorphic, Cambrian, Silurian, and Devonian rocks ; hence upland surface waters collected from gathering grounds consisting of the first-named formations contain larger proportions of total solid impurity. Still these proportions are but moderate, and these rocks form some of the best collecting surfaces in Great Britain. Many of the large manufacturing towns of Lancashire and Yorkshire are supplied with water for potable and manufacturing purposes, by the storage, in vast reservoirs, of the upland drainage from these formations. Being but slightly absorbent, they yield to the impounded rivulets and streams a large proportion of the actual rainfall. The total solid impurity in these waters varied from 4·58 parts in 100,000 parts, or 3·21 grains per gallon, in the water supplied to the town of Lancaster from Bleasdale Fells, to 15 parts in 100,000, or 10·5 grains per gallon, which we found in the water supplied to Leeds from gathering grounds at Eccup. On the average of forty-seven samples the total solid impurity was 8·75 parts in 100,000, or 6·12 grains per imperial gallon of water.

PART II. CLASSIFICATION.

Surface waters from the Lower Tertiaries.

Organic elements.—There is a good deal of peat upon these gathering grounds, and consequently the water flowing from them often contains rather a large proportion of vegetable organic matter. The weight of the chief elements of this organic matter (organic carbon and organic nitrogen) in the forty-seven samples enumerated in the foregoing table of analytical results ranged from ·045 part in 100,000 parts, or ·032 grain per imperial gallon, in the *Rochdale Road Calder*, which was, however, chiefly supplied by springs at the time our sample was taken; to 1·518 part in 100,000 parts, or 1·063 grain per gallon, in the water of the Harperrig reservoir on the slopes of the Pentland Hills near Edinburgh; the mean of forty-seven samples being ·41 part in 100,000 parts, or ·287 grain per imperial gallon. The remarks which we have made at page 34 respecting the organic matter in upland surface water from igneous rocks are equally applicable to organic matter found in the waters we are now discussing. That it is almost universally of vegetable origin may be inferred from the large proportion of carbon to nitrogen which it contains:

Maximum	- - -	$N : C = 1 : \infty$
Minimum	- - -	$N : C = 1 : 2{\cdot}75$
Average	- - -	$N : C = 1 : 9{\cdot}96$

The minimum proportion occurs in the water of the *Rochdale Road Calder* which, as stated above, was chiefly spring water at the time the sample was taken; and we have shown at page 8, that when peaty water becomes spring water, there is always a great diminution in the proportion of carbon to nitrogen. Omitting this sample the minimum proportion would be $N : C = 1 : 3{\cdot}99$.

The vegetable character of the organic matter is confirmed in all the samples except five, by the absence of all evidence of previous sewage or animal contamination.

Previous sewage or animal contamination.—In only five samples is there any evidence of previous contamination of this kind. These occur in the *Burnley Road Calder*, to the extent of 130 parts in 100,000 parts of water; in the *Ramsden Clough Calder*, in the proportion of 120 parts in 100,000; and in the waters supplied to Halifax and to Sheffield to the extent of 10 parts per 100,000 in each case. One of the samples supplied to Manchester also exhibited 30 parts per 100,000. Even the highest proportion is very small, nevertheless the cause of its occurrence ought to be sought out and the water judged as explained on page 17.

Hardness.—The upland surface waters from the Millstone Grit and Coal Measures are but slightly harder than those collected from Igneous rocks and from Metamorphic, Cambrian, Silurian, and Devonian rocks. The hardness is nearly all of the permanent kind; that is to say, it is not removed by boiling the water. Of all the waters which we have examined from these formations, that supplied to Lancaster from Bleasdale Fells was the softest. It had only $\frac{9}{10}$ths of a degree of hardness. The hardest sample was that supplied to Preston, which had 9°. The mean hardness of the forty-seven samples was 4°·7.

General character.—The waters collected from the uncultivated surfaces of the Millstone Grit and Coal Measures are always well adapted for manufacturing purposes, and generally for domestic use. They are soft and therefore suitable for washing and cleansing operations, but they are, as a rule, somewhat peaty, and therefore liable to be slightly unpalatable and to be tinged of a yellow or brownish colour. These waters are generally turbid and ought always to be subjected to prolonged subsidence, or, preferably, to sand filtration, before distribution to consumers. When the proportion of peaty matter becomes so large as to raise the organic carbon above 0·2 part in 100,000 parts, or 0·14 grain per imperial gallon, the water ought not, except under the pressure of necessity, to be supplied for domestic use, as it will usually be more or less unpalatable. The freedom of these waters, with very few exceptions, from all evidence of previous sewage or animal contamination affords favourable testimony to their wholesomeness.

SECTION IV.—UPLAND SURFACE WATER FROM LOWER LONDON TERTIARIES AND BAGSHOT BEDS.

The following table shows the chemical composition of three samples of upland surface water from the Lower London Tertiaries and Bagshot Beds. The two first-named

PART II. CLASSIFICATION.

samples were collected by ourselves, and all three were analysed in the laboratory of the Commission:—

Surface waters from Calcareous Strata.

COMPOSITION OF UPLAND SURFACE WATER FROM LOWER LONDON TERTIARIES AND BAGSHOT BEDS.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Water supplied to Bournemouth, March 11, 1873.	5·92	**·282**	**·039**	0	0	·039	**0**	2·35	0	1·8	1·8	Clear.
THAMES BASIN.												
Water supplied to Aldershot Camp, May 1, 1868.	6·14	**·417**	**·048**	·001	0	·049	**0**	1·24	·9	3·2	4·1	Slightly turbid.
One of the affluents of the *Ravensbourne* at Keston near Bromley, April 17, 1873.	13·14	**·439**	**·056**	·012	·020	·086	**0**	2·60	0	5·6	5·6	Turbid.
Average - - - -	8·40	**·379**	**·048**	·004	·007	·058	**0**	2·06	·3	3·5	3·8	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The number of samples of these waters which we have met with is too small to enable us to give any trustworthy opinion as to the quality of water likely to be yielded by the lower London Tertiaries and Bagshot Beds. The three samples enumerated in the above table contain a moderate amount of total solid impurity in solution, and a large proportion of organic elements (organic carbon and organic nitrogen). They exhibit no evidence of previous animal pollution, and are soft, the water supplied to Bournemouth from the Bagshot Beds having less than 2° of hardness. These samples are probably not actually unwholesome, but they contain so much vegetable organic matter as to render them somewhat unpalatable.

DIVISION II.—WATERS FROM CALCAREOUS STRATA.

SECTION I.—UPLAND SURFACE WATER FROM THE CALCAREOUS PORTIONS OF SILURIAN AND DEVONIAN ROCKS.

The following table contains the results of our analysis of three samples of water from the calcareous portion of the Silurian and Devonian formations. All the samples were collected by us:—

COMPOSITION OF UPLAND SURFACE WATER FROM SILURIAN AND DEVONIAN ROCKS.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
SCOTLAND.												
HAWICK, water supply of, April 1, 1870.	14·46	**·103**	**·008**	0	·008	·016	**0**	·83	3·5	5·2	8·7	Clear.
BERWICK-ON-TWEED, the *Whitadder* above Chirnside Paper Mill, April 4, 1870.	12·26	**·327**	**·025**	0	·055	·080	**230**	1·62	0	7·5	7·5	Slightly turbid.
The *Nethan* near junction with *Clyde*, March 15, 1872.	14·40	**·475**	**·046**	0	0	·046	**0**	1·15	0	9·6	9·6	" "
Average - - - -	13·71	**·301**	**·026**	0	·021	·047	**77**	1·20	1·2	7·4	8·6	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

Surface waters from Mountain Limestone.

The Silurian and Devonian series of rocks occasionally include limestone, but this is always compact and usually very sparsely distributed, consequently the upland waters, collected even from the calcareous portions of these formations, present the characteristics of calcareous waters only in a mitigated degree. They are harder than most of the waters from non-calcareous rocks, but much softer than upland water collected from the Mountain Limestone and other more recent calcareous strata. The water supplied to Hawick is satisfactory in all respects; but the *Whitadder* and the *Nethan* are too much polluted with organic matter to be desirable potable waters. The *Whitadder* is not altogether an upland water, as it receives drainage from cultivated land, and hence exhibits some evidence of previous animal contamination.

SECTION II.—UPLAND SURFACE WATER FROM MOUNTAIN LIMESTONE.

The following Table contains the results of analysis of seven samples of upland surface water which we collected from the Mountain Limestone :—

COMPOSITION OF UPLAND SURFACE WATER FROM MOUNTAIN LIMESTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
YORKSHIRE.												
Stream from Malham Tarn, Sept. 30, 1869.	12·45	**·273**	**·030**	·002	0	·032	**0**	·95	9·3	4·3	13·6	Clear.
SKIPTON, water supply of, October 4, 1869.	16·40	**·361**	**·038**	·002	·042	·082	**120**	1·41	3·3	7·3	10·6	Very turbid. Partly from Millstone Grit.
The *Wharfe* at the Strid, Bolton Abbey, October 4, 1869.	16·30	**·364**	**·023**	·001	0	·024	**0**	·92	6·9	7·0	13·9	Clear. Yellow.
The *Hodder* at junction with the *Ribble*, July 31, 1868.	14·06	**·218**	**·038**	0	0	·038	**0**	1·29	4·1	5·7	9·8	Clear.
NORTHUMBERLAND AND DURHAM.												
NEWCASTLE, water supply of, from Whittledean, September 16, 1868.	23·40	**·237**	**·062**	0	0	·062	**0**	1·59	5·8	8·1	13·9	"
HEXHAM, water supply of, September 30, 1871.	19·10	**·328**	**·043**	0	·038	·081	**60**	1·40	8·7	5·9	14·6	"
The *Stonecroft burn*, affluent of the *Tyne*, September 30, 1871.	17·76	**·812**	**·097**	0	0	·097	**0**	1·15	1·7	10·6	12·3	Slightly turbid. Brownish.
Average - - -	17·07	**·370**	**·047**	·001	·011	·059	**26**	1·24	5·7	7·0	12·7	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The investigation of these samples leads to the conclusion that the Mountain Limestone is not a favourable formation for the collection of surface water, if the latter be required for domestic purposes. The water is not of excessive hardness, and is therefore not unsuitable for manufacturing purposes, but out of the seven samples examined there is not one which can be unreservedly recommended for domestic use. The chief objection to these waters is due to the large proportion of peaty matter which they contain in solution. The proportion of organic carbon which they yield on analysis surpasses, in every instance, that which we would recommend to be observed as the maximum whenever practicable (0·2 part in 100,000 parts). Although the organic matter yielding this carbon is almost altogether, if not entirely, of vegetable origin, and therefore not intrinsically unwholesome, still it colours the water of a yellowish or brownish tint and makes it unpalatable; and experience demonstrates that the supply of such coloured and somewhat bitter water often drives the inhabitants of towns to the use of the very unwholesome but much more palatable beverage of polluted shallow wells. The proportion of nitrogen to carbon in the organic matter of these waters varied from N. : C. = 1 : 3·82 in the water supplied to Newcastle from Whittledean to 1 : 15·83 in the *Wharfe* at the Strid near Bolton Abbey, the average being N. : C. = 1 : 8·57.

SECTION III.—UPLAND SURFACE WATER FROM THE CALCAREOUS PORTION OF THE COAL MEASURES.

We have examined twenty-six samples of upland surface water from the calcareous portions of the Coal Measures. These waters are drawn upon for the supply of

Surface waters from calcareous portion of Coal Measures.

many important towns, as will be seen by an inspection of the subjoined table, which contains the analytical results yielded by specimens of these waters collected, with one exception, by ourselves.

COMPOSITION OF UPLAND SURFACE WATER FROM THE CALCAREOUS PORTION OF THE COAL MEASURES.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
BASIN OF THE TRENT.												
Head waters of the *Trent*, April 20, 1871.	24·64	**·721**	**·088**	·003	0	·090	**0**	1·70	·9	13·6	14·5	Very turbid.
BASINS OF THE MERSEY AND RIBBLE.												
One of the sources of the *Irk* at Thorncliffe, June 18, 1868.	19·78	**·153**	**·001**	·009	·061	·069	**363**	1·42	3·7	7·7	11·4	Clear.
ASHTON-UNDER-LYNE, water supply of, July 24, 1868.	24·14	**·200**	**·031**	·010	·028	·067	**45**	1·89	3·2	11·0	14·2	Very turbid.
STOCKPORT, water supply of, from Disley, July 27, 1868.	14·18	**·204**	**·019**	·007	·015	·040	**0**	1·29	0	8·8	8·8	Slightly turbid.
The *Blakewater* above Blackburn, August 5, 1868.	77·86	**·206**	**·005**	·008	·023	·034	**0**	1·39	10·6	10·1	20·7	Clear.
BURNLEY, the *Calder* and *Brun* above the town, August 11, 1868.	27·66	**·181**	**·018**	·003	0	·020	**0**	1·09	8·1	6·9	10·0	"
BASINS OF THE TYNE, WEAR, AND TEES.												
DURHAM, the *Wear* above the town, October 5, 1870.	49·56	**·166**	**·030**	·010	0	·038	**0**	4·60	11·3	10·9	22·2	Slightly turbid.
DURHAM, water supply of, October 5, 1870.	54·50	**·082**	**·020**	0	·041	·061	**90**	4·85	11·6	13·4	25·0	" "
DARLINGTON, the *Tees* above the town, October 6, 1870.	17·92	**·183**	**·020**	0	0	·020	**0**	·95	10·4	3·0	13·4	" "
STOCKTON AND MIDDLESBORO', water supply of, October 6, 1870.	17·24	**·180**	**·013**	·001	0	·014	**0**	·90	8·6	3·6	12·2	Clear.
BISHOP AUCKLAND, water supply of, October 2, 1871.	14·90	**·373**	**·034**	0	·061	·095	**290**	1·10	4·7	5·7	10·4	Turbid.
SCOTLAND.												
BASIN OF THE FORTH.												
The *North Esk* above Penicuick, September 27, 1868.	13·98	**·443**	**·050**	·003	0	·053	**0**	1·09	0	7·1	7·1	Slightly turbid.
EDINBURGH, water supply from Swanston, September 22, 1868.	12·70	**·378**	**·059**	·001	0	·060	**0**	1·39	0	6·2	6·2	Clear.
EDINBURGH, water supply from Colinton, September 22, 1868.	14·10	**·203**	**·042**	0	0	·042	**0**	·89	4·4	4·8	9·2	—
ALLOA, water supply of, August 24, 1872.	14·24	**·307**	**·027**	0	0	·027	**0**	1·00	·3	8·7	9·0	Clear.
BASIN OF THE TWEED.												
JEDBURGH, the *Jed* above the town, March 31, 1870.	17·44	**·234**	**·024**	·002	·012	·038	**0**	1·05	6·3	7·4	13·7	Slightly turbid.
HAWICK, the *Slitrig* above the town, April 1, 1870.	14·70	**·159**	**·012**	0	·039	·051	**70**	·84	1·7	6·7	8·4	Clear.
BASINS OF THE CLYDE AND IRVINE.												
KILMARNOCK, the *Kilmarnock* above the town, April 7, 1870.	19·60	**·539**	**·033**	·002	0	·035	**0**	1·52	·1	11·6	11·7	Slightly turbid. Brownish.
KILMARNOCK, water supply of, April 7, 1870.	12·44	**·508**	**·032**	0	·028	·060	**0**	1·40	1·0	7·6	8·6	Clear.
KIRKINTILLOCH, the *Luggie* above the town, July 25, 1870.	26·78	**·663**	**·072**	·008	0	·079	**0**	1·45	5·8	7·6	13·4	Very slightly turbid.
AIRDRIE, water supply of, July 29, 1870.	23·98	**·381**	**·047**	·002	·014	·063	**0**	1·38	0	9·8	9·8	Slightly turbid.
The *South Calder*, above weir at Coltness House, March 13, 1872.	23·44	**·587**	**·090**	·004	·025	·118	**0**	1·40	3·5	12·1	15·6	Turbid. Yellowish.
The *Avon*, above Hamilton, March 14, 1872.	11·34	**·856**	**·073**	·002	·018	·093	**0**	1·00	0	7·3	7·3	Slightly turbid. Yellow.
The *Mouse*, at junction with the *Clyde*, March 15, 1872.	18·34	**·840**	**·089**	·001	·032	·122	**10**	1·35	0	11·5	11·5	Turbid. Yellow.
WALES.												
MERTHYR TYDFIL, water supply of, June 20, 1871.	10·20	**·152**	**·021**	0	0	·021	**0**	·90	4·2	4·2	8·4	Slightly turbid.
NEWPORT, water supply of, June 21, 1871.	17·30	**·083**	**·020**	0	·018	·038	**0**	1·65	8·2	9·6	17·8	Clear.
Average - -	22·79	**·346**	**·037**	·003	·016	·056	**33**	1·52	4·0	8·3	12·3	

***Note.*—For the translation of these numbers into grains per gallon, *see* note to table on page 29.**

Part II. Classification.

Surface waters from calcareous portion of Coal Measures.

To these analytical results we append the following remarks :—

Total solid impurity.—The calcareous portions of the Coal Measures contain rocks of very variable composition, some of them friable, easily weathered, and yielding considerable quantities of soluble matter to aërated water; others compact, capable of resisting atmospheric disintegration, and yielding up to water but a small amount of soluble ingredients. Collected off such a variety of material, it is not to be wondered at that the upland surface waters of the Coal Measures present great differences in the total amounts of soluble solid impurity which they contain. The samples in the above table contain proportions varying from 10·2 parts in 100,000, or 7·14 grains per imperial gallon, in the water supplied to Merthyr Tydfil, to 77·36 parts in 100,000, or 54·15 grains per gallon, in the *Blakewater* above Blackburn, the average being 22·79 parts in 100,000, or 15·95 grains per imperial gallon. The proportion of total solid impurity in these waters is therefore on the average 2·62 times as great as that contained in upland surface waters gathered upon the non-calcareous portion of the Coal Measures, and upon the Yoredale and Millstone Grits.

Organic elements.—Like the geological formations already described, the upland portions of the Coal Measures are liable to be more or less covered with peat, which often imparts much soluble organic matter to rainwater falling upon or flowing over them. When this is the case, the water acquires a yellowish or brownish-yellow colour, and a slightly bitter taste (*see* page 34). The quantity of the chief organic elements (organic carbon and organic nitrogen) of this soluble organic matter of peat, in the samples contained in the foregoing table, ranged from ·102 part in 100,000 parts, or ·071 grain per gallon, in the water of the *Wear* after filtration through sand, as supplied to Durham, to ·929 part in 100,000 parts, or ·65 grain per gallon, which was found in the *Mouse* at its junction with the *Clyde*. In but very few cases was there evidence that any portion of the organic matter had been derived from animal sources. Omitting the sample from one of the unpolluted sources of the *Irk* which yielded an abnormal result, the proportion of nitrogen to carbon ranged from N : C = 1 : 41·2 in the *Blakewater* above Blackburn, to N : C = 1 : 4·1 in the water supplied to Durham; the mean being N : C = 1 : 10·53.

Previous sewage or animal contamination.—Evidence of previous animal pollution in these waters occurred in only six out of twenty-six samples. One of the sources of the *Irk* exhibited evidence of 363 parts of previous contamination in 100,000 parts. There is a considerable area of manured land near this source of the *Irk*; indeed the spring issues from the soil in a tolerably fertile meadow, and the previous contamination was doubtless due to solid animal manure as distinguished from sewage. The water supply of Bishop Auckland gives evidence of previous contamination to the extent of 290 parts in 100,000; it is abstracted by natural filtration from the *Tees* opposite the town; and, as the river does not there exhibit any such evidence, there must be some infiltration or polluted subsoil water from the adjoining sewers or middens of the town. In the remaining four cases the evidence of previous contamination is slight, and does not call for special notice.

Hardness.—The causes which have been already commented upon as affecting the proportion of total solid impurity also exert an active influence upon the hardness of the waters collected from gathering grounds on the Coal Measures. The twenty-six samples in the analytical table range from 6°·2 of hardness in the water supplied to Edinburgh from Swanston, up to 25° in the water supplied to Durham from the *Wear*. In many cases a considerable proportion of the hardness is temporary, that is, it can be mitigated by boiling the water for half an hour (*see* page 21), but, in a not inconsiderable number of cases, it is all permanent, or nearly so, and cannot be so mitigated. The mean hardness of the twenty-six samples was 12°·3.

General character.—The waters collected from the upland slopes of the Coal Measures are of very variable quality. When soft, they are well adapted for manufacturing purposes and for washing; but they have generally too much peaty matter in solution to be agreeable for drinking. When hard, they are unsuitable for manufactures and for washing, but they then contain much less peaty matter, and are consequently more palatable. Those which contain more than 0·2 part per 100,000 parts, or 0·14 grain per gallon, of organic carbon should be avoided for domestic use; the others should always be subjected either to filtration through sand or to prolonged subsidence before they are supplied as drinking waters. These latter are palatable, and, if free from evidence of previous sewage contamination, wholesome

PART II. CLASSIFICATION.

Surface waters from the Lias and New Red Sandstone.

SECTION IV.—UPLAND SURFACE WATERS FROM THE LIAS, NEW RED SANDSTONE, CONGLOMERATE SANDSTONE, AND MAGNESIAN LIMESTONE.

Several important towns are supplied from these sources. We have collected and analysed nine samples of these waters. The results are given in the subjoined Table:—

COMPOSITION OF UPLAND SURFACE WATERS FROM THE LIAS, NEW RED AND CONGLOMERATE SANDSTONE, AND MAGNESIAN LIMESTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BARNARD CASTLE, the *Blue Beck*, Aug. 1871.	11·98	**·187**	**·024**	·005	0	·028	**0**	1·50	4·4	4·7	9·1	Slightly turbid.
CHESTER, water supply of, May 19, 1873.	16·84	**·219**	**·043**	0	0	·043	**0**	2·00	5·0	5·7	10·7	Turbid.
GLOUCESTER, water supply of, March 18, 1870.	24·82	**·375**	**·042**	0	·026	·068	**0**	1·52	16·0	3·6	19·6	"
CARDIFF, water supply of, October 18, 1872.	23·50	**·212**	**·031**	0	·034	·065	**20**	1·40	7·1	12·9	20·0	Clear.
LEICESTER, water supply of, November 1867.	23·70	**·506**	**·020**	·001	·001	·022	**0**	—	—	—	13·4	Clear and yellow.
LEICESTER, water supply of, August 30, 1871.	26·32	**·485**	**·075**	·001	·005	·081	**0**	1·48	15·8	9·0	24·8	Slightly turbid and yellow.
CREWE, water supply of, May 17, 1873.	11·08	**·186**	**·066**	·008	·027	·100	**20**	1·60	2·9	8·1	6·0	Very turbid.
CARLISLE, water supply of, September 23, 1868.	13·10	**·233**	**·037**	·001	0	·038	**0**	·99	3·5	5·2	8·7	—
MAGNESIAN LIMESTONE.												
RIPON, the *Kex Beck* 8 miles from source, January 27, 1874.	17·84	**·172**	**·036**	·001	0	·037	**0**	1·40	6·4	8·8	14·7	Slightly turbid.
Average - - -	18·80	**·286**	**·042**	·002	·010	·054	**4**	1·49	7·6	6·5	14·1	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results lead to the following conclusions:—

Total solid impurity.—The weathering of the Lias, New Red Sandstone, and Conglomerate Sandstone sets at liberty a considerable amount of mineral matter, chiefly carbonate of lime, soluble in aërated water, whilst the Magnesian Limestone is directly soluble, and the surface water collected from these formations accordingly contains, as a rule, rather a large proportion of total solid impurity. It varied from 11·08 parts in 100,000, or 7·76 grains per gallon, in the water supply of Crewe, to 26·32 parts in 100,000, or 18·42 grains per gallon, in the water supplied to Leicester, the average being 18·8 parts in 100,000, or 13·16 grains per imperial gallon.

Organic elements.— These waters contain less soluble peaty matter than those collected from the mountain limestone. Of the nine samples examined, only three surpass, to an important extent, the limit of organic carbon (0·2 part per 100,000 parts) which we desire to see observed; these are the Gloucester and Leicester water supplies, both of which contain a much larger proportion of peaty matter than is desirable, or perhaps wholesome, in water used for drinking and cooking. The proportion of organic elements (organic carbon and organic nitrogen) in these waters varied from ·208 part in 100,000 parts, or ·146 grain per gallon, in the water of the *Kex Beck* near Ripon, to ·56 part in 100,000 parts, or ·392 grain per gallon, in the water supplied to Leicester. As regards the effect of this peaty organic matter upon the health of water drinkers, see remarks at page 34. The proportion of nitrogen to carbon in the organic matter of these waters varied from N. : C. = 1 : 2·82 in the water with which Crewe is supplied, to N. : C. = 1 : 25·3 in the water supplied to Leicester in November 1867, the average being N. : C. = 1 : 8·26.

Previous sewage or animal contamination.—Only two of the samples exhibited any evidence of previous animal contamination, and, even in these cases, the evidence was very slight. In both instances, however, the water was supplied to towns, and the source of the contamination ought therefore to be investigated.

Hardness.—The upland surface waters from the Lias, New Red and Conglomerate Sandstone, and Magnesian Limestone vary considerably in hardness, owing doubtless to the varying proportions of calcareous matter in these rocks. A large proportion of the hardness is due to the carbonates of lime and magnesia, and these waters would therefore be much improved by undergoing the softening process described at page 205. In the samples investigated by us the hardness varied from 6° in the water supplied to Crewe up to 24°·8 in the water supplied to Leicester in 1871. The average hardness of the samples was 14°·1.

PART II. CLASSIFICATION.

Surface waters from non-calcareous cultivated districts.

General character.—These waters are very similar in quality to those collected on the Coal Measures, but they are considerably harder and therefore less adapted for manufacturing purposes and for washing. They are sometimes tinted yellow by peaty matter and are nearly always turbid; they ought therefore to undergo prolonged subsidence before distribution for domestic use, and whenever the organic carbon much exceeds 0·2 part in 100,000 parts they ought to be filtered. When the organic carbon does not exceed 0·2 part in 100,000 parts, and when sewage and animal pollutions are excluded from them, they are fairly good and wholesome waters for domestic use.

SECTION V.—UPLAND SURFACE WATER FROM OOLITES.

The Oolite rock is so freely permeable to water as to prevent more than a very small proportion of the rainfall from flowing off its surface. We have, in fact, only collected one example of surface water from this formation. The analytical results which it yielded are contained in the following Table:—

COMPOSITION OF UPLAND SURFACE WATER FROM OOLITES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
The *Frome*, above Woodlands Mill, Somersetshire, March 10, 1870.	17·46	**·326**	**·025**	·004	·042	·070	**130**	1·55	6·6	5·8	12·4	Slightly turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The *Frome* above Woodlands Mill is a water of comparatively moderate hardness, but contains a large proportion of organic matter. It is not derived exclusively from upland sources, but contains some drainage from cultivated land, hence it exhibits evidence of previous animal contamination. It is not at present supplied to any town, and at the point whence our sample was drawn, the river would not afford a desirable water for domestic use.

CLASS III.—SURFACE WATERS FROM CULTIVATED LAND.

DIVISION I.—FROM NON-CALCAREOUS DISTRICTS.

The following Table contains the results of our analyses of thirty-one samples of surface water from non-calcareous cultivated districts. The numbers attached to the samples marked with an asterisk are taken from the Appendix to the Report of the Royal Commission on Water Supply, pp. 17, 104 and 119. Nearly all the remaining samples were collected by ourselves.

COMPOSITION OF SURFACE WATERS FROM CULTIVATED LAND IN NON-CALCAREOUS DISTRICTS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
PENRHYN AND FALMOUTH, water supplied to, January 3, 1873.	8·76	**·238**	**·038**	·004	·258	·299	**2,290**	2·75	0	2·7	2·7	Slightly turbid.
TORQUAY AND NEWTON ABBOTT, water supplied to, Sept. 27, 1872.	6·36	**·309**	**·057**	·001	·081	·139	**500**	1·70	·2	2·1	2·3	" "
Affluent of the *Tamar* at Chillaton, September 25, 1872.	9·84	**·224**	**·020**	·002	·105	·127	**750**	1·40	·2	4·4	4·6	" "
LISKEARD, affluent of the *Tidi* at Wheal Wrey, Sept. 24, 1872.	10·52	**1·124**	**·112**	·056	·043	·201	**570**	2·20	·1	3·1	3·2	Very turbid.

Surface waters from non-calcareous cultivated districts.

COMPOSITION OF SURFACE WATERS FROM CULTIVATED LAND, &c.—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BODMIN, water supply of, January 1, 1872.	9·56	·148	·031	·002	·075	·108	450	2·80	·7	5·6	6·3	Slightly turbid.
BARNSTAPLE, water supply from the *Yeo*, October 1, 1872.	9·94	·126	·018	0	·098	·116	660	1·55	0	5·9	5·9	Clear and colourless.
The *Exe* above junction with the *Culm*, May 26, 1870.	9·90	·164	·043	·011	·016	·068	0	1·47	0	4·9	4·9	Slightly turbid.
The *Exe* above junction with the *Culm*, September 26, 1871.	8·98	·137	·029	·005	·058	·091	300	1·70	0	5·4	5·4	" "
The *Exe* above junction with the *Culm*, October 22, 1871.	6·76	·218	·023	·001	·080	·104	490	1·60	0	4·9	4·9	" "
TAUNTON, water supply of, Sept. 4, 1873.	8·58	·254	·035	·001	·183	·219	1,520	1·50	0	2·6	2·6	Slightly turbid. Palatable.
HEREFORD, water supply from the *Wye*, Sept. 6, 1873.	6·50	·490	·016	·001	0	·017	0	·70	0	3·6	3·6	Turbid. Brown.
The *Kent*, just above Kendal, March 17, 1871.	6·48	·149	·020	0	·044	·064	120	·90	0	3·9	3·9	Slightly turbid.
KENDAL, water supply of, March 23, 1871.	8·50	·128	·021	·001	·093	·115	620	1·10	0	4·2	4·2	" "
BOLTON, Lancashire, water supply of, from Heaton reservoir, June 24, 1868.	11·84	·355	·024	·018	·044	·083	269	1·39	·3	5·7	6·0	—
BOLTON, Lancashire, water supply of, from Sweetlove's reservoir, June 24, 1868.	7·74	·333	·047	·015	·029	·088	94	1·14	·7	2·8	3·5	—
BURY and RADCLIFFE, Lancashire, water supply of, June 24, 1868.	11·00	·229	·000	·032	·066	·092	598	1·22	·5	4·9	5·4	Turbid.
BATLEY, Yorkshire, Great Bent Dyke (Yateholme), Feb. 1871.	5·26	·152	·017	·004	·047	·067	180	·85	·5	1·8	2·3	Slightly turbid.
BATLEY, Yorkshire, Netherley Clough (Ramsden reservoir), February 1871.	5·26	·161	·021	0	·050	·071	180	·95	·4	1·9	2·3	" "
BATLEY, Yorkshire, Rake Dyke (Holme reservoir), Feb. 1871.	6·36	·183	·019	·001	·074	·094	430	·95	·1	2·5	2·6	" "
CHULMLEIGH, Devon, water supply of, October 31, 1868.	11·24	·273	·051	·007	·186	·243	1,594	2·08	1·3	4·5	5·8	—
MACCLESFIELD, Cheshire, water supply of, June 16, 1868.	10·10	·188	·005	·020	·030	·051	146	1·11	4·6	4·8	9·4	Slightly turbid.
The *Wey*, above Godalming, April 21, 1868.*	14·83	·538	·065	·001	·079	·145	480	1·42	·3	8·0	8·3	Clear. Slightly greenish yellow.
The *Wey* at junction with the *Thames*, October 28, 1868.*	18·10	·307	·077	·005	·090	·171	620	1·83	4·0	6·1	10·1	——
TUNBRIDGE, water supplied to, from *Medway*, Feb. 21, 1873.	15·08	·207	·052	·009	·180	·239	1,550	2·40	1·0	7·0	8·0	Turbid.
WALES.												
Stream in Domen Valley, near Aberystwith, December 7, 1869.	7·80	·157	·030	·001	·073	·104	420	1·70	0	2·1	2·1	Clear.
The *Carno*, above Pont-y-ddolgoch, June 12, 1867.*	6·49	·335	·007	·003	·049	·058	190	1·04	0	3·0	3·0	Clear and colourless.
SCOTLAND.												
DUNDEE, water supply of, from Monikie, Sept. 15, 1870.	13·52	·415	·063	·006	·047	·115	200	1·46	1·3	5·3	6·6	Very turbid. Brownish yellow.
DUNDEE, water supply of, from Monikie, March 12, 1872.	11·16	·418	·059	·001	·081	·141	500	1·75	0	6·0	6·0	Turbid. Brownish yellow.
The *Gala*, above Galashiels, March 30, 1870.	9·74	·326	·035	·002	·046	·083	160	1·06	·9	4·4	5·3	Slightly turbid.
GALASHIELS, water supply of, April 2, 1870.	10·44	·125	·011	0	·382	·393	3,500	1·28	1·6	4·4	6·0	Clear and colourless.
The *Tweed*, above Kelso, April 4, 1870.	8·90	·155	·015	·002	·059	·076	290	1·20	0	4·8	4·8	Slightly turbid.
Average - - -	9·52	·276	·034	·007	·089	·128	635	1·49	·6	4·3	4·9	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results lead to the following conclusions :—

Total solid impurity.—The cultivation of a non-calcareous soil does not appear to add much soluble matter to the rain water falling on it. The total solid impurity in the samples enumerated in the foregoing table was, on the average, not much in excess of that found in the upland surface waters from non-calcareous strata.

Average amount of total solid impurity in 100,000 parts of upland surface water from non-calcareous formations - - -	6·32 parts.
Average amount of total solid impurity in 100,000 parts of water from cultivated land in non-calcareous districts - -	9·52 "

The proportion of total solid impurity in the thirty-one samples mentioned in the foregoing table varied from 5·26 parts in 100,000, or 3·68 grains per gallon, in the water

Surface waters from non-calcareous cultivated districts.

supplied to Batley in Yorkshire from gathering grounds, to 18·1 parts in 100,000, or 12·67 grains per imperial gallon, in the *Wey* above Godalming; and averaged 9·52 parts in 100,000, or 6·66 grains per gallon.

Organic elements.—The analytical results contained in the foregoing table show conclusively, that the cultivation of land diminishes, as a rule, the amount of organic matter dissolved by the water flowing off the soil. At all events this is the case when the comparison is made between water from uncultivated peat on the one hand, and water from land under tillage on the other. Peat is sodden with water, and its pores are not aërated. It moreover contains a considerable proportion of soluble organic matter; rain falling upon it takes up the latter, and has but little opportunity of getting rid of it by oxidation. On the other hand, even the portion of the rain which falls upon cultivated land and then flows off again, makes its way to a considerable extent through the broken-up surface soil, and the organic matter which it contains is subjected in some degree to that powerful oxidizing influence which we have shown to be exerted by air and soil combined. (*See* page 57.)

The sum of the organic elements contained in the samples which we have examined varied from ·136 part in 100,000 parts, or ·095 grain per gallon, in the water supplied to Galashiels; to 1·236 part in 100,000 parts, or ·865 grain per gallon, in an affluent of the *Tidi*, near Liskeard; the average being ·310 part in 100,000 parts, or ·217 grain per gallon. Out of thirty-one samples, there are only eighteen which could reasonably be objected to on the ground of excessive proportion of organic elements; but it must not be overlooked that the organic matter is here liable to be of animal origin, and consequently these waters are not desirable for domestic use; and when the evidence of previous animal contamination is strong, they ought to be rejected as suspicious or doubtful, if not dangerous. This rejection should be absolute in all cases in which nightsoil is used upon the land. These waters are almost invariably turbid; on this account, and also because of the animal matter with which they are constantly liable to be polluted, they should always be efficiently filtered before distribution for domestic use. The proportion of organic nitrogen to organic carbon varied from $N : C = 1 : \infty$ in the water supplied to Bury and Radcliffe; to $N : C = 1 : 3·81$ in the *Exe* above its junction with the *Culm*, near Exeter, and averaged $N : C = 1 : 10·64$.

Previous sewage or animal contamination.—A very large proportion of the manure used in agriculture consists of refuse animal matters. Notwithstanding the use of mineral substances, such as the phosphates of lime and the salts of ammonia, there are probably but very few fields under tillage or grass which do not receive, either farmyard manure, the droppings of sheep and cattle, privy stuff, or guano. Thus water collected from the surfaces of such fields is almost always polluted with animal matters, which, by decomposition and oxidation, yield nitrates, nitrites, and ammonia. These latter compounds, constituting, as they do, the evidence of anterior pollution by animal matters, are very rarely absent, and are generally present in considerable proportion, in surface water collected from cultivated land. Consequently, nearly every sample of water belonging to this class which we have examined has exhibited marked evidence of previous animal contamination. In the case of the water supply of Galashiels this evidence showed that the water had been polluted by an amount of animal matter equal to that which would be introduced into it by an admixture of 3½ per cent. of average London sewage. Most of the samples in the foregoing table, however, represent the drainage from uncultivated land which has mingled with that from cultivated districts, and in such samples the evidence of previous contamination is but moderate.

Hardness.—Many of these waters are very soft, and the remainder are of a moderate degree of hardness. In the thirty-one samples enumerated in the foregoing table the hardness varied from 2°·1 in the stream in Domen Valley, near Aberystwith, to 10°·1 in the *Wey*, at its junction with the *Thames*, and averaged 4°·9.

General character.—The surface waters draining from non-calcareous cultivated districts contain usually but a moderate amount of organic matter, some of which, however, is of animal origin, and therefore objectionable. They are, as a rule, soft, and, after efficient filtration, colourless or nearly so, and palatable. Being usually turbid and subject to animal contamination, they should always be carefully filtered through at least two feet of sand before they are supplied for domestic use, and when the organic carbon much exceeds 0·2 part in 100,000 parts of water it is very undesirable to employ them for drinking, although they would still be available for washing or for manufacturing purposes.

DIVISION II.—SURFACE WATERS FROM CALCAREOUS STRATA IN CULTIVATED DISTRICTS.

PART II. CLASSIFICATION. — Surface waters from cultivated calcareous districts.

Calcareous strata yield, by weathering and disintegration, soils of a more fertile character than those from which lime is nearly or wholly absent; consequently a large proportion of the total area of calcareous soil in Great Britain is cultivated; and therefore sources of water from such soil are much more numerous than those from calcareous but non-cultivated districts. We have analysed no less than one hundred and twenty-four samples from calcareous districts more or less in cultivation, and the results are contained in the following table. The data attached to the samples marked with an asterisk are extracted from the Appendix to the Report of the Royal Commission on Water Supply, pp. 104 and 119.

COMPOSITION OF SURFACE WATERS FROM CULTIVATED CALCAREOUS DISTRICTS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
STONEHOUSE, DEVON, water supply of, June 2, 1873.	29·70	**·099**	**·036**	0	·321	·357	**2,890**	3·70	11·8	7·6	19·4	Slightly turbid. Palatable.
WEST COWES, I. W., water supply of, March 8, 1873.	22·44	**·636**	**·138**	·004	·167	·308	**1,380**	3·20	·6	8·1	8·7	Very turbid. Brownish.
EAST COWES, I. W., water supply of, March 8, 1873.	26·60	**·510**	**·097**	·001	·354	·452	**3,230**	3·60	2·5	9·9	12·4	Very turbid.
The *Lukeley*, above Newport, I. W., November 4, 1871.	34·00	**·072**	**·025**	·003	·298	·325	**2,680**	3·30	16·5	7·7	24·2	Very slightly turbid.
The *Pan*, at Panbridge, above Newport, I. W., Nov. 4, 1871.	26·40	**·303**	**·064**	·008	·177	·248	**1,520**	4·15	10·0	7·4	17·4	Turbid.
The *Yar*, above Sandown, September 29, 1873.	22·52	**·252**	**·064**	0	·158	·222	**1,260**	3·85	5·1	6·4	11·5	Slightly turbid.
The *Yar*, above Sandown, April 8, 1874.	20·20	**·254**	**·039**	·008	0	·046	**0**	3·80	3·8	7·1	10·9	Very turbid.
SOUTHAMPTON, water supply of, March 12, 1873.	30·72	**·113**	**·023**	·001	·308	·332	**2,770**	1·80	18·4	6·1	24·5	Slightly turbid.
NORWICH, water supply from the *Wensum*, June 18, 1872.	30·92	**·432**	**·080**	·014	·036	·128	**160**	3·10	21·3	5·3	26·6	Slightly turbid.
SPALDING, water supply, November 24, 1873.	28·48	**·179**	**·043**	0	0	·043	**0**	2·70	8·0	9·7	17·7	Clear.
WIGAN, water supply, August 7, 1868.	24·78	**·350**	**·048**	·007	·071	·125	**450**	1·79	3·5	8·6	12·1	—
WIGAN, water supply, May 10, 1874	22·38	**·294**	**·070**	·003	·079	·151	**490**	1·90	1·7	13·5	15·2	Slightly turbid.
SEVERN BASIN.												
TROWBRIDGE, the *Biss*, above the town, March 11, 1870.	35·86	**·325**	**·028**	·003	·150	·180	**1,200**	1·93	21·6	5·0	26·6	" "
The *Frome*, (Gloucesterhsire,) above the highest mill, March 18, 1870.	27·50	**·062**	**·009**	0	·298	·307	**2,660**	1·05	19·6	4·0	23·6	Clear and colourless.
LEAMINGTON, water supply of, May 12, 1870.	68·92	**·180**	**·035**	0	·191	·226	**1,590**	2·30	15·9	11·6	27·5	Slightly turbid.
STROUD, upper water supply of, April 18, 1871.	42·34	**·499**	**·093**	·030	·346	·464	**3,390**	1·90	26·3	6·3	32·6	Very turbid.
The *Axe*, above Mendip paper mill, Wells, May 18, 1872.	23·24	**·112**	**·029**	·026	·190	·240	**1,790**	2·10	13·7	4·2	17·9	Slightly turbid.
RUGBY, water supply of, from the *Avon*, May 12, 1868.	26·24	**·123**	**·037**	·002	·382	·421	**3,512**	2·03	6·8	9·1	15·9	—
WORCESTER, water supply of, from the *Severn*, August 1, 1873.	28·12	**·250**	**·039**	·002	·116	·157	**860**	6·70	5·6	8·4	14·0	Slightly turbid.
TEWKESBURY, water supply of, from the *Severn*, September 6, 1873.	19·26	**·405**	**·043**	0	·041	·084	**90**	3·50	0	10·0	10·0	Clear. Light brown colour.
NUNNEY near Frome, millpond above village, November 1870.	30·74	**·091**	**·030**	·003	·207	·239	**1,770**	1·60	21·8	4·9	26·7	Slightly turbid.
SOMERTON, Somerset, brook above sewers, January, 1871.	40·40	**·272**	**·040**	·003	·636	·678	**6,060**	2·80	21·2	7·9	29·1	" "
King's Cliff Stream, near Bridgewater March 13, 1871.	13·22	**·181**	**·055**	·001	·222	·278	**1,910**	2·17	1·0	7·6	8·6	Very turbid.
Durleigh Stream, near Bridgwater, March 13, 1871.	25·74	**·241**	**·036**	·001	·148	·185	**1,170**	2·37	11·3	6·7	18·0	Turbid.
Raulet Common and *Severn Wells Streams*, near Bridgowater, mixed, March 13, 1871.	19·64	**·280**	**·027**	·001	·183	·211	**1,520**	2·10	6·1	5·9	12·0	Very turbid.
BASIN OF THE THAMES.												
BANBURY, water supply of, from the *Cherwell*, October 17, 1868.	36·60	**·382**	**·054**	·003	·230	·287	**2,010**	2·09	13·6	10·5	24·1	—
The *Cherwell*, above Oxford, April 29, 1868.*	32·95	**·265**	**·025**	·001	·264	·290	**2,330**	1·56	17·6	5·1	22·7	Turbid. Very slightly yellow.
The *Cherwell*, above Oxford, at Marston Ferry, May 30, 1873.	30·08	**·274**	**·062**	·012	·186	·258	**1,640**	2·15	13·7	8·7	22·4	Slightly turbid.
The *Windrush*, above Bourton, August 2, 1873.	24·02	**·071**	**·038**	·004	·377	·418	**3,480**	1·30	14·7	4·6	19·3	"

COMPOSITION OF SURFACE WATERS FROM CULTIVATED CALCAREOUS DISTRICTS—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
The *Windrush*, above Witney, Dec. 9, 1870.	28·30	**·105**	**·033**	·001	·293	·327	**2,620**	1·13	18·0	5·0	23·0	Turbid.
The *Leach*, at junction with the *Thames*, May 3, 1873.	27·98	**·122**	**·037**	·004	·328	·368	**2,990**	1·40	18·0	5·3	23·3	Slightly turbid.
The *Cole*, at junction with the *Thames*, May 3, 1873.	29·40	**·276**	**·064**	·009	·148	·219	**1,230**	1·80	17·1	4·4	21·5	" "
The *Coln*, 1½ miles from junction with the *Thames*, May 3, 1873.	26·68	**·098**	**·029**	·003	·180	·211	**1,500**	1·40	15·4	4·9	20·3	" "
The *Ray*, at junction with the *Thames*, May 3, 1873.	35·04	**·554**	**·123**	·023	·225	·367	**2,120**	2·60	17·5	6·7	24·2	Turbid.
The *Churn*, at junction with the *Thames*, May 3, 1873.	26·86	**·149**	**·050**	·011	·167	·226	**1,440**	1·45	15·6	4·4	20·0	Slightly turbid.
The *Ampney Brook*, at junction with the *Thames*, May 3, 1873.	26·04	**·081**	**·023**	·001	·359	·383	**3,280**	1·45	15·6	5·0	20·6	" "
Stream from Thames Head and Ewen springs, at junction with the *Thames*, May 3, 1873.	27·00	**·085**	**·028**	·003	·287	·317	**2,570**	1·40	14·7	5·6	20·3	Slightly turbid. Palatable.
The *Swillbrook*, near its source, May 3, 1873.	31·35	**·220**	**·068**	·008	·071	·146	**460**	1·45	19·7	5·7	25·4	Slightly turbid.
The *Swillbrook* at junction with the *Thames*, May 3, 1873.	29·04	**·123**	**·040**	·004	·217	·260	**1,880**	1·65	16·6	4·9	21·5	" "
The Purderop reservoir at foot, near Swindon, May 5, 1873.	19·32	**·588**	**·098**	·012	0	·108	**0**	1·80	7·4	5·9	13·3	Turbid.
The *Thame* at junction with the *Thames*, April 30, 1868.*	38·53	**·397**	**·072**	·001	·080	·153	**490**	1·83	19·2	6·4	25·6	Clear and colourless.
The *Thame* at junction with the *Thames*, May 29, 1873.	31·74	**·402**	**·103**	·010	·098	·209	**740**	2·15	17·3	5·4	22·7	Very turbid.
The *Ock* at junction with the *Thames*, May 29, 1873.	33·16	**·399**	**·085**	·024	·125	·230	**1,130**	2·05	19·9	4·9	24·8	Turbid.
The *Evenlode* at junction with the *Isis*, May 29, 1873.	29·50	**·363**	**·104**	·001	·234	·339	**2,030**	1·90	15·7	7·0	22·7	Very turbid
Coomb's Stream, Stow-on-the-Wold, July 2, 1873.	30·30	**·147**	**·043**	0	·776	·819	**7,440**	1·20	15·7	7·3	23·0	" "
The *Pang* at junction with the *Thames*, November 20, 1873.	33·58	**·114**	**·034**	0	·294	·328	**2,620**	1·90	19·8	5·9	25·7	Clear.
The *Kennet* above Hungerford, April 20, 1868.*	25·58	**·195**	**·031**	·003	·113	·146	**830**	·54	18·1	3·6	21·7	Clear and colourless.
READING, water supplied to, from the *Kennet*, March 19, 1870.	25·90	**·205**	**·017**	·001	·187	·155	**1,060**	1·25	20·4	2·4	22·8	
The *Kennet* just above Reading, April 24, 1868.	25·62	**·228**	**·039**	·001	·029	·069	**0**	1·18	17·2	2·4	19·6	Turbid. Slightly greenish yellow.
The *Kennet* at junction with the *Thames*, May 31, 1873.	27·36	**·234**	**·056**	·013	·101	·168	**800**	1·60	18·4	4·6	23·0	Very turbid.
The *Loddon* at Twyford Bridge, May 29, 1873.	23·80	**·306**	**·072**	·005	·077	·153	**490**	1·85	13·6	3·8	17·4	Turbid.
The *Wye* as it enters the *Thames*, October 9, 1873.	36·96	**1·338**	**·307**	·014	0	·319	**0**	2·70	22·9	4·3	27·2	Very turbid. Slight earthy taste & odour.
The *Colne* above Watford, November 11, 1870.	31·50	**·133**	**·043**	·001	·322	·366	**2,910**	1·50	21·5	3·9	25·4	Clear and colourless.
The *Colne* at junction with the *Thames*, October 28, 1868.*	32·14	**·282**	**·071**	·017	·302	·387	**2,840**	1·59	17·8	3·9	21·7	——
The *Wey* opposite the waterworks well at Guildford, Oct. 4, 1873.	18·16	**·246**	**·075**	0	·148	·223	**1,160**	2·20	7·6	5·0	12·6	Slightly turbid.
The *Mole*, one mile above junction with the *Thames*, May 4, 1868.*	23·51	**·166**	**·022**	0	·231	·253	**1,990**	1·78	11·7	4·4	16·1	Turbid. Yellowish.
The *Mole* at Ditton bridge, January 31, 1873.	25·00	**·236**	**·042**	·007	·328	·376	**3,020**	1·90	11·3	5·6	16·9	Turbid.
The *Wandle* below Beddington sewage farm, May 11, 1868.*	30·00	**·100**	**·031**	0	·414	·445	**3,820**	—	13·2	8·5	21·7	Very slightly turbid. Colourless. Many cysts and animalculæ.
The *Lee* at New River intake, Jan. 24, 1873.	34·40	**·287**	**·067**	·005	·381	·452	**3,530**	1·80	19·7	6·0	25·7	Turbid.
The *Lee* and *Mimram* (mixed), above Hertford, May 5, 1868.*	25·88	**·125**	**·025**	0	·246	·271	**2,140**	1·48	17·8	2·1	19·9	Very turbid. Yellowish.
HERTFORD, water supply of, from the *Lee*, January 24, 1873.	33·96	**·322**	**·068**	·003	·396	·466	**3,660**	1·85	20·1	4·7	24·8	Turbid.
The *Lee* at intake of East London Water Company, February 1, 1873.	36·90	**·240**	**·057**	·015	·384	·453	**3,640**	1·95	18·9	8·0	26·9	"
The *Cray* above Joynson's Mill, July 6, 1870.	30·06	**·168**	**·100**	·013	·310	·421	**2,890**	1·38	20·6	3·1	23·7	"
The *Thames* at Lechlade, April 18, 1868.*	28·43	**·133**	**·033**	·003	·157	·192	**1,270**	1·06	16·8	5·1	21·9	Clear and colourless.
The *Thames* at Medley Lock (Isis), April 29, 1868.*	28·40	**·199**	**·028**	·001	·218	·247	**1,870**	—	10·5	7·7	18·2	Turbid. Yellowish.
The *Thames* below Oxford, April 29, 1868.*	31·60	**·216**	**·028**	0	·277	·305	**2,450**	—	10·9	8·2	19·1	Turbid. Greenish yellow.
The *Thames* at Abingdon, April 30, 1868.*	31·60	**·234**	**·026**	·002	·245	·273	**2,150**	—	13·0	9·0	22·0	Turbid. Very slightly yellow.
The *Thames* above Reading, April 24, 1868.*	32·70	**·291**	**·032**	·001	·286	·319	**2,550**	—	12·8	8·2	21·0	Turbid. Yellowish.
The *Thames* above Reading, May 31, 1873.	28·80	**·217**	**·057**	·007	·178	·241	**1,520**	1·80	16·8	5·3	22·1	Turbid.
The *Thames* below Reading, May 31, 1873.	28·86	**·261**	**·071**	·007	·167	·244	**1,410**	1·70	15·8	6·9	22·7	Very turbid.

Surface waters from cultivated calcareous districts.

Composition of Surface Waters from Cultivated Calcareous Districts—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
The *Thames* at Shiplake, April 25, 1868.*	30·00	**·263**	**·032**	·001	·215	·248	**1,840**	—	12·5	7·5	20·0	Turbid. Greenish yellow.
The *Thames* just above Shiplake Mill, May 31, 1873.	28·42	**·245**	**·068**	·007	·155	·229	**1,290**	1·70	15·9	7·4	23·3	Turbid.
The *Thames* at Medmenham, April 25, 1868.*	30·40	**·245**	**·036**	0	·229	·265	**1,970**	—	11·9	7·5	19·4	Turbid. Yellowish.
The *Thames* just above Windsor, May 2, 1868.*	31·00	**·259**	**·028**	·002	·205	·235	**1,750**	—	14·8	7·4	22·2	Turbid. Slightly yellow.
The *Thames* opposite wells supplying Windsor Castle, Sept. 29, 1873.	26·92	**·195**	**·064**	0	·169	·233	**1,370**	1·90	17·4	4·7	22·1	Clear.
The *Thames* at Old Windsor Lock, Sept. 29, 1873.	27·12	**·186**	**·051**	0	·059	·110	**270**	1·90	16·2	5·9	22·1	"
The *Thames* two miles below Windsor sewers, May 2, 1868.*	30·40	**·289**	**·029**	·003	·211	·243	**1,820**	—	15·0	7·4	22·4	Turbid. Yellowish.
The *Thames* at weir above Staines, May 2, 1868.*	31·20	**·304**	**·027**	0	·215	·242	**1,830**	—	10·3	10·5	20·8	Turbid. Slightly yellow.
The *Thames* at weir above Staines, October 28, 1868.*	31·40	**·304**	**·097**	·004	·173	·273	**1,440**	1·66	17·4	4·6	22·0	——
The *Thames* at Sunbury, January 31, 1873.	31·24	**·314**	**·049**	·002	·305	·356	**2,750**	1·80	17·2	7·0	24·2	Turbid.
The *Thames* above Hampton, May 4, 1868.*	27·87	**·260**	**·024**	0	·196	·220	**1,640**	1·48	15·7	4·3	20·0	Very slightly turbid. Faint yellow tint.
The *Thames* above Hampton, October 28, 1868.*	29·90	**·263**	**·057**	·006	·205	·267	**1,780**	1·76	16·9	4·7	21·6	——
The *Thames* above Hampton, January 4, 1871.	32·50	**·212**	**·064**	·007	·353	·423	**3,270**	1·98	19·2	4·7	23·9	Turbid.
The *Thames* above Hampton, January 31, 1873.	31·84	**·285**	**·050**	·002	·331	·383	**3,010**	1·80	18·5	5·1	23·6	Slightly turbid.
The *Thames* above Hampton, February 3, 1873.	31·78	**·246**	**·033**	·005	·355	·392	**3,270**	1·75	17·9	6·6	24·5	" "
The *Thames* above Hampton, February 5, 1873.	32·10	**·224**	**·042**	·003	·375	·419	**3,450**	1·80	18·9	5·0	23·9	" "
The *Thames* above Hampton, February 7, 1873.	29·84	**·276**	**·053**	·009	·346	·406	**3,210**	1·80	15·2	6·6	21·8	Turbid.
The *Thames* at Thames Ditton, January 31, 1873.	31·36	**·325**	**·076**	·003	·312	·391	**2,820**	1·75	18·3	5·6	23·9	"
Basin of the Great Ouse.												
The *Ouse* above Bedford, October 10, 1868.	47·90	**·620**	**·088**	·004	1·005	1·096	**9,760**	2·68	13·5	15·1	28·6	——
Cambridge, water from Hobson's conduit, April 10, 1873.	38·12	**·130**	**·021**	·002	·717	·740	**6,870**	2·90	17·6	10·3	27·9	Clear and colourless.
Ely, water supply of, Dec. 29, 1873	46·64	**·300**	**·039**	·002	·156	·197	**1,260**	2·80	24·2	12·1	36·3	" "
Lynn, water supply of, June 19, 1872.	22·34	**·177**	**·041**	·002	·283	·326	**2,530**	2·05	11·0	5·9	16·9	Turbid.
Thetford, the *Snarehill* above the town, February 7, 1871.	42·80	**·570**	**·079**	·009	·439	·525	**4,140**	2·88	19·7	10·3	30·0	"
Thetford the *Lesser Ouse* above the town, February 7, 1871.	44·10	**·416**	**·088**	·004	·630	·721	**6,010**	3·00	20·1	9·0	29·1	Slightly turbid.
Basin of the Trent.												
The *Bourne* near Birmingham, November 17, 1869.	36·00	**·211**	**·039**	·006	·275	·319	**2,480**	1·82	18·1	8·6	26·7	Turbid.
The *Bourne* at Whitaker, May 16, 1873.	32·10	**·116**	**·040**	·003	·277	·319	**2,470**	1·70	18·3	5·6	23·9	"
The *Blythe* at Whitaker, November 17, 1869.	38·46	**·453**	**·074**	·006	·153	·232	**1,260**	1·93	7·2	10·9	18·1	"
The *Blythe* at Whitaker from storage reservoir, May 16, 1873.	28·64	**·463**	**·132**	·004	0	·135	**0**	1·70	8·4	11·9	20·3	Slightly turbid.
Plant's Brook at pumping station, December 7, 1869.	24·38	**·350**	**·054**	·012	·320	·384	**2,980**	1·40	4·7	10·9	15·6	" "
Plant's Brook at pumping station, April 14, 1870.	22·26	**·323**	**·038**	·007	·245	·289	**2,190**	1·52	7·1	6·1	13·2	" "
Plant's Brook at pumping station, May 16, 1873.	19·64	**·440**	**·092**	·008	·063	·162	**380**	1·60	6·1	7·0	13·1	" "
Hawthorn Brook near Birmingham, April 14, 1870.	19·20	**·091**	**·010**	·002	·571	·583	**5,410**	1·46	3·4	7·7	11·1	Clear.
Perry Brook near Birmingham, April 14, 1870.	30·00	**·260**	**·032**	·005	·583	·619	**5,550**	1·90	10·1	9·5	19·6	Turbid.
The *Witton Brook* near King's Vale Well, May 16, 1873.	22·28	**·323**	**·053**	·008	·756	·816	**7,310**	2·20	0	10·0	10·0	
Wolverhampton, water supplied to, from Tettenhall reservoir, May 17, 1873.	26·92	**·466**	**·155**	·011	·169	·333	**1,460**	2·05	7·3	9·6	16·9	Very turbid.
Wolverhampton, the *Worf*, Sept. 25, 1873.	27·20	**·392**	**·046**	·006	·194	·245	**1,670**	2·30	13·9	7·6	21·5	Slightly turbid.
Wolverhampton, *Albrighton Brook*, September 25, 1873.	31·10	**·306**	**·092**	·005	·355	·451	**3,270**	2·00	13·5	8·0	21·5	Clear.
Brook at Wilnecote Hall, near Tamworth, April, 1868.	37·90	**·087**	**·030**	·008	·413	·450	**3,880**	1·91	15·2	9·5	24·7	——
Lichfield, water supply of, May 17, 1873.	34·24	**·209**	**·039**	·002	·583	·624	**5,530**	2·80	12·1	9·7	21·8	Slightly turbid.
Lincoln, water supply of, July 12, 1872.	18·88	**·286**	**·038**	0	·095	·133	**630**	3·60	·4	7·6	8·0	Turbid.
Boston, water supply of, July 15, 1873.	19·88	**·152**	**·033**	0	0	·033	**0**	2·15	10·6	3·8	14·4	"

COMPOSITION OF SURFACE WATERS FROM CULTIVATED CALCAREOUS DISTRICTS—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
PODEHOLE, Deeping Fen Drainage, Nov. 24, 1873.	110·40	**1·327**	**·159**	·080	0	·225	**340**	12·75	25·2	42·1	67·3	Turbid.
The *Dover Beck* near Nottingham, February 12, 1869.	14·24	**·240**	**·017**	·006	·461	·483	**4,340**	1·30	4·4	4·8	9·2	Very turbid.
The *Dover Beck* near Nottingham, March 1, 1869.	15·70	**·183**	**·047**	·005	·321	·372	**2,930**	1·34	1·5	9·7	11·2	Slightly turbid.
RETFORD, the *Idle* above canal feeder, December, 1870.	22·12	**·227**	**·048**	·003	·134	·184	**1,040**	1·56	7·2	9·8	17·0	——
Nethergreen Brook, Greaseley, Notts, June, 1871.	37·74	**·220**	**·036**	·006	·076	·117	**490**	3·70	10·9	11·2	22·1	Turbid.
WORKSOP, stream at Manor, September 6, 1873.	42·00	**·223**	**·029**	·002	·637	·668	**6,070**	2·40	13·3	19·6	32·9	„
WORKSOP, stream at Hob Wood, September 6, 1873.	46·20	**·069**	**·023**	0	·809	·832	**7,770**	2·00	15·0	24·2	39·2	Slightly turbid.
WORKSOP, stream above Stubbing Bridge, September 6, 1873.	44·72	**·132**	**·032**	0	·332	·364	**3,000**	3·20	17·6	21·5	39·1	Turbid.
WORKSOP, stream at Netherthorpe, September 6, 1873.	42·24	**·103**	**·026**	·001	·409	·436	**3,780**	2·00	15·9	23·6	39·5	Clear.
WORKSOP, stream at Shireoaks, September 6, 1873.	40·92	**·118**	**·031**	0	·527	·558	**4,950**	1·90	8·3	26·9	35·2	Slightly turbid.
MERSEY BASIN.												
NORTHWICH, water supply from *Wade Brook*, May 27, 1868.	27·96	**·633**	**·049**	0	·064	·113	**320**	2·43	2·4	11·6	14·0	Very turbid.
Rostherne Mere near Knutsford, March 1872.	20·34	**·548**	**·072**	·002	·053	·127	**230**	2·65	4·8	10·6	15·4	Slightly turbid.
BASIN OF THE OUSE.												
The *Don* at Heathorpe above Doncaster, October 7, 1869.	40·90	**·294**	**·020**	·020	·254	·290	**2,380**	6·23	2·6	7·9	10·5	Turbid.
Frickley Stream, near Doncaster, July 2, 1872.	31·70	**·377**	**·095**	·010	·415	·518	**3,910**	3·00	3·8	13·9	17·7	Very turbid.
Hooton Robert's Brook, near Doncaster, July 3, 1872.	25·00	**·314**	**·109**	·020	·300	·425	**2,840**	2·80	5·5	11·6	17·1	„
Stream in Ravensfield Park above fishponds, July 23, 1872.	26·30	**·185**	**·028**	·002	·382	·412	**3,520**	2·30	4·5	11·0	15·5	Turbid.
The *Barlow Brook* above Coal Mines, October 13, 1871.	15·76	**·242**	**·044**	0	·094	·138	**620**	1·15	·7	9·6	10·3	Slightly turbid.
CHESTERFIELD, water supply of, October 14, 1871.	15·80	**·226**	**·044**	0	·088	·132	**560**	1·25	2·9	7·4	10·3	„
RIPON, water supply from the *Ure*, January 27, 1874.	17·04	**·239**	**·037**	·001	0	·038	**0**	1·20	2·5	9·3	11·8	Turbid. Palatable.
WAKEFIELD, water supply of from the *Calder*, September 15, 1868.	44·76	**·431**	**·062**	·001	·065	·128	**337**	4·47	5·9	9·5	15·4	Very turbid.
WAKEFIELD, water supply of, from the *Calder*, September 18, 1869.	40·00	**·437**	**·049**	·004	·095	·147	**660**	4·19	7·8	5·8	13·6	Clear.
YORK, water supply of, June 10, 1873.	30·08	**·180**	**·024**	0	·070	·094	**380**	1·80	11·5	15·1	26·6	Clear.
TEES BASIN.												
The *Skerne* above Darlington, May, 1870.	46·52	**·199**	**·040**	·002	·119	·161	**890**	2·50	6·4	12·9	19·3	Slightly turbid.
WALES.												
CARDIFF, the *Feeder* at Herbert Street Bridge, used for supplying ships, October 16, 1872.	15·46	**·694**	**·123**	·030	·087	·185	**300**	1·00	·8	7·0	7·8	Turbid.
SCOTLAND.												
BERWICK-ON-TWEED, water supply of, April 4, 1870.	33·50	**·149**	**·022**	·003	·789	·813	**7,590**	3·79	7·8	11·8	19·6	Clear.
The *Blackadder* just before junction with the *Whitadder*, April 4, 1870.	23·60	**·361**	**·035**	·003	·116	·153	**860**	1·90	4·7	8·3	13·0	Slightly turbid.
Whitedam Head Brook near Berwick, September 20, 1870.	32·00	**·130**	**·030**	·001	·612	·643	**5,810**	3·25	10·5	5·8	16·3	Turbid.
The *Till* above *Braidford Burn*, March 18, 1872.	14·40	**·217**	**·038**	·002	·080	·120	**500**	1·95	·5	9·1	9·6	Slightly turbid.
LEITH, water supply from Gilmerton, March 10, 1873.	20·84	**·290**	**·050**	0	·231	·281	**1,990**	1·50	5·2	8·1	13·3	Very turbid.
GRANTON, water supply of, March 24, 1873.	39·88	**·216**	**·053**	·002	·269	·324	**2,390**	3·40	14·9	12·6	27·5	Clear.
The *Eden* above Cupar, August 22, 1872.	19·86	**·269**	**·051**	·005	·194	·249	**1,660**	1·90	·6	8·3	8·9	Turbid.
The *Dighty Burn* above Rose Mill, near Dundee, May 4, 1871.	13·76	**·105**	**·017**	0	·306	·323	**2,740**	1·40	2·9	6·6	9·5	Slightly turbid.
MONTROSE, water supplied to, from Kinnaber, March 11, 1872.	18·68	**·102**	**·017**	0	·509	·526	**4,770**	3·10	3·5	9·6	13·1	Clear and colourless.
Average - -	30·08	**·268**	**·053**	·005	·257	·314	**2,306**	2·24	12·4	8·2	20·6	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The analytical investigation of these numerous samples from calcareous and cultivated districts illustrates very fully the character of the water obtainable from this description

PART II. CLASSIFICATION.

Surface waters from cultivated calcareous districts.

of gathering ground. In addition to the import of the columns headed "ammonia," "nitrogen as nitrates and nitrites," "total combined nitrogen," and "chlorine,"—discussed at pages 12, 13, and 18, we have to offer the following remarks upon the foregoing numerical data.

Total Solid Impurity.—The proportion of total solid matter in solution in these samples is almost constantly high; only in rarely occurring instances, does it descend below 20 parts in 100,000, or 14 grains per imperial gallon. The mineral portion of this impurity consists chiefly of the carbonates and sulphates of lime, the nitrates of lime and soda, and chloride of sodium. The organic portion constitutes but a small fraction of the whole. In the 144 samples enumerated in the foregoing table, the total solid impurity varied from 13·22 parts in 100,000, or 9·25 grains per gallon, in the *King's Cliff Stream,* near Bridgewater; to 110·4 parts per 100,000, or 77·28 grains per imperial gallon, in the water from Podehole, the average being 29·53 parts per 100,000, or 20·67 grains per gallon.

Organic elements.—The foregoing analyses confirm the conclusion arrived at by the study of the composition of surface waters derived, on the one hand, from upland non-calcareous strata, and, on the other, from cultivated non-calcareous strata; they show that cultivation, by breaking up and aërating the surface of the land, favours the oxidation of any organic matter which dissolves in the water, to such an extent as to more than compensate for the addition of such matter in the manures applied to the soil. But although the water is thus rendered more palatable; it must not be forgotten that the organic matter, if present in smaller proportion, is of much more objectionable quality, than that contained in surface waters from uncultivated and unmanured land; indeed when any portion of the manure consists of human excrements, the organic matter dissolved in the water becomes not merely disgusting, but also dangerous. In the samples which we have analysed, the proportion of organic elements (organic carbon and organic nitrogen) varied from ·071 part in 100,000 parts, or ·05 grain per gallon, in the Gloucestershire *Frome,* to 1·645 part in 100,000 parts, or 1·151 grain per gallon in the *Wye* as it enters the *Thames,* and averaged ·321 part in 100,000 or ·225 grain per imperial gallon. The proportion of nitrogen to carbon in the soluble organic matter of these waters varied from N : C = 1 : 14·7 in the *Don* above Doncaster; to N : C = 1 : 1·68 in the *Cray* in Surrey, and averaged N : C=1 : 5·66.

Previous sewage or animal contamination.—Most calcareous soils are highly cultivated, and the ready transformation of the nitrogen of animal manure into nitrates and nitrites impresses upon the surface water draining from them strong evidence of previous animal contamination. Out of 144 samples which we have examined, there are only eight which do not furnish conclusive testimony to their previous pollution with animal matter, and of these three were drawn from lakes or large storage reservoirs in which this evidence had doubtless been destroyed as described at page 16, and a fourth (the Spalding water supply) had had it destroyed by admixture with ferruginous fen drainage. The maximum evidence of anterior pollution was found in the *Ouse* just above Bedford. This river exhibited evidence of previous contamination equal to that which would be caused by the admixture of nearly 10 per cent. of average London sewage with its water. This water, after flowing about 70 miles and receiving the sewage of Cambridge and other places, is afterwards drunk by the inhabitants of Ely.

Hardness.—Calcareous soils always yield hard water, and when they are broken up and pulverised in the operations of agriculture, the solution of the calcareous salts is facilitated; it is therefore not surprising that all the samples which we have examined are hard, and that most of them are very hard; that is to say, have a hardness of more than 20°, which renders them very unsuitable for washing, cleansing, and manufacturing purposes. In the 144 samples enumerated in the foregoing table, the hardness varied from 7°·8 in the *Feeder* at Newport, South Wales, to 67°·3 in the water from Podehole, the average hardness being 20°·6. The hardness of these waters is chiefly of the kind termed temporary, that is, it can be to a great extent removed either by boiling the water for half an hour, or by adding a certain small proportion of lime to it. After being thus softened by the latter process, which is known as Clark's method of softening water (*see* description of this process at page 205), the hardness of these waters would range from 2° up to about 12°, and there are only about thirty samples in the foregoing table, the small temporary hardness of which would render this process of little or no benefit.

General character.—The surface waters from calcareous cultivated land are polluted with but a moderate amount of organic matter; but as some of this matter is almost always of animal origin, they are always undesirable, and may at any time become dangerous for domestic use. If necessity compels their use, great care ought to be taken to secure their efficient filtration before they are delivered to consumers. This affords some, though by no means complete, protection from the propagation of zymotic

Part II. Classification.

Drainage water from sewage farms.

diseases through the agency of such waters. Moreover these waters are generally very turbid, and on this account alone require filtration, after which they are mostly bright, sparkling, and palatable. They are generally very hard, and, unless artificially softened, occasion a great waste of soap when they are used for washing.

Closely connected with surface waters from cultivated soils, are the land drainage waters from sewage farms, from land through which sewage is intermittently filtered, and from cultivated land upon which manures of various kinds are employed. It is true that water flowing from land drains, laid at depths varying from three to six feet, is not, strictly speaking, surface water; but the conditions to which it has been exposed are not widely different from those to which much of the so-called surface water draining from land has been subjected, inasmuch as it has either flowed from the surface of a catchwater sewage farm, or passed through only a small thickness of soil to the drains, and has, as a rule, made the transit from surface to drain in a few hours, thus affording much less time for the oxidation of organic matter within the pores of aërated soil, than that which elapses during the passage of surface water to shallow wells. Of all waters of this description, those which flow from the surface, or from the drains, of sewage farms are, generally, most impure, because here the time during which the foul sewage is exposed to the purifying action of plant and soil is reduced to a minimum.

The following are the results of our analyses of samples of drainage waters from sewage farms:—

Composition of Land Drainage Water from Sewage Farms.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.										
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Drainage from Barking Sewage Farm, April 22, 1868.	79·25	**1·366**	**·329**	·800	2·955	3·943	**35,820**	—	—	—	—
Drainage from Barking Sewage Farm, June 23, 1869.	79·50	**·887**	**·236**	·425	2·535	3·121	**28,530**	11·50	·9	29·9	**30·8**
Drainage from Barking Sewage Farm, September 5, 1871.	91·30	**·676**	**·198**	·005	4·143	4·345	**41,150**	13·40	·7	39·3	**40·0**
Drainage from Barking Sewage Farm, November, 9, 1871.	83·32	**·395**	**·094**	·003	3·937	4·033	**39,070**	13·10	·4	36·0	**36·4**
Drainage from Aldershot Sewage Farm, May 1, 1868.	39·00	**·504**	**·129**	·622	1·312	1·953	**17,920**	—	—	—	—
Drainage from Aldershot Sewage Farm, July 16, 1869.	18·60	**·665**	**·132**	·486	1·152	1·684	**15,200**	3·55	0	3·9	**3·9**
Drainage from Aldershot Sewage Farm, Shurvile Outlet, October 30, 1871.	24·60	**·108**	**·055**	·029	1·712	1·791	**17,040**	4·05	0	9·2	**9·2**
Drainage from Aldershot Sewage Farm, Alma Outlet, October 30, 1871.	66·00	**·329**	**·146**	·228	6·499	6·833	**66,550**	12·80	5·2	24·8	**30·0**
Drainage from Bedford Sewage Farm, September 10, 1868.	76·76	**·575**	**·163**	·023	·398	·580	**3,848**	7·15	26·7	19·3	**46·0**
Drainage from Bedford Sewage Farm, October 10, 1868.	78·30	**·742**	**·381**	·010	·600	·989	**5,760**	7·25	—	—	—
Drainage from Bedford Sewage Farm, July 24, 1869.	81·70	**·558**	**·034**	·095	·505	·617	**5,510**	8·17	36·3	20·3	**56·6**
Drainage from Bedford Sewage Farm, November 16, 1871.	76·80	**·273**	**·053**	·003	·338	·393	**3,090**	7·40	36·9	18·3	**55·2**
Drainage from Romford Sewage Farm, October 22, 1870.	79·90	**1·244**	**·247**	·036	1·418	1·695	**14,160**	9·45	25·9	17·7	**43·6**
Drainage from Romford Sewage Farm, November 26, 1870.	85·60	**·844**	**·233**	·040	1·143	1·409	**11,440**	9·30	27·9	20·6	**48·5**
Drainage from Altrincham Sewage Farm, November 24, 1871.	60·40	**·898**	**·049**	·660	·682	1·274	**11,940**	7·20	2·6	33·8	**36·4**
Drainage from Norwood Sewage Farm, September 24, 1868.	81·68	**1·621**	**·214**	·013	·843	1·068	**8,220**	9·73	18·64	14·26	**32·90**
Drainage from Norwood Sewage Farm, October 8, 1868.	95·30	**1·516**	**·189**	·006	·587	·781	**5,600**	9·93	15·84	22·14	**37·98**
Drainage from Norwood Sewage Farm, October 22, 1868.	88·40	**1·372**	—	1·080	·710	—	**15,670**	9·93	17·68	16·70	**34·38**
Drainage from Norwood Sewage Farm, November 19, 1868.	78·00	**1·473**	**·285**	1·366	·167	1·577	**12,600**	9·73	11·80	22·90	**34·70**
Drainage from Norwood Sewage Farm, December 3, 1868.	79·60	**1·258**	**·323**	1·052	·694	1·883	**15,280**	8·54	4·18	27·74	**31·92**
Drainage from Norwood Sewage Farm, December 17, 1868.	103·00	**1·187**	**·120**	1·254	·796	1·948	**17,970**	8·74	8·18	30·45	**38·63**
Drainage from Norwood Sewage Farm, December 31, 1868.	77·80	**1·291**	**·098**	·497	1·450	1·957	**18,270**	6·75	9·30	25·56	**34·86**
Drainage from Norwood Sewage Farm, January 14, 1869.	86·50	**1·221**	—	·721	·287	—	**8,490**	7·84	15·97	21·35	**37·32**
Drainage from Norwood Sewage Farm, January 21, 1869, after two nights' frost.	94·30	**1·173**	**·265**	·720	·088	·946	**6,490**	8·44	19·31	18·99	**38·30**
Drainage from Norwood Sewage Farm, January 25, 1869, after seven nights' frost.	100·30	**1·431**	**·419**	1·095	·072	1·393	**9,420**	10·13	24·23	16·37	**40·60**

COMPOSITION OF LAND DRAINAGE WATER FROM SEWAGE FARMS—*continued.*

DESCRIPTION.	Dissolved Matters.										
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Drainage from Norwood Sewage Farm, January 28, 1869.	77·30	**1·280**	**·406**	1·195	·240	1·630	**11,920**	7·55	18·99	17·02	36·01
Drainage from Norwood Sewage Farm, February 11, 1869.	83·80	**1·130**	**·133**	·300	·549	·929	**7,640**	6·80	20·30	19·97	40·27
Drainage from Norwood Sewage Farm, February 25, 1869.	73·20	**1·577**	**·391**	·988	·423	1·628	**12,050**	5·70	16·86	17·19	34·05
Drainage from Norwood Sewage Farm, March 12, 1869.	83·10	**1·294**	**·107**	·965	·381	1·283	**11,440**	—	—	—	46·95
Drainage from Norwood Sewage Farm, March 25, 1869.	97·80	**1·061**	**·189**	·342	·462	·933	**7,120**	7·50	16·54	20·93	37·47
Drainage from Norwood Sewage Farm, April 8, 1869.	81·60	**1·376**	**·321**	·885	·547	1·596	**12,440**	8·00	19·68	17·16	36·84
Drainage from Norwood Sewage Farm, April 22, 1869.	102·50	**1·495**	**·260**	·842	·081	1·034	**7,420**	8·80	19·32	20·34	39·66
Drainage from Norwood Sewage Farm, May 6, 1869.	84·30	**1·483**	**·410**	1·131	·026	1·367	**9,250**	7·75	15·36	22·11	37·47
Drainage from Norwood Sewage Farm, May 20, 1869.	83·00	**1·602**	**·354**	·730	·498	1·453	**10,670**	7·50	14·03	19·67	33·70
Drainage from Norwood Sewage Farm, June 3, 1869.	97·10	**1·683**	**·250**	·415	·167	·759	**4,770**	9·64	17·80	20·92	38·72
Drainage from Norwood Sewage Farm, June 17, 1869.	79·80	**1·360**	**·221**	·894	0	·957	**7,040**	8·50	17·95	16·69	34·64
Drainage from Norwood Sewage Farm, July 1, 1869.	95·10	**1·577**	**·271**	·905	·950	1·966	**16,630**	10·50	24·23	16·06	40·29
Drainage from Norwood Sewage Farm, July 15, 1869.	94·00	**2·160**	**·274**	·408	·705	1·315	**10,090**	13·10	23·63	11·95	35·58
Drainage from Norwood Sewage Farm, July 29, 1869.	93·60	**1·889**	**·210**	·135	·354	·675	**4,330**	10·20	20·77	17·01	37·78
Drainage from Norwood Sewage Farm, August 12, 1869.	93·80	**2·095**	**339**	·130	·608	1·054	**6,830**	11·80	20·91	14·36	35·27
Drainage from Norwood Sewage Farm, August 26, 1869.	74·30	**1·605**	**·370**	·673	0	·924	**5,220**	11·40	17·27	18·63	35·90
Drainage from Norwood Sewage Farm, September 9, 1869.	89·20	**2·085**	**·300**	·300	·403	·950	**6,180**	10·90	19·91	16·93	36·84
Drainage from Norwood Sewage Farm, September 24, 1869.	87·00	**2·034**	**·517**	1·128	1·390	2·836	**22,870**	10·60	17·50	16·37	33·87
Drainage from Croydon Sewage Farm, September 24, 1868.	37·80	**·723**	**·119**	·006	·115	·239	**880**	2·73	21·03	5·93	26·96
Drainage from Croydon Sewage Farm, October 8, 1868.	37·90	**·605**	**·120**	·005	·382	·506	**3,540**	2·58	21·06	6·52	27·58
Drainage from Croydon Sewage Farm, October 22, 1868.	49·00	**·644**	**·069**	·008	·353	·429	**3,280**	3·18	19·10	7·70	26·80
Drainage from Croydon Sewage Farm, November 5, 1868.	39·90	**·801**	—	·248	·651	—	**8,230**	2·98	20·05	7·69	27·74
Drainage from Croydon Sewage Farm, December 3, 1868.	40·20	**·766**	**·239**	·534	·289	·968	**6,970**	3·77	22·57	7·55	30·12
Drainage from Croydon Sewage Farm, December 31, 1868.	48·70	**·632**	**·124**	·130	1·271	1·502	**13,460**	3·47	17·50	14·42	31·92
Drainage from Croydon Sewage Farm, January 14, 1869.	44·70	**·604**	**·186**	·166	·941	1·264	**10,460**	3·08	20·82	11·92	32·74
Drainage from Croydon Sewage Farm, January 21, 1869, after two nights' frost.	46·00	**·620**	**·242**	·466	·210	·836	**5,620**	3·18	21·13	9·32	30·45
Drainage from Croydon Sewage Farm, January 25, 1869, after seven nights' frost.	45·10	**·562**	**·235**	·275	·686	1·147	**8,800**	2·58	18·50	10·67	29·17
Drainage from Croydon Sewage Farm, January 28, 1869.	34·50	**·614**	**·093**	·165	·425	·654	**5,290**	2·88	21·96	7·84	29·80
Drainage from Croydon Sewage Farm, February 11, 1869.	38·40	**·979**	**·138**	·125	·091	·332	**1,620**	2·70	20·24	10·21	30·45
Drainage from Croydon Sewage Farm, February 25, 1869.	39·90	**·541**	**·089**	·098	·776	·946	**8,250**	2·60	13·58	17·19	30·77
Drainage from Croydon Sewage Farm, March 12, 1869.	37·30	**·545**	**·097**	·246	·538	·838	**7,090**	2·30	—	—	27·58
Drainage from Croydon Sewage Farm, March 25, 1869.	38·80	**·427**	**·077**	·090	·596	·747	**6,380**	2·40	19·64	8·47	28·11
Drainage from Croydon Sewage Farm, April 8, 1869.	36·20	**·637**	**·122**	·150	·396	·642	**4,880**	2·50	19·61	7·90	27·51
Drainage from Croydon Sewage Farm, April 22, 1869.	39·10	**·702**	**·129**	·124	·241	·472	**3,110**	2·24	20·42	6·49	26·91
Drainage from Croydon Sewage Farm, May 6, 1869.	37·10	**·758**	**·083**	·032	·245	·354	**2,390**	2·45	21·98	4·93	26·91
Drainage from Croydon Sewage Farm, May 20, 1869.	37·10	**·644**	**·080**	·020	·284	·380	**2,680**	2·15	21·04	6·77	27·81
Drainage from Croydon Sewage Farm, June 3, 1869.	33·90	**·531**	**·127**	·062	·183	·361	**2,020**	2·40	18·40	7·90	26·30
Drainage from Croydon Sewage Farm, June 17, 1869.	29·10	**·291**	**·082**	·042	0	·117	**30**	2·18	18·54	7·76	26·30
Drainage from Croydon Sewage Farm, July 1, 1869.	32·10	**·761**	**·036**	·050	·301	·378	**3,100**	2·28	20·05	5·36	25·41
Drainage from Croydon Sewage Farm, July 15, 1869.	38·10	**·605**	**·124**	·008	·201	·332	**1,760**	2·60	21·08	4·93	26·01
Drainage from Croydon Sewage Farm, July 29, 1869.	36·90	**·628**	**·077**	·090	0	·151	**420**	2·60	20·93	7·48	28·41

COMPOSITION OF LAND DRAINAGE WATER FROM SEWAGE FARMS—*continued.*

DESCRIPTION.	Dissolved Matters.										
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Drainage from Croydon Sewage Farm, August 12, 1869.	39·10	**·582**	**·385**	·278	·325	·939	**5,220**	2·60	20·14	6·77	26·91
Drainage from Croydon Sewage Farm, August 26, 1869.	30·80	**·362**	**·054**	·018	0	·069	**0**	2·80	17·89	6·92	24·81
Drainage from Croydon Sewage Farm, September 9, 1869.	32·70	**·591**	**·105**	·038	·147	·283	**1,460**	2·50	23·78	6·15	29·93
Drainage from Croydon Sewage Farm, September 24, 1869.	35·50	**·606**	**·105**	·068	·147	·308	**1,710**	2·44	15·23	5·21	20·44
Drainage from Croydon Sewage Farm, December 23, 1869.	52·30	**·795**	**·072**	·265	1·164	1·454	**13,500**	3·70	13·80	16·70	30·50
Drainage from Croydon Sewage Farm, December 30, 1869.	45·00	**·772**	**·076**	·530	·678	1·190	**10,820**	2·95	17·00	12·30	29·30
Average -	64·02	**·982**	**·191**	·388	·756	1·266	**10,443**	6·36	17·56	15·40	33·09

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results show that, in some cases, the drainage water from sewage farms is less polluted by organic matter than *Thames* water as delivered in London for human consumption; but this degree of purity, attained occasionally at the Aldershot, Croydon, and Bedford sewage farms, must be regarded as exceptional, for, as a rule, such drainage waters are much more polluted with organic matter than surface waters from land manured in the usual manner. In the samples contained in the above table the proportion of organic elements (organic carbon and organic nitrogen) varied from ·163 part per 100,000 parts, or ·114 grain per gallon, to 2·551 parts per 100,000, or 1·786 grain per gallon; and averaged 1·173 part per 100,000 parts, or ·821 grain per imperial gallon. It is not necessary to enter further into the quality of these waters, since we unhesitatingly condemn the whole of them as dangerous and totally unfit for drinking.

The purification of sewage by downward intermittent filtration yields, so far as our experience extends, drainage water much less polluted than that which is furnished by land under sewage irrigation, when the irrigated fields are not under-drained. The results of analysis of numerous samples of water draining from intermittent filters, on an experimental scale, will be found in our First Report (*Mersey* and *Ribble* basins), Vol. I., pages 63 to 69; and to these we now add the analytical results yielded by six samples of water collected from the outfall drain of the intermittent filters upon which the sewage of Merthyr Tydfil has been cleansed during the past three years.

COMPOSITION OF DRAINAGE WATER FROM INTERMITTENT FILTERS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Drainage from intermittent filters at Merthyr Tydfil, June 19, 1871.	34·60	**·249**	**·056**	·075	·231	·349	**2,610**	3·00	9·4	8·9	18·3	Slightly turbid.
Ditto, ditto, October 20, 1871, at 11 a.m.	32·72	**·103**	**·012**	·025	·194	·226	**1,830**	2·70	7·2	9·9	17·1	Turbid.
Ditto, ditto, October 20, 1871, at 5 p.m.	34·64	**·123**	**·044**	·063	·337	·433	**3,570**	2·90	12·4	10·0	22·4	Do.
Ditto, ditto, October 20, 1871, average of half-hourly samples, from 10.25 a.m. to 5.25 p.m.	33·48	**·123***	**·031***	·058	·300	·379*	**3,160**	2·60	12·1	9·4	21·5	Do.
Ditto, ditto, at 6 p.m., July 15, 1872, and at 9.30 a.m., July 16, 1872.	36·28	**·199**	**·014**	·060	·341	·404	**3,580**	3·25	11·8	8·1	19·9	Do.
Ditto, ditto, October 17, 1872 -	31·88	**·142**	**·033**	·095	·211	·322	**2,570**	2·60	7·2	11·7	18·9	Slightly turbid.
Average - -	33·93	**·156**	**·032**	·063	·269	·352	**2,887**	2·84	10·0	9·7	19·7	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Judged by popular standards, these samples would be pronounced to be fairly good potable waters. They were colourless, transparent when collected, and palatable, and

* Erroneously given as organic carbon ·333; organic nitrogen, ·107; and total combined nitrogen, ·455, in our Fourth Report, page 56.

PART II. CLASSIFICATION.

Drainage water from specially manured land.

even when viewed with reference to their chemical composition, were considerably superior to the average of *Thames* water which is habitually used for all household purposes in London; indeed there is a close resemblance in chemical composition between the effluent water issuing from the intermittent sewage filters at Merthyr Tydfil and that portion of the London water supply which is drawn from the *Thames*, as is seen from the following comparison:—

RESULTS OF ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								
	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Total Hardness.
Average composition of *Thames* water supplied to London during 1872.	27·09	·261	·039	·001	·206	·246	1,750	1·85	20·7
Average composition of drainage water from intermittent filters at Merthyr Tydfil.	33·93	·156	·032	·063	·269	·352	2,887	2·84	19·7

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

It is evident from this comparison that the resemblance is not confined to the organic elements, but extends also to the hardness. The organic matter in the Merthyr drainage is, however, more highly nitrogenised, for whilst the average proportion of nitrogen to carbon in the *Thames* water in the year 1872 was N : C = 1 : 6·69, the following was the average proportion in the Merthyr drainage:—N : C = 1 : 4·87.

Notwithstanding the comparative freedom of the Merthyr drainage from organic pollution, it is much more unfit than *Thames* water for human consumption, on account of the almost exclusively animal origin of the organic matter which it contains.

We have also studied the composition of drainage water from land dressed with farmyard manure, and with mineral manures free from organic matter, and have likewise analysed numerous samples of water draining from land which had been cropped, but continuously unmanured, for long periods. In these inquiries we have received important assistance from J. B. Lawes, Esq., F.R.S., and Dr. J. H. Gilbert, F.R.S., who furnished us with numerous samples of drainage water from experimental plots of land upon Mr. Lawes' farm at Rothamsted.

These plots have a good natural drainage into the chalk, but they are also artificially drained, and the drain pipes from which our samples were collected are laid at a depth varying from three to four feet below the surface. One of these plots had been heavily manured with an annual dressing of 14 tons of farmyard manure per acre since the year 1844, and had been continuously cropped with wheat since that time. We submitted to analysis eight samples of drainage water from this plot, with the following results:—

COMPOSITION OF DRAINAGE WATER FROM LAND MANURED WITH 14 TONS FARMYARD MANURE PER ACRE PER ANNUM SINCE 1844.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
Collected January 22, 1868	23·50	—	—	·004	·352	—	3,233	·90	—	—	—	
Ditto, February 7, 1870	26·20	·263	·040	·010	·720	·768	6,960	1·05	11·1	5·9	17·0	
Ditto, February 8, 1870	21·52	·465	·048	·008	·810	·365	2,850	·60	5·7	7·2	12·9	
Ditto, January 5, 1872	51·20	·452	·141	·026	2·592	2·754	25,810	3·35	11·5	20·6	32·1	Turbid.
Ditto, January 6, 1872	29·08	1·233	·260	·006	·582	·847	5,550	1·40	7·8	11·9	19·7	Very turbid.
Ditto, October 26, 1872	42·96	·815	·121	·052	·932	1·096	9,430	2·80	12·1	13·3	25·4	Do.
Ditto, November 30, 1872	34·12	1·243	·335	0	·179	·514	, 70	·90	1·4	8·0	9·4	Do.
Ditto, December 9, 1872	20·04	·356	·072	·002	·222	·296	1,920	1·05	6·6	5·4	12·0	Slightly turbid.
Ditto, December 17, 1872	24·32	·304	·074	·001	·452	·527	4,210	1·40	8·7	7·3	16·0	Turbid.
Ditto, January 3, 1873	18·80	·355	·079	·002	·267	·348	2,370	1·10	6·6	6·0	12·6	Slightly turbid.
Ditto, January 10, 1873	14·00	·181	·036	0	·094	·130	60	1·00	3·3	5·4	8·7	Slightly turbid.
Ditto, January 19, 1873	14·00	·316	·120	·002	·084	·206	540	·70	3·7	5·6	9·3	Turbid.
Ditto, February 26, 1873	16·96	·244	·049	0	·082	·131	500	·65	3·5	6·6	10·1	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The plot (2) from which the above samples were collected was dressed with farmyard manure and cropped with turnips in 1839. In the four following years it received no manure, but bore the following crops; in 1840, barley; in 1841, peas; in 1842, wheat;

and in 1843, oats. From that year to the present it has annually received 14 tons of farmyard manure per acre.

PART II. CLASSIFICATION.

Drainage water from specially manured land.

These analyses show that the drainage water from this very heavily manured land varied in quality between wide limits, owing, no doubt, to the varying intensity of the rainfall. Thus January and February 1873 were very wet months, and the large volume of water passing through the soil diluted the soluble impurities, which would otherwise have been contained within a smaller volume of water; and consequently the proportions of all the ingredients were remarkably low in the samples collected in those months.

The *total solid impurity* varied from 51·2 parts in 100,000 to 14 parts in 100,000, and averaged 25·9 parts in 100,000. The *organic elements* varied from 1·578 part in 100,000 to ·217 part in 100,000, and averaged ·633 part in 100,000. The evidence of *previous animal contamination* ranged from 25,810 parts in 100,000 to only 500 parts in 100,000, and averaged 5,036 parts in 100,000, whilst the hardness oscillated between 32°·1 and 8°·7. Though often better, as regards chemical composition, than many waters consumed in large towns, these drainage waters from land dressed with animal manure cannot be employed for drinking or cooking without considerable risk to health. Even after efficient filtration, we could not recommend such water for domestic use, although it would doubtless be less dangerous than water from streams contaminated with sewage, and from shallow wells near privies and cesspools.

The foregoing table, when compared with those on pages 55, 56, and 57, illustrates an important difference between the composition of water which has been polluted chiefly with solid excremental matters, such as farmyard manure, and water which has received sewage, that is to say, liquid as well as solid excrements. The solid excrements, both of man and animals, contain but little common salt or chlorides, and consequently but little chlorine; on the other hand, common salt is a large constituent of urine, and therefore of sewage. The proportion of chlorine in the drainage water from land dressed with 14 tons of farmyard manure per acre varied, in the samples analysed, from ·6 part per 100,000 parts of water to 3·35 parts per 100,000, and averaged 1·3 part per 100,000 parts of water, whilst in the effluent water from the intermittent filters at Merthyr Tydfil (*see* page 57), it ranged from 2·6 parts per 100,000 to 3·25 parts per 100,000, and averaged 2·84 parts per 100,000. In the drainage water from sewage farms it oscillated from 2·15 parts in 100,000 parts of water to 13·4 parts in 100,000, and averaged 6·36 parts in 100,000.

The original animal pollution of the waters enumerated in these analytical tables varied between wide limits, as is evident from an inspection of the columns headed "Total Combined Nitrogen," and this must be taken into account in approximately deducing the ratio between the chlorine and animal pollution from the three tables. In the drainage waters from sewage farms (*see* pages 55–57) the ratio of total combined nitrogen to chlorine ranged from N : Cl. = 1 : 40·58 to N : Cl. = 1 : 1·87, and averaged N : Cl. = 1 : 7·33.

In the drainage water from the intermittent filters at Merthyr Tydfil (*see* page 57) this ratio varied from N : Cl. = 1 : 11·95 to N : Cl. = 1 : 6·7, and averaged N : Cl. = 1 : 8·37.

Whilst in the drainage from land dressed with farmyard manure (*see* page 58) the ratio ranged from N : Cl. = 1 : 7·69 to N : Cl. = 1 : 1·22, and averaged N : Cl. = 1 : 2·97.

These results show that whilst on the average the proportion of chlorine to nitrogen in water contaminated with sewage, is much greater than it is in water polluted by farmyard manure, yet the instances to the contrary are sufficiently numerous to prevent the deduction of an inflexible rule applicable to individual samples of polluted water from unknown sources. A low proportion of chlorine to nitrogen only indicates a strong probability that the polluting matter was solid animal refuse as distinguished from sewage.

The three following tables contain the results of our analysis of samples of drainage water from land which had not received any nitrogenous manure for many years, but had borne an annual crop of wheat.

PART II. CLASSIFICATION.

Drainage water from unmanured land.

COMPOSITION OF DRAINAGE WATER FROM LAND UNMANURED BUT CONTINUOUSLY BEARING WHEAT CROPS SINCE 1852.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
Collected January 13, 1868 - -	22·70	—	—	·004	·517	—	4,883	1·40	—	—	—	
Ditto, November 23, 1868 - -	29·48	—	—	·001	1·475	—	14,440	1·60	9·1	12·1	21·2	
Ditto, December 8, 1868 - -	48·40	—	—	0	2·268	—	22,360	3·80	10·3	22·4	32·7	
Ditto, from December 16 to December 17, 1869.	24·68	·242	·037	·006	·692	·734	6,650	1·14	9·0	8·8	17·8	Drains in full flow.
Ditto, February 7, 1870 - -	21·04	·191	·010	·006	·243	·258	2,160	·90	13·5	4·3	17·8	
Ditto, January 5, 1872 - -	34·40	·217	·057	·002	1·312	1·371	12,820	1·40	9·4	11·2	20·6	Slightly turbid.
Ditto, May 18, 1872 - -	16·50	·150	·024	0	·031	·055	0	1·05	14·1	3·9	18·0	Do.
Ditto, June 11, 1872 - - -	23·60	·168	·058	0	0	·058	0	1·20	13·7	4·3	18·0	Turbid.
Ditto, October 26, 1872 - -	22·52	·178	·030	·003	·366	·398	3,370	·95	9·5	7·4	16·9	Slightly turbid.
Ditto, January 19, 1873 - -	17·44	·099	·039	·002	·057	·098	270	·80	10·6	4·7	15·3	Clear.
Ditto, February 26, 1873 - -	13·80	·111	·020	0	·131	·151	990	·85	8·9	4·6	13·5	Slightly turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Two plots (3 and 4) delivered into the common drain from which the above samples were collected. Both plots were dressed with farmyard manure, and bore a crop of turnips in 1839. In the four following years, they were unmanured, but were cropped as follows:—In 1840, with barley; in 1841, with peas; in 1842, with wheat; and in 1843 with oats. Both plots have since annually grown crops of wheat; one has remained unmanured continuously, whilst the other received a yearly dressing, from 1844 to 1852 inclusive, consisting of sulphate of ammonia, and superphosphate of lime made with muriatic acid. Neither plot has therefore received any animal manure since the year 1839.

COMPOSITION OF DRAINAGE WATER FROM LAND UNMANURED SINCE 1864.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
Collected January 5, 1872 - -	35·12	1·213	·277	·001	1·318	1·596	12,870	1·25	14·2	10·6	24·8	Slightly turbid.
Ditto, October 26, 1872 - -	25·52	·182	·052	·002	·464	·518	4,340	1·20	11·5	10·0	21·5	Do.
Ditto, February 26, 1873 - -	23·68	·288	·073	0	·184	·257	1,520	·80	10·9	4·7	15·6	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

This plot of land (16) was dressed with farmyard manure and cropped with turnips in 1839. In the following four years it was unmanured, but bore successive crops of barley, peas, wheat, and oats. From 1844 to 1851 inclusive this plot received various mineral manures, generally some ammonia salts, and several times some rape cake. From 1852 to 1864, both inclusive, it received yearly per acre 300 or 200 lbs. sulphate of potash, 200 or 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia (Epsom salts), $3\frac{1}{2}$ cwts. superphosphate of lime, 400 lbs. sulphate of ammonia, and 400 lbs. muriate of ammonia. In the years 1864, 1865, and 1866, half of it also received some soluble silicates. With this exception it has been continuously unmanured since 1864, and it has not received any animal organic manure since the year 1839, and not any vegetable organic manure since 1848.

COMPOSITION OF DRAINAGE WATER FROM LAND (IN WHEAT) TO WHICH NO NITROGENOUS MANURE HAD BEEN APPLIED SINCE 1851.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary	Hardness. Permanent.	Hardness. Total.	
Collected January 18, 1868 - -	38·90	—	—	·005	·881	—	**8,531**	1·80	—	—	—	
Ditto, November 23, 1868 - -	46·72	—	—	·001	1·644	—	**16,130**	2·40	9·7	22·7	32·4	
Ditto, December 8, 1868 - -	51·08	—	—	·001	1·623	—	**15,920**	2·00	0	17·5	17·5	
Ditto, December 15, 1869 - -	31·52	**·188**	**·022**	·002	·649	·673	**6,190**	1·42	8·1	14·2	22·3	Turbid. First dribble from drain.
Ditto, from December 16, to December 17, 1869.	32·64	**·217**	**·032**	·003	·702	·737	**6,720**	1·23	10·8	11·5	22·3	Turbid. Drain in full flow.
Ditto, February 7, 1870 - -	28·08	**·202**	**·023**	·004	·494	·520	**4,650**	·90	10·3	8·3	18·6	
Ditto, January 5, 1872 - -	48·24	**·159**	**·060**	·001	1·418	1·479	**13,870**	1·45	15·1	20·6	35·7	Very slightly turbid.
Ditto, May 18, 1872 - - -	23·80	**·135**	**·020**	0	·071	·091	**390**	·75	15·8	6·0	21·8	Slightly turbid.
Ditto, June 11, 1872 - - -	28·48	**·181**	**·066**	·001	0	·067	**0**	·90	17·7	5·3	23·0	Turbid.
Ditto, October 26, 1872 - -	38·72	**·220**	**·040**	·001	·360	·401	**3,290**	1·10	9·6	17·9	27·5	Slightly turbid.
Ditto, January 19, 1873 - -	29·56	**·108**	**·022**	·008	·157	·186	**1,320**	·85	12·2	9·6	21·8	Clear.
Ditto, February 26, 1873 - -	26·48	**·316**	**·076**	0	·088	·164	**560**	1·00	5·6	6·7	12·3	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

This plot of land (5) was dressed with farmyard manure in 1839, and bore a crop of turnips in that year. During the next four years it received no manure, but bore successive crops of barley, peas, wheat, and oats. From 1844 to 1851 inclusive, various mineral manures, generally some ammonia-salts, and several times rape cake, were applied. From that year to 1858 inclusive it received the following annual dressing per acre: 300 lbs. sulphate of potash, 200 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, and 3½ cwts. superphosphate of lime, made for this and all the other experimental plots from calcined bones. The same kind of dressing has been continued every subsequent year, except that the weight of sulphate of potash has been reduced from 300 lbs. to 200 lbs., and that of sulphate of soda from 200 lbs. to 100 lbs. In the years 1864, 1865, and 1866, some soluble silicates were added to half of this plot; and in 1868 and afterwards, these were replaced by chopped straw (produced in the previous season). The land has therefore received no organic animal manure since 1839, nor nitrogenised mineral manure since the year 1851.

The composition of drainage water from unmanured land, or from soil to which no organic manure had been applied for many years, presents, as might be expected, a marked contrast with that of the drainage waters enumerated in the three analytical tables on pages 55, 57, and 58. It is, however, chiefly with the last of the three tables (viz.: that showing the composition of water draining from land to which farmyard manure had been applied, page 58,) that the comparison is most instructive, because the drainage waters mentioned in that table are from a neighbouring plot of the same field, whereas the effluent waters (detailed in tables on pages 55, 56, and 57), were from sewage farms and intermittent filters in totally different localities where the soil had little in common with that of the plots at Rothamsted.

Total Solid Impurity.—The total solid impurity dissolved in the drainage water from land unmanured since 1852, was present in the following proportions in 100,000 parts:—

Maximum - - - - -	48·4 parts.
Minimum - - - - -	13·8 „
Average - - - - - -	24·9 „

The total solid impurity in 100,000 parts of the drainage water from land unmanured since 1864 exhibited the following proportions:—

Maximum - - - - -	35·12 parts.
Minimum - - - - - - -	23·68 „
Average - - - - - -	28·11 „

This land had received no organic manure since 1848.

The total solid impurity in 100,000 parts of the drainage water from land (in wheat) to which no nitrogenous or organic manure had been applied since 1851, exhibited the following proportions:—

Maximum - -	51·08 parts.
Minimum - - -	23·80 „
Average - - -	35·35 „

PART II. CLASSIFICATION.

Drainage water from land uncropped and unmanured.

Organic Elements.—Notwithstanding that the experimental plots referred to in the three preceding tables had received no organic manure for a long period, they still yielded drainage waters containing considerable proportions of organic matter which was usually highly nitrogenised, and therefore probably of animal origin, and derived in part from the dressings of farmyard manure, which all the plots received as early as the year 1839,—a conclusion which is strongly supported by the presence in the waters of large proportions of nitrogen as nitrates and nitrites (see further remarks on the origin of these at page 12). The organic elements (organic carbon and organic nitrogen) found in 100,000 parts of these waters exhibited the following proportions:—

Proportion of Organic Elements in 100,000 parts of Water.	Unmanured since 1851 (Plots 3, 4).	Unmanured since 1864 (Plot 16).	No Organic or Nitrogenous Manure since 1851 (Plot 5).
Maximum - - - - - -	·279	1·490	·392
Minimum - - - - - -	·131	·234	·130
Average - - - - - -	·204	·695	·232

Although the land from which the samples enumerated in the three preceding tables had received no animal manure for a long series of years, it had borne yearly crops of wheat which could scarcely fail to influence the composition of the water draining from the soil. It is therefore interesting to compare the drainage waters of these plots with that collected from land at Rothamsted, which has remained both unmanured and uncropped since 1869, when it grew wheat without manure, after roots sown in 1868, with 2 cwts. guano and 2½ cwts. superphosphate, but which failed in consequence of the drought. The following table contains the results of our analyses of several samples of drainage water from such land:—

COMPOSITION OF WATER FROM LAND BOTH UNMANURED AND UNCROPPED.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Water from land drained 20 inches deep, November 20–23, 1870.	63·28	**·108**	**·045**	0	4·936	4·981	**49,040**	2·15	1·0	11·9	12·9	Clear.
Ditto, drained 40 inches deep, November 20–23, 1870.	36·24	**·147**	**·049**	0	2·345	2·394	**23,130**	2·86	5·1	8·3	13·4	Clear.
Ditto, drained 60 inches deep, November 20–23, 1870.	39·24	**·127**	**·042**	0	2·853	2·895	**28,210**	2·60	7·2	8·3	15·5	Clear.
Ditto, drained 20 inches deep, December 15–17, 1870.	40·04	**·184**	**·064**	0	3·176	3·240	**31,440**	3·80	3·4	11·2	14·6	Turbid.
Ditto, drained 40 inches deep, December 15–17, 1870.	38·60	**·235**	**·082**	0	2·389	2·471	**23,570**	3·00	2·7	10·4	13·1	Turbid.
Ditto, drained 60 inches deep, December 15–17, 1870.	36·68	**·371**	**·116**	·026	2·489	2·626	**24,780**	2·15	·3	8·2	3·5	Turbid.
Ditto, drained 20 inches deep, October 30–31, 1872.	30·24	**·114**	**·045**	·001	2·636	2·682	**26,050**	·60	5·0	11·6	16·6	Slightly turbid.
Ditto, drained 40 inches deep, October, 30–31, 1872.	27·32	**·096**	**·032**	0	2·106	2·138	**20,740**	·80	5·3	11·3	16·6	Slightly turbid.
Ditto, drained 60 inches deep, October 30–31, 1872.	32·68	**·098**	**·037**	·001	2·365	2·403	**23,340**	1·05	4·0	8·6	12·6	Slightly turbid.
Ditto, drained 20 inches deep, February 25–26, 1873.	18·00	**·142**	**·045**	·002	·607	·654	**5,770**	·95	4·9	7·1	12·0	Turbid.
Ditto, drained 40 inches deep, February 25–26, 1873.	19·24	**·127**	**·026**	·001	·789	·816	**7,580**	·95	3·7	6·0	9·7	Turbid.
Ditto, drained 60 inches deep, February 25–26, 1873.	22·36	**·168**	**·040**	·002	·759	·801	**7,290**	·95	6·5	3·9	10·4	Turbid.
Ditto, drained 20 inches deep, April 2–30, 1874.	27·44	**·174**	**·075**	·024	2·146	2·241	**21,340**	·95	4·4	9·3	13·7	Slightly turbid.
Ditto, drained 40 inches deep, April 2–30, 1874.	23·08	**·117**	**·054**	·012	1·602	1·666	**15,800**	·95	4·4	7·6	12·0	Clear.
Ditto, drained 60 inches deep, April 2–30, 1874.	26·40	**·098**	**·042**	·020	1·732	1·790	**17,160**	·95	3·6	9·4	13·0	Clear.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

It is thus evident that even water, which drains from land both fallow and unmanured for several years, contains a considerable proportion of highly nitrogenised organic matter in solution; and the columns headed "nitrogen as nitrates and nitrites" and "previous sewage or animal contamination" demonstrate how large is the amount of such matter which was undergoing oxidation in the pores of the soil. The proportion of nitrogen as nitrates and nitrites was often many fold that found in the water draining from the unmanured, but continuously cropped plots; owing no doubt chiefly to the absence of the roots of plants requiring these salts for their food in the uncropped land, but also partly to the peculiar drainage of this land, which caused a more thorough aëration of the soil.

Part II. Classification.

Drainage water from specially manured land.

It is useless discussing the applicability or otherwise of these waters to domestic purposes, since the conditions under which they were taken never occur on the large scale. Land is never cropped continuously in this country without the application of manure. These results are interesting only for comparison, and as proofs of the great length of time required for the complete decomposition of animal manure after it is incorporated with the soil. On the other hand the practice of manuring land by substances exclusively inorganic, though still quite exceptional, is probably increasing; and therefore the study of the water draining from such land in high cultivation is not entirely devoid of practical interest.

The next analytical table shows the composition of eight samples of drainage water from similar land, to which no animal organic manure had been applied since 1839, but which had been dressed with nitrates and non-nitrogenous mineral salts in 1852, and each year since.

Composition of Drainage Water from Land Manured with Nitrates and Non-Nitrogenous Mineral Salts.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 13, 1868	35·70	—	—	·002	1·392	—	**13,618**	1·45	—	—	—	
Ditto, December 8, 1868	63·68	—	—	0	3·367	—	**33,350**	6·00	3·2	11·5	14·7	
Ditto, December 16 and 17, 1869	38·80	**·247**	**·036**	·002	1·704	1·742	**16,740**	1·20	9·4	11·5	20·9	Turbid. Full flow.
Ditto, February 7, 1870	29·80	**·213**	**·051**	·002	·883	·936	**8,530**	·81	12·9	3·3	16·2	
Ditto, January 5, 1872	50·52	**·151**	**·060**	·001	2·311	2·372	**22,800**	1·80	19·8	13·7	33·5	Slightly turbid.
Ditto, May 18, 1872	38·10	**·180**	**·053**	0	1·647	1·700	**16,150**	1·25	19·1	5·1	24·2	Turbid.
Ditto, October 26, 1872	43·08	**·252**	**·057**	·002	·975	1·034	**9,450**	1·45	17·5	5·3	22·8	Slightly turbid.
Ditto, February 26, 1873	21·44	**·255**	**·075**	·010	·264	·347	**2,400**	·70	6·2	4·4	10·6	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The two plots of land (9*a* and 9*b*), which delivered into a common drain from which the samples in the foregoing table were collected, bore a crop of turnips, and were dressed with farmyard manure in 1839. In the four following years they received no manure; but successive crops of barley, peas, wheat, and oats were taken from them. They were cropped with wheat in 1844, and every year since. During the first eight years (1844–1851) one, or both, received salts of ammonia seven times, superphosphate twice, and rape cake twice, the last-named manure being applied at the rate of 2,000 lbs. per acre to one of the plots in 1849. One of them received annually, from 1852 to 1858 inclusive, 300 lbs. sulphate of potash, 200 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, and 550 lbs. of nitrate of soda. From 1858 to the present time a reduction of 100 lbs. of each has been made in the weights of sulphate of potash and sulphate of soda annually applied. Between 1864 and 1866, it also received some soluble silicates. The other plot received 550 lbs. of nitrate of soda in 1852 and every year since, no other manure having been applied to it. Thus these plots have received no animal organic manure since the year 1839, but vegetable organic manure twice, and in large quantity in 1849.

The proportions of total solid impurity and organic elements in these samples do not differ in any marked manner from those found in the samples draining from land which had received no manure for many years, but the direct application of nitrates adds considerably, as might be expected, to the proportion of nitrogen as nitrates and nitrites in the drainage water. Comparing samples collected on the same days we find that 100,000 parts of water draining from land to which no nitrogenous manure had been applied since 1851 (*see* table, page 61) contained on the average ·705 part of nitrogen in the form of nitrates and nitrites, whilst 100,000 parts of water draining from the neighbouring plot, to which, besides other mineral manure, 550 lbs. of nitrate of soda had been annually applied, contained on the average 1·568 parts of nitrogen as nitrates and nitrites. If we assume that the last-named plot would have produced, without the

Part II. Classification.

Drainage water from specially manured land.

nitrate of soda, as much nitrogen in these forms as was yielded by the first-named plot, it follows that ·863 part of nitrogen as nitrates and nitrites was derived from the nitrate employed as manure.

The following five tables contain the results of our analyses of numerous samples of drainage water from contiguous plots in high cultivation receiving annually, for a long series of years, various dressings of manure composed exclusively of mineral substances, but containing, in all cases, combined nitrogen in the shape of ammoniacal salts.

Composition of Drainage Water from Land (in Wheat) Manured Annually since 1844 with a Mixture of Mineral and Ammoniacal Salts.

Results of Analysis expressed in Parts per 100,000

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 13, 1868 * * -	65·50	—	—	·004	2·812	—	**27,830**	4·45	—	—	—	
Ditto, December 8, 1868 * * -	70·72	—	—	·001	2·948	—	**29,170**	7·00	11·7	35·6	47·3	
Ditto, December 15, 1869 * * -	40·88	**·175**	**·046**	·002	1·820	1·868	**17,900**	3·90	9·4	22·1	31·5	Turbid. First dribble from drain.
Ditto, from December 16, to December 17, 1869. * *	59·68	**·177**	**·059**	0	2·946	3·005	**29,140**	4·65	8·6	30·6	39·2	Turbid. Drain in full flow.
Collected February 7, 1870 * * -	41·52	**·205**	**·025**	·002	1·354	1·381	**13,240**	2·22	12·1	15·7	27·8	
Ditto, January 5, 1872 * - -	70·16	**·157**	**·052**	·001	2·777	2·830	**27,460**	4·30	18·7	31·3	50·0	Very slightly turbid.
Ditto, January 5, 1872 * * -	86·24	**·194**	**·065**	·001	4·744	4·810	**47,130**	6·85	16·3	42·7	59·0	Do.
Ditto, January 5, 1872 * * * -	123·96	**·180**	**·083**	·001	7·841	7·925	**78,100**	11·25	11·6	65·0	76·6	Slightly turbid.
Ditto, May 18, 1872 * - -	36·30	**·203**	**·029**	0	·051	·080	**190**	1·10	19·4	10·3	29·7	Do.
Ditto, May 18, 1872 * * - -	31·80	**·167**	**·032**	0	·059	·091	**270**	1·95	20·7	7·0	27·7	Clear.
Ditto, May 18, 1872 * * * - -	38·10	**·197**	**·052**	·006	·094	·151	**670**	1·60	20·0	10·3	30·3	Slightly turbid.
Ditto, June 11, 1872 * - -	39·88	**·243**	**·053**	·008	0	·060	**0**	1·25	19·1	10·6	29·7	Turbid.
Ditto, June 11, 1872 * * - -	33·64	**·158**	**·034**	0	0	·034	**0**	·80	13·6	7·6	21·2	Slightly turbid.
Ditto, October 26, 1872 * - -	65·64	**·232**	**·066**	·014	1·354	1·432	**13,340**	4·80	13·2	30·3	43·5	Do.
Ditto, October, 26, 1872 * * -	90·70	**·188**	**·038**	·064	2·303	2·394	**23,240**	8·20	14·1	43·4	57·5	Do.
Ditto, October 26, 1872 * * * -	81·10	**·188**	**·051**	·022	1·808	1·877	**17,940**	7·60	16·1	32·9	49·0	Do.
Ditto, January 19, 1873 * - -	47·12	**·148**	**·032**	·002	·454	·488	**4,240**	1·95	13·6	18·6	32·2	Clear.
Ditto, January 19, 1873 * * -	53·88	**·116**	**·040**	·002	1·294	1·336	**12,640**	2·50	17·0	19·7	36·7	Clear.
Ditto, January 19, 1873 * * * -	67·48	**·119**	**·036**	·002	1·522	1·560	**14,920**	3·30	14·1	25·4	39·5	Clear.
Ditto, February 26, 1873 * -	27·28	**·282**	**·063**	·002	·122	·187	**920**	1·00	7·0	7·4	14·4	Very turbid.
Ditto, February 26, 1873 * * -	33·60	**·257**	**·068**	·002	·461	·531	**4,310**	1·35	9·0	10·1	19·1	Turbid.
Ditto, February 26, 1873 * * * -	30·28	**·393**	**·105**	·008	·441	·553	**4,160**	1·35	6·5	10·6	17·1	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

In the above table the samples marked with a single asterisk were taken from a plot (6) which had received an annual dressing per acre consisting of 200 lbs. of sulphate of potash, 100 lbs. of sulphate of soda, 100 lbs. of sulphate of magnesia, 3½ cwts. of superphosphate of lime, 100 lbs. of sulphate of ammonia, and 100 lbs. of muriate of ammonia. The samples marked with two asterisks were drawn from a plot (7) which received the following annual dressing per acre: 200 lbs. of sulphate of potash, 100 lbs. of sulphate of soda, 100 lbs. of sulphate of magnesia, 3½ cwts. of superphosphate of lime, 200 lbs. of sulphate of ammonia, and 200 lbs. of muriate of ammonia. Lastly, the samples marked with three asterisks drained from a plot (8) which received the following dressing per acre per annum, 200 lbs. of sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, 300 lbs. sulphate of ammonia, and 300 lbs. muriate of ammonia.

Composition of Drainage Water from Land Manured with only Ammonia Salts since 1850.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 5, 1872 -	73·44	—	—	·001	5·561	—	**55,300**	7·35	7·3	46·4	53·7	Slightly turbid.
Ditto, May 18, 1872 - -	34·70	**·139**	**·032**	0	·935	·967	**9,030**	2·00	17·4	8·8	26·2	Do.
Ditto, June 11, 1872 - -	31·84	**·137**	**·034**	·001	·304	·339	**2,730**	1·20	15·4	9·4	24·8	Do.
Ditto, October 26, 1872 - -	67·60	**·146**	**·040**	·010	1·887	1·935	**18,630**	7·90	10·1	29·4	39·5	Do.
Ditto, January 19, 1873 - -	37·32	**·115**	**·055**	·002	1·502	1·559	**14,720**	2·40	12·5	15·4	27·9	Clear.
Ditto, February 26, 1873 - -	25·28	**·271**	**·077**	·018	·705	·797	**6,880**	1·45	7·3	9·9	17·2	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Two contiguous plots (10*a* and 10*b*) drain into the common pipe from which the above samples were drawn. Both were dressed with farmyard manure and cropped with turnips in 1839, they then received no manure for four years, but bore successive crops of barley, peas, wheat, and oats. In 1844, and since, they have yearly been cropped with wheat; both of them received non-nitrogenous mineral manure in 1844, but since that year one has been dressed annually with 200 lbs. sulphate of ammonia and 200 lbs. muriate of ammonia only. The other plot received, in 1845, 200 lbs. sulphate of ammonia and 200 lbs. muriate of ammonia, and each year since (excepting 1846 and 1850). It also received non-nitrogenous mineral manure in the years 1844, 1848, and 1850. These plots have therefore received no animal organic manure since 1839; one has been dressed with ammonia salts only since 1844, and the other in the same way since 1850.

PART II. CLASSIFICATION.

Drainage water from specially manured land.

Composition of Drainage Water from Land Manured with Salts of Ammonia and Superphosphate of Lime.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 5, 1872 - -	93·12	**·090**	**·064**	·001	6·681	6·746	**66,500**	9·25	9·8	53·0	62·8	Clear.
Ditto, May 18, 1872 - -	39·60	**·128**	**·028**	0	·829	·857	**7,970**	2·30	21·4	11·5	32·9	Do.
Ditto, June 11, 1872 - -	36·96	**·176**	**·032**	·001	·059	·092	**280**	1·20	19·1	11·5	30·6	Turbid.
Ditto, October 26, 1872 - -	62·60	**·165**	**·036**	·010	1·681	1·725	**16,570**	7·00	15·7	28·1	43·8	Clear.
Ditto, January 19, 1873 - -	51·52	**·121**	**·041**	·003	1·779	1·822	**17,490**	2·75	13·9	21·5	35·4	Do.
Ditto, February 26, 1873 - -	30·60	**·169**	**·035**	·008	·738	·780	**7,130**	1·50	8·5	12·4	20·9	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The pipe from which the above samples were taken drains a plot (11) of land which was dressed with farmyard manure, and bore a crop of turnips in 1839. During the four subsequent years no manure was applied to it, but it was cropped successively with barley, peas, wheat, and oats. In 1844, and since, it has been yearly sown with wheat; in 1844, 1845, 1846, 1847, and 1848, with various amounts of superphosphate, with ammonia salts, or rape cake; and, in 1849, and since, it has annually received per acre 200 lbs. of sulphate of ammonia, 200 lbs. muriate of ammonia, and 3½ cwts. of superphosphate of lime. In 1868, and since, one half of it has also received some cut straw produced the previous season. This plot has, therefore, received no animal organic manure since the year 1839, nor has it received vegetable organic manure (except straw) since 1848.

Composition of Drainage Water from Land Manured with Salts of Ammonia, Superphosphate of Lime, and Sulphates of Potash and Soda.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 5, 1872 - -	101·64	**·109**	**·047**	0	5·771	5·818	**57,390**	8·05	16·6	51·5	68·1	Clear.
Ditto, ditto * - -	105·60	**·124**	**·051**	0	5·915	5·966	**58,830**	9·10	9·9	59·7	69·6	Do.
Ditto, May 18, 1872 - -	43·90	**·172**	**·031**	0	·409	·440	**3,770**	2·10	28·1	11·9	40·0	Slightly turbid.
Ditto, ditto * - -	48·40	**·219**	**·051**	0	·318	·369	**2,860**	2·10	21.4	14·6	36·0	Do.
Ditto, June 11, 1872 - -	46·64	**·150**	**·030**	·001	·007	·038	**0**	1·30	19·8	12·4	32·2	Do.
Ditto, ditto * - -	44·24	**·185**	**·071**	·002	0	·073	**0**	1·40	13·1	14·8	27·9	Do.
Ditto, October 26, 1872 - -	83·60	**·114**	**·039**	·006	1·738	1·782	**17,110**	6·60	16·9	32·9	49·8	Do.
Ditto, ditto * - -	90·80	**·188**	**·074**	·016	2·197	2·284	**21,780**	7·40	18·3	40·7	59·0	Clear.
Ditto, January 19, 1873 -	58·56	**·121**	**·028**	·006	1·498	1·531	**14,710**	2·75	13·6	21·2	34·8	Do.
Ditto, ditto * - -	59·60	**·132**	**·043**	·004	1·699	1·745	**16,700**	3·10	17·0	25·1	42·1	Do.
Ditto February 26, 1873 -	32·12	**·217**	**·053**	·006	·681	·739	**6,540**	1·30	6·1	13·6	19·7	Turbid.
Ditto, ditto * - -	32·76	**·412**	**·118**	·001	·624	·743	**5,930**	1·40	7·1	13·2	20·3	Do.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The above table includes samples from two separate but contiguous drainage areas. Those samples to which no asterisk is attached were from a plot (12) dressed with a manure of which sulphate of soda was a constituent, whilst those distinguished by an asterisk were collected from a plot (13) to which sulphate of potash had been applied instead of sulphate of soda. Both plots were dressed with farmyard manure, and cropped with

Part II. Classification.

Drainage water from specially manured land.

turnips in 1839. They were then left unmanured for four years, but bore successive crops of barley, peas, wheat, and oats. In 1844, and every year since, they have been cropped with wheat; and, almost from the beginning of that period, have been dressed with 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, and 3½ cwts. of superphosphate of lime per acre per annum. Half of each plot has received some chopped straw in 1868 and since. Here the treatment of the two plots diverges. The plot from which the unmarked samples were drawn received an annual dressing of 549¾ lbs. of sulphate of soda from 1852 to 1858 inclusive, and 366½ lbs. afterwards; whilst the plot yielding the samples marked with an asterisk got an annual supply of 300 lbs. of sulphate of potash from 1852 to 1858 inclusive, and 200 lbs. afterwards. It will be seen from these details that neither plot received any animal organic manure subsequent to the year 1839.

Composition of Drainage Water from Land Manured with Salts of Ammonia, Superphosphate of Lime, and Sulphate of Magnesia.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
Collected January 5, 1872 -	105·92	**·163**	**·054**	·001	5·784	5·839	**57,530**	9·50	9·1	62·0	71·1	Clear.
Ditto, May 18, 1872 - -	47·80	**·247**	**·041**	0	·227	·268	**1,950**	2·15	24·4	12·9	37·3	Slightly turbid.
Ditto, October 26, 1872 - -	91·90	**·221**	**·049**	·014	2·224	2·285	**22,040**	7·60	17·9	40·3	58·2	Clear.
Ditto, January 19, 1873 - -	52·40	**·122**	**·032**	·002	1·334	1·368	**13,040**	2·50	16·9	19·1	36·0	Do.
Ditto, February 26, 1873 - -	33·28	**·353**	**·092**	·006	·596	·693	**5,690**	1·25	7·3	13·3	20·6	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The history of the plot (14) from which these samples were drawn is exactly like that of the last, excepting that in the place of sulphate of soda or sulphate of potash it was dressed with sulphate of magnesia (Epsom salts), of which it annually received 420 lbs. from 1852 to 1858 inclusive, and 280 lbs. annually afterwards. No animal organic manure was applied to this plot after the year 1839.

The mineral manures added to all these plots being soluble in water, there is, as might be expected, a great increase in the total solid impurity, when these drainage waters are compared with those collected from the unmanured plots, and even with that taken from the plot which was continuously and heavily manured with comparatively insoluble farmyard manure. A certain portion of the soluble salts enters the growing crops; the remainder, at first absorbed by the soil, is gradually washed out of it.

The organic elements are present in but moderate proportions in the samples from all the plots.

The second Table on page 65 exhibits a remarkable action of sulphate of potash, as distinguished from sulphate of soda, in determining the elimination of soluble organic matter from the soil. By comparison of the pairs of samples collected on the same days it will be seen that the water yielded by the plot to which sulphate of potash had been added invariably contained a considerably larger proportion both of organic carbon and organic nitrogen. In all other respects the two plots had been similarly treated.

Although ammonia is added in large quantities in every case, yet it is present in but very minute proportions in the drainage waters; on the other hand, the nitrogen in the form of nitrates is much increased beyond the proportion found in the drainage from the otherwise similarly treated unmanured plots. It is therefore evident that some of the ammonia, introduced into the soil as sulphate and muriate, is transformed by oxidation into nitric acid or nitrous acid, and discharged in the drainage water as nitrates and nitrites, which afford in all these cases false testimony as to the previous contamination of the water with animal matters. If these mineral and nitrogenous manures were in general use amongst farmers, they would thus evidently interpose a serious obstacle in the way of the correct estimation of the previous sewage or manure contamination of potable waters; but such manures are still so far from generally employed in the ordinary practice of the farmer, as to make the risk of a false interpretation of analytical results from this cause, in the case of surface or drainage waters from cultivated lands, practically *nil*.

The hardness of these waters is usually too great to permit of their use for washing. It is only after very heavy and long-continued rain that it falls below 20°. The sulphate of magnesia and superphosphate of lime, which were constituents of the manure applied to most of the plots, add directly to the hardness of the drainage waters.

PART II. CLASSIFICATION.

Drainage water from specially manured land.

One of the adjacent experimental plots at Rothamsted, whilst receiving annually similar mineral manures, was also supplied with a liberal dressing of vegetable manure in the form of rape cake. This and the neighbouring plot, which received no rape cake, had a common drain from which five samples of water were collected. The analytical results yielded by these samples are contained in the following table :—

COMPOSITION OF DRAINAGE WATER FROM LAND MANURED WITH MINERAL SALTS, SULPHATE OF AMMONIA, AND RAPE CAKE.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Collected January 5, 1872	116·24	**·127**	**·059**	·001	7·245	7·305	**72,140**	5·75	10·8	66·6	77·4	Slightly turbid.
Ditto, May 18, 1872	42·60	**·226**	**·047**	0	·215	·262	**1,830**	·95	23·9	12·4	36·3	Turbid.
Ditto, October 26, 1872	54·84	**·197**	**·041**	·004	·774	·818	**7,450**	1·90	15·3	23·3	38·6	Slightly turbid.
Ditto, January 19, 1873	39·20	**·123**	**·080**	·002	·304	·386	**2,740**	·95	18·0	12·6	30·6	Clear.
Ditto, February 26, 1873	28·56	**·640**	**·156**	·012	·247	·413	**2,250**	1·00	4·7	11·0	15·7	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The two contiguous plots of land (15*a* and 15*b*) from which the above samples drained were cropped with turnips in 1839, and dressed with farmyard manure; in 1840, 1841, 1842, and 1843 they bore in succession crops of barley, peas, wheat, and oats without the application of any manure. In 1844, and since, they have been annually cropped with wheat. From 1844 to 1851 the manuring was not quite so systematic and comparative as afterwards. From 1851 to 1858 inclusive one of these plots received annually per acre 300 lbs. of sulphate of potash, 200 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. of superphosphate of lime made with muriatic instead of sulphuric acid, and 400 lbs. of sulphate of ammonia. The other plot received the same salts in the same quantities, except that only 300 lbs. of sulphate of ammonia were supplied, whilst 500 lbs. of rape cake were added. From 1858 down to present time, the only difference in the treatment of the two plots has been the reduction of the annual weight of sulphate of potash applied to each from 300 lbs. to 200 lbs., and of the weight of sulphate of soda, from 200 lbs. to 100 lbs.

These numbers show that rape cake occasionally imparts to drainage water a large amount of soluble organic matter. Thus the sample collected on the 26th of February 1873 was so strongly polluted with organic matter, as to be quite unfit for domestic purposes. In other respects these samples did not materially differ from those drawn from the plots to which mineral nitrogenous manure alone had been applied.

Taking the whole series of drainage waters from the Rothamsted experimental plots, it is evident that their chief characteristic is their changeable quality, which is not only observed in comparing the water from plots treated with different kinds of manure, but quite as much so when samples, drawn at different times from the same plot, are compared. This latter variability need not, however, excite surprise, if the very various conditions under which water passes through, and drains from manured land be taken into consideration. After the application of soluble manures, the first rain which reaches the drains must be highly charged with the soluble matters which have been applied to the land and not assimilated by the crop since it was last washed out. Again, during a long period of comparatively dry weather, various originally insoluble constituents of the soil are gradually rendered soluble in water, and the nitrogen of animal organic matter is converted into nitrates and nitrites, which are also easily soluble. After these processes have been going on in the soil for weeks or even months, the next fall of rain which penetrates to the drains must of necessity be laden with these soluble matters, whereas a long continued and heavy fall of rain must, at last, furnish drainage water containing comparatively a very small proportion of dissolved constituents. A comparison of each of the foregoing tables with the rainfall data given in Appendix No. 1, affords abundant illustration of the effects of these last named conditions. This great changeability in the composition of different samples collected from one and the same plot is due also in some degree to the action of growing plants; thus manured plots which in winter yield drainage water rich in nitrates, sometimes furnish in summer samples which are absolutely free from these salts. (*See* tables on pages 64 and 65.)

The great and continual variation in the proportions of the different constituents in the drainage waters from the several experimental plots renders it difficult, from a mere inspection of the foregoing tables, to gain a clear conception of the influence of different

PART II. CLASSIFICATION.

Shallow well waters.

manures upon separate portions of the same soil, each bearing the same crop from year to year. This is, however, readily seen in the following table, which contains the results of analysis of samples taken on October 26, 1872, from the different experimental plots:—

Composition of Contemporaneous Samples from Experimental Plots at Rothamsted Farm. October 26, 1872.

Results of Analysis expressed in Parts per 100,000.

—	Plot No. 2.	Plots Nos. 3,4.	Plot No. 5.	Plot No. 6.	Plot No. 7.	Plot No. 8.	Plot No. 9.	Plot No. 10.	Plot No. 11.	Plot No. 12.	Plot No. 13.	Plot No. 14.	Plot No. 15.	Plot No. 16.
Total Solid Impurity	42·96	22·52	38·72	65·64	90·70	81·10	43·08	67·60	62·60	83·60	90·80	91·90	54·84	25·52
Organic Carbon	·815	·178	·220	·232	·188	·188	·252	·146	·165	·114	·188	·221	·197	·182
Organic Nitrogen	·121	·030	·040	·066	·038	·051	·057	·040	·036	·039	·074	·049	·041	·052
Ammonia	·052	·003	·001	·014	·064	·022	·002	·010	·010	·006	·016	·014	·004	·002
Nitrogen as Nitrates and Nitrites.	·932	·366	·360	1·354	2·303	1·808	·975	1·887	1·681	1·738	2·197	2·224	·774	·464
Total combined Nitrogen	1·096	·398	·401	1·432	2·394	1·877	1·034	1·935	1·725	1·782	2·284	2·285	·818	·518
Previous Sewage or Animal Contamination.	9,430	3,370	3,290	13,340	23,240	17,940	9,450	18,630	16,570	17,110	21,780	22,040	7,450	4,340
Chlorine	2·80	·95	1·10	4·80	8·20	7·60	1·45	7·90	7·00	6·60	7·40	7·60	1·90	1·20
Temporary Hardness	12·1	9·5	9·6	13·2	14·1	16·1	17·5	10·1	15·7	16·9	18·3	17·9	15·3	11·5
Permanent Hardness	13·3	7·4	17·9	30·3	43·4	32·9	5·3	29·4	28·1	32·9	40·7	40·3	23·3	10·0
Total Hardness	25·4	16·9	27·5	43·5	57·5	49·0	22·8	39·5	43·8	49·8	59·0	58·2	38·6	21·5

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The quantity and composition of the manure applied annually per acre to the above-mentioned plots were as follows:—

Plot No. 2. 14 tons farmyard manure.

Plots Nos. 3 and 4. Unmanured since 1852.

Plot No. 5. 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, and occasionally some soluble silicates or chopped straw.

Plot No. 6. 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, 100 lbs. sulphate of ammonia, 100 lbs. muriate of ammonia, and occasionally some soluble silicates or chopped straw.

Plot No. 7. 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, and occasionally some soluble silicates or chopped straw.

Plot No. 8. 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, 300 lbs. sulphate of ammonia, 300 lbs. muriate of ammonia, and occasionally some soluble silicates or chopped straw.

Plot No. 9. Half of the plot received 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, and 550 lbs. nitrate of soda, and the other half received 550 lbs. nitrate of soda.

Plot No. 10. 200 lbs. sulphate of ammonia, and 200 lbs. muriate of ammonia.

Plot No. 11. 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, 3½ cwts. superphosphate of lime, and some chopped straw.

Plot No. 12. 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, 3½ cwts. superphosphate of lime, 366½ lbs. sulphate of soda, and some chopped straw.

Plot No. 13. 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, 3½ cwts. superphosphate of lime, 200 lbs. sulphate of potash, and some chopped straw.

Plot No. 14. 200 lbs. sulphate of ammonia, 200 lbs. muriate of ammonia, 3½ cwts. superphosphate of lime, 280 lbs. sulphate of magnesia, and some chopped straw.

Plot No. 15. Half of the plot received 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. superphosphate of lime, made with muriatic instead of sulphuric acid, and 400 lbs. sulphate of ammonia; the other half received 200 lbs. sulphate of potash, 100 lbs. sulphate of soda, 100 lbs. sulphate of magnesia, 3½ cwts. of superphosphate of lime made with muriatic acid, 300 lbs. sulphate of ammonia, and 500 lbs. rape-cake.

Plot No. 16. Unmanured since 1864.

The ammonia-salts were always applied in the Autumn, and the nitrate of soda about the middle of March.

Of the bearings of these results upon the practice of agriculture, it is beyond the scope of our instructions to speak; but we may be permitted to remark that the composition of these drainage waters, considered in connexion with the manures applied to and the crops yielded by the different plots of land, affords information of the highest value to the agriculturist.

CLASS IV.—SHALLOW WELL WATERS.

It is stated that about fifteen millions of the British population live in towns and urban districts. Even if we assume, which is not yet the case, that all these people are supplied by waterworks, the remaining twelve millions of country population derive their water, almost exclusively, from shallow wells, and these are, so far as our experience extends, almost always horribly polluted by sewage, and by animal matters of the most disgusting origin. The common practice in villages, and even in many small towns, is to dispose of the sewage and to provide for the water supply of each cottage, or pair of cottages, upon the premises. In the little yard or garden attached to each tenement or pair of tenements, two holes are dug in the porous soil; into one of these, usually the shallower of the two, all the filthy liquids of the house are discharged; from the other, which is sunk below the water line of the porous stratum, the water for drinking and other domestic uses is pumped. These two holes are not unfrequently within twelve feet of each other, and sometimes even closer. The contents of the filth hole or cesspool gradually soak away through the surrounding soil and mingle with the water below. As the contents of the water hole, or well, are pumped out, they are immediately replenished from the surrounding disgusting mixture, and it is not therefore very surprising to be assured that such a well does not become dry even in summer. Unfortunately, excrementitious liquids, especially after

Part II. Classification.

Shallow well waters on Silurian rocks and Gneiss.

they have soaked through a few feet of porous soil, do not impair the palatability of water; and this polluted liquid is consumed from year to year without a suspicion of its character, until the cesspool and well receive infected sewage, and then an outbreak of epidemic disease compels attention to the polluted water. Indeed our acquaintance with a very large proportion of this class of potable waters has been made in consequence of the occurrence of severe outbreaks of typhoid fever amongst the persons using them. (For further remarks upon this subject, *see* page 140.)

We have examined a very large number of waters belonging to this class, which we have subdivided into fourteen sections, founded upon the geological character of the stratum upon which the well is situated. Sometimes, however, the well is not actually sunk into this stratum, but into a superficial bed of porous drift.

Section I.—Waters from Shallow Wells on Silurian Rocks and Gneiss.

The following table contains the results of our analyses of fifteen samples of potable water from shallow wells sunk in or upon Silurian rocks and Gneiss. With the exception of the first three, all the samples were collected by ourselves:

Composition of Water from Shallow Wells in or upon Silurian Rocks and Gneiss.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
WALES.												
Aberayron.												
Union Well, No. 1, May 27, 1873 -	11·96	**·125**	**·036**	0	·153	·189	**1,210**	3·20	0	4·2	4·2	Slightly turbid, palatable.
„ „ No. 2, „ „ „ -	24·96	**·093**	**·024**	0	·604	·628	**5,720**	4·40	·5	9·1	9·6	Slightly turbid, palatable.
„ „ No. 3, „ „ „ -	12·84	**·213**	**·060**	·004	·217	·280	**1,880**	2·80	0	4·2	4·2	Turbid, palatable.
Kendal, Westmoreland.												
Well in King's Head Yard, March 17, 1871.	100·20	**·362**	**·110**	·625	2·465	3·090	**29,480**	17·00	22·3	19·2	41·5	Clear and palatable.
Llanidloes.												
Town Pump, October 8, 1872 -	17·56	**·062**	**·013**	·001	·660	·674	**6,290**	4·25	·1	5·0	5·1	Slightly turbid, palatable.
Machynlleth.												
Pump near Mr. Lloyd's house, October 7, 1872.	29·56	**·066**	**·028**	·001	1·913	1·942	**18,820**	4·65	1·2	8·7	9·9	Slightly turbid. Palatable.
Newtown (Montgomery).												
Pump in Pump Court, April 27, 1870.	41·86	**·059**	**·011**	·004	·561	·575	**5,320**	6·08	8·1	8·9	17·0	Clear. Palatable.
SCOTLAND.												
Alford-on-the-Don.												
Well at Alford, March 8, 1872 -	16·80	**·048**	**·007**	0	·033	·040	**10**	2·85	·4	8·9	9·3	Clear and palatable.
Balmoral.												
Well used for drinking at Balmoral Castle, March 11, 1872.	7·50	**·111**	**·018**	0	247	·265	**2,150**	1·15	·6	4·4	5·0	Clear, colourless, and palatable.
Galashiels.												
Well opposite skinnery, March 30, 1870.	14·80	**·027**	**·005**	·002	·291	·298	**2,610**	1·70	·3	9·3	9·6	Clear and palatable.
Sandy's well, March 30, 1870 -	15·16	**·059**	**·010**	0	·424	·434	**3,920**	2·00	1·8	5·7	7·5	Clear and palatable.
Mr. Thompson's well, March 30, 1870.	16·98	**·134**	—	0	·475	—	**4,430**	2·20	4·5	4·3	8·8	Clear, sparkling, and palatable.
Hawick.												
John Scott's well, Teviot Crescent, April 1, 1870.	21·98	**·049**	**·009**	0	·248	·257	**2,160**	1·20	7·3	5·6	12·9	Clear and palatable.
Peebles.												
Well at Railway Station, April 5, 1870.	20·00	**·047**	**·016**	0	·799	·815	**7,670**	2·92	3·2	9·2	12·4	Clear.
Selkirk.												
Water supply from large well near the *Ettrick*, April, 2, 1870.	6·32	**·053**	**·003**	0	·078	·081	**460**	·90	·1	3·3	3·4	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Part II. Classification.

Shallow well waters on Devonian rocks.

With the exception of the water obtained from the pump near Mr. Lloyd's house at Machynlleth, and the sample from Kendal, which exhibit great evidence of previous sewage contamination, and those from well No. 3 at Aberayron Union Workhouse, the Kendal well, and Mr. Thompson's well at Galashiels, which contain a large proportion of organic matter, this section presents very favourable specimens of shallow well waters. The proportion of total solid impurity is, for such water, very low, the organic elements (organic carbon and organic nitrogen) are present in very small quantity and the indication of previous sewage or animal contamination is not considerable, whilst the water is either soft or only moderately hard. Nearly all the samples were clear and palatable, but, although they compare very favourably with most of the samples of shallow well waters in the following tables, there are only two which can be recommended as reasonably safe for domestic use; these are the water furnished by the well at Alford on the *Don*, and that supplied to Selkirk from a large well sunk close to the unpolluted *Ettrick*, from which it derives nearly the whole of its water by percolation.

Further remarks on these waters will be found in the descriptive part of this report (Part IV., page 301), under the names of the different towns and villages.

Section II.—Waters from Shallow Wells on Devonian Rocks.

The following table contains the results of our analyses of twenty-nine samples of water drawn from shallow wells sunk either in or upon Devonian rocks. The Scotch samples and those from Helston, Padstow, Penrhyn, Truro, and Wadebridge were collected by ourselves. The remainder of the samples were forwarded to us through the Local Government Act Office.

Composition of Water from Shallow Wells in or upon Devonian Rocks.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
Bodmin, Cornwall.												
St. Leonard's pump, January 1, 1872.	19·36	**·123**	**·028**	·001	·390	·419	**3,590**	3·40	1·9	10·7	12·6	Turbid. Palatable.
Apud-le-Bore pump, January 1, 1872.	25·12	**·039**	**·025**	0	1·144	1·169	**11,120**	4·20	1·6	13·3	14·9	Turbid. Palatable.
Prison Lane pump, (No. 57), January 1, 1872.	23·12	**·794**	**·172**	·014	·755	·939	**7,350**	3·85	1·0	12·4	13·4	Clear. Palatable.
Church Style Mouths well, February 23, 1872.	14·72	**·004**	**·003**	0	·408	·411	**3,760**	3·00	0	8·3	8·3	Clear. Palatable.
St. Nicholas pump, January 1, 1872.	42·64	**·121**	**·042**	·001	1·161	1·204	**11,300**	6·00	1·1	20·1	21·2	Slightly turbid. Palatable.
Bree Shute well, February 23, 1872	38·28	**·073**	**·030**	0	1·688	1·718	**16,560**	5·60	·8	16·9	17·7	Clear and palatable.
Prison Lane pump, (No. 119), January 1, 1872.	60·00	**·086**	**·030**	·003	3·149	3·181	**31,190**	8·80	19·9	22·9	42·8	Clear and palatable.
Helston, Cornwall.												
Iron Pump, Meneage Street, January 3, 1873.	44·40	**·067**	**·017**	0	2·082	2·099	**20,500**	8·10	0	15·6	15·6	Slightly turbid. Palatable.
Ivybridge, Devonshire.												
Mr. Boon's well, June 2, 1871	12·40	**·238**	**·132**	·560	·021	·614	**4,500**	3·00	·1	4·9	5·0	Turbid.
Mr. Bryant's well, June 2, 1871	12·08	**·295**	**·123**	·630	·049	·691	**5,360**	2·90	·8	4·6	5·4	"
Well at Mr. Allen's Cottages, June 2, 1871.	15·96	**·067**	**·014**	0	·383	·397	**3,510**	3·20	·4	6·3	6·7	Clear and palatable.
Well at Mr. Sherwell's Cottages, June 2, 1871.	18·00	**·043**	**·016**	0	·613	·629	**5,810**	3·00	·3	7·3	7·6	Clear and palatable.
Well adjoining Mr. Head's premises, August 19, 1872.	12·16	**·161**	**·021**	·001	·252	·274	**2,210**	3·70	2·4	3·2	5·6	Clear and palatable.
Liskeard, Cornwall.												
Castle well, September 23, 1873	30·10	**·035**	**·031**	0	1·246	1·277	**12,140**	5·10	0	10·9	10·9	Clear and palatable.
Dean well, September 23, 1873	15·84	**·063**	**·024**	0	·591	·615	**5,590**	3·50	0	7·7	7·7	Clear and palatable.
New Quay, Cornwall.												
Pump at Mr. Treffry's, near Prout's Hotel, October 24, 1871.	56·70	**·029**	**·015**	·002	·299	·316	**2,690**	15·25	16·4	17·4	33·8	Slightly turbid.
Fort pump, October 24, 1871	77·14	**·029**	**·023**	·001	1·854	1·878	**18,230**	17·00	18·3	26·0	44·3	Clear.
Pump near Mrs. Dyer's house, October 24, 1871.	52·90	**·205**	**·047**	·002	·741	·790	**7,110**	10·80	13·9	13·9	27·8	Turbid.

Shallow well waters in the Millstone Grit.

COMPOSITION OF WATER FROM SHALLOW WELLS IN DEVONIAN ROCKS—*continued.*

DESCRIPTION.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
Town Pump near Commercial Hotel, October 24, 1871.	58·70	·051	·041	0	1·257	1·298	12,250	11·65	21·3	19·4	40·7	Very slightly turbid.
Pump at Mr. George Bocking's house, October 24, 1871.	54·18	·051	·013	·004	·464	·480	4,350	9·80	20·8	17·7	38·5	Turbid.
Pump near Dr. Clarke's house, October 24, 1871.	54·90	·148	·027	·015	·296	·335	2,760	18·50	17·3	17·7	35·0	Very turbid.
PADSTOW, CORNWALL.												
Public well in Rosa's Lane, January 5, 1873.	73·90	·168	·052	0	2·624	2·676	25,920	9·80	8·8	19·9	28·7	Slightly turbid.
PENRHYN, CORNWALL.												
Budock well (5 feet deep), January 3, 1873.	20·40	·049	·008	·001	·959	·968	9,280	4·60	0	8·0	8·0	Slightly turbid. Palatable.
TRURO, CORNWALL.												
Public pump (well 25 feet deep), June 8, 1871.	54·46	·096	·025	·001	·701	·727	6,700	10·10	10·6	15·4	26·0	Very slightly turbid.
WADEBRIDGE, CORNWALL.												
Pump in Molesworth Arms Hotel, September 23, 1872.	52·60	·063	·013	·002	1·115	1·130	10,850	7·80	12·5	13·8	26·3	Clear and palatable.
SCOTLAND.												
ARBROATH.												
Mr. Wilson's well, 121, High Street, March 11, 1872.	105·20	·168	·064	0	4·197	4·261	41,650	16·25	7·9	47·8	55·7	Clear and palatable.
FORFAR.												
Well in West High Street, March 11, 1872.	15·64	·053	·017	0	·328	·345	2,960	1·60	2·0	7·1	9·1	Very slightly turbid. Palatable.
Well at East Town End, March 11, 1872.	63·20	·073	·038	0	4·196	4·234	41,640	8·40	10·2	19·1	29·3	Clear and palatable.
INVERNESS.												
Pump in Well Street, March 8, 1872.	15·60	·139	·006	0	·033	·039	10	4·20	·3	7·6	7·9	Clear, colourless, and palatable.

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

The waters from shallow wells in or upon Devonian Rocks contained in the above table are, as a rule, much more polluted than those from wells situated in Silurian strata, but this is partly owing to the circumstance that a considerable number of them were sent to us for investigation, owing to outbreaks of epidemic disease amongst the populations using them. Many of them are frightfully contaminated with sewage, and amongst the entire series the following only could be used for domestic purposes without serious risk to health:—

St. Leonard's pump, Bodmin, Cornwall.
Church Style Mouths Well, Bodmin, Cornwall.
Well at Mr. Allen's cottages, Ivybridge, Devonshire.
,, Mr. Sherwell's ,, ,, ,,
Pump at Mr. Treffry's, near Prout's Hotel, New Quay, Cornwall.
,, Mr. George Bocking's house ,, ,,
,, near Dr. Clarke's ,, ,, ,,
Dean Well, Liskeard, Cornwall.
Well in West High Street, Forfar, Scotland.
Pump in Well Street, Inverness ,,

But even of these less polluted samples, the last is the only one that could be used for drinking with reasonable safety. Nearly all the samples were palatable, and many were clear and sparkling. Nearly half of the samples were soft enough to be used for washing. As the hardening ingredients of these waters must be derived chiefly from animal excretions it is not surprising that, with very few exceptions, the softest are those which exhibit least past and present pollution.

SECTION III.—WATERS FROM SHALLOW WELLS IN OR ON THE YOREDALE AND MILLSTONE GRITS.

The following table contains a list of samples of water taken from shallow wells in or upon this geological formation, which is naturally calculated to yield water of great purity, but which, owing to the access of excrementitious matters to the wells, fur-

PART II. CLASSIFICATION.

Shallow well water in Millstone Grit.

nishes, as the following analytical table shows, a highly polluted beverage. Not any of these samples were collected by ourselves. The highly polluted ones were without exception sent for analysis, in consequence of outbreaks of fever. The remainder were sent for investigation in order to ascertain if they were suitable for domestic supply.

COMPOSITION OF WATER FROM SHALLOW WELLS ON THE YOREDALE AND MILLSTONE GRITS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
ENGLAND.												
CHULMLEIGH. NORTH DEVON.												
Public well, near churchyard, October 31, 1868.	59·16	**·411**	**·072**	·004	1·929	2·004	**19,000**	4·37	9·4	15·5	24·9	
Public well in the square, October 31, 1868.	71·96	**·540**	**·098**	·010	1·812	1·918	**17,880**	13·90	8·5	11·5	20·0	
Pump at Church Lands Charity Cottages, October 31, 1868.	103·98	**·859**	**·166**	·007	5·015	5·187	**49,890**	10·52	5·7	32·1	37·8	
GAINFORD, near DARLINGTON.												
St. Mary's well, between churchyard and river, November 8, 1871.	59·60	**·054**	**·019**	0	1·599	1·618	**15,670**	3·80	24·2	24·3	48·5	Clear and palatable.
Well in Hornsby's yard, the Green, November 8, 1871.	65·20	**·546**	**·135**	·001	·999	1·135	**9,680**	5·60	23·3	36·4	59·7	Very turbid. Yellowish.
Well in Pearson's yard, Back Lane, November 8, 1871.	133·00	**·313**	**·100**	0	5·100	5·200	**50,680**	9·30	14·4	54·4	68·8	Clear. Faint yellow colour.
Mr. Adamson's well, River Bank, November 8, 1871.	83·60	**·119**	**·051**	0	3·172	3·223	**31,400**	6·10	25·0	40·0	65·0	Slightly turbid. Palatable.
Mr. Metcalf's well, High Row, November 8, 1871.	105·60	**·110**	**·050**	0	4·535	4·585	**45,030**	7·80	37·2	45·7	82·9	Clear and palatable.
Mr. Nicholson's well, east side of Green, November 8, 1871.	133·60	**·669**	**·216**	·001	4·915	5·132	**48,840**	13·00	24·9	65·1	90·0	Clear. Yellowish. Palatable.
HAWES, BEDALE, YORKSHIRE.												
Pump in Cattle Market, April 5, 1872.	34·22	**·049**	**·023**	0	·383	·406	**3,510**	1·60	17·9	13·4	31·3	Clear and palatable.
Dyer's Garth well, April 5, 1872 -	19·58	**·071**	**·007**	0	·006	·013	**0**	1·05	13·0	5·6	18·6	Clear and palatable.
Blackburn Sike, Flag well, April 5, 1872.	11·38	**·177**	**·019**	·001	·013	·033	**0**	·65	4·2	6·7	10·9	Slightly turbid. Palatable.
White Hart well (now closed), April 6, 1872.	27·76	**·067**	**·015**	0	·371	·386	**3,390**	2·05	14·6	8·1	22·7	Clear and palatable.
HEBDEN BRIDGE, YORKSHIRE.												
Birch Cliff well, March 10, 1873 -	10·40	**·057**	**·016**	0	·209	·225	**1,770**	1·30	0	5·1	5·1	Slightly turbid. Palatable.
Well in Foster Mill Lane, March 10, 1873.	14·00	**·056**	**·013**	·001	·518	·532	**4,870**	2·05	0	6·0	6·0	Clear and palatable.
Well in Royd Terrace (Hollins), March 10, 1873.	13·88	**·043**	**·020**	·001	·484	·505	**4,530**	1·70	0	6·9	6·9	Slightly turbid. Palatable.
Well in Rawtenstall Wood, March 10, 1873.	5·92	**·042**	**·007**	·001	·040	·048	**90**	·95	0	2·9	2·9	Clear and palatable.
Well at William Green's, West End, March 10, 1873.	17·12	**·055**	**·010**	0	·428	·438	**3,960**	1·35	0	7·9	7·9	Clear and palatable.
Well at New Road, Bridge Lane, March 10, 1873.	10·68	**·047**	**·008**	0	·232	·240	**2,000**	1·30	·2	5·1	5·3	Clear and palatable.
LANCASTER.												
Abyssinian tube through clay, County Asylum, December 6, 1871.	20·96	**·039**	**·018**	·005	·153	·175	**1,250**	2·60	8·1	7·6	15·7	Turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results permit of the division of the samples into two categories; first, highly polluted waters, which will include all the samples from Chulmleigh and Gainford; and second, unpolluted or moderately polluted waters, which will embrace those from Hebden Bridge, Hawes, and Lancaster. All the samples belonging to the first category consisted chiefly of soakage from sewers and cesspools, and the numbers placed opposite to them, in the columns headed "organic carbon" and "organic nitrogen," leave no reasonable doubt that, with one exception, they all contained considerable quantities of actual or undecomposed soluble sewage matter. It is needless to say that they were all entirely unfit for human consumption. The samples belonging to the second category are mostly of good quality, they exhibit but moderate evidence of previous animal pollution, and this is of little significance because, with the exception of the Blackburn Sike Flag Well at Hawes, they contain but traces of unoxidized organic matter. The water has been exhaustively purified by very slow filtration through earth or rock before it reached the respective wells.

SECTION IV.—WATERS FROM SHALLOW WELLS IN OR ON THE COAL MEASURES.

PART II. CLASSIFICATION. — Shallow well waters in Coal measures.

We have examined numerous samples of water from shallow wells on the Coal Measures. Those from England were sent to us for investigation; but, with the exception of the one from Hamilton Palace, those from Scotland were personally collected by ourselves. The following table contains the results of our analyses:—

COMPOSITION OF WATERS FROM SHALLOW WELLS IN OR UPON THE COAL MEASURES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
ENGLAND AND WALES.												
DURHAM.												
Well at the Vicarage, Ferry Hill, near Durham, October 3, 1871.	91·28	**·156**	**·058**	0	3·316	3·374	**32,840**	6·75	15·2	55·2	70·4	Clear and palatable.
Medical Officer of Health's private well, October 5, 1870.	113·72	**·124**	**·045**	0	6·268	6·313	**62,360**	9·75	24·3	45·7	70·0	Clear and palatable.
HEATH, NEAR WAKEFIELD.												
Bowling Green Well, June 4, 1872	33·40	**·127**	**·020**	0	·880	·900	**8,480**	1·80	3·5	12·5	16·0	Turbid. Palatable.
HORBURY, NEAR WAKEFIELD.												
Mr. Mortimer's well, Westfield, January 6, 1872.	63·60	**·115**	**·042**	·001	·911	·954	**8,800**	3·65	1·5	47·8	49·3	Slightly turbid. Palatable.
Cottage Well in Captain Hartley's yard, January 6, 1872.	168·00	**·448**	**·109**	·007	6·671	6·786	**66,450**	14·95	3·8	80·5	84·3	Slightly turbid. Palatable.
Well at Woolpacks inn, January 6, 1872.	90·30	**·689**	**·162**	·004	0	·165	**0**	10·40	13·7	55·9	69·6	Turbid. Palatable.
Hall Cliffe well, January 6, 1872 -	46·00	**·271**	**·072**	·003	1·043	1·117	**10,130**	3·10	7·9	28·5	36·4	Very turbid. Palatable.
Captain Hartley's kitchen well, January 6, 1872.	141·60	**·377**	**·169**	·003	2·174	2·345	**21,440**	29·00	11·4	51·5	62·9	Turbid.
Mr. Johnson's well at Quarry Hill, January 6, 1872.	139·36	**·160**	**·089**	0	6·968	7·057	**69,360**	14·75	3·6	82·1	85·7	Slightly turbid. Palatable.
NEWBIGGIN-BY-THE-SEA. NORTHUMBERLAND												
Well sunk by Local Board, October 12, 1871.	220·92	**·360**	**·093**	·129	0	·199	**740**	17·50	28·2	112·6	140·8	Very turbid.
Mr. Duncan's Well, October 12, 1871.	156·00	**·299**	**·077**	·007	4·462	4·545	**44,360**	22·45	16·8	57·5	74·3	„ „
Pump at end of Woodhorn Lane, October 12, 1871.	77·60	**·138**	**·027**	·001	·418	·446	**3,870**	16·25	22·2	30·7	52·9	„ „
OGLEY HAY, NEAR WALSALL.												
The Rev. J. Singleton's well, January 20, 1873.	9·40	**·077**	**·023**	·005	·222	·249	**1,940**	1·05	·1	4·6	4·7	Slightly turbid. Palatable.
Well No. 2, January 20, 1873 -	34·64	**·038**	**·019**	·006	1·850	1·874	**18,230**	5·40	2·6	14·8	17·4	Slightly turbid. Palatable.
Well No. 3, „ „ -	51·80	**·040**	**·016**	·006	3·561	3·582	**35,340**	10·60	·6	25·4	26·0	Slightly turbid. Palatable.
Well No. 4, „ „ -	120·70	**·139**	**·020**	·170	10·102	10·262	**102,100**	21·50	0	32·5	32·5	Clear and palatable.
Well No. 5, „ „ -	18·96	**·024**	**·009**	·001	·571	·581	**5,400**	1·60	5·7	7·9	13·6	Slightly turbid. Palatable.
OLDHAM, LANCASHIRE.												
Nook pump, May 8, 1869 - -	29·86	**068**	**·019**	·006	1·037	1·061	**10,100**	1·77	0	11·5	11·5	Clear and palatable.
SHEFFIELD.												
Jacob's Well, South Yorkshire Asylum, Sep. 27, 1870.	18·50	**1·200**	**·126**	·110	0	·217	**590**	2·20	2·0	1·4	3·4	Very turbid, and offensive. Swarming with vibrios, bacteria, and other living organisms.
SWANSEA.												
Sketty Hall, sample A, July, 1873	26·32	**·060**	**·022**	0	·356	·378	**3,240**	2·80	10·0	7·4	17·4	Slightly turbid. Palatable.
„ „ sample B, July, 1873	14·40	**·151**	**·045**	0	·107	·152	**750**	2·60	0	8·7	8·7	Very turbid. Palatable.
WAKEFIELD.												
Abyssinian pump, near the *Calder*, August 31, 1870.	21·06	**·081**	**·015**	·018	0	·030	**0**	2·50	7·2	2·9	10·1	Clear and palatable.
WHITWICK, near ASHBY-DE-LA-ZOUCH.												
Shallow Well, No. 1, June 23, 1868	26·40	**·135**	**·016**	0	·317	·333	**2,854**	1·64	2·6	10.5	13·1	—
„ „ No. 2, „ „	30·58	**·073**	**·023**	·004	·345	·372	**3,170**	1·94	8·2	7·5	15·7	—
„ „ No. 4, „ „	32·78	**·103**	**·003**	·003	·323	·351	**3,160**	1·59	6·9	9·0	15·9	—
„ „ No. 5, „ „	82·08	**·208**	**·028**	·010	1·545	1·559	**14,990**	5·36	10·5	13·5	24·0	—
„ „ No. 6, „ „	26·20	**·071**	**·024**	·006	·040	·069	**133**	·99	12·0	3·9	15·9	—

Shallow well waters in Coal measures.

COMPOSITION OF WATERS FROM SHALLOW WELLS IN OR UPON THE COAL MEASURES—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
SCOTLAND.												
CUPAR, FIFESHIRE.												
Burnside well, March 6, 1872	34·00	·054	·017	0	·938	·955	9,060	2·70	11·2	10·3	21·5	Clear and palatable.
Castlefield pump, March 6, 1872	51·20	·047	·022	·001	2·721	2·744	26,900	5·90	10·3	17·5	27·8	Clear and palatable.
Market Cross well, March 7, 1872	65·76	·043	·018	·001	3·317	3·336	32,860	7·95	9·9	23·6	33·5	Clear and palatable.
Kirkgate well, March 7, 1872	88·20	·230	·091	·002	5·702	5·795	56,720	12·85	2·6	33·8	36·4	Slightly turbid. Palatable.
Private well in Provost's Garden, March 7, 1872.	38·88	·048	·025	0	1·577	1·602	15,450	3·60	12·4	15·4	27·8	Clear and palatable.
Well at Marybank, March 7, 1872	53·56	·038	·007	·017	2·307	2·328	22,890	5·35	17·7	16·6	34·3	Clear and palatable.
HAMILTON, LANARKSHIRE.												
Well at Hamilton Palace, July 28, 1870.	86·64	·058	·041	·004	3·754	3·798	37,250	10·30	13·0	22·6	35·6	Clear and palatable.
KILMARNOCK.												
Well in High Street, 25 feet deep, April 7, 1870.	109·08	·173	·067	·062	5·880	5·998	58,990	13·25	5·8	38·1	43·9	Turbid. Palatable.
The Cross well, Oct. 3, 1870	96·48	·057	·024	·001	3·313	3·338	32,820	12·00	10·7	25·0	35·7	Clear and palatable.
KIRKINTILLOCH.												
Well in Kerr Street field, July 25, 1870.	20·96	·133	·027	·005	·137	·168	1,090	1·60	6·7	5·2	11·9	Slightly turbid. Palatable.
Whitelaw's well, July 25, 1870	31·44	·239	·126	·001	1·511	1·638	14,800	4·80	3·5	10·5	14·0	Clear and palatable.
Findlay's pump, July 25, 1870	71·00	·299	·147	·001	2·806	2·954	27,750	8·79	12·2	16·3	28·5	Clear and palatable.
Freeland Place well, July 25, 1870	68·28	·187	·140	·016	3·746	3·899	37,270	7·44	4·9	20·9	25·8	Very turbid. Palatable.
MUSSELBURGH.												
Bicker's well, August 2, 1870	65·46	·242	·115	0	3·102	3·217	30,700	5·90	8·1	19·1	27·2	Clear and palatable.
Carry's well, August 2, 1870	124·28	·207	·073	0	6·143	6·216	61,110	16·30	10·6	31·0	41·6	Clear. Closed since 1866.
Newbiggin's well in Wonder Street, August 2, 1870.	100·68	·253	·086	0	5·118	5·204	50,860	12·30	13·1	22·6	35·7	Clear and palatable.
Cran's well, Eskside, August 2, 1870.	27·64	·030	·015	0	0	·015	0	2·70	6·7	5·2	11·9	Slightly turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

An inspection of the foregoing table shows that a large number of these samples are of very filthy origin, and the large proportion of chlorine present in most of them points unmistakably to the infiltration of urine into the wells. One of the worst samples is that from Jacob's Well, now abandoned, at the South Yorkshire Asylum, near Sheffield. This water contained a very large proportion of organic matter in solution. It was very turbid and offensive, and swarmed with vibrios, bacteria, and other living organisms. A critical description of the other samples will be found in Part IV., page 301, of this report under the heads of the respective towns in or near which they were collected. With very few exceptions these waters are dangerous to the public health, and few of them are sufficiently soft to be of any use for washing.

SECTION V.—WATERS FROM SHALLOW WELLS IN OR ON MOUNTAIN LIMESTONE AND MAGNESIAN LIMESTONE.

The following table contains the results of analysis of a number of these waters which we have investigated. The Chepstow sample alone was collected by us:—

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND AND WALES.												
CHEPSTOW, (*Mountain Limestone.*)												
Public pump behind office of Local Board of Health, June 19, 1871.	103·80	·190	·047	·001	3·668	3·716	36,370	13·35	27·2	41·4	68·6	Slightly turbid. Palatable.
DARRINGTON, NEAR PONTEFRACT.												
Well in Darrington village, December 22, 1871.	108·88	·154	·070	·002	4·812	4·884	47,820	8·60	40·1	48·5	88·6	Slightly turbid. Palatable.
George Fisher's well, Feb. 22, 1872	72·48	·126	·054	·002	1·812	1·868	17,820	4·60	23·4	38·6	62·0	Slightly turbid. Palatable.

Shallow well waters in New Red Sandstone.

COMPOSITION OF WATERS FROM SHALLOW WELLS IN OR ON MOUNTAIN LIMESTONE AND MAGNESIAN LIMESTONE—*continued.*

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
MANSFIELD.												
Well in Corn Exchange Lane, November 1, 1873.	69·36	**·128**	**·031**	0	2·082	2·113	**20,500**	6·20	23·4	33·4	56·8	Clear and palatable.
PONTEFRACT.												
Baghill pump, Jan. 24, 1872.	70·76	**·098**	**·031**	·001	·898	·930	**8,670**	3·45	27·7	37·3	65·0	Clear and palatable.
WETHERBY.												
Pump in Red Lion Yard, March, 1874.	45·84	**·037**	**·010**	0	·793	·803	**7,610**	2·40	18·3	22·4	40·7	Clear and palatable.
Pump in Church Lane, March, 1874	78·48	**·130**	**·025**	0	2·681	2·706	**26,490**	4·65	24·2	28·0	52·2	Slightly turbid. Palatable.
Pump in Eccles Yard, March, 1874	50·36	**·104**	**·022**	0	·527	·549	**4,950**	2·40	22·5	21·8	44·3	Slightly turbid Palatable.
Pump in Union Workhouse, March 1874.	47·92	**·059**	**·022**	0	·558	·580	**5,260**	2·60	23·2	23·9	47·1	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

All these samples of water are excessively hard and therefore quite useless for washing. The sample from Baghill pump at Pontefract is palatable, and could be used for domestic purposes without serious risk to health. This water is believed to come from a carboniferous sandstone, it contains only a moderate proportion of organic elements, and the evidence of previous sewage contamination which it exhibits, though high, is not excessive. The pump in Church Lane, Wetherby, yields dangerous water, but the other samples from the same place might be used for domestic purposes with comparatively little risk to health. The water from the remaining wells in the table, though palatable, is highly polluted and quite unfit for dietetic purposes.

SECTION VI.—WATERS FROM SHALLOW WELLS IN OR ON NEW RED SANDSTONE.

The New Red Sandstone and the porous drift which often overlies it are very fertile sources of shallow well waters. This formation is largely developed both in the Midland and Northern counties of England; we have examined no less than eighty-seven samples of water from it. Those from Birmingham, Darlington, Dawlish, Kidderminster, Leamington, Leyland, Newark, Stafford, and Stockton-on-Tees, and a few of the samples from other towns were collected by us, the remainder were sent to us for analysis through the Local Government Act Office. The following table shows the composition of these waters:—

COMPOSITION OF WATERS FROM SHALLOW WELLS IN THE NEW RED SANDSTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
BIRMINGHAM.												
Pump in No. 5 Court, Hurst Street, September 18, 1873.	240·20	**·340**	**·105**	·620	14·717	15·333	**151,960**	36·50	27·5	99·6	127·1	Clear. Strong saline taste.
Pump in No. 8 Court, Great Lister Street, September 18, 1873.	215·60	**·094**	**·057**	·005	7·576	7·637	**75,480**	39·00	8·0	87·7	95·7	Slightly turbid. Slight saline taste.
Pump in No. 16 Court, Stamforth Street, September 18, 1873.	194·80	**·454**	**·186**	·014	6·437	6·635	**64,170**	37·50	26·3	66·6	92·9	Slightly turbid. Palatable.
Pump in No. 17 Court, Cregoe Street, September 18, 1873.	189·00	**·106**	**·018**	·070	12·721	12·796	**127,460**	22·00	6·6	80·5	87·1	Do.
Pump in No. 43 Court, Bell Barn Road, September 18, 1873.	158·00	**·114**	**·053**	·003	11·012	11·067	**109,820**	19·50	0	65·8	65·8	Do.
Pump in Pump Yard, Whittall Street, September 18, 1873.	175·60	**·239**	**·080**	·001	6·620	6·701	**65,890**	24·50	3·0	65·8	68·8	Do.
Pump at No. 30, Ravenhurst Street, September 18, 1873.	91·80	**·448**	**·056**	·080	3·149	3·271	**31,830**	11·00	13·6	30·7	44·3	Do.
Pump in No. 207, Hagley Road, Edgbaston, September 18, 1873.	56·00	**·098**	**·029**	·035	3·872	3·929	**38,690**	7·04	3·4	22·1	25·5	Do.

Shallow well waters in New Red Sandstone.

COMPOSITION OF WATERS FROM SHALLOW WELLS IN THE NEW RED SANDSTONE—*continued*.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
CONGLETON, CHESHIRE.												
Town pump at Star Inn, May 29, 1868.	38·00	**·177**	**·044**	·002	1·076	1·122	**10,456**	3·18	4·0	13·1	17·1	Palatable.
Pump at Foundry Bank, August 24, 1872.	36·40	**·128**	**·029**	·007	·671	·706	**6,450**	3·10	1·1	16·3	17·4	Slightly turbid. Palatable.
Pump in Wallworth's Yard, August 24, 1872.	53·12	**·110**	**·025**	·010	1·516	1·549	**14,920**	4·70	1·2	20·3	21·5	Slightly turbid. Palatable.
Silver Street well, August 24, 1872	38·40	**·067**	**·009**	0	·388	·397	**3,560**	1·60	4·9	16·0	20·9	Clear and palatable.
Town pump well, August 24, 1872.	46·82	**·090**	**·027**	·006	1·561	1·593	**15,340**	4·00	4·9	15·7	20·6	Clear and palatable.
Pump at Stonehouse Green, August 24, 1872.	36·20	**·076**	**·019**	·001	·620	·640	**5,890**	1·60	4·9	16·0	20·9	Slightly turbid. Palatable.
Pump in Garden Street, August 24, 1872.	50·92	**·143**	**·024**	0	2·022	2·046	**19,900**	3·90	0	21·2	21·2	Clear and palatable.
The Tanhouse well, August 24, 1872.	50·80	**·132**	**·035**	·016	·077	·125	**580**	2·40	6·5	18·6	25·1	Slightly turbid. Palatable.
Astbury Street well, August 24, 1872.	129·72	**·661**	**·058**	·200	7·215	7·438	**73,480**	12·80	8·9	42·6	51·5	Turbid. Palatable.
COVENTRY.												
Well in Cow Lane, Oct. 22, 1873 -	137·60	**·237**	**·055**	0	3·294	3·349	**32,620**	18·20	37·0	35·7	72·7	Slightly turbid. Palatable.
CRATHORNE, YORKSHIRE.												
Orchard Well 5 feet deep, Sep. 1870	123·92	**·442**	**·101**	·027	1·637	1·760	**16,270**	12·50	6·4	36·2	42·6	Very slightly turbid. Palatable.
Pump drawing from well 20 feet deep, Sep. 1870.	75·12	**·417**	**·077**	·003	·079	·158	**490**	7·80	22·3	19·6	41·9	Slightly turbid. Palatable.
DARLINGTON, DURHAM.												
Blackwell pump, October 6, 1870 -	127·00	**·129**	**·033**	0	6·724	6·757	**66,920**	8·45	36·9	41·7	78·6	Clear and palatable.
DAWLISH, DEVONSHIRE.												
Well at Marine Terrace, January 9, 1873.	84·70	**·099**	**·012**	·122	7·026	7·138	**70,940**	14·80	0	30·6	30·6	Slightly turbid. Palatable.
GREASELEY, NOTTS.												
Morley's pump (well 45 feet deep), July 20, 1871.	136·60	**·255**	**·056**	·001	5·991	6·048	**59,600**	16·30	22·2	40·7	62·9	Slightly turbid. Palatable.
Elias Paxton's well, July 20, 1871	157·70	**·245**	**·064**	·020	2·345	2·425	**23,290**	12·40	35·1	63·5	98·6	Slightly turbid. Palatable.
HUGGLESCOTE, LEICESTERSHIRE.												
Pump at Mr. Finkleton's cottages, January 4, 1872.	62·80	**·141**	**·067**	·005	2·677	2·748	**26,490**	6·10	3·6	39·2	42·8	Turbid. Palatable.
Pump at Westman's house, between Coalville and Hugglescote, January 4, 1872.	92·00	**·106**	**·083**	·052	3·819	3·945	**38,300**	8·80	0	59·0	59·0	Slightly turbid. Palatable.
Mr. Moore's pump at west end of Hugglescote road, January 4, 1872.	48·20	**·122**	**·069**	0	2·965	3·034	**29,330**	8·40	0	37·1	37·1	Clear and palatable.
HURWORTH NEAR DARLINGTON.												
Pump near churchyard, May 20, 1870.	105·96	**·355**	**·092**	0	4·438	4·530	**44,060**	9·90	30·1	11·2	41·3	Clear and palatable.
Pump at west end of village, May 20, 1870.	49·82	**·121**	**·013**	·001	·554	·568	**5,230**	2·60	14·1	12·3	26·4	Clear and palatable.
Well at Rectory, May 20, 1870 -	109·68	**·275**	**·138**	0	2·620	2·758	**25,880**	5·41	32·3	3·8	36·1	Clear and palatable.
Mr. Hopper's pump, May 20, 1870	156·96	**·254**	**·159**	·002	9·896	10·057	**98,660**	13·00	22·2	20·4	42·6	Clear and palatable.
Mrs. Almond's pump, May 20, 1870.	118·78	**·221**	**·137**	·001	7·015	7·153	**69,840**	10·15	27·4	25·0	52·4	Clear and palatable.
Mr. Broughton's pump, May 20, 1870.	60·60	**·106**	**·012**	0	·134	·146	**1,020**	3·05	22·1	23·1	45·2	Clear and palatable.
KIDDERMINSTER.												
Well in Alderman Tovey's Yard, April 29, 1870.	83·64	**·253**	**·069**	·090	3·069	3·212	**31,110**	8·38	26·9	14·4	41·3	Clear and palatable.
Well in "Three Tuns" Yard, April 29, 1870.	83·52	**·102**	**·056**	0	5·322	5·378	**52,900**	8·20	11·3	17·3	28·6	Clear and palatable.
LEAMINGTON.												
Mr. Jones's well, May 12, 1870 -	134·04	**·095**	**·025**	0	6·086	6·111	**60,540**	14·20	35·6	28·3	63·9	Clear and palatable.
LEYLAND, NEAR PRESTON, LANCASHIRE.												
Well in Pembroke Place, 16 feet deep, May 17, 1873.	66·04	**·481**	**·121**	·005	2·405	2·530	**23,770**	4·20	0	35·4	35·4	Slightly turbid. Palatable.
MALPAS, NEAR CHESTER.												
Town well. October 14, 1871 -	23·50	**·123**	**·080**	·002	·409	·491	**3,790**	1·40	12·0	10·7	22·7	Slightly turbid. Palatable.

COMPOSITION OF WATERS FROM SHALLOW WELLS IN THE NEW RED SANDSTONE—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Mrs. Holland's pump, Oct. 14, 1871	89·20	**·387**	**·123**	·001	4·335	4·459	**43,040**	11·85	13·1	25·4	38·5	Slightly turbid. Palatable.
Town well, 2nd sample, after cleansing and repairs, Nov. 21, 1871.	24·64	**·029**	**·016**	·014	·354	·382	**3,340**	1·60	10·6	10·6	21·2	Slighly turbid. Palatable.
NEWARK, NOTTS.												
Water supplied from well near the *Trent*, July 11, 1873.	57·82	**·131**	**·042**	0	·088	·130	**560**	2·40	13·0	18·9	31·9	Slightly turbid. Palatable.
NEWENT, GLOUCESTERSHIRE.												
Well No. 108, August 22, 1870 -	51·86	**·157**	**·081**	0	2·278	2·359	**22,460**	2·25	4·5	17·5	22·0	Clear and palatable.
„ No. 109 „ „ -	113·76	**·256**	**·088**	0	5·407	5·495	**53,750**	7·70	25·6	17·0	42·6	Clear and palatable.
„ No. 111 „ „ -	84·64	**·130**	**·069**	0	3·144	3·213	**31,120**	8·50	4·9	28·1	33·0	Clear and palatable.
„ No. 112 „ „ -	232·12	**·293**	**·236**	0	11·394	11·630	**113,620**	28·60	25·3	31·1	56·4	Slightly turbid. Palatable.
„ No. 114 „ „ -	96·60	**·178**	**·047**	0	4·165	4·212	**41,330**	6·90	10·4	22·6	33·0	Clear and palatable.
„ No. 117 „ „ -	99·36	**·211**	**·056**	0	3·787	3·843	**37,550**	8·30	20·9	15·2	36·1	Clear and palatable.
„ No. 119 „ „ -	131·80	**1·490**	**·314**	·003	5·076	5·392	**50,460**	23·10	17·6	30·8	48·4	Clear and palatable.
„ No. 32 „ „ -	132·40	**·238**	**·131**	0	6·607	6·738	**65,750**	16·87	25·2	20·7	45·9	Clear and palatable.
„ No. 67 „ „ -	89·76	**·151**	**·116**	0	4·727	4·843	**46,950**	5·25	15·2	24·8	40·0	Clear and palatable.
„ No. 120 „ „ -	42·88	**·101**	**·065**	0	1·054	1·119	**10,220**	1·78	5·9	12·7	18·6	Clear and palatable.
„ No. 63 „ „ -	93·76	**·132**	**·084**	0	3·439	3·523	**34,070**	10·15	14·0	23·4	37·4	Clear and palatable.
„ No. 113 „ „ -	122·40	**·221**	**·123**	0	5·472	5·595	**54,400**	13·60	25·5	15·8	41·3	Turbid. Palatable.
NEWNHAM, GLOUCESTERSHIRE.												
Mrs. Margarett's well, November 19, 1870.	150·52	**·123**	**·058**	·004	7·018	7·079	**69,890**	12·33	20·8	73·5	94·3	Slightly turbid. Palatable.
Mr. E. Shurmer's well, November 19, 1870.	82·72	**·107**	**·033**	·001	2·220	2·254	**21,890**	3·90	35·7	32·9	68·6	Clear and palatable.
Mr. Everett's well, Nov. 19, 1870 -	113·00	**·261**	**·070**	·005	3·621	3·695	**35,930**	6·90	42·2	40·7	82·9	Slightly turbid Palatable.
Mr. M. F. Carter's well, November 19, 1870.	58·16	**·070**	**·032**	0	·672	·704	**6,400**	3·15	40·8	7·8	48·6	Slightly turbid. Palatable.
Well in Sailor's Square, November 19, 1870.	109·28	**·229**	**·139**	·002	4·449	4·590	**44,190**	6·00	27·8	46·5	74·3	Slightly turbid. Palatable.
Mr. T. Goold's well, November 19, 1870.	94·32	**·163**	**·031**	0	2·620	2·651	**25,880**	5·10	39·9	37·2	77·1	Clear and palatable.
RETFORD, EAST, NOTTS.												
Pump at north end of Market Place, July 11, 1873.	27·80	**·076**	**·028**	0	·179	·207	**1,470**	2·65	5·8	12·9	18·7	Slightly turbid. Palatable.
Public pump in square near White Hart Hotel, August 26, 1870.	36·00	**·118**	**·035**	·007	·268	·309	**2,420**	3·70	9·0	12·0	21·0	Clear and palatable.
Public pump in square near Grove Street, August 26, 1870.	47·04	**·241**	**·109**	·038	·477	·617	**4,760**	4·40	13·8	14·3	28·1	Slightly turbid. Palatable.
Spa Lane well, August 26, 1870 -	208·80	**·994**	**·202**	·159	9·529	9·862	**96,280**	18·50	40·3	68·5	108·8	Clear. Bright yellow.
Well in Sultan's Row, August 26, 1870.	188·84	**·935**	**·112**	·161	4·384	4·629	**44,850**	23·70	7·7	23·9	31·6	Clear. Bright yellow.
Well in Turk's Head Yard, August 26, 1870.	20·64	**·091**	**·027**	0	0	·027	**0**	1·60	10·8	8·8	19·6	Clear and palatable.
Well at Grammar School, August 26, 1870.	50·80	**·704**	**·105**	0	·701	·806	**6,690**	1·90	20·0	16·8	36·8	Clear and palatable.
RETFORD, WEST, NOTTS.												
Well in Protestant Place, August 20, 1870.	80·16	**·101**	**·036**	0	1·483	1·519	**14,510**	7·35	20·8	34·9	55·7	Clear and palatable.
Well in Mermaid Yard, August 20, 1870.	131·32	**·367**	**·092**	0	7·356	7·448	**73,240**	11·82	14·1	43·3	57·4	Clear and palatable.
RETFORD, CLARBOROUGH, NOTTS.												
Well in Rex's Yard, Aug. 20, 1870	99·16	**·425**	**·102**	0	2·455	2·557	**24,230**	7·75	4·4	35·6	40·0	Clear and palatable.
Well in yard of Dog and Duck, August 20, 1870.	119·40	**·327**	**·138**	0	5·396	5·534	**53,640**	9·30	21·3	51·0	72·3	Clear and palatable.
Well in Iremonger's Yard, August 20, 1870.	128·28	**·282**	**·099**	0	4·892	4·991	**48,600**	12·75	20·6	51·7	72·3	Clear and palatable.
Well in Chapman's Row, Spital Hill, August 20, 1870.	111·00	**·360**	**·117**	0	3·805	3·922	**37,730**	7·75	20·7	45·2	65·9	Clear and palatable.
RETFORD, ORDSALL, NOTTS.												
Halebigan well, August 20, 1870 -	201·20	**2·349**	**·346**	·042	4·583	4· 64	**45,860**	26·80	35·6	80·0	115·6	Clear and palatable.

COMPOSITION OF WATERS FROM SHALLOW WELLS IN THE NEW RED SANDSTONE—*continued.*

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
STAFFORD.												
Pump in Station-master's yard, May 17, 1873.	81·40	**·370**	**·076**	0	·534	·610	**5,020**	11·12	17·0	12·4	29·4	Clear and palatable.
Well in yard of Swan Hotel, May 17, 1873.	141·60	**·266**	**·080**	·004	8·064	8·147	**80,350**	12·90	12·9	38·6	51·5	Clear. Slight saline taste.
Pump at cottages in Backwall, May 17, 1873.	208·40	**·415**	**·101**	·260	11·995	12·310	**121,770**	20·00	17·8	51·0	68·8	Slightly turbid. Slight saline taste.
STOCKTON-ON-TEES.												
Well in court-yard of J. Dodds, Esq., M.P., October 7, 1870.	133·12	**·195**	**·047**	0	1·927	1·974	**18,950**	16·70	46·7	39·0	85·7	Slightly turbid. Palatable.
Mr. Trotter's well, October 7, 1870	150·08	**·195**	**·037**	·014	1·913	1·962	**18,930**	25·30	52·0	35·1	87·1	Slightly turbid. Palatable.
WILNECOTE, NEAR TAMWORTH.												
Well at Long's Buildings, June 1868.	44·90	**·083**	**·084**	·006	1·027	1·116	**10,000**	4·14	1·3	15·9	17·2	—
Well in Morris's Yard, June 1868	60·20	**·136**	**·027**	·018	2·058	2·100	**20,410**	5·77	1·4	20·3	21·7	—
Public pump at head of village, June 1868.	157·24	**·244**	**·093**	·013	7·872	7·976	**78,510**	12·03	0	57·5	57·5	—
WORKSOP, NOTTS.												
Park Street well, May 28, 1873 -	66·48	**·267**	**·061**	0	2·126	2·187	**20,940**	6·60	15·7	28·5	44·2	Turbid. Palatable.
Well at Peacock Inn, Everton Road, May 28, 1873.	56·40	**·550**	**·151**	·065	1·799	2·004	**18,210**	4·15	8·2	32·5	40·7	Clear and palatable.
Well at Bargh's Row, Merecroft, May 28, 1873.	112·28	**·288**	**·071**	0	5·262	5·333	**52,300**	8·00	25·5	41·1	66·6	Slightly turbid. Palatable.
Well at New Road, May 28, 1873 -	137·08	**·349**	**·096**	0	5·066	5·162	**50,340**	9·60	19·2	62·8	82·0	Clear and palatable.
Mr. Dobree's well, May 28, 1873 -	56·32	**·124**	**·039**	0	2·179	2·218	**21,470**	5·40	10·9	26·9	37·8	Clear and palatable.
Mr. Appleton's well, May 28, 1873	69·32	**·400**	**·098**	0	3·490	3·588	**34,580**	5·60	0	35·9	35·9	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The New Red Sandstone, and the Drift Sand or Gravel with which it is frequently covered are excellent water-bearing strata; nevertheless the sources of pollution surrounding shallow wells are so general, numerous and potent, as to leave but few of the many samples enumerated in the foregoing table of sufficient purity for safe domestic use, although most of them were clear and palatable. The total solid impurity which is present in the unpolluted water of the strata is but moderate in quantity; but in the great majority of the above samples it is excessive; ranging as high as 240 parts per 100,000, or 168 grains per gallon, which was found in water from one of the filthy shallow wells of Birmingham. Owing to the highly oxidizing power of the New Red Sandstone, and of the Drift which often covers it, the proportion of organic elements in these waters is generally more moderate than that met with even in unpolluted surface waters; but the organic matter is, as a rule, derived from sewage or refuse animal matters, and is therefore highly objectionable. A reference to the column headed "previous sewage or animal contamination" shows how largely sewers, cesspools, and middens contribute to the contents of these wells. Finally, the hardness of these waters is in most cases so excessive, as to render them quite useless for washing. Descriptions of the different groups of samples will be found in Part IV., page 301, under the names of the various towns and villages mentioned in the foregoing table.

SECTION VII.—SHALLOW WELLS IN OR ON THE LIAS.

The following table contains the results of our analyses of numerous samples of water from shallow wells in the Lias. With the exception of that from Cheltenham we did not collect any of these samples. They were nearly all sent to us for investigation through the Local Government Act Office, in consequence of severe outbreaks of fever amongst the populations using the wells:—

Shallow well waters in Lias.

Composition of Water from Shallow Wells in or upon the Lias.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
ENGLAND.												
Bitteswell near Lutterworth, Leicestershire.												
Mr. See's well, April 13, 1872	140·60	**·264**	**·099**	·001	3·787	3·887	**37,560**	13·90	40·1	28·5	68·6	Clear and palatable.
Public pump below Almshouses, April 13, 1872.	120·80	**·205**	**·033**	0	0	·033	**0**	12·20	29·1	55·2	84·3	Slightly turbid, palatable.
Miss Powell's well, Old Schoolhouse, April 13, 1872.	114·80	**·485**	**·071**	·001	2·541	2·613	**25,100**	12·55	30·8	47·8	78·6	Slightly turbid, palatable.
Smart's pump, April 13, 1872	158·80	**·420**	**·142**	·001	7·915	8·058	**78,840**	17·30	26·6	62·0	88·6	Slightly turbid, palatable.
Public pump below church, April 13, 1872.	114·50	**·090**	**·057**	0	4·321	4·378	**42,890**	14·80	32·9	28·5	61·4	Slightly turbid, palatable.
The Rev. G. Mornington's pump, April 13, 1872.	65·04	**·150**	**·034**	·001	·880	·915	**8,490**	4·75	33·7	10·6	44·3	Clear and palatable.
Bracebridge near Lincoln.												
Butter's well, 11 feet deep, April, 1871.	91·20	**·413**	**·080**	·001	3·004	3·085	**29,730**	16·60	18·3	22·4	40·7	Clear and palatable.
Cheltenham.												
Pump at Plough Hotel, April 18, 1874.	120·08	**·115**	**·058**	·004	3·936	3·997	**39,070**	9·64	27·4	39·2	66·6	Clear and palatable.
Hillmorton near Rugby.												
Upper public well, Lower Street, March 2, 1869.	58·84	**·237**	**·027**	·002	3·662	3·691	**36,320**	4·60	0	14·3	14·3	Palatable.
Well in Pryse's yard, top of town, March 2, 1869.	306·85	**1·144**	**·216**	·060	19·858	20·123	**198,750**	40·50	5·9	111·0	116·9	"
Dandy well, Upper Street, March 2, 1869.	49·48	**·417**	**·038**	·025	1·011	1·070	**10,000**	8·20	3·4	7·9	11·3	"
Dunkley's well, Rathbone's Yard, Upper Street, March 2, 1869.	190·85	**·650**	**·119**	·005	9·235	9·358	**92,070**	24·00	31·4	39·9	71·3	"
Bottom public well, Lower Street, March 2, 1869.	95·00	**·194**	**·026**	·001	3·901	3·928	**38,700**	8·10	14·4	18·3	32·7	"
Well in Mr. Billington's Yard, July 29, 1873.	49·16	**·279**	**·071**	·040	1·740	1·844	**17,410**	6·40	0	20·7	20·7	Slightly turbid. Palatable.
Little Bowden, Market Harboro'.												
Well at Mr. Fisher's house, June 1, 1869.	163·40	**·375**	**·189**	·024	·613	·822	**6,010**	30·80	1·5	1·2	2·7	——
Oakham, Rutland.												
Well under Mr. J. Cave's sitting room, April, 1872.	97·80	**·129**	**·060**	·001	3·697	3·758	**36,660**	10·60	24·7	16·0	40·7	Clear and palatable.
Well in St. John's Court, John Street, April, 1872.	204·10	**·217**	**·103**	·152	8·136	8·364	**82,290**	23·60	34·4	61·3	95·7	Clear and palatable.
Well in Cook's Yard, Northgate Street, April, 1872.	142·80	**·133**	**·051**	·001	6·795	6·847	**67,640**	13·40	35·2	29·1	64·3	Clear and palatable.
Somerby, Oakham, Rutlandshire.												
Town well supplying end of village, May, 1871.	37·20	**·082**	**·031**	0	·320	·351	**2,880**	1·75	23·8	5·3	29·1	Slightly turbid. Palatable.
Plant's pump, May, 1871	124·12	**·059**	**·029**	0	1·120	1·149	**10,880**	12·90	22·0	43·7	65·7	Slightly turbid. Palatable.
Well at Pickwell Jetty, May, 1871.	159·40	**·093**	**·037**	0	5·385	5·422	**53,530**	24·70	18·6	41·4	60·0	Clear and palatable.
Wesson's pump, May, 1871	100·60	**·052**	**·072**	0	6·637	6·709	**66,050**	10·50	27·1	34·3	61·4	Clear and palatable.
Somerton, Somerset.												
Well in Cow Square, January 17, 1871.	72·64	**·189**	**·059**	0	1·846	1·905	**18,140**	5·65	28·7	12·4	41·1	Slightly turbid. Palatable.
Well near Townhall, January 17, 1871.	54·08	**·061**	**·023**	0	·984	1·007	**9,520**	2·75	30·0	8·3	38·3	Clear and palatable.
Well in Kirkham Street, January 17, 1871.	94·04	**·326**	**·102**	·001	2·980	3·083	**29,490**	8·65	31·5	13·2	44·7	Slightly turbid. Palatable.
Well near Walton's Lodging House, January 17, 1871.	199·20	**·804**	**·143**	·005	9·449	9·596	**94,210**	24·10	38·7	37·0	75·7	Slightly turbid and slightly yellow.
Well at Cook's Holes, January 17, 1871.	93·28	**1·792**	**·298**	·001	3·546	3·845	**35,150**	9·15	25·5	21·7	47·2	Slightly turbid.
Ringer's well, January 17, 1871	72·28	**1·280**	**·111**	0	1·755	1·866	**17,230**	5·60	32·3	14·9	47·2	Clear.
Well in Langport Road, January 17, 1871.	100·68	**·841**	**·144**	·080	·815	1·025	**8,490**	6·35	31·2	20·3	51·5	Very turbid.
Well at Bartlett's Buildings, January 17, 1871.	89·24	**·291**	**·061**	·004	2·219	2·283	**21,900**	8·30	29·6	19·7	49·3	Slightly turbid. Palatable.
Well at Pound's Pool, January 17, 1871.	53·60	**·275**	**·063**	·005	1·259	1·326	**12,310**	4·35	21·4	14·3	35·7	Slightly turbid. Palatable.

Shallow well waters in Lias.

COMPOSITION OF WATER FROM SHALLOW WELLS IN OR UPON THE LIAS—*continued.*

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Well at Mr. Poole's, January 17, 1871.	102·72	**·209**	**·066**	·001	2·606	2·673	**25,750**	17·80	22·4	18·3	40·7	Slightly turbid. Palatable.
Well at Mr. Erith's, January 17, 1871.	61·60	**·128**	**·035**	·003	1·042	1·079	**10,120**	4·30	32·3	7·7	40·0	Clear and palatable.
SOUTHAM, WARWICKSHIRE.												
Burnell's well, December 3, 1869 -	95·00	**·316**	**·029**	·014	·581	·622	**5,610**	4·00	·6	28·7	29·3	Slightly turbid. Palatable.
Martin's well, December 3, 1869 -	85·60	**·183**	**·030**	0	·354	·384	**3,220**	5·30	0	35·7	35·7	Slightly turbid. Palatable.
Market Hill well, December 3, 1869	87·20	**·201**	**·027**	0	·389	·416	**3,570**	3·90	8·6	22·6	31·2	Slightly turbid. Palatable.
Well at Park Lane Cottages, December 3, 1869.	145·74	**·489**	**·057**	·003	4·639	4·698	**46,100**	11·90	25·8	31·8	57·6	Turbid.
Reynold's well, December 3, 1869 -	113·60	**·493**	**·071**	0	3·775	3·846	**37,430**	9·50	34·2	26·0	60·2	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

In regard to mineral constituents, these waters closely resemble those derived from shallow wells in the New Red Sandstone, but owing to the less porous character of the Lias, a larger proportion of organic impurity has escaped oxidation; and consequently these waters are much more seriously polluted by the actual presence of animal organic matter than is the case with waters from shallow wells in the New Red Sandstone. The proportion of total solid impurity rarely descends below 50 parts per 100,000, or 35 grains per gallon, and mounts up to a maximum of 307 parts in 100,000, or 215 grains per gallon. The organic elements are generally present in very large proportion, but the organic matter being of animal origin, the palatability of the water is rarely interfered with. Most of these waters consist chiefly of the soakage from sewers and cesspools, as is shown by the column headed "previous sewage or animal contamination:" and in one case, that of the well at Pryse's Yard, at Hillmorton near Rugby, the foul soakage was twice as strong as London sewage in excremental pollution.

The hardness of these polluted lias waters is generally so great as to render them quite unfit for washing. A large proportion of the samples were more or less turbid when they reached our laboratory. Amongst the thirty-eight samples, there are only two which could be used for drinking or cooking without serious risk to health.

These are,—

Town well supplying end of the village of Somerby.
Well near Townhall, Somerton.

SECTION VIII.—WATERS FROM SHALLOW WELLS IN OR ON THE OOLITES.

The following table contains the results of our analyses of samples of water from shallow wells in or upon the Oolitic formations. The samples from Bedford, Cirencester, Frome, Oakham, Thame, and Witney were collected by ourselves. Those from Brackley and Warkton were forwarded to us through the Local Government Act Office:—

COMPOSITION OF WATER FROM SHALLOW WELLS IN OR UPON THE OOLITES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
BEDFORD.												
Pillory pump, October 10, 1868 -	140·74	**·325**	**·088**	0	2·497	2·585	**24,650**	15·29	29·1	25·4	54·5	Clear and palatable.
BRACKLEY, NORTHAMPTONSHIRE.												
Well at Mr. A. Weston's, July 20, 1871.	121·60	**2·662**	**·531**	·034	3·801	4·360	**37,970**	13·50	30·7	22·2	52·9	Very brown and turbid.
Mr. Stephen Howard's well, July 20, 1871.	84·88	**·203**	**·085**	0	4·432	4·517	**44,000**	7·90	10·8	33·5	44·3	Very slightly turbid.

COMPOSITION OF WATER FROM SHALLOW WELLS IN OR UPON THE OOLITES—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
The Rev. H. W. Smith's well, July 20, 1871.	100·80	**·277**	**·063**	·005	4·953	5·020	**49,250**	10·70	25·0	29·3	54·3	Very turbid.
Mr. W. F. Ramsey's well, July 20, 1871.	66·68	**·237**	**·077**	·002	2·019	2·098	**19,890**	6·20	24·4	16·3	40·7	Turbid.
The Vicar's well, August 21, 1871	70·80	**·307**	**·083**	·002	1·744	1·829	**17,140**	3·80	42·2	20·6	62·8	—
CIRENCESTER.												
Market Place pump, November 4, 1870.	31·00	**·041**	**·008**	0	·362	·370	**3,300**	1·60	18·4	4·6	23·0	Slightly turbid Palatable.
Bowley's pump, November 4, 1870	54·16	**·123**	**·019**	·001	1·414	1·434	**13,830**	3·65	34·6	9·7	44·3	Clear and palatable.
Sheep Street well, November 4, 1870	55·88	**·332**	**·074**	·036	·802	·906	**8,000**	5·10	26·7	8·3	35·0	Very turbid.
Well at Railway Station, November 4, 1870.	59·20	**·144**	**·019**	0	·626	·645	**5,940**	2·80	32·4	5·5	37·9	Clear and palatable.
Chapel well, near Park Street, November 7, 1870.	61·40	**·283**	**·069**	·134	·469	·648	**5,470**	6·09	38·4	7·3	45·7	Clear and palatable.
FARINGDON, BERKS.												
Well 16 feet deep at Hinton Manor, February 5, 1872.	101·50	**·201**	**·066**	·001	3·510	3·577	**34,790**	11·05	42·6	24·5	67·1	Turbid. Palatable.
FROME, SOMERSET.												
Shallow well in Blue House School, March 10, 1870.	86·30	**·367**	**·064**	·025	2·525	2·610	**25,140**	6·67	29·4	20·9	50·3	—
THAME.												
Well at Holly Green Farm, Bredlow, September 17, 1873.	53·08	**·495**	**·100**	·006	·520	·625	**4,930**	5·90	22·3	7·7	30·0	Slightly turbid. Palatable.
House well at Chilton Grove, September 17, 1873.	93·80	**1·386**	**·326**	·022	1·714	2·058	**17,000**	9·20	21·4	27·1	48·5	Very turbid. Palatable.
Field well at Chilton Grove, September 17, 1873.	173·80	**·494**	**·075**	·125	0	·173	**710**	8·80	34·1	17·4	51·5	Clear. Saline taste.
Town pump, Friday Street, September 18, 1873.	269·60	**·759**	**·283**	·006	12·220	12·508	**121,930**	44·50	23·0	55·9	78·9	Slightly turbid. Saline taste.
WARKTON, near KETTERING, NORTHAMPTONSHIRE.												
Upper Town well, December 15, 1869.	89·14	**·602**	**·060**	·007	4·263	4·329	**42,370**	9·00	26·1	8·8	34·9	Very turbid.
Lower Town well, December 15, 1869.	110·68	**·384**	**·063**	·004	5·178	5·244	**51,490**	11·00	33·5	17·3	50·8	Slightly turbid.
Goode's well, December 15, 1869 -	71·22	**·708**	**·098**	·007	2·015	2·119	**19,890**	7·10	26·3	10·1	36·4	Turbid.
Rectory well, December 15, 1869 -	72·00	**·266**	**·033**	0	1·191	1·224	**11,590**	8·70	30·7	9·3	40·0	Clear.
Melking's well, December 15, 1869	49·38	**·126**	**·021**	0	1·233	1·254	**12,010**	3·20	26·6	10·1	36·7	"
Mutton's well, December 15, 1869	74·14	**·308**	**·058**	·001	2·566	2·625	**25,350**	6·55	28·9	14·2	43·1	"
Chaplin's well, April 5, 1870 -	49·00	**·448**	**·056**	·005	·178	·238	**1,500**	1·23	36·0	3·1	39·1	Slightly turbid.
WITNEY, OXFORDSHIRE.												
Well in Wiggins's Yard, opposite Blanket Hall, December 9, 1870	145·00	**·527**	**·250**	·240	4·432	4·880	**45,980**	22·90	37·9	16·4	54·3	Slightly turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

It will be seen from an inspection of the above table, that a large number of these wells in or upon the Oolites are much polluted by sewage. The proportions of total solid impurity and organic matter are in most cases high, and the hardness is generally too great to permit of the use of the water for washing. The only well-waters in the foregoing list which would be reasonably safe for domestic purposes are those drawn from the Market Place pump, and the well at the railway station, Cirencester. In the interests of the public health the remaining wells ought to be promptly closed, for, although several of them yield clear and palatable water, they all contain in solution organic matter of animal origin.

SECTION IX.—WATERS FROM SHALLOW WELLS IN OR ON THE UPPER AND LOWER GREENSAND AND WEALDEN BEDS.

The Upper and Lower Greensand are excellent water bearing strata, but the shallow wells sunk into them, and into the superficial deposit overlying the Wealden, are generally much polluted, as is seen from the following table containing the results of our analyses

Part II. Classification.

of twenty-one samples of such waters. Only the first two of these samples were collected by ourselves.

Shallow well waters in Greensand, &c.

Composition of Water from Shallow Wells in or upon the Upper and Lower Greensand and Wealden Beds.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
ENGLAND.												
Cambridge.												
Pump at road side, near Old Barton Toll-gate, March 5, 1873.	85·96	**·079**	**·027**	·074	0	·088	**290**	8·50	22·9	31·5	54·4	Turbid. Palatable.
Devizes.												
Well in Waite's Court, Sheep Street, August 18, 1873.	165·00	**·265**	**·054**	0	6·264	6·318	**62,320**	16·2	35·8	44·7	80·5	Slightly turbid. Slight saline taste.
Dorking.												
Well at Burford Lodge, August 12, 1873.	29·16	**·057**	**·032**	0	1·294	1·326	**12,620**	6·40	30·2	7·1	37·3	Clear and palatable.
Pepper Harrow, Surrey.												
Old well at Pepper Harrow Rectory, August, 1869.	71·40	**·014**	**·012**	·001	6·722	6·735	**66,910**	14·30	3·2	19·2	22·4	—
Petersfield.												
Well at Mr. J. Soames's, December 9, 1873.	44·88	**·254**	**·073**	·002	3·168	3·243	**31,380**	5·40	4·3	12·5	16·8	Slightly turbid. Palatable.
Sandringham.												
Pump at Sandringham House stables, December 10, 1871.	29·60	**·043**	**·022**	·003	2·122	2·146	**20,920**	5·80	·6	14·3	14·9	Clear and palatable.
New pump in court yard, December 10, 1871.	46·60	**·234**	**·056**	·018	1·275	1·346	**12,580**	6·40	8·6	17·1	25·7	Very slightly turbid. Palatable.
Original pump near house, December 10, 1871.	37·96	**·223**	**·068**	·001	1·310	1·379	**12,790**	5·25	7·6	15·4	23·0	Slightly turbid. Palatable.
From tap in kitchen, December 10, 1871.	38·12	**·480**	**·196**	·002	1·320	1·518	**12,900**	5·25	8·4	13·7	22·1	Slightly turbid. Palatable.
No. 48 - - - - -	31·56	**·054**	**·007**	0	·961	·968	**9,290**	2·15	15·3	8·9	24·2	Clear and palatable.
No. 52 - - - - -	52·80	**·301**	**·048**	0	1·284	1·332	**12,520**	10·00	15·5	16·6	32·1	Slightly turbid. Palatable.
No. 62 - - - - -	10·52	**·044**	**·012**	0	0	·012	**0**	4·10	0	3·8	3·8	Slightly turbid. Palatable.
No. 68 - - - - -	21·36	**·143**	**·027**	·003	1·076	1·105	**10,460**	4·70	3·2	7·4	10·6	Turbid. Palatable.
No. 119 - - - - -	37·70	**·166**	**·041**	0	·532	·573	**5,000**	3·60	12·0	11·3	23·3	Very turbid. Palatable.
No. 127 - - - - -	11·60	**·044**	**·006**	·032	·512	·544	**5,060**	2·10	·2	4·9	5·1	Clear and palatable.
No. 128 - - - - -	44·64	**·025**	**008**	·004	·044	·055	**150**	3·10	27·4	15·4	42·8	Turbid. Palatable.
No. 131 - - - - -	44·00	**·180**	**041**	0	1·230	1·271	**11,980**	5·00	16·5	16·3	32·8	Slightly turbid. Palatable.
No. 134 - - - - -	74·12	**·227**	**047**	·001	4·576	4·624	**45,450**	4·85	16·7	29·7	46·4	Slightly turbid. Palatable.
No. 68 bis - - - -	45·40	**·333**	**·075**	·012	0	·085	**0**	3·40	19·0	12·0	31·0	Very turbid.
No. 119 bis - - - -	45·16	**·485**	**·112**	·008	0	·119	**0**	3·40	16·6	13·4	30·0	" "
Staplehurst.												
Well at Toronto House (on Weald-clay), September 12, 1872.	381·10	**·202**	**·048**	·160	·064	·244	**1,640**	82·50	8·0	4·0	12·0	Bad odour. Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The numbers in the foregoing table exhibit wide differences in the composition of these waters. The water from the pump near Old Barton toll-gate, about five miles from Cambridge, is wholesome so far as organic pollution is concerned, but it is harder than is desirable for drinking and is, on this account, useless for washing. On the other hand, the well in Waite's Court, Sheep Street, Devizes, yields water possessing a slightly saline taste and containing products of most disgusting origin. The remaining samples in the table are of intermediate quality. Some of the water used at and around Sandringham House is of very objectionable quality. The Greensand formations are powerfully oxidizing strata, and the proportion of organic elements in these waters is generally very low, if the sewage with which they are polluted has not passed too rapidly through the intervening porous strata. Thus the water from the old well at Pepper Harrow Rectory, Surrey, though it is fed chiefly by sewage, contains but very minute traces of organic matter. The hardness of these waters is very variable, but it is generally more moderate than that of the shallow well water from the Oolites.

PART II. CLASSIFICATION — Shallow well waters in Chalk.

SECTION X.—WATERS FROM SHALLOW WELLS IN OR ON THE CHALK.

The following table contains the results of our analyses of numerous samples of water from shallow wells, sunk either into the Chalk itself, or into gravel immediately overlying the chalk. The samples from Norwich, Streatley, and Marlborough were collected by ourselves, and most of the remainder were forwarded to us through the Local Government Act Office, in consequence of outbreaks of epidemic disease amongst the populations drinking them.

COMPOSITION OF WATER FROM SHALLOW WELLS IN OR UPON THE CHALK.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
ENGLAND.												
CANTERBURY.												
Well near gasworks, January 30, 1871.	65·76	**·249**	**·096**	·165	1·707	1·939	**18,110**	5·18	22·9	14·3	37·2	Very turbid.
Public pump in Cobden Place, November 4, 1870.	68·12	**·047**	**·023**	·024	2·362	2·405	**23,500**	6·60	27·7	9·4	37·1	Clear and palatable.
Public pump in passage out of Sun Inn Yard, November 4, 1870.	108·00	**·156**	**·143**	·405	4·946	5·422	**52,470**	13·10	30·0	24·3	54·3	Clear.
DEAL, KENT.												
Pump in Market-Place from well under Town Hall, August 28, 1873.	146·00	**·241**	**·034**	1·700	6·345	7·779	**77,130**	19·20	33·0	34·3	67·3	Clear. Slight saline taste.
Public pump in Fish Market, August 28, 1873.	159·16	**·300**	**·340**	·340	5·969	6·589	**62,170**	28·50	24·0	47·1	71·1	Slightly turbid. Slight saline taste.
FAKENHAM, NORFOLK.												
Well at South Creake Vicarage, February 5, 1873.	32·92	**·255**	**·103**	·016	·639	·755	**6,200**	2·80	17·2	6·4	23·6	Slightly turbid. Palatable.
GREAT BOOKHAM, SURREY.												
Well in sand 12 feet deep, January 24, 1872.	76·64	**·145**	**·061**	·001	3·530	3·592	**34,990**	4·10	12·0	37·3	49·3	Slightly turbid. Palatable.
Well in sand 18 feet deep, January 24, 1872.	83·96	**·772**	**·151**	·012	2·282	2·443	**22,600**	10·75	21·1	28·2	49·3	Very turbid Palatable.
MAIDENHEAD, BERKS.												
Shallow well, May 23, 1872 -	112·60	**·395**	**·043**	·240	4·852	5·093	**50,180**	26·05	19·5	29·0	48·5	Slightly turbid. Palatable.
Well near railway station, July 26, 1873.	100·00	**·276**	**·193**	·750	4·880	5·690	**54,660**	12·20	32·3	33·5	65·8	Slightly turbid. Palatable.
MARLBOROUGH.												
Well in Bull and Castle Hotel Yard, August 22, 1873.	32·84	**·067**	**·027**	0	·713	·740	**6,810**	1·90	20·5	8·0	28·5	Clear and palatable.
Well in the College Yard, August 22, 1873.	32·48	**·049**	**·015**	0	·613	·628	**5,810**	1·90	15·6	10·1	25·7	Clear and palatable.
NORWICH.												
Well in Toper Square, June 18, 1872.	118·32	**·102**	**·034**	0	5·766	5·800	**57,340**	10·00	31·8	28·7	60·5	Turbid. Palatable.
STREATLEY, BERKS.												
Well at Streatley House, November 19, 1870.	49·30	**·068**	**·032**	0	1·292	1·324	**12,600**	4·25	22·7	6·6	29·3	Turbid. Palatable.
SUDBURY, SUFFOLK.												
Gross's well, the Four Swans, May 1868.	104·60	**·060**	**·028**	·010	4·950	4·986	**49,260**	9·81	34·0	16·7	50·7	—
Green's well, the Horn Inn, May 1868.	64·24	**·014**	**·007**	·008	2·061	2·075	**20,360**	5·29	28·1	10·8	38·9	—
James Harding's well, May 1868 -	70·70	**·024**	**·009**	·005	2·263	2·276	**22,350**	5·53	25·6	15·0	40·6	—
Old Post Office pump, May 1868 -	131·80	**·178**	**·103**	·015	2·741	2·856	**27,210**	11·93	39·7	31·8	71·5	—
Well at Post Office, May 1868 -	84·04	**·358**	**·250**	0	3·686	3·936	**36,540**	7·20	30·1	15·0	45·1	—
Well at Rose and Crown Hotel, May 1868.	81·10	**·129**	**·070**	·002	5·625	5·697	**55,950**	7·99	29·6	14·7	44·3	—

Shallow well waters in London Clay.

COMPOSITION OF WATER FROM SHALLOW WELLS IN OR UPON THE CHALK—*continued.*

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
THETFORD, NORFOLK.												
Man's pump, adjoining Marble Arch, February 7, 1871.	105·68	**·229**	**·085**	0	5·911	5·996	**58,790**	11·11	22·7	23·0	45·7	Clear.
Pump at Bell Inn, February 7, 1871.	51·80	**·139**	**·050**	·394	1·165	1·539	**14,570**	5·50	22·6	8·1	30·7	"
Benton's pump in Back Street, February 7, 1871.	71·00	**·122**	**·035**	·002	3·450	3·487	**34,200**	6·10	21·8	16·0	37·8	"
Pump at Railway Hotel, February 7, 1871.	33·52	**·037**	**·014**	·001	·825	·840	**7,940**	1·79	18·3	5·6	23·9	"
Pump at Red Lion Hotel, February 7, 1871.	73·52	**·108**	**·048**	·001	3·703	3·752	**36,720**	6·25	23·0	17·7	40·7	"
Pump at Mr. Barnard's house, February 7, 1871.	93·40	**·343**	**·092**	·120	3·464	3·655	**35,310**	7·56	35·6	13·7	49·3	
WATLINGTON, OXFORDSHIRE.												
Burnham's well, December 3, 1869	79·20	**·381**	**·043**	·033	2·632	2·702	**26,270**	8·80	25·4	10·9	36·3	Slightly turbid.
Munday's well, December 3, 1869 -	45·72	**·129**	**·025**	0	1·044	1·069	**10,120**	2·70	23·4	11·8	35·2	" "
Mr. Westcar Peel's well, December 3, 1869.	64·76	**·265**	**·047**	·002	2·443	2·492	**24,130**	5·00	23·7	11·8	35·5	Clear.
WOULDHAM, NEAR ROCHESTER.												
New well, Providence Place, December 26, 1868.	53·48	**·148**	**·071**	·003	1·504	1·577	**14,740**	4·57	16·2	18·7	34·9	—
Parish pump, December 26, 1868 -	56·32	**·079**	**·051**	·001	2·300	2·352	**22,690**	4·47	20·6	18·3	38·9	—
Mrs. Pye's pump in the Square, December 26, 1868.	81·40	**·140**	**·077**	·001	3·536	3·614	**35,050**	11·91	20·1	27·5	47·6	—
Langford's pump, December 26, 1868.	88·86	**·125**	**·074**	0	3·245	3·319	**32,130**	11·62	22·8	21·5	44·3	—

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

A glance at the column headed "previous sewage or animal contamination," in the foregoing table, reveals the fact that nearly all these samples of water from shallow wells in or upon the Chalk were greatly polluted by excrementitious matters. The total solid impurity in these waters ranges as high as 159·16 parts in 100,000 parts of water, or 111·41 grains per gallon. The proportion of organic elements (organic carbon and organic nitrogen) is generally moderate, but in one case it amounts to ·923 part in 100,000 parts or ·646 grain per gallon. In the entire series of thirty-three samples there are only three which could be used for domestic purposes without serious risk to health; these are the waters from the pump at the Railway Hotel, Thetford; the well in Bull and Castle Hotel yard, Marlborough, and the well in the College yard, Marlborough. In almost every case, the hardness is so excessive as to preclude the use of the water for washing.

The wells at Great Bookham are probably sunk into the Tertiary-sand resting upon Chalk; those at Sudbury are excavated in gravel upon Chalk.

SECTION XI.—WATERS FROM SHALLOW WELLS IN GRAVEL ON THE LONDON CLAY.

The analytical results recorded in the following table were yielded by samples of water from the gravel overlying the London Clay. With the exception of the waters from Ashford and Chelmsford, all the samples were collected by ourselves.

Shallow well waters in Gravel on London Clay.

COMPOSITION OF WATER FROM SHALLOW WELLS IN GRAVEL RESTING ON LONDON CLAY.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ENGLAND.												
ASHFORD, MIDDLESEX.												
Well at Ashford House, Middlesex, January 1869.	101·38	·663	·127	·005	5·775	5·906	57,470	10·67	7·2	36·0	43·2	—
CHELMSFORD.												
Well at Hastford End, March 4, 1872.	84·10	·149	·012	·001	0	·013	0	16·80	15·0	8·9	23·9	Slightly turbid. Palatable.
LEE BRIDGE, MIDDLESEX.												
Abyssinian pump in garden, No. 32, October 26, 1871.	68·46	·263	·112	·052	1·214	1·369	12,250	4·37	14·7	18·9	33·6	Turbid.
Abyssinian pump in garden, No. 33, October 26, 1871.	66·56	·328	·200	·104	1·149	1·434	12,024	4·16	13·1	19·7	32·8	Slightly turbid.
Abyssinian pump in garden, No. 15, October 26, 1871.	64·79	·282	·082	·005	·896	·982	8,680	4·37	10·9	21·4	32·3	Very turbid.
Abyssinian pump in garden, No. 115, October 26, 1871.	81·53	·458	·265	·118	1·701	2·059	17,620	7·77	8·1	25·0	33·1	Turbid.
Abyssinian pump in garden, No. 134, October 26, 1871.	52·53	·120	·034	·001	·796	·831	7,650	3·49	10·9	18·6	29·5	Very slightly turbid.
Abyssinian pump between gardens Nos. 79 and 80, October 26, 1871.	68·46	·213	·051	0	1·713	1·764	16,810	3·93	13·1	14·3	27·4	Very turbid.
Pump in Windmill well, October 26, 1871.	32·67	·152	·044	·052	trace	·087	110	1·96	6·7	15·4	22·1	Turbid.
Well at house next to Lee Bridge, October 26, 1871.	59·56	·366	·064	·001	·111	·176	800	3·93	8·6	22·9	31·5	Clear.
LONDON.												
Well in Royal Institution, April 1868.	93·70	·440	·085	·001	4·355	4·441	43,240	—	—	—	32·5	Clear and palatable.
Well at 23, St. James' Square, Sept. 1873.	81·24	·105	·056	0	2·602	2·658	25,700	5·60	17·4	26·9	44·3	Clear and palatable.
Well on Duck Island, St. James's Park, April 7, 1869.	100·10	·548	·105	·408	·885	1·326	11,890	15·60	33·7	19·7	53·4	Clear.
Well in Lavender Sweep, Wandsworth, March, 1871.	106·94	·281	·039	0	1·391	1·430	13,590	6·63	15·7	45·7	61·4	"
Well at St. Ann's Hill, Wandsworth, March, 1871.	76·00	·479	·109	·002	4·857	4·968	48,270	6·28	5·0	27·9	32·9	"
Well at Southwark Water Company's Works, Battersea, April 6, 1871.	31·80	·203	·049	·005	·194	·247	1,660	1·90	17·9	5·7	23·6	Slightly turbid.
Well at Stoke Lodge, Hyde Park Gate, November 2, 1871.	70·10	·183	·073	·001	1·737	1·811	17,060	2·45	20·8	28·5	49·3	Turbid. Palatable.
Well at Stoke Lodge, Hyde Park Gate, November 8, 1871.	67·32	·186	·061	·001	1·581	1·643	15,500	4·40	20·9	32·8	53·7	Turbid. Palatable.
Public pump in the Temple, August 2, 1870.	75·32	·178	·057	·038	2·570	2·658	25,690	5·80	21·6	13·9	35·5	Clear and palatable.
Pump in Duncannon Street, drawing from well beneath St. Martin's Church, June 4, 1872.	96·50	·159	·049	0	4·911	4·960	48,790	10·50	21·6	21·2	42·8	Clear and palatable.
New Inn well, St. Clement Danes, June 4, 1872.	101·10	·205	·020	·150	3·616	3·760	37,080	8·10	29·8	20·9	50·7	Clear and palatable.
Pump at corner of Queen's Head Court, Gray's Inn Road, June 4, 1872.	119·60	·192	·042	·003	5·357	5·401	53,270	11·60	33·3	24·5	57·8	Slightly turbid. Palatable.
Pump at S.E. corner of Red Lion Square, June 4, 1872.	152·80	·287	·076	2·650	5·431	7·689	75,810	13·40	24·4	46·4	70·8	Slightly turbid. Palatable.
Pump at railing of garden, Queen Square, Bloomsbury, June 4, 1872.	276·50	·342	·191	1·550	18·179	19·646	194,230	18·80	34·5	106·0	140·5	Clear and palatable.
Pump at crossing between Devonshire St. and Gloucester St., Queen Square, Bloomsbury, June 4, 1872	136·60	·372	·103	1·550	4·198	5·577	54,420	13·80	37·7	30·4	68·1	Slightly turbid. Palatable.
Pump in King's Square, St. Luke's, City Road, June 4, 1872.	167·50	·505	·604	2·750	1·748	4·617	39,810	15·40	49·2	32·1	81·3	Clear and palatable.
Pump in Plantation Place, Victoria Road, Hammersmith, June 4, 1872.	130·40	·190	·041	·016	3·988	4·042	39,690	10·80	26·0	33·4	59·4	Clear and palatable.
Maritime Almshouses well, Mile End Old Town, June 5, 1872.	33·00	·097	·017	0	0.	·017	0	8·15	6·4	7·9	14·3	Very turbid. Palatable.
Maritime Almshouses well, Mile End Old Town, June 29, 1872.	37·72	·045	·015	·001	0	·016	0	8·00	6·1	11·6	17·7	Turbid. Palatable.
Well at Fountain Inn, Mile End Road, June 5, 1872.	160·90	·413	·194	·620	10·451	11·156	109,300	17·40	19·9	46·7	66·6	Clear and palatable.
Pump in Wellclose Square, Saint George's in the East, June 5, 1872.	396·50	·278	·087	0	25·840	25·927	258,080	34·60	26·7	164·3	191·0	Slightly turbid Slight saline taste.
Public pump in churchyard, Cannon Street Road, St. George's-in-the-East, June 4, 1872.	81·20	·207	·028	·100	2·959	3·069	30,090	5·10	28·8	22·7	51·5	Slightly turbid. Palatable.
Pump in Glacis Garden, north side of Tower, June 5, 1872.	126·20	·221	·095	0	4·385	4·480	43,530	15·90	41·5	37·1	78·6	Clear and palatable.

Shallow well waters in Gravel on London Clay.

Composition of Water from Shallow Wells in Gravel on London Clay—*continued.*

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Pump at corner of Idol Lane, and St. Dunstan's Alley, St. Dunstan's-in-the-East, June 5, 1872.	122·50	**·149**	**·046**	·002	6·350	6·398	**63,200**	14·30	24·4	38·5	62·9	Clear and palatable.
Pump at St. Michael's, Cornhill, June 5, 1872.	84·10	**·361**	**·171**	1·550	1·838	3·285	**30,820**	10·10	31·6	17·7	49·3	Slightly turbid. Palatable.
Aldgate pump, June 5, 1872	123·10	**·144**	**·141**	·220	6·851	7·173	**70,000**	12·85	37·1	40·0	77·1	Clear and palatable.
Pump at St. John's, Hampstead, North End, Hampstead Heath, June 7, 1872.	40·10	**1·006**	**·137**	·180	·184	·419	**2,500**	4·40	0	20·6	20·6	Water fleas. Slightly fishy odour.
No. 1 public pump, Broadway, St. Paul's Deptford, June 10, 1872.	55·40	**·040**	**·005**	·001	·755	·761	**7,240**	4·85	18·1	16·9	35·0	Clear and palatable.
Well at Trinity Almshouses, Mile End Road, June 27, 1872.	79·92	**·644**	**·110**	·320	0	·374	**2,300**	3·60	45·9	15·4	61·3	Clear and palatable.
Pump near S. E. entrance to Kensington Gardens, September 8, 1873.	48·88	**·208**	**·035**	0	·287	·322	**2,550**	6·40	0	24·8	24·8	Clear and palatable.
Pump in Wandsworth Road, Clapham, September 8, 1873.	133·32	**·453**	**·133**	·018	6·757	6·901	**67,360**	15·00	8·2	48·5	56·7	Clear and palatable.
Pump at corner of Clifton Street, Larkhall Lane, Clapham, September 8, 1873.	122·20	**·287**	**·051**	·510	5·793	6·264	**61,810**	8·40	9·0	48·5	57·5	Turbid. Palatable.
Pump near Wandsworth Road Railway Station, Larkhall Lane, Clapham, September 8, 1873.	144·28	**·435**	**·129**	·019	4·383	4·528	**43,670**	12·20	·7	44·3	45·0	* Palatable.
Pump in Manor Street, Clapham, September 8, 1873.	138·08	**·112**	**·040**	·070	9·353	9·451	**93,790**	23·50	1·5	51·5	53·0	Very turbid. Slight saline taste.
Pump in Saint Paul's Close, Matrimony Place, Clapham, September 8, 1873.	87·96	**·424**	**·104**	·030	3·748	3·877	**37,410**	5·80	9·2	37·2	46·4	† Palatable.
Pump in Wandsworth Road, near Union Road, Clapham, September 8, 1878.	121·68	**·329**	**·110**	·210	5·728	6·011	**58,690**	10·40	18·1	48·5	66·6	Turbid. Palatable.
Pump in Rectory Grove, opposite Fitzwilliam Road, Clapham, September 8, 1873.	132·40	**·463**	**·015**	·230	7·124	7·328	**72,810**	10·40	13·5	49·3	62·8	Slightly turbid. Palatable.
Romford, Essex.												
Pump at Breton's farmhouse, November 9, 1871.	107·6	**·671**	**·158**	·057	3·826	4·031	**38,410**	11·60	28·6	28·5	57·1	Clear.
Wimbledon, Surrey.												
Well at Sunnyside, 25 feet deep, March 1871.	46·00	**·223**	**·035**	0	·633	·668	**6,010**	4·20	12·1	18·6	30·7	Clear.

* Suspended matter. Mineral - 2·92; Organic - ·92; Total - 3·84

† Suspended matter. Mineral - 1·24; Organic - ·84; Total - 2·08

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The gravel upon London Clay constituted formerly an important water-bearing stratum supplying the great majority of the population of London (*see* page 282). Even now, as the foregoing table shows, a considerable number of shallow wells sunk into this stratum are still in use in the metropolis. These wells, though yielding for the most part bright and palatable water, are horribly polluted, and are, as a rule to which the above table furnishes very few exceptions, supplied chiefly by infiltration from sewers and cesspools. As the water they yield is not suitable for washing, and as it cannot be drunk without imminent danger to health, these wells ought, with one or two exceptions, to be closed without delay. For further remarks upon these waters see Part IV., page 301, of this Report.

Section XII.—Waters from Shallow Wells in Bagshot Beds.

The following table contains the results of our analyses of eight samples of water from shallow wells in the Bagshot Beds. The samples from Christchurch, Harrow, and Woking were collected by ourselves, whilst those from Wokingham were sent to our laboratory through the Local Government Act Office:—

COMPOSITION OF WATERS FROM SHALLOW WELLS IN BAGSHOT BEDS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
CHRISTCHURCH, HANTS.												
Public well, No. 4, in High Street, March 12, 1873.	85·10	**·179**	**·086**	·001	2·218	2·305	**21,870**	18·50	11·6	17·7	29·3	Clear and palatable.
Public well, No. 3, in Pit, High Street, March 12, 1873.	125·60	**·528**	**·119**	·025	7·706	7·846	**76,950**	16·80	5·4	36·7	42·1	Slightly turbid. Palatable.
HARROW-ON-THE-HILL.												
Mr. John Chalmers Morton's well, November 4, 1870.	53·92	**·078**	**·027**	·004	·057	·087	**280**	8·90	10·4	21·8	32·2	—
WOKING, SURREY.												
Abyssinian pump, near Woking Prison, November 7, 1868.	23·18	**·228**	**·098**	·004	0	·101	**0**	2·48	7·5	5·6	13·1	—
WOKINGHAM, BERKS.												
Well in court near Peach Street, January 24, 1872.	188·40	**·758**	**·154**	·018	3·820	3·989	**38,030**	31·00	16·2	64·3	80·5	Very turbid. Palatable.
Pump at Allan's cottages, January 24, 1872.	286·80	**1·295**	—	·630	17·940	—	**184,270**	31·15	19·8	111·9	131·7	Slightly turbid Palatable.
Pump in Police Street, January 24, 1872.	123·70	**·404**	**·087**	·001	6·876	6·964	**68,450**	18·75	18·5	45·8	64·3	Slightly turbid. Palatable.
Pump in Mr. Cook's garden, January 24, 1872.	52·52	**·317**	**·062**	·001	1·399	1·462	**13,680**	7·80	21·5	25·7	47·2	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results show that out of eight samples examined six were abominably polluted with excrementitious matters, the sewage which fed the pump at Allan's cottages, Wokingham, having been of at least double the strength of London sewage. The only samples, which could be used for drinking and cooking with reasonable safety, are those obtained from Mr. J. Chalmers Morton's well at Harrow, and from the Abyssinian pump near Woking prison. The use of the remaining samples for domestic purposes would be dangerous. Except the water from the Abyssinian pump at Woking, all the samples were much too hard for use in washing.

SECTION XIII.—WATERS FROM SHALLOW WELLS IN THE FLUVIO-MARINE SERIES.

The only samples of water which we have examined from this formation were collected from wells at Your Majesty's marine residence at Osborne, Isle of Wight.

The following table contains the results of our analyses of these samples :—

COMPOSITION OF WATER FROM SHALLOW WELLS IN THE FLUVIO-MARINE SERIES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
OSBORNE, ISLE OF WIGHT.												
Well supplying kitchen offices, March 8, 1873.	14·72	**·142**	**·026**	0	0	·026	**0**	2·90	4·8	5·9	10·7	Turbid. Palatable.
Cross Passage pump, March 8, 1873.	18·30	**·228**	**·055**	·001	·046	·102	**150**	3·30	1·8	6·6	8·4	Very turbid. Brown. Palatable.
Pavilion well, March 8, 1873	17·24	**·267**	**·061**	·001	·228	·290	**1,970**	2·40	1·7	6·7	8·4	Turbid. Palatable.
Well in Entrance Yard, March 8, 1873.	30·00	**·361**	**·065**	·002	·026	·093	**0**	5·80	·8	12·3	13·1	Very turbid. Palatable.
Water supply to Osborne Cottage, September 19, 1873.	23·82	**·181**	**·019**	·001	0	·020	**0**	4·10	8·6	7·4	16·0	Very turbid. Palatable.
Trial well, Dec. 18, 1873	9·84	**·075**	**·022**	·007	0	·028	**0**	3·20	0	4·6	4·6	Palatable.
Trial well, No. 1, Jan. 19, 1874	26·76	**·319**	**·032**	·016	0	·045	**0**	4·90	2·3	8·0	10·3	Palatable.
Trial well, No. 2, Jan. 19, 1874	16·32	**·137**	**·019**	·001	0	·020	**0**	3·80	0	8·6	8·6	Palatable.
Trial well, No. 3, Feb. 18, 1874	54·84	**·233**	**·038**	·004	0	·041	**0**	4·45	12·1	22·7	34·8	Palatable.
Trial well, No. 4, Jan. 19, 1874	66·12	**·429**	**·093**	·001	3·640	3·734	**36,090**	7·20	7·1	29·3	36·4	Palatable.
Trial well, No. 5, Jan. 19, 1874	13·08	**·063**	**·010**	0	0	·010	**0**	3·00	0	7·7	7·7	Palatable.
Trial well, No. 6, Jan. 19, 1874	8·16	**·118**	**·023**	0	0	·023	**0**	3·80	0	7·4	7·4	Palatable.
Well at Albert Cottage, Feb. 18, 1874.	54·84	**·233**	**·038**	·004	0	·041	**0**	4·45	12·1	22·7	34·8	Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

For remarks on these waters, see Part IV., Section IV., of this Report, page 403.

Part II. Classification.

Shallow well waters in Alluvium and Gravel.

Section XIV.—Water from Shallow Wells in Alluvium and Gravel.

In the following table will be found the results of our analyses of numerous samples of water from the Alluvium and Gravel. The samples from Barking, Guildford, Newport, Peterborough, and Windsor were collected by ourselves.

Composition of Water from Shallow Wells in Alluvium and Gravel.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Askern, near Doncaster.												
Mr. Middleton's well, July 29, 1870	177·56	**·412**	**·058**	·019	1·742	1·816	**17,260**	10·60	34·4	118·6	53·0	Clear.
Mr. Pettit's well, July 29, 1870 -	71·76	**·342**	**·067**	0	1·721	1·788	**16,891**	4·90	12·4	17·3	29·7	,,
Mr. Haigh's well, July 29, 1870 -	320·72	**·365**	**·077**	·072	0	·136	**270**	5·50	34·1	118·3	152·4	Turbid.
Barking, Essex.												
Well at farmhouse, on Barking Farm, November 9, 1871.	143·60	**·625**	**·130**	0	8·569	8·699	**85,370**	20·10	4·3	62·8	67·1	Slightly turbid.
Bridgwater.												
Pump in Fish Market, Sept. 4, 1873	142·80	**·117**	**·073**	·007	7·041	7·120	**70,150**	22·20	9·9	59·7	69·6	Slightly turbid. Slight saline taste.
East Acton, Middlesex.												
Well at East Acton, Aug. 31, 1871	114·32	**·144**	**·027**	0	2·899	2·926	**28,670**	16·50	36·4	40·7	77·1	Clear.
Guildford.												
Water supply, October 4, 1873 -	28·58	**·060**	**·017**	0	·413	·430	**3,810**	1·80	14·5	7·0	21·5	Clear and palatable.
Hillingdon, near Uxbridge.												
Well at the Grove, June 27, 1872 -	105·00	**·484**	**·078**	·072	3·295	3·432	**33,220**	13·90	19·7	22·4	42·1	Clear and palatable.
Leigh, Essex.												
The Bay pump, November 28, 1871	94·00	**·109**	**·027**	·020	·215	·258	**1,990**	32·60	2·7	1·9	4·6	Very slightly turbid. Palatable.
The Strand pump, November 28, 1871.	108·20	**·122**	**·021**	0	·660	·681	**6,280**	36·25	13·1	1·9	15·0	Slightly turbid. Palatable.
The Churchyard well, Nov. 28, 1871	112·12	**·210**	**·065**	0	5·047	5·112	**50,150**	13·75	14·3	45·7	60·0	Slightly turbid. Palatable.
Newport, Wales.												
Pump at King's Head Hotel, June 22, 1871.	56·52	**·024**	**·016**	0	1·767	1·783	**17,350**	5·20	17·8	23·6	41·4	Clear.
Bane's well, June 21, 1871 -	62·80	**·053**	**·015**	0	2·027	2·042	**19,950**	6·35	23·1	29·1	52·2	,,
Peterborough.												
Town pump, June 11, 1873 -	213·80	**·321**	**·113**	0	7·768	7·881	**77,360**	22·10	27·3	64·3	91·6	Clear. Slight saline taste.
Surbiton, Surrey.												
Well at Knowles Cottage, Surbiton Hill, March 18, 1870.	74·88	**·504**	**·081**	·001	4·086	4·168	**40,550**	6·40	6·7	25·6	32·3	—
Washingborough, Lincoln.												
Rectory pump, January 24, 1872 -	34·04	**·067**	**·019**	0	1·030	1·049	**9,980**	2·20	17·6	13·1	30·7	Clear and palatable.
J. Wells's pump, January 24, 1872	33·76	**·064**	**·019**	0	1·285	1·304	**12,530**	2·20	16·8	14·6	31·4	Slightly turbid. Palatable.
Mr. Howard's pump, January 24, 1872.	37·64	**·105**	**·030**	0	1·372	1·402	**13,400**	2·40	14·5	14·0	28·5	Turbid. Palatable.
Mr. Ruston's pump, January 24, 1872.	61·72	**·149**	**·040**	0	2·726	2·766	**26,940**	6·55	15·7	20·0	35·7	Slightly turbid. Palatable.
Mr. Thornbury's pump, January 24, 1872.	39·64	**·119**	**·022**	0	1·234	1·256	**12,020**	2·75	17·2	11·2	28·4	Slightly turbid. Palatable.
Mr. Dudding's pump, Jan. 24, 1872	41·48	**·076**	**·018**	0	1·489	1·507	**14,570**	3·05	12·5	15·7	28·2	Slightly turbid. Palatable.
Whittlesey, Cambridgeshire.												
Abyssinian pump in field, 5 feet deep, November 14, 1872.	59·68	**·319**	**·071**	·001	·553	·625	**5,220**	1·70	27·0	15·4	42·4	Turbid. Palatable.
Well No. 2 in town, 15 feet deep, November 14, 1872.	250·20	**·931**	**·940**	3·050	10·848	14·300	**133,280**	28·20	35·7	54·4	90·1	Clear. Palatable.
Abyssinian pump in field, 6 feet deep, November 14, 1872.	68·52	**·327**	**·070**	·002	·348	·420	**3,180**	2·30	30·9	16·9	47·8	Slightly turbid. Palatable.
Well No. 4 in town, 15 feet deep, November 14, 1872.	286·10	**·922**	**·201**	·740	11·265	12·075	**118,420**	26·40	13·5	89·3	102·8	Slightly turbid. Palatable.
Windsor.												
Well at pumping station, Old Windsor Lock, Sept. 29, 1873.	36·96	**·112**	**·040**	0	·330	·370	**2,980**	2·90	21·5	7·9	29·4	Clear. Palatable.
Large pump well, supplying Windsor Castle, Sept. 29, 1873.	30·08	**·015**	**·010**	·001	·063	·074	**320**	2·00	18·0	5·9	23·9	Clear. Palatable.
Small pump well, supplying Windsor Castle, Sept. 29, 1873.	32·54	**·100**	**·022**	0	·274	·296	**2,420**	1·90	19·4	5·1	24·5	Clear. Palatable.
Water supply to Windsor and Eton, Sept. 29, 1873.	33·34	**·124**	**·028**	·002	·198	·228	**1,680**	2·00	16·0	9·4	25·4	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results show that whilst a large number of the shallow wells on the Alluvium and Gravel yield palatable water, only thirteen samples enumerated in the above table could be used for domestic purposes without much risk to health. These are the waters from the Bay and Strand pumps at Leigh, from the pump at the King's Head and Bane's Well, Newport, from the following pumps at Washingborough—Rectory, J. Wells', Mr.

Part II. Classification. — Unpolluted deep well water.

Howard's, Mr. Thornbury's, and Mr. Dudding's, and from the wells at Guildford and Windsor. The animal organic matter with which all these samples were polluted had been to a great extent destroyed by oxidation before the sample was taken. All the shallow well waters from this geological formation contained large proportions of solid impurity in solution, and with two exceptions, they were too hard to be used for washing without great waste of soap. The Whittlesey wells are sunk in gravel upon Oxford Clay. A more detailed account of most of these samples will be found in Part IV., p. 301, of this Report under the names of the towns and villages in which they were respectively collected.

CLASS V.—DEEP WELL WATERS.

DIVISION I.—UNPOLLUTED DEEP WELL WATERS.

The samples of water belonging to this division were obtained from wells or bore-holes of a depth rarely less than 100 feet, and reaching in one case as far as 1,285 feet. In many cases these wells were partly or wholly supplied by surface polluted water. Such water, when it penetrates only to shallow wells, still retains a considerable proportion of its polluting organic matter in an unoxidized condition; but when it descends through 100 feet or upwards of porous soil or rock, the exhaustive filtration to which it has been subjected, in passing downwards through so great a thickness of material, and the rapid oxidation of the dissolved organic matters in a porous and aërated medium, afford a considerable guarantee that all noxious constituents have been removed, even from such portions of the water as have passed perpendicularly downwards. Still more so must this obviously be the case with the even much larger portion which reaches a well in a more or less horizontal direction, through far greater thicknesses of porous medium. On this account, the evidence of previous sewage or animal contamination, which such waters often exhibit, loses much of its significance; more especially as the mineral compounds which furnish this evidence are, in themselves quite innocuous. It is only when the evidence becomes very strong, or in other words, when the water which feeds these wells starts from the surface in a very highly polluted condition, that deep well waters ought to be regarded with suspicion. In the following tables, we have distinguished such originally highly polluted waters by printing the evidence of their previous sewage or animal contamination in black type. In all other cases, this evidence (which however we do not deem it right to suppress) ought, in our opinion, to be disregarded; because it implies an amount of risk which may be considered as *nil*, if the direct access of water from the upper strata be prevented.

The two following tables contain the results of our analyses of seven samples of water from deep wells sunk into Devonian rocks and Millstone Grit. All the samples were collected by ourselves, except those from Hereford and Ivybridge.

Section I.—Unpolluted Waters from Deep Wells in Devonian Rocks.

Composition of Unpolluted Water from Deep Wells in Devonian Rocks.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
ENGLAND.														
Hereford. Well at Lunatic Asylum, May 11, 1871.	—	—	45·30	**·083**	**·015**	0	·506	·521	4,740	3·40	26·2	6·3	32·5	Very turbid. Palatable.
Ivybridge. Artesian well adjoining Mr. Allen's house, Aug. 19, 1872.	—	—	8·94	**·021**	**·005**	0	·044	·049	120	1·90	·5	3·1	3·6	Slightly turbid. Palatable.
Mansfield. Well at waterworks, Nov. 1, 1873.	75	9°·7	25·24	**·053**	**·014**	0	·599	·613	5,670	1·40	6·0	16·4	22·4	Slightly turbid. Palatable.
SCOTLAND.														
Arbroath. Nolt Loan well, March, 11, 1872.	—	5·0	27·24	**·046**	**·011**	0	·155	·166	1,230	4·20	5·9	11·0	16·9	Clear and palatable.
Dundee. Artesian well at Bow Bridge Works, Sep. 14, 1870.	238	10·0	40·34	**·030**	**·016**	·001	·696	·713	6,650	3·90	6·1	10·2	16·3	Very turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

PART II. CLASSIFICATION.

SECTION II.—UNPOLLUTED WATERS FROM DEEP WELLS IN MILLSTONE GRIT.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN MILLSTONE GRIT.

DESCRIPTION.	Depth of Well in feet.	Temperature Centigrade.	Dissolved Matters.											Remarks.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BRADFORD, YORKSHIRE. Messrs. Ingham and Sons' well, Oct. 4, 1869.	360	12·8	55·40	**·150**	**·005**	·028	·038	·066	290	3·23	6·8	7·3	14·1	Clear. Slight odour of sulphuretted hydrogen.
GLOSSOP, DERBYSHIRE. Bore hole in Dinting Vale Printworks, July 28, 1868.	—	—	26·32	**·092**	**·020**	·003	·019	·042	0	·89	9·8	5·9	15·7	Clear and palatable.
Average of Sections I. & II.	—	—	32·68	**·068**	**·012**	·005	·294	·310	2,671	2·70	8·8	8·6	17·4	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results suggest the following remarks :—

Total Solid Impurity.—The Devonian rocks and Millstone Grit contain but a very small proportion of soluble matters, nevertheless six out of the seven samples of the foregoing tables held rather a large proportion of mineral matters in solution. Only in the case of the water from the artesian well at Ivybridge, did this proportion become small. The total solid impurity varied from 8·94 parts in 100,000, or 6·26 grains per gallon, in the water from the well at Ivybridge; to 55·4 parts in 100,000, or 38·78 grains per gallon, in the well at Bradford. In no case did the proportion rise high enough to render the water objectionable for drinking and cooking. The average proportion was 32·68 parts per 100,000 or 22·88 grains per gallon.

Organic Elements.—The proportion of organic elements in all these waters was very small. It is only the most unoxidizable portion of the organic matter dissolved in the water which can escape destruction during its slow percolation through hundreds of feet of porous and aërated soil or rock. The proportion of organic elements varied from ·026 part in 100,000 parts of water, or ·018 grain per gallon, in the artesian well at Ivybridge; to ·155 part per 100,000 parts, or ·108 grain per gallon, in the deep well at Messrs. Ingham and Sons' Dyeworks, Bradford. As the water of this latter well is only used for manufacturing purposes, no special precautions are taken to prevent the access of impurities to the well; and this, for a deep well water, somewhat high proportion of organic elements is probably due to slight accidental pollution. The average proportion of organic elements in these samples was ·08 part per 100,000 parts, or ·056 grain per gallon.

The proportion of nitrogen to carbon in the organic matter contained in these waters varied from N : C = 1 : 1·87 in the water of the artesian well at Dundee; to N : C = 1 : 30 in the water of the Bradford well, and averaged N : C = 1 : 7·74 ; or, omitting the sample from the Bradford well which was probably recently contaminated with organic matter, N : C = 1 : 4·03.

Previous sewage or animal contamination.—The water from the bore-hole at Glossop exhibited no evidence of previous pollution; and in no case was this evidence sufficiently strong, in the samples now under consideration, to cast a reasonable suspicion upon their wholesomeness. The evidence of previous sewage or animal contamination is therefore unemphasised in the above tables, that is to say, it is not, in our opinion, of any importance as affecting the salubrity of the water.

Hardness.—Amongst the seven samples, there was one (the sample from Ivybridge) very soft, and another (the sample from Hereford) excessively hard, the remaining five samples were of medium hardness. The hardness varied from 3°·6 to 32°·5 and averaged 17°·4. The very hard water from the Hereford well owed its hardness chiefly to carbonate of lime, its permanent hardness being only 6°·3 to which it would be reduced if softened with lime. The highest permanent hardness (16°·4) occurred in the water from a well at Mansfield. All the remaining hard samples would be satisfactorily softened by Clark's process (*see* page 205).

General character.—All these samples were palatable and wholesome and of most excellent quality for drinking and cooking. The turbidity which characterised some of them was due to accidental causes; that of the water from the artesian well at Dundee

Deep well waters in Coal Measures.

was owing to the very recent date of the boring, the well having been only finished ten days when our sample was taken. For washing and cleansing purposes several of the samples would be much improved by being subjected to Clark's softening process. The water from the Bradford well contained, when fresh drawn, traces of sulphuretted hydrogen, which, however, rapidly disappeared on exposure to the air. We have noticed the presence of the same gas in several other artesian waters of undoubted purity; it is probably due to the reduction of the sulphates in the water. It does not affect the wholesomeness of the water.

SECTION III.—UNPOLLUTED WATERS FROM DEEP WELLS IN THE COAL MEASURES.

The numbers in the following table show the results of our analyses of nine samples of potable water from deep wells and coal pits deriving their water from the Coal Measures. The samples from Accrington, Blackburn, and the two earlier samples from Castleford were collected by ourselves; the remainder were sent to us for investigation through the Local Government Act Office.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THE COAL MEASURES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature Centigrade.	Dissolved Matters.												REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.		
ACCRINGTON, LANCASHIRE.		°													
Water supply from coal-pit, June 11, 1869.	—	—	33·42	**·045**	**·017**	0	·012	·029	0	1·40	7·7	2·2	9·9		Clear and palatable.
BEDLINGTON, NORTHUMBERLAND.															
From Bedlington Pit, July 20, 1871.	—	—	144·88	**·051**	**·035**	0	0	·035	0	4·70	28·2	15·3	43·5		Clear and palatable.
BLACKBURN, LANCASHIRE.															
From Little Harwood abandoned coalpit, Aug. 5, 1868.	210	9·8	36·96	**·117**	**·055**	·002	·029	·086	0	1·29	9·2	1·2	10·4		Clear and palatable.
CASTLEFORD, YORKSHIRE.															
Well at waterworks, Sep. 20, 1869.	99	—	126·50	**·106**	**·014**	·170	·340	·494	4,480	58·87	9·2	13·5	22·7		Turbid. Chalybeate.
Well at waterworks, March 2, 1871.	—	8·3	71·70	**·198**	**·023**	·080	0	·089	340	30·75	10·4	9·7	20·1		Turbid.
Well at waterworks, Dec. 15, 1871.	—	—	125·00	**·177**	**·027**	·140	·017	·159	1,000	59·85	5·7	23·6	29·3		Turbid. Palatable.
New trial well, No. 2, Dec. 15, 1871.	—	—	65·60	**·134**	**·064**	·002	0	·066	0	3·50	15·4	40·5	55·9		Turbid. Chalybeate.
New trial well, No. 3, Dec. 15, 1871.	—	—	79·40	**·133**	**·045**	·002	0	·047	0	2·75	26·5	48·5	75·0		Slightly turbid. Palatable.
PONTEFRACT, YORKSHIRE.															
From new bore hole at waterworks, Jan. 24, 1872.	—	—	64·48	**·114**	**·025**	·001	1·468	1·494	**14,370**	4·35	23·9	31·3	55·2		Turbid.
Average - -	—	—	83·10	**·119**	**·034**	·044	·207	·278	2,243	18·05	15·1	20·6	35·7		

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results suggest the following observations :—

Total solid impurity.—The proportion of mineral impurities, present in deep well water from the Coal Measures, is always large but varies between wide limits. In the foregoing samples it varied from 33·42 parts per 100,000, or 23·39 grains per gallon, in the water supplied to Accrington from a coal pit; to 144·88 parts per 100,000, or 101·42 grains per gallon, which was found in a sample of water from the Bedlington pit, the average being 83·1 parts per 100,000, or 58·17 grains per imperial gallon. There were no noxious constituents amongst this saline matter.

Organic elements.—As the Coal Measures abound in organic matter, it is not surprising that the deep well waters extracted from them should contain, as a rule, larger proportions of organic elements (organic carbon and organic nitrogen) than are met with in similar waters obtained from other strata. In the samples enumerated in the foregoing table, the proportion was least in the water from the Accrington coal pit (·062 part per 100,000 parts) and greatest in the water drawn from the well at the new waterworks Castleford on March 2nd, 1871 (·221 part per 100,000 parts), the average proportion being ·153 part per 100,000 parts, or ·107 grain per gallon. The proportion of nitrogen to carbon in the

PART II. CLASSIFICATION.

organic matter contained in these waters varied from N : C = 1 : 1·46 in the water from Bedlington Pit; to N : C = 1 : 8·61 in the water from Castleford Waterworks, March 2, 1871, and averaged N : C = 1 : 4·29.

Deep well waters in Magnesian Limestone.

Previous sewage or animal contamination.—None of the coal pit waters in the above table exhibited any evidence of previous animal pollution. The first well sunk in 1869 for the supply of Castleford derived its water from a source which was polluted by the middens and cesspools of the town. The water exhibited considerable though diminishing evidence of previous sewage contamination. In the following year two new trial wells were sunk, and the water yielded by them was free from this evidence. The only sample in the foregoing table in which it is strong enough to create suspicion is that from the Pontefract waterworks. When the protection to the bore-hole from surface percolation is completed, this evidence, or the greater part of it, will probably disappear.

Hardness.—In only two of the samples which we have examined, was the hardness moderate. It ranged in the whole series from 9°·9 in the water from the Accrington colliery to 75° in that from the Castleford trial well No. 3, and averaged 35°·7. The hardness of many of these waters would be greatly reduced by the application to them of Clark's softening process (*see* page 205). Nevertheless, even the softened water would, in several cases, be still very hard.

General character.—The deep well waters from the Coal Measures are generally palatable although liable to have a slight chalybeate taste, and to contain rather large quantities of saline matter in solution. They are contaminated with an unusually large proportion of organic matter, which is not however of a very objectionable kind. They are wholesome, though not quite desirable waters for domestic supply, being, as a rule, very hard and therefore unfit for washing.

SECTION IV.—UNPOLLUTED WATERS FROM DEEP WELLS IN MAGNESIAN LIMESTONE.

The following table contains the results of analysis of three samples of water collected by us from deep wells in the Magnesian Limestone.

COMPOSITION OF UNPOLLUTED DEEP WELL WATER FROM MAGNESIAN LIMESTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
MANSFIELD WOODHOUSE. Mr. R. Peat's Well, Nov. 1, 1873	54·32	**·139**	**·039**	0	1·188	1·227	**11,560**	3·20	23·4	26·0	49·4	Slightly turbid.
PONTEFRACT, YORKSHIRE. Water supply, January 24, 1872 -	84·92	**·054**	**·021**	0	2·673	2·694	**26,410**	5·55	26·5	40·8	67·3	Clear.
SUNDERLAND, DURHAM. Water supply, Sep. 16, 1868 - -	44·18	**·035**	**·030**	0	·416	·446	3,840	4·17	·8	13·9	14·7	Clear.
Average - - -	61·14	**·076**	**·030**	0	1·426	1·456	**13,937**	4·31	16·9	26·9	43·8	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The Dolomite or Magnesian Limestone is but slightly developed in Great Britain, and is rarely resorted to as a water-bearing stratum. The above are the only instances of deep wells sunk into this formation with which we have become acquainted, although we have obtained several samples of shallow well and spring waters from it. (*See* pages 74 and 115.) The water supplied to Sunderland from deep wells in the Dolomite is of excellent quality for drinking and cooking. It contains but a minute proportion of organic elements. Its hardness, though not great, is nearly all permanent, and it is, therefore, not well adapted for washing. Dolomite being a double carbonate of lime and magnesia imparts both these substances to the water, 100,000 lbs. of which contained 5·89 lbs. of lime and 3·96 lbs. of magnesia. The evidence of previous sewage or animal contamination shown by this sample is not sufficient to cast any suspicion

Deep well water in New Red Sandstone.

upon the wholesomeness of the water. The other samples are of suspicious quality, owing to the strong evidence they exhibit of previous sewage or animal contamination. Moreover, the water from Mr. Peat's well contains an appreciable amount of animal organic matter.

SECTION V.—UNPOLLUTED WATERS FROM DEEP WELLS IN NEW RED SANDSTONE.

The New Red Sandstone is one of the best water-bearing strata in Great Britain, and many deep wells are sunk into it, from which large volumes of water are raised. The examples in the following table illustrate fully the quality of the water obtained from this source. We personally collected all the samples, except those from Nottingham and some of those from Wolverhampton and Worksop.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THE NEW RED SANDSTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well and Bore hole in feet.	Temperature. Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
BIRKENHEAD, CHESHIRE.														
Well at Spring Hill Waterworks, May 16, 1868.	399	—	18·80	**·041**	**·038**	0	·366	·404	3,340	3·40	·2	9·7	9·9	Clear and palatable.
Well at Flaybrick Hill Waterworks, May 16, 1868.	527	—	14·20	**·047**	**·015**	0	·175	·190	1,430	3·48	·8	4·9	5·7	Clear and palatable.
BIRMINGHAM.														
Well at Messrs. R. Heaton and Sons' Mint, Nov. 30, 1872.	300	10·2	31·32	**·052**	**·016**	0	·995	1·011	9,630	3·60	0	15·8	15·8	Slightly turbid. Palatable.
BIRMINGHAM WATERWORKS.														
Aston Well, May 16, 1873.	400	10·8	19·42	**·034**	**·006**	0	·176	·182	1,440	2·00	9·7	5·4	15·1	Clear and palatable.
Perry Well, May 16, 1873	—	12·0	23·24	**·031**	**·007**	0	·469	·476	4,370	1·75	7·8	6·6	14·4	Clear and palatable.
Shortheath Well, Witton, May 16, 1873.	—	10·2	15·08	**·009**	**·004**	0	·447	·451	4,150	1·30	4·6	5·1	9·7	Clear and palatable.
King's Vale well, May 16, 1873.	—	12·5	18·06	**·037**	**·012**	0	·677	·689	6,450	1·80	3·8	7·4	11·2	Slightly turbid. Palatable.
KIDDERMINSTER.														
Well in Messrs. Brenton and Lewis's Carpet Mill, April 28, 1870.	160	12·2	18·26	**·015**	**·004**	0	·169	·173	1,370	1·60	4·8	6·6	11·4	Clear and palatable.
LIVERPOOL WATERWORKS.														
Soho Well (closed), May 21, 1868.	123	—	59·98	**·066**	**·024**	·001	2·195	2·220	**21,640**	7·51	3·9	16·2	20·1	Clear and palatable.
Bootle Extension Well, May 21, 1868.	312	10·4	34·40	**·091**	**·027**	·001	·418	·446	3,870	3·18	0	13·7	12·6	Very turbid. Palatable.
Green Lane Well, May 21, 1868.	370	11·0	26·40	**·020**	**·020**	0	·416	·436	3,840	2·68	4·0	9·6	13·6	Slightly turbid. Palatable.
Dudlow Lane Well, May 21, 1868.	245	—	19·64	**·004**	**0**	·003	·679	·681	6,500	2·61	·5	6·5	7·0	Turbid. Palatable.
Windsor Well, May 21, 1868.	453	11·2	32·00	**·076**	**·033**	0	·411	·444	3,790	2·87	2·1	12·8	14·9	Clear and palatable.
Water Street Well, May 21, 1868.	156	—	51·42	**·018**	**·013**	·001	1·975	1·989	**19,440**	7·94	1·6	11·6	13·2	Clear and palatable.
NOTTINGHAM.														
Mr. Thackray's Well, in town, Feb. 12, 1869.	201	—	62·84	**·050**	**·020**	0	3·508	3·528	**34,760**	5·60	9·6	10·2	19·8	Clear and palatable.
Water supply from Bagthorpe Well, March 1, 1869.	120	—	26·04	**·027**	**·007**	·002	·817	·826	7,870	1·50	14·9	11·3	26·2	Clear and palatable.
Mr. Fisher's Well, Feb. 7, 1871.	200	—	45·82	**·039**	**·035**	·005	2·036	2·075	**20,080**	3·35	13·8	15·9	29·7	Slightly turbid. Palatable.
Bagthorpe Well-water as used at Lunatic Asylum, Oct. 11, 1871.	120	—	26·40	**·017**	**·013**	·039	·781	·826	7,810	1·95	12·7	10·9	23·6	Clear and palatable.
Bagthorpe Well, Nov. 22, 1871	120	—	24·80	**·026**	**·019**	0	·770	·789	7,380	1·80	10·4	11·0	21·4	Clear and palatable.
ST. HELEN'S, LANCASHIRE.														
Waterworks Well, May 23, 1868.	270	10·1	21·66	**0**	**0**	0	·436	·436	4,040	1·94	5·9	6·8	12·7	Clear and palatable.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THE NEW RED SANDSTONE—*cont.*

DESCRIPTION.	Depth of Well and Borehole in feet.	Temperature. Centigrade.	Dissolved Matters.												Remarks.
			Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
											Temporary.	Permanent.	Total.	
TRANMERE, CHESHIRE.														
Water supply, May 22, 1868	428	10·4	22·14	**0**	**0**	·004	·274	·278	2,450	2·88	2·8	8·5	11·3	Clear and palatable.
WALLASEY, CHESHIRE.														
Water supply, May 16, 1868	246	11·0	37·80	**·030**	**·008**	·002	·278	·288	2,480	3·18	1·2	7·9	9·1	Clear and palatable.
WOLVERHAMPTON.														
Goldthorn Hill Well, Waterworks, May 17, 1873.	180	10·1	40·40	**·041**	**·014**	0	·714	·728	6,820	2·00	19·1	10·3	29·4	Clear and palatable.
Goldthorn Hill Well, Waterworks, Sep. 25, 1873.	—	—	40·92	**·068**	**·010**	·002	·703	·715	6,730	1·80	19·4	10·3	29·7	Clear and palatable.
Artesian Well, Waterworks, Sep. 25, 1873.	—	—	25·46	**·032**	**·011**	0	·037	·048	50	1·90	9·7	11·8	21·5	Slightly turbid. Palatable.
Tettenhall Well, Waterworks, Sep. 25, 1873.	—	—	31·68	**·064**	**·023**	·002	·163	·188	1,330	1·70	17·5	11·3	28·8	Clear and palatable.
WORKSOP.														
Deep bore of Prior Well Brewery Co., Oct. 31, 1873	214	11·0	30·08	**·026**	**·006**	·003	0	·009	0	3·60	10·9	17·9	28·8	Clear and palatable.
Bore-hole at Lady Lee, September 6, 1873.	—	—	39·32	**·048**	**·007**	·022	0	·025	0	3·50	15·6	20·0	35·6	Clear and palatable.
Average - -	—	—	30·63	**·036**	**·014**	·003	·717	·734	6,895	2·94	7·4	10·5	17·9	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results, yielded by numerous samples of deep well waters from the New Red Sandstone in widely distant localities, enable us to draw the following conclusions :—

Total solid impurity.—The New Red Sandstone imparts to water, percolating through it or filling its pores, but a moderate proportion of soluble mineral matters. It is only in wells which are fed with water originally highly polluted, such as the Soho and Water Street wells at Liverpool, and two of the wells at Nottingham, that the proportion of total solid impurity rises to a high figure. Amongst the foregoing samples it varied from 14·2 parts in 100,000, or 9·94 grains per gallon, in the water from the Flaybrick Hill well at Birkenhead; to 62·84 parts per 100,000, or 43·99 grains per gallon, in the well water which was supplied to Nottingham in 1869; and averaged 30·63 parts per 100,000, or 21·44 grains per imperial gallon.

Organic elements.—The New Red Sandstone, being a porous and ferruginous rock, exerts a powerful oxidizing influence upon the dissolved organic matter contained in the water which percolates through it. To such an extent is this oxidation carried, that in some cases, as in those of the deep well waters supplying St. Helen's and Tranmere, every trace of organic matter is converted into innocuous mineral compounds. Even when the oxidizing process is not thus exhaustive, the quantity of organic matter still left in the water is exceedingly small, and only discoverable by the most delicate and recondite methods of analysis. In the foregoing samples, the maximum proportion of organic elements (organic carbon and organic nitrogen) was only ·118 part in 100,000 parts of water, or ·083 grain per gallon; whilst the average proportion was only ·050 part per 100,000 parts, or ·035 grain per gallon. The minimum, maximum, and average proportion of nitrogen to carbon observed in the foregoing analytical results were :—Minimum N : C = 1 : 6·86 in the water from the bore-hole at Lady Lee, Worksop: Maximum N : C = 1 : 1 in the water from the Green Lane Well, Liverpool: Average N : C = 3·12

Previous sewage or animal contamination.—The New Red Sandstone rock constitutes one of the most effective filtering media known, and being at the same time a powerful destroyer of organic matter, the evidence of previous pollution, in water drawn from deep wells in this rock, may be safely ignored, unless the previous animal contamination has been very great indeed. When this evidence amounts to from 10 per cent. to 20 per cent., the quality of the water ought to be regarded with some slight amount of suspicion, but when the proportion of 20 per cent. is exceeded the water may easily, through imperfections in the filtration process, become dangerous, and ought therefore to be rejected for domestic supply. Such suspicious and dangerous waters are indicated in the foregoing table by printing their previous sewage contamination in black type.

Part II. Classification. — Deep well water in Lias.

All the samples of water in the table being unpolluted by actual sewage or animal matter, such of them as do not exhibit evidence of previous sewage or animal contamination to the extent of 10 per cent. or 10,000 parts in 100,000, may, in our opinion, be safely regarded as wholesome waters, their previous contamination being ignored. We have therefore expressed that previous contamination in unemphasised figures in the foregoing table. Of the wells yielding the four samples in the table, which exhibit excessive previous pollution, the Soho well in Liverpool has been closed since the year 1866, and the Water Street well, Liverpool, about two years later, whilst of the two offending wells in Nottingham, one (Mr. Thackray's) in the centre of a densely populated neighbourhood, is used only for manufacturing purposes, but the other (Mr. Fisher's) which is situated near to Mr. Thackray's well, is still used for the partial supply of Radford, a suburb of Nottingham.

Hardness.—The New Red Sandstone is a calcareous stratum, the quartz sand constituting the great bulk of it being usually cemented together by carbonate or sulphate of lime. Hence very soft water cannot be expected to issue from this rock, and it is found, in fact, that the hardness usually varies from moderate to excessive, the latter term being, as a rule, only applicable to such samples as exhibit a high degree of previous pollution. Naturally, the New Red Sandstone yields water of medium hardness—varying from 10° to 15°. Only in the water from the well at Flaybrick Hill, Birkenhead, and from the Dudlow Lane well near Liverpool does the hardness approximate to that of really soft water. In the samples enumerated in the foregoing table, the hardness varied from 5°·7 in the Flaybrick Hill water to 35°·6 in the water from the bore-hole at Lady Lee, Worksop—the average hardness being 17°·9. In almost every case when the water is hard, or excessively hard, it would be softened by lime according to the method devised by the late Dr. Clark, see page 205.

General character.—The unpolluted waters drawn from deep wells in the New Red Sandstone are almost invariably clear, sparkling, and palatable, and are among the best and most wholesome waters for domestic supply in Great Britain. They contain, as a rule, but a moderate amount of saline impurity, and either none, or but the merest traces of organic impurity. The hardness is usually moderate, and only when the water is derived from originally impure sources does it become excessive. There is every reason to believe that a vast quantity of hitherto unutilized water of most excellent quality is to be had at moderate expense from this very extensive geological formation.

Section VI.—Unpolluted Waters from Deep Wells in Lias.

We have become acquainted with only two samples of unpolluted water belonging to this section. Submitted to analysis they yielded the following results:—

Composition of Unpolluted Water from Deep Wells in the Lias.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Depth of Well in feet.	Dissolved Matters.											Remarks.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
										Temporary.	Permanent.	Total.	
Northampton.													
Waterworks well, May 11, 1868	191	57·76	**·168**	**·024**	·003	0	·026	0	5·15	8·6	1·7	10·3	Clear and palatable.
Somerton, Somerset.													
Well at Mr. Ord's Brewery, Jan. 17, 1871.	—	84·20	**·124**	**·030**	0	·778	·808	7,460	3·70	35·3	14·7	50·0	Slightly turbid. Palatable.
Average	—	70·98	**·146**	**·027**	·001	·389	·417	3,730	4·42	21·9	8·2	30·1	

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

These waters contained a large proportion of total solid impurity, and one of them was excessively hard. They were palatable, but the proportion of organic elements was, for deep well water, rather high. The previous animal contamination in the Somerton sample, though considerable, was not sufficient to cast suspicion upon the wholesomeness of the water.

PART II. CLASSIFICATION.

Deep well water in Oolites.

SECTION VII.—UNPOLLUTED WATERS FROM DEEP WELLS IN THE OOLITES.

The following table contains the results of our analyses of five samples of water from deep wells sunk into Oolitic rocks. All the samples were collected by ourselves except the one from Stow-on-the-Wold:—

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THE OOLITES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
CIRENCESTER.														
Thames Head well, May 2, 1873.	60	10·5	27·44	**·037**	**·018**	0	·316	·334	2,840	1·35	18·0	5·0	23·0	Clear and palatable.
NORTHAMPTON.														
Well on Berrywood estate, March 2, 1871.	—	—	26·60	**·023**	**·005**	·001	·374	·380	3,430	1·80	14·4	5·6	20·0	Turbid. Palatable.
SCARBOROUGH.														
New supply from bore at Cayton, Dec. 9, 1873.	—	12·0	41·90	**·054**	**·011**	0	·539	·550	5,070	3·40	12·1	9·1	21·2	Clear and palatable.
Bore at Grand Hotel, Dec. 9, 1873.	214	12·2	39·78	**·041**	**·008**	·110	0	·099	590	3·70	16·1	3·6	19·7	Clear and palatable.
STOW-ON-THE-WOLD, GLOUCESTERSHIRE.														
District well in the town, June 11, 1873.	120	—	32·30	**·028**	**·009**	0	1·898	1·907	**18,660**	3·20	8·8	10·6	18·9	Clear and palatable.
Average	—	—	33·60	**·037**	**·010**	·022	·625	·654	6,118	2·69	13·8	6·8	20·6	

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

These analytical numbers furnish the following information:—

Total solid impurity.—Nearly the whole of the solid impurity contained in solution in the samples enumerated in the foregoing table consisted of innocuous saline substances, chiefly salts of lime and magnesia. The proportions varied from 26·6 parts in 100,000, or 18·62 grains per gallon, in the sample from Northampton, to 41·9 parts per 100,000, or 29·33 grains per gallon, in the water from the bore at Cayton, near Scarborough, the average being 33·6 parts per 100,000, or 23·52 grains per gallon.

Organic elements.—These analyses and those of the Oolitic spring waters given at page 118, show that the Oolitic rocks are not inferior to the New Red Sandstone in the energy with which they oxidize and destroy the organic matters present in the water percolating through them. There remained in the deep well waters just enumerated but the merest traces of organic matter, the proportions of organic elements varying from ·028 part per 100,000 parts, or ·02 grain in an imperial gallon, in the sample from Northampton; to ·065 part per 100,000 parts, or ·045 grain per gallon, in the water from Cayton well, the Scarborough average being ·047 part per 100,000 parts, or ·033 grain per gallon,—a quantity the minuteness of which is almost inconceivable. The maximum, minimum, and average proportions of nitrogen to carbon in these Oolitic waters were as follows:—

Maximum - - - N : C = 1 : 2·06
Minimum - - - N : C = 1 : 5·12
Average - - - N : C = 1 : 3·96

Previous sewage or animal contamination.—In one out of the five foregoing samples the evidence of previous contamination is sufficient to cast suspicion upon the wholesomeness of the water. This suspected sample is from the well at Stow-on-the-Wold, the previous animal contamination of which is, in consequence, printed in emphasised type.

Hardness.—Water from Oolitic beds is always hard, but the hardness is chiefly of the temporary character, especially if the original contamination has not been excessive, and it can therefore be very greatly reduced by the application of Clark's softening process. See page 205. The hardness of the waters in the foregoing table varies from 18°·9 to 23° and averages 20°·6. If the waters were softened by Clark's process, the hardness would vary between 3°·6 and 10°·6 and average 6°·8, but if the originally much polluted sample be excluded the average would be only 5°·8.

General character.—If the original water feeding these wells has not been grossly polluted, the quality of the Oolitic deep well waters is most excellent for drinking and all domestic purposes except washing. These waters are bright, sparkling, and palatable, and, if the previous sewage contamination does not exceed 10,000 parts in 100,000, they may be safely regarded as perfectly wholesome. The Oolites contain vast volumes of this magnificent water stored in their pores and fissures; but it is generally allowed to flow in rivers like the *Thames* until it becomes hopelessly polluted, before it is taken up for domestic supply. Though the hardness of the Oolitic waters is great, it is nearly all removed by the inexpensive process of liming. The Oolites absorb immense volumes of rain water, and it cannot be doubted that a considerable proportion of this could be secured for domestic supply in its pristine condition of purity at a moderate cost.

SECTION VIII.—UNPOLLUTED WATERS FROM DEEP WELLS IN HASTINGS SAND, LOWER AND UPPER GREENSAND AND WEALD CLAY.

We have collected numerous samples of water from deep wells sunk into the Hastings Sand and the Greensands, and Weald Clay, and the results yielded by them, on analysis, are given in the following table:—

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN HASTINGS SAND, THE LOWER AND UPPER GREENSAND, AND WEALD CLAY.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters.											REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
HASTINGS SAND.														
TUNBRIDGE.														
Well at waterworks, Feb. 21, 1873.	—	9°·6	34·76	**·036**	**·006**	0	·501	·507	4,690	2·90	15·1	7·0	22·1	Clear and palatable.
LOWER AND UPPER GREENSAND.														
ASHFORD, KENT.														
Well at waterworks, April, 1870.	—	—	40·00	**·085**	**·015**	·002	0	·017	0	2·80	27·8	6·4	34·2	Slightly turbid. Palatable.
Water supply from No. 2 Henwood well, Feb. 28, 1873.	21	11·3	36·32	**·063**	**·010**	·004	·008	·021	0	2·80	19·2	7·7	26·9	Slightly turbid. Palatable.
BRIGHTON.														
Well at workhouse school, Jan. 18, 1873.	1285	9·9	35·36	**·078**	**·007**	0	·068	·075	360	8·40	3·2	1·2	4·4	Clear and palatable.
CAMBRIDGE.														
Bore-hole at Coprolite works, Barton, March 5, 1873.	—	10·2	72·04	**·104**	**·017**	·040	·492	·542	4,930	7·60	18·3	26·0	44·3	Slightly turbid. Palatable.
Running pump in garden of St. John's College, March 5, 1873.	—	10·4	75·52	**·069**	**·021**	·074	0	·082	290	7·60	21·7	18·3	40·0	Turbid. Palatable.
Overflowing well in Old Library Court, King's College, March 5, 1873.	—	12·0	79·20	**·073**	**·030**	·068	0	·086	240	7·60	17·4	23·3	40·7	Slightly turbid. Slight odour of sulphuretted hydrogen.
Overflowing well at Harston, March 13, 1873.	200	—	28·24	**·028**	**·003**	·050	0	·044	90	1·90	1·1	2·5	3·6	Clear and palatable.
EASTBOURNE.														
Well at waterworks, Feb. 22, 1873.	100	10·0	43·12	**·058**	**·010**	·004	·130	·143	1,010	10·00	13·8	7·1	20·9	Slightly turbid. Palatable.
FOLKESTONE.														
Waterworks well, No. 2, Aug. 9, 1873.	39	11·5	48·96	**·107**	**·021**	0	0	·021	0	5·60	23·7	10·4	34·1	Clear and palatable.
Waterworks well, No. 3, Aug. 9, 1873.	43	11·5	41·14	**·091**	**·021**	·004	0	·024	0	4·20	24·6	7·0	31·6	Clear and palatable.
Waterworks well, No. 4, Aug. 9, 1873.	41	11·3	40·50	**·120**	**·016**	·013	0	·027	0	4·20	22·9	8·1	31·0	Clear and palatable.
GOSPORT.														
Well at waterworks, March 7, 1873.	—	5·6	38·16	**·069**	**·017**	·054	·106	·167	1,180	5·90	7·0	7·9	14·9	Slightly turbid. Palatable.

Deep well waters in Greensands, &c.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN HASTINGS SAND, &c.—*continued.*

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
REDHILL.														
Overflowing well at railway station, February 14, 1873.	—	11°·0	38·52	·054	·006	·001	0	·007	0	2·40	20·6	5·1	25·7	Slightly turbid. Palatable.
SWANAGE, DORSET.														
Well at waterworks, March 10, 1873.	113	7·0	66·22	·059	·020	0	·338	·358	3,060	5·60	19·5	23·3	42·8	Clear and palatable.
VENTNOR.														
Spring Hill well, Nov. 16, 1872.	—	11·5	29·48	·043	·003	·001	·014	·018	0	4·15	16·7	5·1	21·8	Clear and palatable.
Waterworks well, near Railway Station, Nov. 16, 1872.	—	10·5	34·72	·056	·011	0	·061	·072	290	8·10	21·7	4·6	26·3	Slightly turbid. Palatable.
WATLINGTON, OXON.														
Brewery well, Dec. 3, 1869	—	—	39·20	·067	·011	0	1·074	1·085	10,420	1·60	18·7	11·2	29·9	Clear and palatable.
WEALD CLAY.														
HEMSTEAD PARK, KENT.														
Principal well, February 28, 1874.	100	11·0	54·56	·067	·017	0	·830	·847	7,980	9·30	17·2	15·3	32·5	Clear and palatable.
Well in dairy yard, Feb. 28, 1874.	60	11·5	33·00	·040	·009	0	·307	·316	2,750	9·95	6·7	11·6	18·3	Clear and palatable.
Average	—	—	45·20	·068	·014	·016	·196	·223	1,864	5·38	16·8	10·5	27·3	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical results suggest the following remarks:—

Total solid impurity.—The deep well waters from the Hastings Sand, the Greensands, and the Weald Clay contain invariably a large proportion of solid impurity in solution, but it is nearly all saline matter which, although it imparts great hardness, is not injurious to health. The total solid impurity in these waters varies from 28·24 parts per 100,000, or 19·77 grains per gallon, in the water of the overflowing well at Harston, Cambridge, to 79·2 parts per 100,000, or 55·44 grains per gallon, in the water of the overflowing well in the Old Library Court, King's College, Cambridge; the average being 45·2 parts per 100,000, or 31·64 grains per imperial gallon.

Organic elements.—The Hastings Sand and the two Greensands are porous and oxidizing strata, which rapidly destroy or remove the organic matter contained in the water percolating through them, leaving generally but mere traces behind. The proportion of organic elements (organic carbon and organic nitrogen) in these waters is, therefore, almost invariably very small. It varied in the foregoing samples from ·031 part per 100,000 parts, or ·022 grain per gallon, in the water of the overflowing well at Harston, Cambridge; to ·136 part per 100,000 parts, or ·095 grain per gallon, in the water of No. 4 Waterworks Well at Folkestone; and averaged ·082 part per 100,000, or ·057 grain per gallon. The proportions of nitrogen to carbon in the foregoing samples were:—

Minimum - N : C = 1 : 14·33
Maximum - N : C = 1 : 2·43
Average - N : C = 1 : 6·15

Previous sewage or animal contamination.—The Greensands contain, almost invariably, protoxide of iron, which probably exercises a reducing effect upon the nitrates and nitrites present in the water, removing their oxygen and transforming a portion of their nitrogen into ammonia, whilst the remaining nitrogen escapes as gas. In some cases even the sulphates present in the water are attacked and reduced, and sulphuretted hydrogen generated. The evidence of previous animal contamination is thus diminished or even obliterated altogether, whilst the water acquires a considerable proportion of ammonia. Thus seven out of the twenty samples in the foregoing table exhibit no evidence whatever of previous animal pollution, although it cannot be doubted that most of them were so polluted when they first sank beneath the surface of the soil. In only one case, that of the sample from Watlington, does the evidence become strong enough to cast a slight suspicion upon the wholesomeness of the water.

Hardness.—These waters vary in hardness between very wide limits; if they reach the sands without previously passing over or through the Chalk or other calcareous

Deep well water in Chalk.

stratum, they retain their softness unimpaired, as the sands themselves do not often contain more than traces of calcareous ingredients. The wells at Harston near Cambridge, and at the workhouse school, Brighton, yield soft water of this description, whilst in most other cases the water is excessively hard. The hardness in the foregoing samples varied from 3°·6 to 44°·3, and averaged 27°·3.

General character.—These waters are not unfrequently slightly turbid, owing to the friable character of the water-bearing stratum. They are generally pleasant to drink, but occasionally they have a slight odour and flavour of sulphuretted hydrogen when first drawn from the well; these soon disappear however by exposure to the air. They are good wholesome waters for drinking and cooking, but are generally too hard for washing. When this is the case they can be softened by the application of Clark's process (*see* page 205). Altogether, the study of these water-bearing strata has produced upon us the impression that, both with regard to the quantity and quality of the deep-well water which they yield, these formations are considerably inferior to the New Red Sandstone, Oolites, and Chalk.

SECTION IX.—UNPOLLUTED WATERS FROM DEEP WELLS IN THE CHALK.

Of all water-bearing strata, the chalk is perhaps held most in favour for the sinking of deep shafts and bore-holes. This is no doubt due both to the abundant supply of water which it is capable of furnishing, and to the facility with which the operations of boring and sinking in it can be accomplished. The following table contains the results of our analyses of very numerous samples of deep well water from this source. The numbers attached to the samples marked with an asterisk are extracted from the Appendix to the Report of the Royal Commission on Water Supply, page 104. With very few exceptions the remaining samples were collected by ourselves.

COMPOSITION OF UNPOLLUTED WATERS FROM DEEP WELLS IN THE CHALK.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature Centigrade.	Dissolved Matters.											REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BRIGHTON.														
Goldstone Bottom Well, Waterworks, Jan. 18, 1873.	160	9°·6	30·24	**·048**	**·009**	0	·644	·653	6,120	3·10	14·8	6·4	21·2	Clear and palatable.
Lewes Road Well, Waterworks, Jan. 18, 1873.	100	10·0	32·40	**·055**	**·011**	0	·989	1·000	9,570	3·70	14·6	6·9	21·5	Clear and palatable.
BURY ST. EDMUNDS.														
Well at Waterworks, Nov. 17, 1871.	—	5·0	39·00	**·089**	**·020**	0	·481	·501	4,490	2·15	22·6	7·4	30·0	Clear and palatable.
CANTERBURY.														
Well at Waterworks, Oct. 29, 1870.	—	10·8	33·60	**·012**	**·012**	0	·426	·438	3,940	2·10	22·1	4·2	26·3	Clear and palatable.
DEAL.														
Waterworks well, July 24, 1869.	115	—	33·20	**·032**	**·013**	0	·698	·711	6,660	2·80	20·4	5·9	26·3	Clear and palatable.
Waterworks well, March 1, 1873.	115	11·3	34·06	**·050**	**·007**	·002	·803	·812	7,730	3·00	18·2	5·4	23·6	Clear and palatable.
Waterworks well, Aug. 28, 1873.	115	—	31·74	**·056**	**·024**	·004	·702	·729	6,730	2·90	20·2	6·1	26·3	Slightlyturbid Palatable.
DORCHESTER, DORSET.														
Well at Waterworks, March 10, 1873.	130	8·3	29·90	**·040**	**·010**	·001	·411	·422	3,800	2·20	18·3	5·3	23·6	Clear and palatable.
DOVER.														
Well at Waterworks, March 1, 1873.	220	11·3	29·60	**·034**	**·008**	·001	·452	·461	4,210	2·60	18·6	5·0	23·6	Clear and palatable.
Well in Dover Castle, March 1, 1873.	367	13·0	36·56	**·028**	**·005**	·001	·773	·779	7,420	4·00	18·3	5·0	23·3	Clear and palatable.
DUNBRIDGE, HANTS.														
Well at Queenwood College, October 13, 1873.	169	11·5	29·54	**·044**	**·005**	0	·541	·546	5,090	2·20	16·1	6·3	22·4	Clear and palatable.
WORTHING.														
New well at Waterworks, July 17, 1868.	—	—	32·44	**·007**	**0**	·002	·420	·422	3,901	3·08	16·4	8·3	24·7	Clear and palatable.
GREAT GRIMSBY.														
Well at Docks, Jan. 10, 1873.	300	11·5	32·40	**·025**	**·007**	0	·107	·114	750	5·00	14·5	7·6	22·1	Clear and palatable.

Deep well waters in Chalk.

COMPOSITION OF UNPOLLUTED WATERS FROM DEEP WELLS IN THE CHALK—*continued.*

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
HULL.														
Well at Springhead Waterworks, Jan. 11, 1873.	—	11·5	31·66	·032	·012	0	·406	·418	3,740	1·95	21·3	4·7	26·0	Clear and palatable.
Well at Coburg Villa Hessle, March 20, 1872.	—	—	33·54	·093	·016	0	·640	·656	6,080	2·20	20·1	8·1	28·2	Clear and palatable.
IPSWICH.														
Water supply from well, Nov. 30, 1874.	—	9·0	48·60	·064	·017	·002	·943	·962	9,130	3·90	23·7	12·3	36·0	Clear and palatable.
NORWICH.														
Artesian well at Carrow works, Sept. 17, 1868.	400	—	38·14	·074	·027	0	1·001	1·028	9,690	2·58	23·3	6·4	29·7	Clear and palatable.
RAMSGATE.														
Well at Waterworks, Whitehall, March 1, 1873.	100	10·0	40·90	·052	·013	0	·806	·819	7,740	5·20	20·4	5·9	26·3	Clear and palatable.
SUDBURY, SUFFOLK.														
Webb's well, May 13, 1870	—	—	44·90	·050	·012	0	1·005	1·017	9,730	2·41	28·1	6·5	34·6	Slightly turbid. Palatable.
Prior's well, May 13, 1870	—	—	44·94	·045	·007	0	·506	·513	4,740	3·65	24·6	7·4	32·0	Clear and palatable.
Bore-hole, No. 5, May 13, 1870.	—	—	43·80	·090	·020	·019	·500	·536	4,840	2·10	30·2	5·3	35·5	Turbid. Palatable.
Bore-hole, No. 5, April 5, 1872.	—	—	44·00	·042	·018	0	·339	·357	3,070	5·05	29·6	8·2	37·8	Turbid. Palatable.
TAVERHAM, NORFOLK.														
Well at "Times" Paper Mill, Sept. 17, 1868.	150	—	27·30	·059	·024	0	·428	·452	3,960	2·73	14·4	5·1	19·5	Clear and palatable.
THAMES BASIN.														
Amwell, New River Co.'s well at, May 5, 1868.*	—	11·0	31·88	·076	·009	0	·406	·415	3,740	1·39	16·5	5·9	22·4	Clear and palatable.
Basingstoke, water supply of, October 11, 1873.	340	11·2	29·26	·041	·016	0	·661	·677	6,290	1·60	19·0	6·1	25·1	Clear and palatable.
Well at Belvidere, Feb. 11, 1873.	70	11·5	40·52	·100	·037	0	2·079	2·116	**20,470**	3·35	10·8	11·6	22·4	Clear and palatable.
Blackmore End, near Wheathamstead, well at, April 11, 1874.	175	10·3	38·32	·029	·007	0	·303	·310	2,710	3·00	27·0	4·0	31·0	Clear and palatable.
Ditto, well at Farm at, April 11, 1874.	150	10·8	54·60	·035	·030	0	·890	·920	8,580	6·30	31·7	7·4	39·1	Slightly turbid. Palatable.
Well at High Elms, Bromley, Oct. 30, 1870.	150	—	30·48	·041	·026	0	·440	·466	4,080	1·18	21·3	3·5	24·8	Clear and palatable.
Bushey Station, well at, Nov. 11, 1870.	249	10·0	36·08	·034	·018	0	·174	·192	1,420	1·90	19·7	6·0	25·7	Clear and palatable.
Bore-hole in Bushey Meadows, Nov. 11, 1870.	—	10·6	33·88	·027	·006	·006	·314	·325	2,870	1·35	23·8	3·8	27·6	Clear and palatable.
Bore-hole in Bushey Meadows, March 5, 1873.	—	—	33·16	·071	·026	·029	·343	·393	3,350	1·40	23·2	4·3	27·5	Clear and palatable.
Mr. Majoribank's well near Bushey, March 5, 1873.	—	—	38·20	·038	·017	·003	·605	·624	5,750	1·80	21·9	6·9	28·8	Turbid. Palatable.
Caterham Waterworks well, May 12, 1868.*	—	11·0	31·08	·020	·006	0	·027	·033	0	1·35	14·4	9·0	23·4	Clear and palatable.
Caterham Waterworks well, Feb. 14, 1873.	490	11·2	27·68	·028	·009	0	·021	·030	0	1·55	15·2	6·0	21·2	Clear and palatable.
Chatham, well at waterworks, March 8, 1871.	—	—	33·84	·049	·006	·001	·365	·372	3,340	2·40	22·9	4·3	27·2	Clear and palatable.
Crayford, Kent Water Co.'s well, Feb. 8, 1873.	200	11·4	35·20	·031	·005	0	·505	·510	4,730	2·25	20·3	5·4	25·7	Clear and palatable.
Croydon, well at waterworks, May 11, 1868.*	—	13·5	32·00	·040	·007	·001	·551	·559	5,280	—	12·9	9·1	22·0	Clear and palatable.
Deptford, New well at Kent Water Co.'s works, Feb. 8, 1873.	—	12·2	42·94	·048	·005	·001	·545	·551	5,140	2·50	20·1	9·6	29·7	Clear and palatable.
Deptford, Bath well at Kent Water Co.'s works, Feb. 8, 1873.	—	12·2	35·44	·044	·007	0	·363	·370	3,310	2·30	18·6	8·0	26·6	Clear and palatable.
Deptford, Garden well at Kent Water Co.'s works, Feb. 8, 1873.	250	12·2	40·96	·056	·011	0	·354	·365	3,220	2·40	20·2	8·6	28·8	Clear and palatable.
Gravesend, waterworks well, Jan. 17, 1873.	200	9·7	36·52	·030	·009	0	·582	·591	5,500	2·40	20·0	7·9	27·9	Clear and palatable.
Grays, well of South Essex Water Co., Feb. 15, 1873.	—	8·8	41·74	·058	·018	0	·908	·926	8,760	4·70	18·6	7·4	26·0	Clear and palatable.
Grays, open shaft at South Essex Water Co.'s works, Feb. 15, 1873.	—	10·8	44·80	·064	·017	·001	·929	·947	8,980	5·05	20·7	8·7	29·4	Clear and palatable.

Deep well waters in chalk.

COMPOSITION OF UNPOLLUTED WATERS FROM DEEP WELLS IN THE CHALK—*continued.*

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
Great Bookham, Mr. H. D. Barclay's well, Jan. 23, 1872.	113	° —	38·40	**·019**	**·012**	·002	·900	·914	8,700	2·45	24·7	5·3	30·0	Clear and palatable.
Great Bookham, Mr. Wood's well, Jan. 23, 1872.	70	—	35·90	**·094**	**·037**	·003	·698	·737	6,680	1·75	19·7	6·6	26·3	Very turbid. Palatable.
Hertford, well at waterworks, Jan. 24, 1873.	—	9·4	37·06	**·026**	**·008**	0	·497	·505	4,650	1·90	21·4	4·6	26·0	Clear and palatable.
Highmore Well, Oxfordshire, Nov. 19, 1870.	—	10·0	46·80	**·061**	**·031**	·001	1·372	1·404	**13,410**	3·25	31·4	5·7	37·1	Turbid. Palatable.
Nettlebed well, Oxfordshire, Nov. 19, 1870.	318	10·1	48·10	**·053**	**·038**	·001	1·167	1·206	**11,360**	2·92	31·1	6·7	37·8	Clear and palatable.
Plumstead, Kent Water Company's well, Feb. 11, 1873.	600	12·0	50·80	**·081**	**·011**	0	·338	·349	3,060	4·60	16·8	13·8	30·6	Clear and palatable.
Gallow's Tree well, near Reading, Nov. 19, 1870.	—	9·5	23·30	**·051**	**·017**	·001	·105	·123	740	1·00	16·4	2·7	19·1	Slightly turbid. Palatable.
Kidmore End well, near Reading, Nov. 19, 1870.	180	8·3	66·34	**·071**	**·040**	·002	2·277	2·319	**22,470**	4·56	38·6	11·4	50·0	Very turbid. Palatable.
Rickmansworth, well by Lord Ebury's Park, Feb. 18, 1871.	—	—	36·12	**·033**	**·014**	0	trace	·014	0	1·68	27·3	4·6	31·9	Clear and palatable.
Shortlands, Bromley, Kent Water Company's well, Feb. 8, 1873.	—	11·5	30·64	**·021**	**·007**	0	·354	·361	3,220	1·60	19·3	4·6	23·9	Turbid, from workmen in adjoining well. Palatable.
Sittingborne, well at Waterworks, April 22, 1873.	400	11·7	34·00	**·131**	**·010**	·002	·343	·355	3,130	2·10	23·1	4·4	27·5	Clear and palatable.
Stoke Row well, near Nettlebed, Nov. 19, 1870.	378	9·4	29·20	**·052**	**·024**	0	·059	·083	270	1·18	21·9	3·5	25·4	Clear and palatable.
Streatley, Bower's Farm well, Nov. 19, 1870.	—	9·4	62·64	**·108**	**·064**	0	1·129	1·193	**10,970**	11·10	33·3	11·0	44·3	Clear and palatable.
Streatley, Hill Cottage well, Nov. 19, 1870.	72	9·4	30·38	**·044**	**·030**	0	·490	·520	4,580	1·20	20·3	3·4	24·2	Very turbid. Palatable.
Tring, well at Chiltern Water Company's Works, Nov. 6, 1868.	507	9·2	28·60	**·036**	**·010**	·001	·094	·105	630	1·39	23·0	3·3	26·3	Clear and palatable.
Watford, well at Waterworks, Nov. 11, 1870.	100	11·2	38·20	**·030**	**·015**	·001	·752	·768	7,210	1·60	24·2	4·6	28·8	Clear and palatable.
Watford, well at Waterworks, March 5, 1873.	100	—	37·26	**·042**	**·011**	·001	·774	·786	7,430	1·80	22·2	6·0	28·2	Clear and palatable.
Watford, Sedgwick's Brewery well, Nov. 11, 1870.	180	11·1	35·16	**0**	**0**	0	·635	·635	6,030	1·50	21·9	6·0	27·9	Clear and palatable.
Woodgreen well, Nov. 19, 1870.	—	10·0	48·28	**·056**	**·046**	·006	·822	·873	7,950	4·80	28·8	6·6	35·4	Turbid. Palatable.
Wouldham, well at Cement Company's Works, Dec. 26, 1868.	—	—	30·00	**·079**	**·051**	·002	·834	·887	8,040	2·23	14·9	7·4	22·3	—
Wouldham, new well in chalk pit, April 1869.	—	—	25·98	**·067**	**· 24**	·001	·605	·630	5,740	2·10	13·9	6·4	20·3	—
WINCHESTER.														
Waterworks well, March 12, 1873.	200	—	29·56	**·048**	**·018**	0	·624	·642	5,920	1·70	17·0	6·0	23·0	Clear and palatable.
Average -	—	—	36·88	**·050**	**·017**	·001	·610	·628	5,801	2·76	21·2	6·5	27·7	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

A study of the analytical results recorded in this table leads to the following conclusions:—

Total solid impurity.—The amount of total solid matters dissolved in water from deep wells sunk into the Chalk is always large, but a very minute proportion only is organic, the remainder being innocuous to health, and consisting chiefly of bicarbonate of lime, that is to say, chalk combined with carbonic acid. In the samples enumerated in the foregoing tables, the total solid impurity varied from 23·3 parts per 100,000, or 16·3 grains per gallon, in the water of the Gallows Tree well, near Reading; to 66·34 parts per 100,000, or 46·44 grains per gallon, in the water from a well in the village of Kidmore End, near Reading. The average proportion in the sixty-six samples was 36·88 parts per 100,000, or 25·72 grains per imperial gallon.

Organic elements.—Chalk is an excellent filtering and cleansing material for water, and, whilst it absorbs a larger proportion of the rainfall than does any other stratum, the water is again yielded to deep wells, in a condition of freedom from organic matter

PART II. CLASSIFICATION.

Deep well waters in Chalk.

not surpassed by the water from any other geological formation. In the foregoing samples, the proportion of organic elements varied from *nil*, in the water from the well 180 feet deep at Sedgwick's Brewery, Watford, to ·172 part per 100,000 parts, or ·12 grain per gallon, in the water from a well at Bower's Farm, near Streatley, the average proportion in the sixty-six samples being only ·067 part per 100,000 parts, or ·047 grain per imperial gallon.

The proportion of nitrogen to carbon in chalk water varied from N : C = 1 : 13·1, in the water from the well at Sittingbourne Waterworks; to N : C = 1 : 1 in the water from the well at Canterbury Waterworks. On the average the proportion was N : C = 1 : 3·86.

Previous sewage or animal contamination.—The water entering the Chalk is almost always, to some extent, polluted by animal matter before it leaves the surface. The pollution is slight, if the rain falls upon the grassy slopes of a chalk down; it is much more considerable when the rain soaks through highly-manured soil; and it is greatest when the chalk is cut up and honeycombed by sewers and cesspools. Thus the well at Caterham waterworks, and that by Lord Ebury's park, near Rickmansworth, exhibit no evidence whatever of such pollution, whilst the well at Belvedere, in Kent, situated in the midst of market gardens, and that at Kidmore End, near Reading, surrounded by cottages with their gardens and privies or cesspools, show strong evidence of such anterior pollution. Amongst the entire series of samples, however, the two last-named stand alone upon the marginal line which divides suspicious from dangerous waters. There can be little doubt, that if these wells were suitably protected against the admission of water from the upper strata directly into their shafts, this evidence of previous pollution would be at once greatly reduced. Of the remaining samples, only three belong to the class of suspicious waters. These are the wells at Highmore and Nettlebed, Berks; and at Bower's Farm, Streatley. The water from even the worst of all the remaining wells is reasonably safe and wholesome.

Hardness.—All the samples in the foregoing table are hard, many of them excessively so, but in nearly all cases a very large proportion of the hardness is of the kind called *temporary*, and can be removed by boiling the water for half an hour or adding a small quantity of slaked lime to it. In the samples enumerated in the foregoing table, the hardness varied from 19°·1 in the water from the Gallows Tree well, near Reading, to 50° in that of the well at Kidmore End, also near Reading, and averaged 27°·7. But if these waters were subjected to Clark's softening process, the hardness would range from 2°·7 to 13°·8 and would average only 6°·5.

General Character.—The unpolluted deep well waters from the Chalk rank amongst the best and most wholesome with which we have become acquainted. They are almost invariably colourless, palatable, and brilliantly clear. In almost every case in which turbidity is mentioned in the foregoing table, the water was either drawn up by a bucket and rusty chain, or taken from an unfinished bore-hole; the turbidity is therefore either transitory or due to radically defective methods of raising the water.

The Chalk constitutes magnificent underground reservoirs in which vast volumes of water are not only rendered and kept pure, but stored and preserved at a uniform temperature of about 10° C. (50° F.), so as to be cool and refreshing in summer, and far removed from the freezing point in winter. It would probably be impossible to devise, even regardless of expense, any artificial arrangement for the storage of water that could secure more favourable conditions than those naturally and gratuitously afforded by the Chalk, and there is reason to believe that the more this stratum is drawn upon for its abundant and excellent water, the better will its qualities as a storage medium become. Every 1,000,000 gallons of water abstracted from the Chalk carries with it in solution on an average 1¼ ton of the chalk through which it has percolated, and thus makes room for an additional volume of about 110 gallons of water. The porosity or sponginess of the Chalk must therefore go on augmenting, and the yield from wells judiciously sunk ought within certain limits, to increase with their age.

The only drawback to these waters is their hardness, but this disadvantage is greatly reduced by the circumstance, that it is chiefly of the "temporary" kind, and can be therefore easily and cheaply removed by the application of Clark's process, as described at page 205.

SECTION X.—UNPOLLUTED WATER FROM DEEP WELLS IN CHALK BELOW LONDON CLAY.

When the Chalk of the London basin passes beneath the clay, it becomes more compact, and consequently less effective as a water-bearing stratum. The quality of the water also undergoes remarkable changes, as shown by the following analytical results yielded by thirteen samples collected, with three exceptions, by ourselves :—

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THE CHALK BENEATH LONDON CLAY.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
BRAINTREE, ESSEX.														
Well at Waterworks, April 3, 1873.	430	12°·2	106·70	·068	·033	·094	0	·110	450	38·80	8·7	5·0	13·7	Clear and palatable.
EPPING.														
Artesian well, July 10, 1872	--	—	64·88	·088	·005	·050	·084	·130	930	6·20	0	·9	·9	Slightly turbid. Palatable.
HARROW, MIDDLESEX.														
Well at Waterworks, Oct. 22, 1868.	408	—	104·42	·063	·067	·001	·012	·080	0	16·58	29·5	19·0	48·5	Clear and palatable.
Well at Waterworks, Nov. 11, 1870.	408	10·6	100·88	·059	·030	·118	0	·127	650	16·30	19·0	25·4	44·4	Clear and palatable.
Well at Waterworks, March 5, 1873.	408	—	98·08	·078	·053	0	0	·053	0	16·00	15·4	25·4	40·8	Clear and palatable.
LONDON.														
Well at Trafalgar Square, May 6, 1869.	383	—	83·40	·150	·012	·070	0	·070	260	16·55	3·0	2·9	5·9	—
Well at Royal Mint, May 31, 1869.	—	—	83·96	·195	·025	·060	0	·074	170	13·92	7·7	9·7	17·4	—
Well at Barclay's Brewery, July 9, 1869.	367	12·1	73·30	·085	·008	·060	0	·057	170	14·08	4·5	2·8	7·3	—
New well at Barclay's Brewery, July 14, 1869.	143	—	71·56	·055	·010	·075	·035	·107	650	12·90	4·0	3·9	7·9	—
Well at Albert Hall, May 1872.	401	—	61·68	·168	·042	·009	·066	·115	410	15·10	3·4	2·2	5·6	Slightly turbid. Palatable.
St. Pancras well, Midland Railway, July 31, 1873.	300	—	65·40	·063	·021	·060	0	·070	170	11·20	3·0	2·3	5·3	Clear and palatable.
WIMBLEDON.														
New Wimbledon, bore-hole on common, July 7, 1868.	200	12·5	33·38	·063	·038	·004	·047	·088	182	2·38	6·3	7·0	13·3	Clear and palatable.
WITHAM, ESSEX.														
Well at Waterworks, April 3, 1873.	600	10·6	67·50	·070	·016	·024	·645	·681	6,320	15·20	21·2	7·0	28·2	Slightly turbid. Palatable.
Average - -	—	—	78·09	·093	·028	·048	·068	·135	797	15·02	9·7	8·7	18·4	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

To these results we append the following remarks :—

Total solid impurity.—The water derived from deep wells in the Chalk beneath London Clay is believed to come partly from the Lower Tertiaries which are situated between the London Clay and the Chalk ; it contains, as a rule, a much larger proportion of solid matters in solution than that found in the water yielded by chalk not capped with clay. These solid ingredients contain but a small quantity of organic matter and include generally a large amount of common salt; hence the proportion of chlorine in the foregoing samples is almost invariably high, and sometimes very high. Besides chloride of sodium, the dissolved solid impurity frequently contains a considerable proportion of bicarbonate of soda. Altogether these saline impurities are not objectionable if they are not present in excessive quantity, but this is the case when they approach the proportion of 100 parts per 100,000 of water, or 70 grains per gallon. The proportion of total solid impurity in the foregoing samples varied from 33·38 parts per 100,000, or 23·37 grains per gallon, in the water from the bore-hole at New Wimbledon ; to 106·7 parts per 100,000, or 74·69 grains per gallon, in the water supplied to Braintree, the average of the thirteen samples being 78·09 parts per 100,000, or 54·66 grains per imperial gallon.

Organic elements.—In these waters the proportion of organic elements varied from ·065 part per 100,000 parts, or ·045 grain per gallon, in the water from the new well at Messrs. Barclay and Co.'s brewery ; to ·22 part in 100,000 parts, or ·154 grain per gallon in the well water at the Royal Mint, the average being ·121 part per 100,000 parts, or ·085 grain per gallon.

PART II. CLASSIFICATION.

The proportion of nitrogen to carbon in the foregoing samples varied from, N : C = 1 : ·94 in the water from Harrow Waterworks, October 22, 1868, to N : C = 1 : 17·6 in the water from Epping, the average proportion being N : C = 1 : 5·65.

Deep well waters in Thanet Sand.

Previous sewage or animal contamination.—The original surface water, by which the Chalk beneath the London Clay is fed, was doubtless as much polluted as that which enters the uncovered Chalk; but, for reasons given at page 17, the evidence of this pollution is often nearly or completely obliterated. In no case does it become strong enough to cast suspicion upon the wholesomeness of the water.

Hardness.—During the transit of the chalk water beneath the London Clay, the bicarbonate of lime which it contains becomes more or less completely replaced by bicarbonate of soda, and the hardness of the water is reduced to the extent to which this takes place. These waters are, therefore, as a rule much softer than those obtained from the free Chalk. In the foregoing samples the hardness varied from 0°·9 in the water from the artesian well at Epping; to 48°·5 in one of the samples drawn from the well at the Harrow waterworks; and averaged 18°·4.

General character.—The water from unpolluted deep wells in the Chalk beneath the London Clay is almost invariably clear, palatable, and wholesome. It contains a large proportion of innocuous saline matter and a very moderate proportion of organic matter, but the organic matter is present in larger quantity in these waters than in those obtained from deep wells in the free Chalk. The foregoing samples are all reasonably safe for domestic use, they are usually moderately soft, and rarely excessively hard.

SECTION XI.—UNPOLLUTED WATER FROM DEEP WELLS IN THANET SAND AND DRIFT.

The following table contains the results of analysis of two samples of water which we collected from deep wells in Thanet Sand at Sheerness, and of two from the Drift at Beccles which were forwarded to us for analysis.

COMPOSITION OF UNPOLLUTED WATER FROM DEEP WELLS IN THANET SAND AND DRIFT.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature Centigrade.	Dissolved Matters.											REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
											Temporary.	Permanent.	Total.	
BECCLES, SUFFOLK.														
Water from bore pipe, February 20, 1874.	137	° —	45·96	**·130**	**·019**	0	0	·019	0	5·20	18·6	12·0	30·6	Turbid. Palatable.
Water from well, February 20, 1874.	91	—	51·52	**·074**	**·019**	0	·438	·457	4,060	5·20	23·7	10·3	34·0	Clear and palatable.
SHEERNESS.														
Old well in Dockyard, April 21, 1873.	450	16·7	61·10	**·133**	—	·190	0	—	1,240	9·10	4·5	3·6	8·1	Clear and palatable.
Well at Waterworks, April 21, 1873.	384	16·7	56·80	**·117**	**·021**	·100	·027	·130	770	5·80	10·8	4·7	15·5	Clear and palatable.
Average - -	—	—	53·84	**·113**	**·020**	·072	·116	·202	1,517	6·32	14·4	7·6	22·0	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

At Sheerness dockyard, there are two deep wells penetrating the Thanet Sand through 350 feet of clay. On the occasion of our visit one of these wells was out of repair, and the sample mentioned in the foregoing table was taken from the other or old well which is 330 feet deep with a boring carried 120 feet deeper. Below the clay the boring passes, first, light sandy loam, second, dark sand and clay, third, dark and stiff clay to 400 feet, and afterwards sand and clay down to a bed of pebbles from which the supply of water comes, any water which might come from the higher beds being excluded from the well and bore-hole. Thirty tons of water per hour are pumped from this well for seven hours per day. The well at the waterworks is of a similar character, but the water contains less common salt and is harder. Owing to the great depth of these wells below the sea level, the temperature of the water is high (16°·7 C. or 62° Fahr.).

The water from both wells was clear, palatable, and wholesome, it sometimes, however, comes to the surface charged with sand and grit. Both samples contained a very large proportion of ammonia derived, in all probability, from the decomposition of nitrates. The proportion of organic matter in both samples was small and the hardness moderate. The inconsiderable amount of evidence of previous animal contamination casts no suspicion upon the quality of the water. For remarks on the samples from Beccles, see page 310.

PART II. CLASSIFICATION. — Polluted deep well waters.

DIVISION II.—POLLUTED DEEP WELL WATERS.

Deep well waters may become polluted, either by the admission of soakage from the superficial strata into the shaft of the well, or by the access of polluted water through open fissures in the rock in which the well is sunk. The following table contains the results of our analyses of numerous deep well waters so polluted. Nearly all the samples were collected by us personally.

COMPOSITION OF POLLUTED WATER FROM DEEP WELLS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
IN DEVONIAN ROCKS.														
BROMYARD.														
Well in tan-yard, Aug. 8, 1869.	—	—	85·12	·177	·048	0	2·279	2·327	22,470	11·25	25·0	16·2	41·2	—
DUNDEE.														
Sandeman's well, Sept. 14, 1870.	—	—	27·50	·119	·027	·025	·532	·580	5,210	3·05	9·6	8·5	18·1	Slightly turbid. Palatable.
IN COAL MEASURES.														
EDINBURGH.														
Well near Holyrood Palace, April 16, 1869.	—	—	92·54	·326	·175	·056	·950	1·171	9,640	7·95	27·9	8·3	36·2	—
IN NEW RED SANDSTONE.														
LICHFIELD.														
Well at South Staffordshire Water Company's Works, May 17, 1873.	56	12·2	32·06	·163	·038	·003	·489	·529	4,590	2·20	9·3	9·0	18·3	Slightly turbid. Palatable.
LIVERPOOL.														
Bevington Bush well (closed), May 21, 1868.	149	—	86·70	·135	·038	·005	8·678	8·721	86,510	12·61	11·5	24·0	35·5	—
OXTON.														
Well in Wirral Water Company's Works, May 16, 1868.	367	10·2	27·80	·249	·034	·001	·376	·411	3,450	3·52	5·6	8·5	14·1	Clear and palatable.
IN LIAS.														
TROWBRIDGE, WILTSHIRE.														
Well at Waterworks (not finished), March 11, 1870.	200	11·1	144·34	·236	·057	·002	·550	·609	5,200	36·70	27·4	29·7	57·1	Clear. Brackish.
IN OOLITE.														
BOURNE, LINCOLNSHIRE.														
Water supply, November 22, 1873.	—	9·5	42·76	·217	·047	0	0	·047	0	2·10	23·4	11·8	35·2	Clear and palatable.
THREESCOMBE, GLOUCESTERSHIRE.														
Well at Mr. Playne's house, March 18, 1870.	60	—	27·48	·106	·020	·002	·778	·800	7,480	2·50	12·6	8·6	21·2	Clear and palatable.
WITNEY, OXFORDSHIRE.														
Well at Messrs. Clinch and Company's Brewery, Dec. 9, 1870.	65	10·3	71·04	·142	·053	·001	·308	·362	2,770	7·80	26·4	12·9	39·3	Clear and palatable.
LOWER GREENSAND.														
SEVENOAKS, KENT.														
Mr. W. Spottiswoode's well, Aug. 1873.	60	—	38·76	·447	·072	0	·252	·324	2,200	5·90	7·2	13·4	20·6	Slightly turbid. Palatable.
IN CHALK.														
ARLESEY, BEDS.														
Old well at Three Counties Asylum, Sept. 3, 1870.	—	—	36·00	·170	·084	0	1·130	1·214	10,980	1·83	19·7	5·3	25·0	Very turbid. Palatable.
CARISBROOK CASTLE, I. W.														
Well in Castle, March 8, 1873.	240	11·3	43·28	·169	·043	·002	1·365	1·410	13,340	6·40	13·9	10·0	23·9	Clear and palatable.

COMPOSITION OF POLLUTED WATER FROM DEEP WELLS—*continued.*

DESCRIPTION.	Depth of Well in feet.	Temperature. Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
			Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
CHARLTON, SURREY.		°												
Well at Kent Water Company's Works, Feb. 11, 1873.	—	11·8	92·80	**·139**	**·028**	0	·901	·929	**8,690**	19·70	21·3	21·3	42·6	Clear and palatable.
DEAL.														
Well at Mr. Hill's Brewery, July 22, 1869.	—	—	202·14	**·139**	**·137**	·065	1·976	2·167	**19,980**	71·82	31·0	16·2	47·2	—
GRAVESEND, KENT.														
Well at Railway Station, Jan. 17, 1873.	70	10·0	68·00	**·127**	**·029**	·076	2·937	3·029	**29,680**	5·40	27·9	14·5	42·4	Clear and palatable.
GREAT BOOKHAM, SURREY.														
Well in Eastwick Lane, Jan. 23, 1872.	101	—	41·36	**·548**	**·155**	·003	1·534	1·691	**15,040**	3·15	22·5	10·0	32·8	Turbid.
Well in Tanner Lane, Jan. 23, 1872.	70	—	32·16	**·821**	**·131**	·011	·518	·658	**4,950**	1·75	20·8	6·1	26·9	Slightly turbid and palatable.
HARWICH.														
Bore-hole intended for town supply, Oct. 24, 1873.	380	—	216·40	**·144**	**·081**	·150	0	·204	**910**	106·0	16·4	34·3	50·7	Slightly turbid. Palatable.
WESTRIDGE, BERKSHIRE.														
Well at Westridge Farm, Nov. 19, 1870.	—	10·0	73·54	**·107**	**·082**	·001	3·401	3·484	**33,700**	9·50	31·0	18·3	49·3	Clear and palatable.
Well at Westridge Green Farm, Nov. 19, 1870.	—	—	77·44	**·294**	**·186**	·026	2·130	2·337	**21,190**	12·40	36·1	15·4	51·5	Slightly turbid. Palatable.
IN CHALK UNDER LONDON CLAY.														
COLCHESTER.														
Well at Waterworks, April 2, 1873.	400	11·4	96·20	**·174**	**·030**	·021	2·582	2·629	**25,670**	21·00	12·7	13·0	25·7	Clear and palatable.
HOUNSLOW.														
Well at Hartlands, Cranford, May 1872.	—	—	82·40	**·273**	**·042**	·001	·846	·889	**8,150**	9·05	26·2	8·1	34·3	Slightly turbid. Palatable.
IN BAGSHOT SAND.														
SUNNINGDALE.														
Well at Broomfield Hall, Nov. 19, 1873.	90	—	22·68	**·189**	**·037**	·025	0	·058	**0**	3·00	2·2	8·7	10·9	Palatable.
WOKING.														
Well in Woking Prison, Nov. 7, 1868.	100	—	31·66	**·224**	**·026**	·004	·064	·093	**350**	3·57	4·9	7·8	12·7	Clear and palatable.
Average	—	—	71·69	**·233**	**·068**	·019	1·383	1·467	**1,686**	14·81	18·9	13·6	32·5	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical data show that deep well waters are liable to become polluted both by mineral and organic impurities; but no sample has been placed in the foregoing table which did not contain such proportions of organic elements, as to lead to the conclusion that organic matter had gained access to the water, without having undergone the purification which results from its passage through a thick stratum of porous and aërated rock. Of the samples just enumerated, the following were but slighted polluted by the presence of actual organic matter, although some of them exhibited strong evidence of previous contamination, which is expressed in emphasised type in the case of all polluted deep well waters, because there is here no guarantee that the originally offensive organic matter has been thoroughly oxidised and destroyed:—

Mr. Sandeman's well, Dundee.
Bevington Bush well, Liverpool. (Closed since 1857.)
Mr. Playne's well at Theescombe.
Messrs. Clinch and Co.'s well, Witney.
Well at Kent Water Co.'s Works, Charlton.
Well at Westridge Farm, Berkshire.

Wherever the previous sewage or animal contamination does not exceed 20,000 parts, there is good ground for anticipating that attention to the upper part of the shaft of the well and its immediate surroundings would remedy the pollution, especially in those cases in which the proportion of organic elements (organic carbon and organic nitrogen) does not much exceed 0·2 part per 100,000 parts. At the time our samples were taken, not one of these wells could be considered free from suspicion, but the following (in addition to the Bevington Bush well, Liverpool, which has been long closed), were dangerous to the health of persons drinking the water and ought to be closed:—

Well in Tanyard, Bromyard.
Well in Brewery near Holyrood Palace (not used by the public).
Mr. W. Spottiswoode's well at Sevenoaks.
Well at Mr. Hill's brewery, Deal.
Well in Eastwick Lane, Great Bookham.
Well in Tanner Lane, Great Bookham.
Well at Westridge Green Farm.
Well at Hartlands, Cranford.

PART II. CLASSIFICATION.

Unpolluted spring waters in Granite and Gneiss.

CLASS VI.—SPRING WATERS.

DIVISION I.—UNPOLLUTED SPRING WATERS.

SECTION I.—UNPOLLUTED WATERS FROM SPRINGS IN GRANITE AND GNEISS.

The following table records the results obtained by the analysis of eight samples of water from springs issuing out of Granite or Gneiss. All the samples were collected by ourselves:—

COMPOSITION OF SPRING WATER FROM GRANITE AND GNEISS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
ENGLAND AND WALES													
CAMBORNE, CORNWALL.													
Spring at Blackrock, Sept. 18, 1872.	10·8°	7·30	·038	·001	0	·193	·194	1,610	3·10	·8	1·9	2·7	Clear and palatable.
MALVERN, WORCESTERSHIRE.													
Spring in tunnel, Aug. 1, 1873.	10·6	9·44	·031	·009	·002	·173	·184	1,420	1·20	·3	5·3	5·6	Clear and palatable.
Upper spring in Green Valley, Aug. 1, 1873.	11·2	6·48	·037	·009	·001	·144	·154	1,130	1·20	0	3·5	3·5	Clear and palatable.
PLYMOUTH.													
Water supply from Dartmoor, June 10, 1871.	12·5	3·50	·050	·019	0	0	·019	0	1·30	0	2·1	2·1	Turbid.
ST. AUSTELL, CORNWALL.													
Spring in Clay pit, June 7, 1871.	9·3	5·60	0	0	·001	·012	·013	0	2·30	1·2	1·7	2·9	Clear and palatable.
Water supply, June 9, 1871	12·0	7·88	·011	·005	·001	·204	·210	1,730	2·65	0	2·3	2·3	Clear and palatable.
SCOTLAND.													
ABERGELDIE.													
Spring at the Castle, March 9, 1872.	7·5	5·92	·049	·009	0	·120	·129	880	1·25	·9	2·9	3·8	Clear and palatable.
BALMORAL.													
Rabate Fountain, March 9, 1872.	6·5	1·40	·119	·014	0	0	·014	0	·55	0	1·2	1·2	Slightly turbid. Palatable.
Average	—	5·94	·042	·008	·001	·106	·115	846	1·69	·4	2·6	3·0	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These analytical numbers lead to the following conclusions as to the quality of unpolluted spring water from Granite and Gneiss.

The total solid impurity of these waters is usually very insignificant. Of all samples of spring, well, or river water from this or any source hitherto examined by us, the water supplied to Your Majesty's Highland residence from the Rabate fountain contained the smallest proportion of solid impurity. The whole of the foreign matter found in this water only amounted to 1·4 part per 100,000 parts, or less than one grain per gallon. The proportion of total solid impurity in the eight samples enumerated in the foregoing table varied from that just given, to 9·44 parts per 100,000, or 6·61 grains per gallon, in the water of the spring at Malvern, the average being 5·94 parts per 100,000, or 4·16 grains per gallon.

Organic elements.—The proportion of organic elements (organic carbon and organic nitrogen) in all these waters was very small. It varied from *nil*, in the spring water issuing from a porcelain clay-pit near St. Austell; to ·133 part in 100,000 parts, or ·093

PART II. CLASSIFICATION.

Spring water from Silurian rocks.

grain per gallon in the water of the Rabate fountain, and averaged ·050 part per 100,000 parts, or ·035 grain per gallon. The proportion of nitrogen to carbon in the organic matter ranged from N : C = 1 : 38 in the water from the spring at Blackrock near Camborne; to N : C = 1 : 2·2 in the water supplied to St. Austell, the average proportion being N : C = 1 : 9·19.

Previous sewage or animal contamination.—In three of the samples there is no evidence of previous pollution by animal matter, and in the remainder that evidence is small and unimportant. In no case does it even distantly approach the numerical expression (10,000 parts in 100,000) which would throw suspicion upon the quality of the water.

Hardness.—The hardness of spring water from Granite and Gneiss is usually very trifling; in the samples mentioned in the foregoing table it varied from 1°·2 in the water of the Rabate fountain water to 5°·6 in the spring in the tunnel at Malvern, and averaged 3°.

General character.—Unpolluted spring water from the Granite and Gneiss is quite wholesome and of most excellent quality for drinking, cooking, and all domestic purposes. It is clear, bright, and palatable, and preserves throughout the year as it issues from the spring a nearly uniform temperature, which varies from about 12°·5 C. in the south of England, to 6°·5 C. in the north of Scotland. It is thus, like other spring waters, cool and refreshing in summer, and, in England at least, far removed from the freezing point in winter. The more disintegrated and weathered the rock, the freer will the water be from organic matter. Thus the rock near Balmoral is but little weathered, that at Malvern is more so, whilst the granite at St. Austell is almost completely decomposed, and a large quantity of it converted into porcelain clay. The effect of this disintegration, upon the elements of organic matter, is seen from the following comparison:—

	Proportion of organic elements in 100,000 parts of water.
Balmoral, water from Rabate fountain - - -	·133
Malvern, average in two spring waters - - -	·043
St. Austell, average of two springs - - - -	·008

SECTION II.—UNPOLLUTED WATER FROM SPRINGS IN SILURIAN ROCKS.

The analytical numbers yielded by fifteen samples of water springing from Silurian rocks are contained in the annexed table. All the samples were collected by ourselves, except that from Llandabarn Flat, Aberystwith, and those from Burwarton and Penrhyn:—

COMPOSITION OF SPRING WATER FROM SILURIAN ROCKS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
										Temporary.	Permanent.	Total.	
ENGLAND AND WALES.	°												
ABERYSTWITH.													
Trefechan Spring, Oct. 5, 1872.	11·8	18·24	**·076**	**·011**	·001	·346	·358	3,150	3·70	0	6·7	6·7	Clear and palatable.
South Spring on Llandabarn Flat, Dec. 23, 1869.	—	6·70	**·094**	**·042**	·005	0	·046	0	1·30	0	2·1	2·1	Clear and palatable.
BURWARTON.													
Spring No. 1. July 3, 1872 -	—	7·70	**·066**	**·015**	0	0	·015	0	·90	·3	5·6	5·9	Slightly turbid. Palatable.
Spring No. 2, July 3, 1872 -	—	10·84	**·048**	**·013**	0	·094	·107	620	1·10	·5	6·9	7·4	Slightly turbid Palatable.
Spring No. 3 July 3, 1872 -	—	17·10	**·027**	**·007**	0	·094	·101	620	1·00	6·9	6·0	12·9	Clear and palatable.
MACHYNLLETH, WALES.													
Garrison Spring, Oct. 7, 1872	11·0	11·88	**·054**	**·009**	·001	·619	·629	5,880	2·40	0	3·4	3·4	Slightly turbid. Palatable.
NEWTOWN, MONTGOMERYSHIRE.													
Canal Road Spring, April 27, 1870	—	27·10	**·084**	**·015**	0	·659	·674	6,270	2·70	1·8	9·2	11·0	Clear and palatable.
Lady Well Spring, April 27, 1870.	10·6	16·30	**·011**	**·003**	0	·295	·298	2,630	1·87	1·3	8·0	9·3	Clear and palatable.
PENRHYN, NEAR BANGOR.													
Spring near Penrhyn Castle, March, 10, 1873.	—	11·80	**·096**	**·016**	0	·110	·126	780	3·10	0	5·6	5·6	Clear and palatable.

Spring water from Silurian rocks.

COMPOSITION OF SPRING WATER FROM SILURIAN ROCKS—*continued.*

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
Ffynon Lechid spring, March 28, 1873.	—	4·10	·014	·011	0	0	·011	0	1·60	0	5·1	3·1	Clear and palatable.
Bronydd Ty-gwyn spring, March 28, 1873.	—	3·04	·038	·014	0	0	·014	0	1·70	0	1·5	1·5	Clear and palatable.
Maes Gwyn spring, March 28, 1873.	—	4·85	·057	·019	0	0	·019	0	1·40	0	3·9	3·9	Clear and palatable.
WHITBECK, CUMBERLAND.													
Spring from abandoned cobalt mine, Sept. 25, 1868.	—	4·44	·038	·020	·003	0	·023	0	1·99	·1	1·6	1·7	Clear and palatable.
SCOTLAND.													
HAWICK, ROXBURGH.													
Spring at foot of cemetery, April 1, 1870.	—	26·40	·053	·014	0	·373	·387	3,410	1·57	6·5	9·3	15·8	Clear and palatable.
MELROSE.													
Water supply, April 5, 1870 -	—	14·50	·013	·002	0	·077	·079	450	1·32	4·5	6·2	10·7	Clear and palatable.
Average - -	—	12·33	·051	·014	·001	·178	·192	1,587	1·84	1·5	5·3	6·8	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Upon these results we have the following remarks to offer :—

Total solid impurity.—The Silurian rocks contain more soluble matter than is met with in Granite or Gneiss, and consequently the total solid impurity found in spring water issuing from the former much exceeds, as a rule, that contained in the water springing from the latter. It varied in the foregoing samples from 3·04 parts in 100,000, or 2·13 grains per gallon, in the water from Bronydd Ty-gwyn spring at Penrhyn ; to 27·1 parts per 100,000, or 18·97 grains per gallon, in the water from the Canal Road spring at Newtown, and averaged 12·33 parts per 100,000, or 8·63 grains per gallon..

Organic elements.—The proportion of organic elements in the samples enumerated in the foregoing table was in all cases very small. It varied from ·014 part in 100,000 parts, or ·01 grain per gallon, in the water from Lady Well spring, Newtown; to ·136 part in 100,000 parts, or ·095 grain per gallon, in the water from the south spring on Llandabarn Flat near Aberystwith, and averaged ·065 part per 100,000 parts, or ·045 grain per gallon. The proportion of nitrogen to carbon in the organic matter ranged from— N : C = 1 : 1·27 in the Ffynon Lechid spring near Penrhyn ; to N : C = 1 : 6·91 in the Trefechan spring, Aberystwith, the average being N : C = 1 : 4·1.

Previous sewage or animal contamination.—In six out of fifteen samples recorded in the foregoing table, there was no evidence whatever of previous animal contamination ; and amongst the remaining samples there was not one, in which this evidence was sufficiently strong to cast any suspicion upon the wholesomeness of the water.

Hardness.—The hardness of spring water from Silurian rocks varied from 1°·5 in the Bronydd Ty-gwyn spring at Penrhyn to 15°·8 in the spring at the foot of the Hawick cemetery, and averaged 6°·8.

General character.—Unpolluted spring water from Silurian rocks contains but a moderate proportion of solid matter in solution, and nearly the whole of this consists of innocuous mineral salts. The proportion of organic matter is very small, and the water is generally soft. This kind of water is always clear and sparkling at the spring, it is also palatable, refreshing and wholesome; and is well adapted for drinking, cooking, and washing purposes.

CLASSIFICATION.

Spring water in Devonian rocks.

SECTION III.—UNPOLLUTED WATER FROM SPRINGS IN DEVONIAN ROCKS, AND OLD RED SANDSTONE.

The following table contains the results of our analyses of twenty-two samples of unpolluted spring water from Devonian rocks and Old Red Sandstone. All the samples were collected by ourselves, except those from Bromyard and Hereford:—

COMPOSITION OF SPRING WATER FROM DEVONIAN ROCKS, AND OLD RED SANDSTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
										Temporary.	Permanent.	Total.	
ENGLAND AND WALES.													
BROMYARD, HEREFORDSHIRE.													
Spring by the brook, Aug. 8, 1869.	—	45·60	·057	·019	·001	1·342	1·362	13,110	2·80	19·3	10·6	29·9	—
CHEPSTOW, MONMOUTHSHIRE.													
Water supply, June 19, 1871	—	7·80	·052	·015	0	·013	·028	0	1·30	·4	5·6	6·0	Turbid. Palatable.
DARTMOUTH, DEVON.	°												
South Town water supply, Sept. 28, 1872.	14·2	19·94	·059	·010	0	·275	·285	2,480	3·00	2·8	7·6	10·4	Clear and palatable.
Water supply at Castle Hotel, Jan. 8, 1873.	11·1	17·36	·060	·016	0	·330	·346	2,980	2·45	1·6	10·0	11·6	Turbid. Palatable.
HELSTON, CORNWALL.													
Five wells shoot, Jan. 4, 1873	12·2	72·72	·071	·019	·006	4·104	4·128	40,770	13·80	0	10·1	10·1	Clear and palatable.
HEREFORD.													
Spring No. 1, Lunatic Asylum, May 11, 1871.	—	40·00	·009	·011	0	·867	·878	8,350	2·88	22·4	6·7	29·1	Clear and palatable.
LISKEARD, CORNWALL.													
Water supply, Sept. 24, 1872	12·0	5·50	·116	·021	·001	·014	·036	0	1·70	·3	1·9	2·2	Slightly turbid.
Pipe Well, in Pipe Lane, Sept. 24, 1872.	11·5	31·68	·029	·006	·001	1·407	1·414	13,760	5·20	0	11·4	11·4	Clear and palatable.
LOSTWITHIEL, CORNWALL.													
Spring supplying town, Sept. 19, 1872.	13·0	15·16	·025	·010	·002	·401	·413	3,710	3·35	0	7·3	7·3	Clear and palatable.
PADSTOW, CORNWALL.													
Spring intended for water supply, Jan. , 1873.	--	39·92	·079	·015	·001	·537	·553	5,060	4·10	19·8	8·1	27·9	Clear and palatable.
PENZANCE.													
Madron spring, Sept. 17, 1872	11·8	8·44	·090	·004	0	·216	·222	1,860	3·60	·0	3·2	3·2	Clear and palatable.
Alverton spring, Sept. 18, 1872	12·3	25·36	·021	·001	0	·933	·934	9,010	3·10	·5	8·9	9·4	Clear and palatable.
REDRUTH, CORNWALL.													
Dopp's Adit, Sept. 18, 1872 -	13·6	15·90	·070	·008	0	·174	·182	1,420	3·45	0	6·0	6·0	Slightly turbid. Palatable.
Drump's Adit, Sept. 18, 1872	11·4	13·82	·124	·008	0	·421	·429	3,890	3·50	0	4·4	4·4	Very turbid. Palatable.
Standpipe, Buller's Row, Sept. 18, 1872.	12·5	12·54	·039	·022	·002	·124	·148	940	2·90	1·2	3·8	5·0	Slightly turbid. Palatable.
ST. GERMANS, CORNWALL.													
Water supplied to Port Elliot, Sept. 29, 1872.	12·0	34·72	·034	·006	0	·881	·887	8,490	3·75	·8	12·4	13·2	Clear and palatable.
TAVISTOCK, DEVON.													
Water supply, Sept. 25, 1872	12·0	6·82	·093	·014	·001	·122	·137	910	1·60	·2	2·3	2·5	Slightly turbid. Palatable.
Spring supplying workhouse, Sept. 25, 1872.	11·3	11·08	·017	·003	0	·365	·368	3,330	2·10	0	5·0	5·0	Clear and palatable.
SCOTLAND.													
BRECHIN.													
Water supply, March 11, 1872.	7·7	16·98	·059	019	0	·390	·409	3,580	1·40	3·7	6·9	10·6	Clear and palatable.
DUNDEE.													
Lady Well spring, Sept. 15, 1870.	11·1	66·90	·026	·034	0	3·260	3·294	32,280	10·00	15·0	9·2	24·2	Clear and palatable.
JEDBURGH.													
Water supply, March 31, 1870.	—	21·94	·021	·003	0	·124	·127	920	1·30	12·7	6·9	19·6	Clear and palatable.
MONTROSE.													
Spring in Glenskenno, March 11, 1872.	7·5	21·06	·038	·007	0	·498	·505	4,660	2·45	5·5	9·9	15·4	Clear and palatable.
Average - -	—	25·06	·054	·012	·001	·764	·777	7,339	3·85	4·8	7·2	12·0	

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

Part II. Classification.

Spring water in Devonian rocks.

These analytical results suggest the following remarks on the quality of unpolluted spring water issuing from Devonian rocks and the Old Red Sandstone:—

Total solid impurity.—The rocks of these formations contain still more soluble matters than their subjacent geological neighbours, as is evidenced by the larger proportions of total solid matters in solution contained in spring waters issuing from the former. The total solid impurity present in the samples in the foregoing table rose to 72·72 per 100,000 in the water of the Five-wells Shoot at Helston, but the large proportions of chlorine and of previous sewage contamination found in this sample prove it to have been originally much polluted. Rejecting this and the other previously much polluted samples, the proportion of total solid impurity ranged from 40 parts per 100,000, or 28 grains per gallon, in the water from spring No. 1 at the Hereford Lunatic Asylum; to 5·5 parts per 100,000, or 3·85 grains per gallon, in the water supplied to Liskeard, and averaged 18·57 parts per 100,000, or 13 grains per gallon.

Organic elements.—The proportion of organic elements found in these waters was exceedingly small. It varied from ·02 part per 100,000 parts, or ·014 grain per gallon, in spring No. 1 at the Hereford Lunatic Asylum, and in the spring supplying Tavistock workhouse; to ·137 part in 100,000, or ·096 grain per gallon, in the water supplied to Liskeard, the average in twenty-two samples being ·066 part per 100,000, or ·046 grain per gallon.

Previous sewage or animal contamination.—In only two cases was the evidence of previous pollution by animal matter strong enough to place the samples in the category of dangerous waters; these were the sample from Five-wells Shoot at Helston, Cornwall, which exhibited a previous sewage or animal contamination of 40,770 parts in 100,000, and the sample from Lady Well spring in Dundee, which showed 32,280 parts per 100,000 of such previous contamination. In two other cases the proportion of previous pollution was sufficient to cast suspicion on the wholesomeness of the water. These were the spring by the brook at Bromyard, and the spring water of Pipe Well in Liskeard, Cornwall. The waters supplied to Chepstow and to Liskeard were alone free from all evidence of this kind, but in all other cases, except those just mentioned, the testimony was insufficient even to render the water suspicious.

Hardness.—The spring waters from the Devonian and Old Red Sandstone rocks contain, as a rule, more calcareous matter than do those issuing from Silurian or Igneous rocks. In the foregoing samples the hardness varied from 2°·2, in the water supply of Liskeard; to 29°·9 in the spring by the brook at Bromyard, and averaged 12°.

General character.—The springs issuing from Devonian rocks and Old Red Sandstone furnish water which is generally of most excellent quality—clear, bright, palatable, and wholesome. It contains but mere traces of organic matter, and is usually soft, or of but moderate hardness. The only samples in the foregoing table, which we could not recommend for domestic use, are those just specially alluded to in the paragraph on previous sewage or animal contamination. It would be desirable to discontinue immediately the use of the two waters there referred to as dangerous. Although unpolluted at the spring, they have originally been contaminated with very large quantities of sewage.

PART II. CLASSIFICATION.

Spring water in Mountain Limestone.

SECTION IV.—UNPOLLUTED WATER FROM SPRINGS IN MOUNTAIN LIMESTONE.

The following table contains the results of our analyses of thirteen samples of water obtained from springs issuing from the Mountain Limestone. All the samples were collected by ourselves:—

COMPOSITION OF SPRING WATER FROM MOUNTAIN LIMESTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.											Remarks.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	
BAKEWELL.													
Spring, proposed supply to, May, 1872.	—	32·10	·034	·005	0	·112	·117	800	1·40	14·3	7·2	21·5	Clear and palatable.
BERWICK-ON-TWEED.	°												
Spring at the Foundry, Tweedmouth, Sept. 20, 1870.	11·7	30·36	·027	·011	0	·529	·540	4,970	3·85	3·1	8·3	11·4	Clear and palatable.
Nine Wells Eye spring, Sept. 20, 1870.	10·3	41·50	·029	·014	0	1·022	1·036	9,900	5·24	6·7	12·9	19·6	Clear and palatable.
BUXTON, DERBYSHIRE.													
So-called chalybeate spring, Oct. 11, 1872.	9·6	21·76	·204	·023	·006	·122	·150	950	·85	2·1	8·9	11·0	Slightly turbid. Palatable. *Contains no iron.*
St. Ann's mineral water, Oct. 11, 1872.	26·9	29·16	·017	0	·001	0	·001	0	3·80	4·4	10·3	14·7	Clear and palatable.
Intermittent spring at Barmer Clough, Oct. 11, 1872.	8·0	32·04	·090	·015	·002	·099	·116	690	·70	20·9	7·0	27·9	Slightly turbid. Palatable.
GIGGLESWICK, YORKSHIRE.													
Intermittent spring, June 14, 1869.	—	20·98	·011	·007	0	·040	·047	80	·98	10·9	5·5	16·4	Clear and palatable.
HOLYWELL, FLINTSHIRE.													
St. Winifred's well, May 19, 1873.	11·1	36·44	·045	·009	0	0	·009	0	6·30	19·1	5·4	24·5	Slightly turbid. Palatable.
MALHAM, YORKSHIRE.													
Spring in Gordale Gorge, Sept. 30, 1869.	7·9	19·90	·176	·012	0	·064	·076	320	·90	12·1	4·5	16·6	Clear and palatable.
Aire Head spring, below Malham, Sept. 30, 1869.	10·0	15·70	·165	·007	·001	·017	·025	0	·99	8·9	3·3	12·2	Clear and palatable.
Spring in Malham Cove, Sept. 30, 1869.	8·0	16·20	·286	·014	0	·012	·026	0	1·15	11·6	4·5	16·1	Clear and palatable.
TOTNESS, DEVON.													
Water supply, Sept. 30, 1872.	12·8	22·14	·019	·003	0	·245	·248	2,130	2·05	8·1	9·1	17·2	Clear and palatable.
WESTON-SUPER-MARE.													
Water supply, Sept. 4, 1873.	13·8	98·50	·028	·006	0	·658	·664	6,260	32·00	19·0	29·5	48·5	Clear. Slight saline taste.
Average	—	32·06	·087	·010	·001	·224	·235	2,008	4·63	10·9	8·9	19·8	

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

Upon these analytical results we have to offer the following remarks on the quality of the waters:—

Total solid impurity.—The total solid impurity contained in the foregoing samples of spring water from the Mountain Limestone varied from 15·7 parts in 100,000, or 10·99 grains per gallon, in the large spring below Malham, constituting one of the chief sources of the *Aire;* to 98·5 parts per 100,000, or 68·95 grains per gallon, in the water supplied to Weston-super-Mare; this large proportion is, however, quite exceptional and is probably caused by access of sea water. Rejecting it from the comparison, the next largest proportion was 41·5 parts per 100,000, or 29·05 grains per gallon, which was found in the Nine Wells Eye spring at Berwick-on-Tweed. Again omitting the sample from Weston-super-Mare; the average proportion of total solid impurity was 26·52 parts per 100,000 or 18·56 grains per gallon.

Organic elements.—These vary in the different samples between wide limits. The proportion ranged from ·017 part per 100,000 parts, or ·012 grain per gallon, in the celebrated hot spring in St. Ann's well, Buxton; to ·3 part per 100,000 parts, or ·21 grain per gallon, present in the water of the so-called spring at the base of Malham Cove which constitutes one of the chief sources of the *Aire*. The average proportion in the thirteen samples was ·097 part per 100,000 parts, or ·068 grain per gallon.

Part II. Classification. — Springs in Millstone Grit.

The proportion of nitrogen to carbon in the organic matter was as follows :—

Maximum - - - - - - - N : C = 1 : 1·57
Minimum - - - - - - - N : C = 1 : ∞
Average - - - - - - - N : C = 1 : 8·54

Previous sewage or animal contamination.—In four out of the thirteen samples there was no evidence whatever of previous pollution by animal matter; in two others the evidence was very slight, and in no case was it strong enough to place the sample in the category of suspicious waters.

Hardness.—All the samples were hard, and the hardness of the exceptional sample from Weston-super-Mare was excessive. Omitting this sample, the hardness ranged from 11° in the so-called chalybeate water of Buxton; to 27°·9 in the intermittent spring at Barmer Clough, five miles to the east of Buxton. The average hardness of the twelve samples was 17°·4.

General character.—Many of the so-called springs in mountain limestone are in reality subterranean rivers, and their water assimilates itself therefore to that collected from the surface of the same stratum. This is the case with the huge springs around Malham, which constitute the sources of the *Aire* (*see* Third Report, Vol. I., p. 3) and the so-called chalybeate spring at Buxton is another instance of the same kind. The water of this last-named spring is sold to patients as a chalybeate, but neither of two samples which we collected on separate occasions contained any appreciable trace of iron. The true spring waters from the Mountain Limestone are clear, colourless, palatable, and wholesome, and suitable for all domestic purposes except washing, for which they are too hard. They may, however, be effectually softened by Clark's process. (*See* page 205.) The pseudo-spring waters are also wholesome, but not quite so palatable owing to the presence of peaty matter. For the same reason they are also generally slightly coloured. The Mountain Limestone at Berwick-on-Tweed is coal-bearing.

Section V.—Unpolluted Water from Springs in the Yoredale and Millstone Grits.

The two tables next following contain the results of our analyses of eight samples of unpolluted spring water from the Yoredale and Millstone Grits, and of fourteen samples from springs issuing from the Coal-measures. All the samples were collected by ourselves, except those from Hawes, Hebden Bridge, Ardsley, Ripon, Saltaire, Sheffield, and Dalkeith :—

Composition of Spring Water from the Yoredale and Millstone Grits.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
Hawes near Bedale, Yorkshire.													
Holme Well, April 5, 1872 -	—	33·48	**·109**	**·028**	·006	·617	·650	5,900	2·20	18·1	7·9	26·0	Slightly turbid. Palatable.
Hebden Bridge, near Halifax.													
Tanpits. Lister spring, March 10, 1873.	—	12·32	**·060**	**·016**	·001	·266	·283	2,350	1·30	0	6·1	6·1	Clear and palatable.
Spring at Wood Top, March 10, 1873.	—	6·52	**·019**	**·005**	0	·021	·026	0	·95	0	3·0	3·0	Slightly turbid. Palatable.
Hexham, Northumberland.													
The Seal well, Sept. 30, 1871	8·2°	29·16	**·017**	**·012**	0	·440	·452	4,080	2·05	10·3	11·5	21·8	Clear and palatable.
Penny well, Sept. 30, 1871 -	7·1	40·80	**·021**	**·008**	0	0	·008	0	3·45	21·4	5·0	26·4	Very turbid. Palatable.
Ilkley, Yorkshire.													
Spring flowing into baths, Dec. 8, 1873.	8·3	11·42	**·023**	**·005**	0	0	·005	0	1·20	2·6	6·0	8·6	Clear and palatable.
Ripon.													
Spring, one source of the *Laver*, Jan. 27, 1874.	—	3·32	**·046**	**·004**	·001	0	·005	0	1·10	0	2·7	2·7	Clear and palatable.
Swansea.													
Water supply, June 21, 1871	—	4·80	**·037**	**·012**	·001	·007	·020	0	1·55	·3	3·2	3·5	Slightly turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Part II. Classification.

Spring water in Coal Measures.

Section VI.—Unpolluted Water from Springs in the Coal Measures.

Composition of Spring Water from the Coal Measures.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
ENGLAND AND WALES.													
Ardsley near Wakefield. Adit from old workings of Middleton coal pit, June 8, 1873.	10·0	39·60	·059	·019	0	0	·019	0	2·35	8·6	17·1	25·7	Turbid and palatable.
Saltaire. Spring near Saltaire, Jan. 26, 1874.	—	23·56	·077	·017	0	·906	·923	8,740	2·30	0	11·0	11·0	Clear and palatable.
Huddersfield. Springs at Longwood, Sept. 23, 1869.	—	11·48	·049	·018	·001	·066	·085	350	1·20	0	6·5	6·5	Clear and palatable.
Rochdale. Spring near churchyard, "Packers Spout," June 26, 1868.	—	37·04	·070	·046	·001	1·813	1·860	**17,818**	2·98	·5	13·9	14·4	Clear and palatable.
Sheffield. Samson's Spring, South Yorkshire Asylum, Sep. 27, 1870.	—	6·84	·039	·010	·008	·119	·136	940	1·05	·3	2·3	2·6	Clear and palatable.
SCOTLAND.													
Ayr. Water supply, April 7, 1870.	—	20·44	·034	·004	·001	·158	·163	1,270	1·85	1·5	10·1	11·6	Clear and palatable.
Dalkeith. Spring proposed for supply of town, Dec. 19, 1871.	—	30·10	·051	·027	0	·309	·336	2,770	1·76	14·5	10·9	25·4	Turbid. Palatable.
Edinburgh. Comiston water, April 6, 1870.	8·1	22·94	·029	·010	·001	·858	·869	8,270	2·00	3·5	8·1	11·6	Clear and palatable.
Colinton water, April 6, 1870.	8·3	13·60	·053	·009	·001	0	·010	0	·95	5·0	4·8	9·8	Clear and palatable.
Swanston water, April 6, 1870.	7·2	13·48	·067	·007	0	·062	·069	300	1·26	4·5	5·6	10·1	Clear and palatable.
Kelso. Water supply from springs, April 4, 1870.	—	32·52	·035	·006	0	·684	·690	6,520	2·25	4·8	11·7	16·5	Clear and palatable.
Linlithgow. Fountain in front of Council Hall, Aug. 1, 1870.	—	26·84	·030	·014	0	·524	·538	4,920	1·80	12·4	5·9	18·3	Slightly turbid. Palatable.
Stirling. The Butt well (large spring), Aug. 21, 1872.	8·5	33·80	·120	·025	0	1·084	1·109	**10,520**	3·35	0	12·4	12·4	Clear and palatable.
St. Ninian's well (large spring), Aug. 21, 1872.	7·8	28·00	·048	·009	0	·712	·721	6,800	1·80	5·4	8·7	14·1	Clear and palatable.
Average of Sections V. & VI.	—	21·91	·050	·014	·001	·393	·408	3,707	1·85	5·2	7·9	13·1	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The numbers contained in the foregoing tables lead to the following conclusions:—

Total solid impurity.—Some of the samples in the foregoing tables contained a moderate proportion of total solid matters in solution, but in most of them were found a large, though never an excessive, proportion. It varied from 3·32 parts per 100,000, or 2·32 grains per gallon, in the spring near Ripon; to 40·8 parts per 100,000, or 28·56 grains per gallon, in the Penny well at Hexham, and averaged 21·91 parts per 100,000, or 15·34 grains per gallon. Nearly the whole of this solid impurity was saline matter, which was in all cases innocuous to health.

Organic elements.—The chief elements (organic carbon and organic nitrogen) of the organic matter forming a minute proportion of the total solid impurity, were found in proportions which varied from ·024 part per 100,000 parts, or ·017 grain per gallon, in the water from a spring at Wood Top, Hebden Bridge, near Halifax; to ·145 part per 100,000 parts, or ·101 grain per gallon, in the water of Butt Well spring at Stirling. The average proportion in the twenty-two samples was ·064 part per 100,000 parts, or ·045 grain per gallon.

Part II. Classification.

Spring water in Magnesian Limestone.

The proportion of nitrogen to carbon in the organic matter of these waters varied from—N : C = 1 : 11·5 in the spring near Ripon; to N : C = 1 : 1·42 in the water from the Seal Well at Hexham, the average being N : C = 1 : 4·42.

Previous sewage or animal contamination.—Seven of the samples presented no evidence of previous animal pollution, and of the remainder, only two exhibited sufficient to raise a suspicion of the wholesomeness of the water. These were the water from the spring near a churchyard in Rochdale, and the other the Butt Well spring in Stirling. In the remaining samples this evidence may be safely disregarded.

Hardness.—The unpolluted spring water both from the Yoredale and Millstone Grits and the Coal-measures varies in hardness between wide limits. In the samples enumerated in the foregoing tables, it ranged from 2°·6, in the water from Sampson's spring, South Yorkshire Asylum, near Sheffield; to 26°·4, in the water from Penny well at Hexham, and averaged 13°·1.

General character.—These waters are clear, palatable, and wholesome. They contain but a very minute proportion of organic matter, and are generally of moderate hardness. They are therefore well suited for drinking, cooking, washing, and all other domestic purposes. The harder samples might, as a rule, be softened by Clark's process (*See* page 205.)

Section VII.—Unpolluted Spring Water from Magnesian Limestone.

The following are the results of our analysis of the only sample of spring water from Magnesian Limestone which we have obtained:—

Composition of Spring Water from Magnesian Limestone.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Pontefract, Yorkshire. Spring in Waterham's Field, Jan. 24, 1872.	66·52	**·058**	**·038**	·002	1·686	1·726	**16,560**	3·40	24·9	34·8	59·7	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

This sample of water had been previously polluted to such an extent as to mask its true character. It contained but a minute proportion of organic matter, although it exhibited so much evidence of previous contamination with animal matter as to relegate it to the class of suspicious waters. It was also excessively hard, and differed from the sample of deep well water from the same stratum used for the supply of Sunderland, and described at page 92, by having a large amount of temporary hardness.

Section VIII.—Unpolluted Water from Springs in the New Red Sandstone.

We have examined numerous samples of unpolluted spring water from the New Red Sandstone, and the analytical results obtained are embodied in the following table. The samples from Birmingham, Leek, Leyland, Runcorn, Warrington, and Coventry were collected by ourselves; the remainder were forwarded to us chiefly through the Local Government Act Office:—

Spring water in New Red Sandstone.

COMPOSITION OF SPRING WATER FROM THE NEW RED SANDSTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ATHERSTONE, WARWICKSHIRE.													
Higher spring proposed for supply of town, June 19, 1873.	—	16·10	**·068**	**·028**	·002	·054	·084	240	1·70	0	10·1	10·1	Clear and palatable.
BARNARD CASTLE.													
Spring in railway rock cutting, Aug. 1871.	—	23·56	**·037**	**·011**	0	0	·011	0	1·50	13·5	7·1	20·6	Turbid. Palatable.
BIRMINGHAM.													
James's spring below Witton reservoir, May 16, 1873.	9·7	15·54	**·052**	**·019**	·001	·504	·524	4,730	1·75	0	8·3	8·3	Clear and palatable.
COVENTRY.													
Allesley Road spring entering tank, Oct. 22, 1873.	10·8	32·66	**·067**	**·018**	0	·338	·356	3,060	1·70	15·7	9·4	25·1	Clear and palatable.
Flowing spring from bore-hole, 200 feet deep, Oct. 22, 1873.	10·8	26·88	**·018**	**·004**	0	·306	·310	2,740	1·60	11·1	8·0	19·1	Clear and palattable.
DAWLISH.													
Spring head, March 19, 1874	—	12·90	**·118**	**·023**	·014	0	·035	0	2·10	2·6	5·4	8·0	Turbid. Palatable.
HUGGLESCOTE, LEICESTERSHIRE.													
Mr. W. Griffin's spring in Donington, Jan. 4, 1872.	—	33·86	**·104**	**·027**	0	·234	·261	2,020	1·40	19·8	15·9	35·7	Slightly turbid. Palatable.
HURWORTH, DURHAM.													
Spring at Cross Bank Hill, May 20, 1870.	—	74·26	**·080**	**·006**	0	0	·006	0	3·37	4·0	25·0	29·0	Clear and palatable.
KNUTSFORD, CHESHIRE.													
Spring at Rosthorne, March, 1872.	—	33·76	**·070**	**·018**	·001	1·256	1·275	**12,250**	3·25	4·9	15·7	20·6	Clear and palatable.
LEEK, STAFFORDSHIRE.													
Spring, Staffordshire Potteries Water Company, May 19, 1873.	—	13·84	**·031**	**·015**	0	·146	·161	1,140	1·30	4·7	4·2	8·9	Clear and palatable.
NOTTINGHAM.													
Spring in forest, Feb. 11, 1869.	—	21·96	**·032**	**0**	0	·844	·844	8,120	1·60	·9	11·0	11·9	Clear and palatable.
RUNCORN, CHESHIRE.													
Public fountain, May 18, 1868.	—	60·80	**·118**	**·011**	0	·382	·393	3,510	7·00	8·1	17·2	25·3	Clear and palatable.
SUDBURY, DERBYSHIRE.													
Spring near village, July 6, 1872.	—	20·30	**·056**	**·014**	0	·354	·368	3,220	1·30	9·3	7·0	16·3	Slightly turbid. Palatable.
Spring in coppice near village, June 17, 1873.	—	19·60	**·097**	**·069**	·001	·221	·291	1,900	1·60	18·8	6·9	25·7	Clear and palatable.
WARRINGTON.													
Spa spring near Winwick, May 25, 1868.	—	24·34	**·027**	**·002**	0	·310	·312	2,780	1·64	7·9	10·2	18·1	Clear and palatable.
Average - -	—	28·69	**·065**	**·017**	·001	·330	·349	3,047	2·19	8·1	10·7	18·8	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Upon these results we have to offer the following observations:—

Total solid impurity.—The New Red Sandstone rarely contains an excessive amount of constituents soluble in water, and nearly the whole of the solid impurity in the foregoing samples consisted of saline matters which were not injurious to health. The total solid impurity in these samples varied from 12·9 parts in 100,000, or 9·03 grains per gallon, in the spring at Dawlish; to 74·26 parts per 100,000, or 51·98 grains per gallon, found in the water of the spring at Cross Bank Hill, Hurworth; and averaged 28·69 parts per 100,000, or 20·08 grains per gallon.

Part II. Classification.

Spring waters in Lias.

Organic elements.—The proportion of organic elements in these waters varied from ·022 part per 100,000 parts, or ·015 grain per gallon, in the water of the flowing spring at Coventry; to ·166 part per 100,000 parts, or ·116 grain per gallon, in the water from the Coppice spring near Sudbury, the average being ·082 part per 100,000 parts, or ·057 grain per gallon.

The proportion of nitrogen to carbon in the organic matter was as follows:—

$$\text{Maximum } N : C = 1 : 1{\cdot}41$$
$$\text{Minimum } N : C = 1 : 13{\cdot}50$$
$$\text{Average } N : C = 1 : 5{\cdot}33.$$

Previous sewage or animal contamination.—The springs at Dawlish, Hurworth, and Barnard Castle exhibit no evidence of previous pollution by animal matter; and amongst the remaining samples there is only one (the spring at Rosthorne near Knutsford) in which this evidence is sufficiently strong to cast suspicion upon the wholesomeness of the water. In the remaining samples it may be safely ignored.

Hardness.—The New Red Sandstone is always more or less calcareous, and this precludes the presence of soft water in its pores and fissures. The hardness of the samples which we have examined varied from 8°, in the spring head at Dawlish; to 35°·7, in the water of Mr. W. Griffin's spring at Donington, near Hugglescote; and averaged 18°·8. Nearly all the harder samples in the foregoing table could be effectively softened (*see* page 205).

General character.—The unpolluted spring waters from the New Red Sandstone are clear, bright, colourless, palatable, and wholesome. They contain but a very small quantity of organic matter, and are well adapted for all domestic purposes, except washing, for which most of them are too hard. Of the samples mentioned in the foregoing table, the spring from which the Staffordshire Potteries Water Company derives a portion of its supply, the spring in a forest near Nottingham from which it was recently proposed to supply that town, the spring in the railway cutting near Barnard Castle, and the spring at Winwick from which the town of Warrington is now supplied, may be mentioned as waters of especially excellent quality for dietetic purposes.

Section IX.—Unpolluted Water of Springs from the Lias.

The following table contains the results of our analyses of seven samples of unpolluted water from springs on the edge of or issuing from the Lias. All the samples were collected by ourselves except the one from Ilminster:—

Composition of Spring Water from the Lias.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
Bath.													
Monkswood spring, Feb. 17, 1871.	10·0	35·18	·131	·012	0	·328	·340	2,960	1·55	23·1	6·0	29·1	Clear and palatable.
Cheltenham.													
Water supply of, May 31, 1873.	14·0	21·22	·123	·036	0	·305	·341	2,730	1·35	9·1	6·0	15·1	Slightly turbid.
Coaley, Gloucestershire.													
Water supply, Sept. 8, 1873 -	13·5	31·42	·024	·006	0	·061	·067	290	2·00	22·6	5·3	27·9	Clear and palatable.
Frocester, Gloucestershire.													
Spring in Buckholt field, Sept. 9, 1873	11·0	31·30	·111	·035	0	0	·035	0	2·40	18·7	7·3	26·0	Slightly turbid. Palatable.
Grantham.													
Spring water supplied to town, July 11, 1873.	15·0	30·20	·048	·018	0	·833	·851	8,010	2·05	17·1	6·5	23·6	Clear and palatable.
Haydon, near Cheltenham.													
Water supply, Nov. 8, 1871 -	8·2	47·40	·024	·010	0	·410	·420	3,780	3·20	32·3	13·4	45·7	Clear and palatable.
Ilminster, Somerset.													
Public spring in town, March 12, 1872.	—	58·12	·049	·014	·009	1·332	1·353	13,070	4·80	26·1	17·4	43·5	Clear and palatable.
Average - -	—	36·41	·073	·019	·001	·467	·487	4,406	2·48	21·3	8·8	30·1	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

Spring waters in Oolites.

These analytical numbers lead to the following conclusions:—

Total solid impurity.—Like the water from deep walls in the Lias, the spring water from this formation is found to contain a large proportion of solid matters in solution; of this, however, nearly the whole consists of mineral matters which make the water very hard, but are otherwise innocuous. In the samples enumerated in the above table, this total solid impurity varied from 21·22 parts per 100,000, or 14·85 grains per gallon, in the spring water supplied to Cheltenham; to 58·12 parts per 100,000, or 40·68 grains per gallon, in the water of the public spring in the town of Ilminster, and averaged 36·41 parts per 100,000, or 25·49 grains per gallon.

Organic elements.—The proportion of the chief elements of organic matter, (organic carbon and organic nitrogen) contained in the foregoing samples, ranged from ·03 part per 100,000 parts, or ·021 grain per gallon, which was found in the spring water supplied to Coaley, Gloucestershire; to ·159 part per 100,000 parts, or ·111 grain per gallon, which was present in the water supplied to Cheltenham; and averaged ·092 part per 100,000 parts, or ·064 grain per gallon. The proportion of nitrogen to carbon in the organic matter dissolved in these waters varied from N : C = 1 : 10·92 in the Monkswood spring, from which a portion of Bath is supplied; to N : C = 1 : 2·4 in the water supplied to Haydon, near Cheltenham. The average proportion in the seven samples was N : C = 1 : 4·3.

Previous sewage or animal contamination.—The evidence of previous pollution by animal matter was altogether wanting in the spring in Frocester, and it was very small in the water supplied to Coaley. Only in the case of the public spring in the town of Ilminster was this evidence sufficient to cast suspicion on the wholesomeness of the water. In all the other cases it may be safely disregarded.

Hardness.—The hardness of these waters varied from 15·1 in the water supplied to Cheltenham; to 45°·7, in the water supplied, by the Cheltenham Local Board, to Haydon, and averaged 30·1. Most of these waters could be rendered very soft by Clark's process (*see* page 205), and the hardness of the remainder would be greatly ameliorated by it.

General character.—The unpolluted spring waters from the Lias are clear, colourless, palatable and wholesome. They contain the usual minute amount of organic matter found in spring waters. They may be used for all domestic purposes except washing, for which they are much too hard. By treatment with a small quantity of lime, however, they may be softened so as to make them available for washing and cleansing operations.

SECTION X.—UNPOLLUTED WATER FROM SPRINGS IN THE OOLITES.

The annexed table contains the results of analysis of thirty-five samples of unpolluted spring water from the Oolites. All the samples were collected by ourselves, except those from Northampton, Nunney, and Warkton:—

COMPOSITION OF SPRING WATER FROM THE OOLITES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
BATH.													
Spring on Hampton Down, Feb. 17, 1871.	8·1	22·40	·140	·007	0	·100	·107	680	1·30	15·1	3·5	18·6	Slightly turbid. Palatable.
Eyford spring, Feb. 17, 1871.	10·0	30·76	·009	·004	0	·130	·134	980	1·46	21·8	5·4	27·2	Clear and palatable.
BOURNE, LINCOLNSHIRE.													
Well-head at Bourne, Nov. 22, 1873.	10·5	42·92	·104	·020	0	0	·020	0	3·10	23·4	11·8	35·2	Clear and palatable.
CHALFORD, GLOUCESTERSHIRE.													
Spring at Chalford, March 18, 1870.	11·7	28·86	·083	·019	0	·285	·304	2,530	·97	20·9	3·6	24·5	Clear and palatable.
FROME, SOMERSETSHIRE.													
Fountain at foot of churchyard, March 10, 1870.	11·7	52·16	·044	·005	·002	1·136	1·143	11,060	2·75	29·7	9·0	38·7	Clear and palatable.
Spring near Frome, March 16, 1870.	—	34·04	·033	·011	·014	·259	·282	2,390	1·34	18·9	5·3	24·2	Clear and palatable.
GLOUCESTER.													
Head spring of *Arle Brook*, Oct. 31, 1873.	11·8	44·52	·040	·010	0	·026	·036	0	1·60	18·4	13·5	31·9	Clear and palatable.

COMPOSITION OF SPRING WATER FROM THE OOLITES—*continued*.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
LONGFORD, GLOUCESTERSHIRE.													
Source of the *Avon*, March 17, 1870.	10°·8	25·56	**·053**	**·007**	0	·398	·405	3,660	1·22	16·8	4·7	21·5	Clear and palatable.
NORTHAMPTON.													
Garner's spring, near Berrywood, March 1871.	—	31·36	**·009**	**·003**	0	·790	·793	7,580	1·76	17·4	5·9	23·3	Clear and palatable.
NUNNEY, NEAR FROME, SOMERSETSHIRE.													
Spring proposed for water supply, Nov. 1870.	—	31·10	**·011**	**·009**	0	·255	·264	2,230	1·26	19·1	6·0	25·1	Clear and palatable.
SCARBOROUGH.													
Old Waterworks supply, Cayton Bay, Dec. 9, 1873.	10·0	30·38	**·030**	**·007**	0	·074	·081	420	3·30	13·5	8·3	21·8	Clear and palatable.
STROUD, GLOUCESTERSHIRE.													
Water supply from Gainer's well, April 12, 1871.	—	32·92	**·014**	**·011**	0	1·157	1·168	**11,250**	2·58	13·8	8·0	21·8	Clear and palatable.
THAMES BASIN.													
Bourton - on - the - Water, springs above, May 31, 1873.	10·0	26·70	**·023**	**·011**	0	·249	·260	2,170	1·15	17·8	4·9	22·7	Clear and palatable.
Bourton - on - the - Water, Eyeford spring, near, Aug. 2, 1873.	10·0	26·86	**·028**	**·004**	·001	·290	·295	2,590	1·25	18·3	5·6	23·9	Clear and palatable.
Cirencester, Cerney springs, near, Nov. 4, 1870.	10·8	33·86	**·052**	**·016**	·001	·282	·299	2,510	1·30	22·8	3·9	26·7	Clear and palatable.
Cirencester, Cowley springs, near, May 2, 1873.	10·0	24·32	**·027**	**·005**	·001	·232	·238	2,010	1·10	14·5	4·9	19·4	Clear and palatable.
Cirencester, the Seven springs, near, May 2, 1873.	10·2	22·60	**·012**	**·009**	·001	·510	·520	4,790	1·10	11·3	5·6	16·9	Clear and palatable.
Cirencester, Syreford spring, near, May 2, 1873.	10·0	22·84	**·029**	**·008**	0	·222	·230	1,900	1·20	13·8	5·1	18·9	Clear and palatable.
Cirencester, Winson spring, near, May 2, 1873.	10·0	27·54	**·029**	**·011**	0	·427	·438	3,950	1·15	17·1	4·4	21·5	Clear and palatable.
Cirencester, Winson, another spring in pond, May 2, 1873.	12·5	26·24	**·059**	**·022**	0	·164	·186	1,320	1·20	17·4	4·4	21·8	Clear and palatable.
Cirencester, Ablington spring, near, May 2, 1873.	12·0	29·04	**·036**	**·008**	·001	·089	·098	580	1·20	16·7	5·4	22·1	Clear and palatable.
Cirencester, Bibury spring, near, May 2, 1873.	10·5	29·16	**·038**	**·007**	0	·161	·168	1,290	1·15	17·9	5·7	23·6	Clear and palatable.
Cirencester, Ampney Park springs, near, May 2, 1873.	10·5	26·70	**·048**	**·015**	·001	·361	·377	3,300	1·20	15·8	5·7	21·5	Clear and palatable.
Cirencester, the Bitnell spring at Ewen, May 2, 1873.	10·1	28·14	**·025**	**·007**	0	·312	·319	2,800	1·40	19·3	4·0	23·3	Clear and palatable.
Daventry, source of the *Cherwell*, May 7, 1873.	9·0	27·30	**·023**	**·009**	0	·434	·443	4,020	1·70	16·7	5·7	22·4	Clear and palatable.
Donnington Mill, one source of *Windrush*, May 30, 1873.	10·0	27·48	**·039**	**·017**	0	·347	·364	3,150	1·40	17·3	6·6	23·9	Slightly turbid. Palatable.
North Leach, Seven Springs above, May 31, 1873.	9·5	29·82	**·040**	**·015**	0	·489	·504	4,570	1·30	20·6	5·1	25·7	Clear and palatable.
Seizincote, Pope's Hole, source of *Evenlode*, May 30, 1873.	9·9	25·82	**·047**	**·010**	·001	·690	·701	6,590	2·20	12·0	7·1	19·1	Clear and palatable.
Starveall, spring above Coppice, May 31, 1873.	9·5	28·76	**·034**	**·012**	0	·590	·602	5,580	1·30	16·9	7·6	24·5	Clear and palatable.
Stow-on-the-Wold, spring at roadside, May 30, 1873.	9·9	24·44	**·037**	**·010**	0	·753	·763	7,210	1·40	14·3	6·3	20·6	Clear and palatable.
Stow - on - the - Wold, spring flowing into tank, May 30, 1873.	9·3	28·32	**·033**	**·021**	0	1·034	1·055	**10,020**	1·40	13·8	8·0	21·8	Clear and palatable.
Taddington, one source of *Windrush*, May 30, 1873.	11·8	31·20	**·047**	**·014**	0	0	·014	0	1·10	25·7	4·3	30·0	Contains traces of iron.
WARKTON, NEAR KETTERING, NORTHAMPTONSHIRE.													
Cornwell's spring, April 5, 1870.	-	40·20	**·071**	**·015**	0	·682	·697	6,500	1·95	24·3	6·3	30·6	Clear and palatable.
Boughton spring, April 5, 1870.	—	42·90	**·099**	**·016**	0	·854	·870	8,220	1·70	30·0	8·0	38·0	Clear and palatable.
YEOVIL, SOMERSETSHIRE.													
Water supply, March 11, 1873.	8·5	24·76	**·044**	**·007**	·001	·300	·308	2,690	1·65	14·8	6·1	20·9	Clear and palatable.
Average - -	—	30·83	**·043**	**·011**	·001	·402	·414	3,730	1·55	18·2	6·2	24·4	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

Spring waters in Greensands, &c.

The analytical determinations contained in the foregoing table lead to the following conclusions:—

Total solid impurity.—The Oolitic rocks consist almost entirely of carbonate of lime: and this substance being soluble in water containing carbonic acid, springs issuing from the Oolites always contain a large proportion of solid impurity, of which the most abundant constituent is carbonate of lime, the remainder consisting almost entirely of mineral saline matter which is also not injurious to health. In the foregoing samples the total solid impurity varied from 22·34 parts per 100,000 or 15·64 grains per gallon, in the water of Syreford spring, Cirencester; to 52·16 parts per 100,000, or 36·51 grains per gallon, in the water of the spring which supplies the fountain at the foot of Frome churchyard; but this last sample originally entered the Oolite as highly polluted water, and might with propriety be excluded from the comparison, in which case the maximum proportion of total solid impurity would be 44·52 parts per 100,000, or 31·16 grains per gallon, which was found in the head spring of *Arle Brook*. The average proportion in the samples, also excluding that from Frome, was 29·69 parts per 100,000, or 20·78 grains per gallon.

Organic elements.—The unpolluted spring water from the Oolites contains, as a rule, but a very minute proportion of organic elements (organic carbon and organic nitrogen). In the samples catalogued in the foregoing table, the proportion varied from ·147 part per 100,000 parts, or ·103 grain per gallon, in the water of the spring on Hampton Down, Bath; to ·012 part per 100,000 parts, or ·008 grain per gallon, in the water from Garner's spring, near Northampton, the average proportion being ·054 part per 100,000 parts, or ·038 grain per gallon.

The proportion of nitrogen to carbon in the organic matter ranged from N : C = 1 : 20 in the water from the spring on Hampton Down, at Bath; to N : C = 1 : 1·22 which was observed in the water of the spring at Nunney. On the average the proportion was N : C = 1 : 4·28.

Previous sewage or animal contamination.—Amongst the thirty-five samples there were only three which did not exhibit some evidence of previous pollution by organic matter of animal origin, but in only three cases was this evidence strong enough to cast suspicion upon the wholesomeness of the water, and even in these cases the suspicion was very slight.

Hardness.—Omitting, for reasons just mentioned, the sample from the churchyard fountain at Frome, the hardness of the Oolitic spring waters varied from 16°·9 in the Seven Springs, Cirencester; to 38° in the Boughton spring at Warkton, near Kettering; the average being 24°. The hardness of these waters was chiefly of the temporary kind.

General character.—Unpolluted spring water from the Oolites is unsurpassed in its comparative freedom from all kinds of organic impurity. It is clear, colourless, palatable, and wholesome, and fit for all household purposes except washing, for which it is too hard. It may, however, always be effectively softened by Clark's inexpensive process, and it then unites all the qualities which are most desirable in water supplied for domestic use. The Oolitic rocks are very porous, absorbing, and holding enormous volumes of water, which are again delivered as springs, usually of great size. As water-bearing strata or as a subterranean reservoir for the purification and storage of water, the Oolitic rocks are equal, if not superior, to the Chalk itself. But this vast store of magnificent water is rarely supplied to communities until it has been hopelessly fouled in river channels, by polluting matters of the most disgusting description.

The next two tables contain the results of analysis of nineteen samples of water from the Lower Greensand and Hastings Sand, and from the Upper Greensand. All the samples were collected by ourselves except the one from Frome.

SECTION XI.—UNPOLLUTED WATER FROM SPRINGS IN THE LOWER GREENSAND AND HASTINGS SAND.

COMPOSITION OF UNPOLLUTED SPRING WATER FROM THE LOWER GREENSAND AND HASTINGS SAND.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
FARNHAM. Spring in Mother Ludlam's Cave, Moor Park, 1868.	—	4·55	**·030**	**·010**	·001	·034	·045	30	—	0	·7	·7	Clear and palatable.

COMPOSITION OF UNPOLLUTED SPRING WATER FROM THE LOWER GREENSAND, &c.—*continued.*

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
HASTINGS.													
Dr. Maccabe's spring, Feb. 21, 1873,	10·0	14·92	·024	·005	0	·433	·438	4,010	4·70	·3	5·7	6·0	Clear and palatable.
HINDHEAD, SURREY.													
Spring on north side of Gibbet Hill, March 7, 1873.	9·2	10·02	·032	·004	0	·196	·200	1,640	3·10	0	3·2	3·2	Clear and palatable.
ST. LEONARD'S, NEAR MAIDSTONE.													
Spring at St. Leonard's, Aug. 8, 1873.	10·0	29·72	·034	·007	0	·151	·158	1,190	2·20	20·7	3·5	24·2	Clear and palatable.
SANDGATE, NEAR FOLKESTONE.													
Spring at Honeywood, Feb. 28, 1873.	12·0	46·74	·057	·007	0	·358	·365	3,260	5·20	20·8	8·9	29·7	Clear and palatable.
SEVENOAKS.													
Spring in railway tunnel, Feb. 21, 1873.	9·0	34·36	·015	·002	0	·416	·418	3,840	2·10	13·7	5·7	19·4	Slightly turbid. Palatable.
SWANAGE.													
Spring flowing into sea, March 10, 1873.	12·3	68·40	·079	·012	0	·287	·299	2,550	5·60	18·1	22·1	40·2	Clear and palatable.
TUNBRIDGE WELLS.													
Spring at Pembury, July 7, 1870.	15·5	12·26	·002	·004	0	·496	·500	4,640	2·83	0	3·3	3·3	Clear and palatable.
WITLEY, SURREY.													
Spring at vicarage, Witley Park, March 7, 1873.	11·1	8·80	·031	·008	·001	·635	·644	6,040	2·20	0	3·5	3·5	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

SECTION XII.—UNPOLLUTED WATER FROM SPRINGS IN THE UPPER GREENSAND.

COMPOSITION OF UNPOLLUTED SPRING WATER FROM THE UPPER GREENSAND.

BISHOPSTONE, WILTSHIRE.													
One of the sources of the *Cole*, May 5, 1873.	10·7	28·88	·054	·013	·001	·271	·285	2,400	1·10	16·7	5·4	22·1	Clear and palatable.
CHISELDON, WILTSHIRE.													
One of the sources of the *Cole*, May 5, 1873.	10·4	43·16	·060	·025	0	·523	·548	4,910	1·50	28·0	6·4	34·4	Clear and palatable.
FROME, SOMERSETSHIRE.													
Spring near Frome, March 16, 1870.	—	11·60	·053	·015	·003	·116	·133	860	1·80	1·0	4·7	5·7	Clear and palatable.
LIDDINGTON, WILTSHIRE.													
One of the sources of the *Cole*, May 5, 1873.	10·4	34·66	·054	·026	0	·246	·272	2,140	1·20	22·3	4·9	27·2	Clear and palatable.
THAMES BASIN.													
Adwell spring, above Adwell farm, Sept. 17, 1873.	9·0	36·62	·135	·028	0	·167	·195	1,350	1·40	24·9	7·6	32·5	Clear and palatable.
VENTNOR.													
Coombe Wood Spring, Sep. 12, 1872.	11·8	45·92	·092	·013	0	1·116	1·129	**10,840**	7·10	9·7	15·1	24·8	Clear and palatable.
Water supply from springs, Sept. 12, 1872.	17·5	34·38	·031	·004	0	·187	·191	1,550	3·00	21·0	4·4	25·4	Slightly turbid. Palatable.
Spring in railway tunnel, Nov. 16, 1872.	10·4	32·80	·048	·006	0	·189	·195	1,570	3·15	21·0	4·7	25·7	Slightly turbid. Palatable.
Spring in Dr. Leeson's Cave, Nov. 16, 1872.	11·5	29·36	·052	·019	·003	·119	·140	890	3·60	14·9	6·6	21·5	Clear and palatable.
WROUGHTON, WILTS.													
Head springs of the *Ray*, May 5, 1873.	10·5	43·84	·123	·028	0	·248	·276	2,160	1·90	25·0	9·4	34·4	Clear and palatable
Average of Sections XI. and XII.	—	30·05	·053	·012	0	·326	·338	2,941	2·98	13·6	6·6	20·2	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

Spring water from Chalk.

The numbers in the two preceding tables may be thus summarised :—

The *total solid impurity* in these waters ranged from 4·55 parts per 100,000, or 3·18 grains per gallon which was found in the water of the spring in Mother Ludlam's Cave near Farnham; to 68·4 parts per 100,000, or 47·88 grains per gallon, which was present in the spring water issuing abundantly from the Greensand at Swanage. It is probable, however, that much of this latter water comes from the Purbeck Limestone. The average proportion in the nineteen samples was 30·05 parts per 100,000, or 21·03 grains per gallon.

Organic elements.—The proportion of the chief elements of the organic matter contained in the samples enumerated in the two preceding tables varied from ·006 part per 100,000 parts, or ·004 grain per gallon, in the spring at Pembury, from which Tunbridge Wells is supplied with water; to ·163 part per 100,000 parts, or ·114 grain per gallon in the water of Adwell spring; and averaged ·065 part per 100,000 parts, or ·045 grain per gallon.

The proportion of nitrogen to carbon in the organic matter of these waters varied from N : C = 1 : 8·14 in the spring at Honeywood, Sandgate; to N : C = 1 : ·5 in the spring at Pembury, but in this sample the carbon and nitrogen are present in such very minute proportions as to be very seriously affected by the possible errors of experiment. The average proportion in the nineteen samples was N : C = 1 : 4·96.

Previous sewage or animal contamination.—All the samples of water from the two Greensands and from the Hastings Sand exhibited some evidence of original pollution with organic matter of animal origin. In the sample from the spring in Mother Ludlam's Cave at Moor Park, near Farnham, this evidence was very slight, and only in the case of the Coombe Wood spring at Ventnor, which issues at the foot of terraces of gardens and villas, does it become strong enough to cast suspicion upon the wholesomeness of the water.

Hardness.—The hardness of these waters varies between wide limits. If the water has not been in contact with calcareous strata before it arrives at the Greensand or Hastings Sand it is very soft, but such a result appears to be rarely attained, and there are few soft waters in the preceding tables, the most conspicuous one being that issuing from a natural cave in the Lower Greensand at Moor Park near Farnham. The hardness of this sample was only 0°·7, and from this the range extended up to 40°·2, which expresses the hardness of the water from the large spring flowing into the sea at Swanage. The mean hardness of the nineteen samples was 20°·2.

General character.—The unpolluted spring water from the Greensands and Hastings Sand is clear, palatable, and wholesome; it contains only a very small quantity of organic matter, and is well adapted for all household purposes except washing, for which many of the samples mentioned in the above table are too hard. With the exception of the waters from Swanage, and Coombe Wood Ventnor, all the samples would be effectually softened by the addition to them of small quantities of slaked lime. (*See* page 205.) The spring in Mother Ludlam's cave which supplies Mr. J. F. Bateman's house in Moor Park, near Farnham, possesses all the qualities which go to make an excellent water for drinking and all domestic purposes.

SECTION XIII.—UNPOLLUTED WATER FROM SPRINGS IN THE CHALK.

The following contains the results of our analyses of thirty samples of water collected from springs issuing out of the Chalk. All the samples were collected by ourselves, except those from Market Rasen and the one marked with an asterisk. The results of analysis of the last-named sample are taken from the Appendix to the Report of the Royal Commission on Water Supply, page 104.

COMPOSITION OF SPRING WATER FROM THE CHALK.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ARUNDEL PARK, SUSSEX.													
Spring feeding the Swanbourne, Oct. 13, 1873.	11·3	26·30	**·054**	**·009**	0	0	·009	0	2·10	18·1	4·8	22·4	Clear and palatable.
Spring near the lodge, Oct. 13, 1873.	11·3	26·28	**·037**	**·007**	0	·080	·087	480	2·20	16·1	8·1	24·2	Clear and palatable.

COMPOSITION OF SPRING WATER FROM THE CHALK—*continued.*

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	REMARKS.
BRIDLINGTON, YORKSHIRE.													
Spring in the Harbour, Jan. 11, 1873.	9·7	25·36	·032	·006	0	·358	·364	3,260	2·25	14·5	5·4	19·9	Clear and palatable.
Water supply from springs, Jan. 11, 1873.	8·5	30·76	·055	·009	0	·573	·582	5,410	3·20	18·9	5·0	23·9	Clear and palatable.
CAMBRIDGE.													
Springs at Cherry Hinton, March 5, 1873.	11·2	31·02	·042	·006	·001	·596	·602	5,640	1·90	17·6	6·3	23·9	Clear and palatable.
EASTBOURNE.													
Spring above the town, Feb. 22, 1873.	10·3	36·46	·070	·011	·001	·736	·748	7,050	3·90	24·2	7·7	31·9	Clear and palatable.
FOLKESTONE.													
Springs at Cherry Gardens, Feb. 28, 1873.	11·0	32·14	·025	·004	0	·313	·317	2,810	2·90	21·3	5·0	26·3	Clear and palatable.
GREAT GRIMSBY.													
Springs supplying town, Jan. 10, 1873.	7·2	27·26	·029	·003	·001	·267	·271	2,360	1·80	14·3	6·3	20·6	Clear and palatable.
HAVANT.													
Springs supplying Portsmouth, March 7, 1873.	11·1	28·48	·040	·007	0	·338	·345	3,060	1·85	17·3	6·0	23·3	Clear and palatable.
Springs at Bedhampton, Havant, March 7, 1873.	11·1	29·62	·053	·008	0	·397	·405	3,650	1·85	15·8	8·1	23·9	Clear and palatable.
The Blue Hole Spring at Bedhampton, March 7, 1873.	11·3	30·34	·076	·011	0	·379	·390	3,470	1·85	19·5	4·4	23·9	Clear and palatable.
Spring at Farlington Waterworks, March 7, 1873.	12·5	38·80	·032	·008	0	·421	·429	3,890	5·55	19·5	5·0	24·5	Clear and palatable.
LEWES.													
Springs in Verrall's pool, Feb. 22, 1873.	9·0	26·44	·057	·013	·001	·335	·349	3,040	2·30	14·2	5·1	19·3	Clear and palatable.
The *Cockshoot stream* from adjacent springs, Feb. 22, 1873.	8·8	29·80	·087	·023	·002	·513	·538	4,830	2·50	18·1	4·6	22·7	Slightly turbid. Palatable.
MARKET RASEN, LINCOLNSHIRE.													
Spring issuing from Greystone, Nov. 12, 1870.	—	33·52	·017	·008	0	·338	·346	3,060	1·60	21·2	6·0	27·2	Clear and palatable.
Spring issuing from Chalk, Nov. 12, 1870.	—	26·20	·012	·013	0	·537	·550	5,050	1·50	16·6	4·3	20·9	Clear and palatable.
Spring issuing from chalk and limestone, Nov. 12, 1870.	—	26·82	·011	·008	·001	·700	·709	6,690	1·60	14·8	4·6	19·4	Clear and palatable.
NEWPORT, ISLE OF WIGHT.													
Spring near Carisbrook, Nov. 4, 1871.	8·6	28·50	·008	·005	·001	·369	·375	3,380	3·30	23·4	6·0	29·4	Clear and palatable.
THAMES BASIN.													
Gravesend, Springhead at, Jan. 17, 1873.	9·2	39·30	·059	·011	0	·863	·874	8,310	2·50	23·2	7·1	30·3	Clear and palatable.
Hughenden, spring at, Oct. 9, 1873.	11·9	29·90	·024	·013	0	·274	·287	2,420	1·40	20·9	3·6	24·5	Clear and palatable.
Lamborne Park, spring in, May 5, 1873.	10·4	27·12	·051	·009	0	·431	·440	3,990	1·10	15·8	5·1	20·9	Clear and palatable.
Letcombe Basset, spring at, May 5, 1873.	10·5	27·36	·047	·013	·001	·298	·312	2,670	1·05	15·2	5·1	20·3	Clear and palatable.
Nine Waters Lane, spring at, source of the *Loddon*, Oct. 11, 1873.	11·8	32·06	·052	·011	·001	·426	·438	3,950	1·50	22·0	4·9	26·9	Clear and palatable.
Sevenoaks, Mr. Spottiswoode's spring, Aug. 8, 1873.	—	34·40	·053	·009	0	·277	·286	2,450	1·30	25·3	6·9	32·2	Slightly turbid. Palatable.
Watford, Otter's pool spring, April 8, 1868.*	11·0	32·36	·026	·012	·002	·422	·436	3,920	1·26	21·0	3·7	24·7	Clear and palatable.
Wendover, the source of the Thame at Well Head, Aug. 6, 1873.	10·8	28·10	·034	·010	0	·369	·379	3,370	1·30	19·4	5·7	25·1	Slightly turbid. Palatable.
West Wycombe, Long Meadow spring, Oct. 9, 1873.	10·9	29·86	·038	·005	0	·336	·341	3,040	1·40	23·3	4·6	27·9	Clear and palatable.
VENTNOR.													
The Wishing Well, St. Boniface Down, Nov. 16, 1872.	10·9	26·40	·097	·018	·006	·078	·101	510	6·40	6·8	5·6	12·4	Turbid. Palatable.
The Wishing Well, St. Boniface Down, March 8, 1873.	11·0	27·68	·064	·013	0	·061	·074	290	7·40	7·0	7·3	14·3	Turbid. Palatable.
WEYMOUTH.													
Chalk springs at Sutton, March 10, 1873.	11·4	26·60	·041	·010	0	·361	·371	3,290	2·80	16·2	4·4	20·6	Clear and palatable.
Average	[illegible]	29·84	·044	·010	·001	·382	·392	3,511	2·45	18·1	5·5	23·6	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION.

The following are the chief conclusions to be drawn from the foregoing analytical table:—

Spring water from Chalk.

Total solid impurity.—Spring water from the Chalk, like that from the Oolites, always contains a somewhat large proportion of total impurity, of which the chief ingredient is carbonate of lime. Nearly the whole of this solid impurity consists of saline matters which are not unwholesome; they however render the water hard and unfit for washing. The total solid impurity in the samples just enumerated ranged from 25·36 parts per 100,000, or 17·75 grains per gallon, in the spring at the bottom of the harbour at Bridlington; to 39·3 parts per 100,000, or 27·51 grains per gallon, in the springhead at Gravesend; and averaged 29·84 parts per 100,000, or 20·89 grains per gallon.

Organic elements.—The highly oxidizing action of the soft Chalk reduces the organic matter contained in the water percolating through it to a very minute proportion, the chief elements of which (organic carbon and organic nitrogen), in the foregoing samples, varied from ·013 part per 100,000 parts, or ·009 grain per gallon, in the water which supplies the town of Newport from a spring near Carisbrooke; to ·11 part per 100,000 parts, or ·077 grain per gallon in the water of the *Cockshoot stream* at Lewes, and ·115 part per 100,000 parts, or ·08 grain per gallon, in the water from the Wishing Well on St. Boniface down, Ventnor. Small as this maximum proportion is, it would doubtless have been still smaller in the *Cockshoot stream,* could we have taken our sample directly from the spring. The latter rises in the midst of a dense mass of decaying vegetable matter which cannot fail to communicate some organic impurity to the water. In the Wishing Well, again, the water is exposed to the purifying action of a comparatively thin stratum of Chalk. The average proportion of organic elements in the thirty samples was ·054 part per 100,000 parts, or ·038 grain per gallon.

The proportion of nitrogen to carbon in the organic matter of these waters ranged from N : C = 1 : 9·33 in the spring water which supplies Great Grimsby; to N : C = 1 : ·92 in the water from a spring at Market Rasen, and averaged N : C = 1 : 4·77.

Previous sewage or animal contamination.—We have only met with one sample of spring water from the Chalk (the spring feeding the *Swanbourne* in Arundel Park, Sussex) which exhibits no trace of evidence of previous pollution with organic matter of animal origin; but in no single case was this evidence sufficiently strong to place the sample in the category of suspicious waters.

Hardness.—All spring water from the Chalk is naturally hard, because chalk is soluble in water containing (as all natural water does) carbonic acid. In the samples registered in the foregoing table, the hardness varied from 12°·4 in the water of the Wishing Well near the summit of St. Boniface Down, Ventnor; to 32°·2 in Mr. Spottiswoode's spring near Sevenoaks. The unusual softness of the sample from the Wishing Well is doubtless due to the short distance through which the water percolates from the summit of the down to the well, the latter being only about 100 feet from the summit. The average hardness of the thirty samples was 23°·6.

General character.—Unpolluted spring water from the Chalk is brilliant, colourless, palatable and wholesome. It contains only a minute trace of organic matter which is highly oxidized and innocuous. Amongst the total number of samples examined by us there was not one which did not participate in these valuable characteristics. These waters are hard, but a large proportion of the hardness is of the temporary kind and can be easily and cheaply removed by the addition of slaked lime to the water. We have already commented upon the excellency of the Chalk as a water-bearing stratum at page 102.

SECTION XIV.—UNPOLLUTED WATER FROM SPRINGS IN FLUVIO-MARINE, DRIFT, AND GRAVEL.

The following table contains the results of our analyses of ten samples of water taken from springs issuing out of Fluvio-Marine, Drift, and Gravel. The samples from Ryde, Ipswich, Bedford, Leyland, and Oxford were alone taken by ourselves. Those from Askern were forwarded to us through the Local Government Act Office:—

COMPOSITION OF SPRING WATER FROM FLUVIO-MARINE, RED CRAG, DRIFT, AND GRAVEL.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.												REMARKS.
	Temperature Centigrade.	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
FLUVIO-MARINE.													
RYDE, I.W.													
Springs near, March 7, 1873 -	5·8	27·62	**·053**	**·013**	0	·485	·498	4,530	2·70	13·5	7·1	20·6	Clear and palatable.
RED CRAG.													
IPSWICH.													
Water-supply from springs, Nov. 1871.	5·5	36·48	**·053**	**·016**	0	1·277	1·293	**12,450**	2·55	17·8	10·4	28·2	Clear and palatable.
GRAVEL.													
ASKERN, NEAR DONCASTER.													
Mr. Townend's spring, July 29, 1870.	—	225·24	**·004**	**·006**	0	·252	·258	2,200	2·10	32·2	94·3	126·5	Clear.
Mr. R. Eridge's spring, July 29, 1870.	—	66·40	**·043**	**·017**	0	·404	·421	3,720	2·70	7·9	25·0	32·9	Slightly turbid. Palatable.
BEDFORD.													
Spring at Waterworks, Oct. 10, 1868.	—	72·46	**·133**	**·021**	·001	·034	·056	30	4·27	29·3	11·5	40·8	Clear and palatable.
Spring near Waterworks, Oct. 10, 1868.	—	74·20	**·137**	**·028**	·002	·004	·034	0	4·07	29·8	12·2	42·0	Clear and palatable.
DONCASTER.													
Spring in Ravenfield Park, July 23, 1872.	—	23·72	**·068**	**·009**	0	·744	·753	7,120	2·75	·7	11·9	12·6	Clear and palatable.
OXFORD.													
Springs at Waterworks, May 30, 1873.	—	27·90	**·156**	**·043**	·003	·167	·212	1,370	2·15	18·5	6·9	25·4	Turbid. Palatable.
Waterworks reservoir, Nov. 18, 1873	7·0	34·56	**·164**	**·030**	·007	·018	·054	0	2·10	21·4	6·1	27·5	Slightly turbid. Palatable.
DRIFT.													
LEYLAND, LANCASHIRE.													
Spring in Mr. Quin's Garden, May 8, 1873.	—	24·62	**·052**	**·011**	0	·154	·165	1,220	2·20	8·4	11·0	19·4	Clear and palatable.
Average - - -	—	61·32	**·086**	**·019**	·001	·354	·374	3,264	2·76	18·0	19·6	37·6	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results may be epitomised as follows :—

Total solid impurity.—The proportion of saline matter, and consequently of total solid impurity, contained in these waters, varies between wide limits. It is as low as 23·72 parts per 100,000, or 16·6 grains per gallon, in the spring in Ravenfield Park, and as high as 225·24 parts per 100,000, or 157·67 grains per gallon in Mr. Townend's spring at Askern. The average proportion of total solid impurity in the ten samples of water was 61·32 parts per 100,000, or 42·92 grains per gallon.

Organic elements.—These geological formations constitute some of the most recent deposits, and the springs issuing from them have frequently passed through but a thin layer of earth; and the purification of the surface water from organic matter is therefore, as might be expected, not unfrequently very imperfect; indeed the springs entering the waterworks at Oxford have all the characters of mere surface water. They contained no less than ·199 and ·194 part of organic elements (organic carbon and organic nitrogen) in 100,000 parts, or ·139 and ·136 grain per gallon, whilst the water from Mr. Townend's spring at Askern contained only ·01 part in 100,000 parts, or ·007 grain per gallon; the average in the ten samples being ·105 part in 100,000 parts, or ·073 grain per gallon.

The proportion of nitrogen to carbon in these waters ranged from N : C = 1 : ·67 in Mr. Townend's spring at Askern; to N : C = 1 : 7·56 in the spring in Ravenfield Park Doncaster, and averaged N : C = 1 : 4·32.

Previous sewage or animal contamination.—In two out of the ten samples enumerated in the foregoing table, there is no evidence of anterior pollution, and only in one case does this evidence rise sufficiently high to render the water decidedly objectionable for domestic use. Suspicion, however, attaches to the water supplied to Oxford, which contains occasionally not only evidence of this kind, but also, for spring water, a somewhat large proportion of highly nitrogenised organic matter.

Polluted spring waters.

Hardness.—All these formations yield hard or very hard water. In the foregoing samples the hardness varied from 12°·6 in the spring in Ravenfield Park; to 126°·5 in the water of Mr. Townend's spring, and averaged 37°·6. In most cases a large proportion of this hardness is permanent, and cannot therefore be removed by the addition of lime; but the waters supplied to Ryde and Oxford would be efficiently softened by the application to them of Clark's process (*see* page 205).

General character.—Unpolluted spring water from Fluvio-marine, Drift, and Gravel is of very variable quality, owing to the varying character and generally small thickness of the beds through which it percolates. Under favourable circumstances it contains only a small proportion of organic matter, but, owing to the causes just mentioned, it more frequently holds in solution, for spring water, a large proportion of organic constituents.

DIVISION II.—POLLUTED SPRING WATERS.

At page 105 we have already remarked upon the causes of the pollution of deep well waters, one of these, viz., the occurrence of fissures in the rock from which the well derives its supply of water, must also obviously be a possible cause of the pollution of springs. Moreover, the porous stratum through which the water has descended from the surface may be of small thickness and the water will then be as much exposed to pollution as it would be if it were drawn from shallow wells. In the Chalk, "swallow holes,"—more or less vertical natural shafts in the Chalk—are fertile sources of pollution to spring water.

In the following table the results of the analyses of such samples of polluted spring water as we have met with are recorded. The samples from Eastwood, Hawes, and Southam, were forwarded to us through the Local Government Act Office, the remainder were collected by ourselves:—

COMPOSITION OF POLLUTED SPRING WATERS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
FROM OLD RED SANDSTONE.													
LANARK, SCOTLAND.													
LANARK, water supply of, Aug. 12, 1872.	—	9·96	**·148**	**·026**	·002	·220	·248	**1,900**	1·80	0	3·9	3·9	Slightly turbid.
FROM YOREDALE AND MILLSTONE GRITS.													
HAWES, BEDALE, YORKSHIRE.													
Town Head well, April 5, 1872	—	28·46	**·174**	**·033**	·005	·131	·168	**1,030**	1·20	20·3	6·3	26·6	Slightly turbid. Palatable.
Mr. H. Whaley's spring, April 5, 1872.	—	13·32	**·171**	**·025**	·001	0	·026	**0**	·75	6·1	6·0	12·1	Slightly turbid. Palatable.
Spilliam Green spring, April 6, 1872.	—	16·48	**·229**	**·027**	·003	·039	·068	**90**	·75	7·8	6·1	13·9	Slightly turbid. Palatable.
HARROGATE.													
Water supply from springs, Haverah Park, Dec. 8, 1873.	7·0	7·90	**·196**	**·045**	·003	0	·047	**0**	1·30	0	4·2	4·2	Slightly turbid. Palatable.
FROM NEW RED SANDSTONE.													
BRISTOL.													
Spring in All Saint's Lane, Feb. 8, 1869.	—	127·28	**·186**	**·030**	·001	4·712	4·743	**46,810**	7·10	32·2	34·7	66·9	Clear and palatable.
EASTWOOD, NOTTS.													
From reservoir supplied by springs, Aug. 1871.	—	37·68	**·154**	**·040**	0	·051	·091	**190**	1·60	19·3	18·0	37·3	Clear and palatable.
FROM THE LIAS.													
OAKHAM, RUTLAND.													
Spring in Coldoverton Road, April 1872.	7·3	101·82	**·292**	**·113**	·001	·322	·436	**2,910**	1·80	43·6	45·0	88·6	Slightly turbid. Palatable.

COMPOSITION OF POLLUTED SPRING WATERS—*continued.*

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
SOUTHAM, WARWICKSHIRE.													
Spring supplying town well, December 3, 1869.	—	57·30	**·282**	**·054**	·011	·397	·460	**3,740**	2·00	25·0	8·5	33·5	Very turbid.
Holywell (public), Dec. 3, 1869	—	71·90	**·164**	**·028**	·006	·217	·250	**1,900**	2·50	24·4	18·4	42·8	Slightly turbid. Palatable.
FROM OOLITE.													
BATH.													
Spring at Batheaston, Feb. 17, 1871.	—	31·60	**·337**	**·013**	·002	·507	·522	**4,770**	1·66	17·5	6·7	24·2	Clear and palatable.
Beacon Hill Spring, Feb. 17, 1871.	—	40·62	**·253**	**·041**	0	1·205	1·246	**11,730**	2·60	19·0	11·0	30·0	Clear and palatable.
Beacon springs, Feb. 17, 1871	—	20·40	**·149**	**·012**	0	·270	·282	**2,380**	1·45	10·7	5·6	16·3	Clear and palatable.
Beechen Cliff springs, Feb. 17, 1871.	—	41·80	**·274**	**·018**	0	1·131	1·149	**10,990**	2·35	20·4	10·9	31·3	Clear and palatable.
Sham Castle springs, Feb. 17, 1871.	—	30·70	**·171**	**·016**	·001	·516	·533	**4,850**	1·65	18·1	7·0	25·1	Clear and palatable.
NAILSWORTH.													
Spring at Pensile, Mar. 17, 1870	—	23·50	**·241**	**·026**	·154	·456	·609	**5,510**	2·15	10·5	6·3	16·8	—
FROM HASTINGS SAND.													
ST. LEONARDS-ON-SEA.													
Spring in Railway Tunnel, Feb. 21, 1873	4·0	41·92	**·224**	**·054**	·088	·478	·604	**5,180**	9·60	4·0	12·9	16·9	Turbid. Palatable.
FROM LOWER GREENSAND.													
SANDGATE, NEAR FOLKESTONE.													
Camp Road springs, Feb. 28, 1873.	10·8	36·90	**·146**	**·030**	·001	·955	·986	**9,240**	5·95	6·9	9·7	16·6	Clear and palatable.
FROM CHALK.													
AMWELL.													
Spring at Amwell, Jan. 24, 1873.	10·0	28·44	**·699**	**·097**	0	·302	·399	**2,700**	1·60	8·4	7·9	16·3	Very turbid.
Spring at Amwell, July 7, 1873.	—	33·32	**·149**	**·034**	0	·327	·361	**2,950**	1·80	18·4	4·9	23·3	Turbid. Palatable.
CATERHAM.													
The "Bourne" under Railway Bridge in Morden Park, Feb. 14, 1873.	7·1	32·84	**·103**	**·032**	0	·707	·739	**6,750**	2·40	18·4	7·3	25·7	Turbid. Palatable
The "Bourne," springs half mile lower, Feb. 14, 1873.	8·9	27·26	**·138**	**·029**	0	·667	·696	**6,350**	1·40	15·9	5·6	21·5	Turbid. Palatable.
HERTFORD.													
Chadwell spring, Jan. 24, 1873	10·0	29·80	**·420**	**·084**	·001	·299	·384	**2,680**	1·80	13·4	6·6	20·0	Very turbid.
MAIDSTONE.													
Springs supplying town, Aug. 8, 1873.	18·0	39·16	**·138**	**·044**	·004	·870	·917	**8,410**	3·50	20·8	7·1	27·9	Slightly turbid. Palatable.
FROM GRAVEL OVER LONDON CLAY.													
COLCHESTER.													
Spring at foot of town, April 2, 1873.	8·9	154·70	**·176**	**·057**	·001	7·395	7·453	**73,640**	27·50	18·9	34·1	53·0	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The polluted spring waters collected in the foregoing table have little in common, except their pollution and hardness, and even as regards these qualities, two of the samples are sharply distinguished from the others; these are the water from Mr. H. Whaley's spring and from Spilliam Green spring, both at Hawes, Bedale, Yorkshire, which are comparatively soft, and polluted chiefly, if not exclusively, by organic matter of vegetable origin. The springs at Eastwood, Notts, though hard are polluted chiefly by vegetable organic matter. By far the worst cases of pollution of spring water that we have met with are those which occurred on the 24th January 1873, to the Amwell and Chadwell springs; the latter being of the greatest importance because it forms an important part of the water supplied to the Metropolis by the New River Company. When we visited this spring on the date just given it was delivering large volumes of very turbid water which could only be rendered to some extent fit for human consumption by the very efficient filtration to which that company always subjects all water sent out from their works. We were informed that this pollution was not of frequent occurrence.

Part II. Classification.

General conclusions.

The following samples in the foregoing table are dangerous to the health of persons using them for domestic purposes.

Dangerous Polluted Spring Waters.

Spring in All Saints Lane, Bristol.
Beacon Hill Spring, Bath.
Beechen Cliff Springs, Bath.
Spring in Railway Tunnel, St. Leonard's-on-Sea.
Camp road springs, Sandgate near Folkestone.
Spring at foot of town, Colchester.

As all these waters are too hard for washing there is no reason why their use by the public should not be as much as possible hindered and discouraged.

All the remaining samples are of suspicious quality except the following which may be used for domestic purposes with reasonable safety:—

Springs at Eastwood, Notts.
Mr. H. Whaley's spring, Hawes, Bedale, Yorkshire.
Spilliam Green spring, Hawes, Bedale, Yorkshire.

General Conclusions on the Classification and Chemical Composition of Potable Waters.—In the foregoing analytical tables we have given the results of the chemical examination of 1,274 samples of potable water collected under the most widely different conditions, and comprehending 81 samples of rainwater, 370 samples of surface water, 419 samples of shallow well water, 182 samples of deep well water, and 222 samples of spring water. This extended investigation of waters which have drained from the surface of, or percolated through the most important geological formations of Great Britain, affords a broad basis hitherto unattainable, upon which to found conclusions as to the relative merits of potable waters from these various sources. The results of this research are quite conclusive, as to the sources from which the best water for domestic purposes is to be obtained. They show that rain-water contains the smallest proportion of total solid impurity, but by no means the smallest proportion of that most objectionable of impurities, organic matter. The rain-drops concentrate within themselves the organic dust and dirt diffused through vast volumes of atmospheric air. Although rain-water, collected from the roofs of houses at a distance from towns, carefully stored and filtered, may doubtless be made into a good and wholesome potable water, we have to report that we have very rarely met with such water. When, however, the rain-water is collected from the surface of uncultivated land, allowed to subside in lakes or reservoirs, or filtered through sand, it becomes of good quality for domestic, and still more so for manufacturing purposes. Numerous large towns, both in England and Scotland, are supplied with water of this description. Non-calcareous strata are generally selected as gathering ground, and then the water is soft and well adapted both for washing and for almost all manufacturing operations. It is nearly always wholesome, but sometimes suffers in palatability by containing an excessive quantity of peaty matter in solution. This evil may be materially abated by the use of sand filters. The water supplied to Liverpool from the slopes of Rivington Pike is thus purified, but it is nearly the only instance with which we have become acquainted; prolonged subsidence in storage reservoirs being usually considered sufficient purification for water of this description.

Seeing that rapid filtration through a few feet of sand can thus materially improve the quality of surface water, by removing some of the organic impurity which it contains in solution, we were prepared to find a much greater improvement when the water was drawn from deep wells or springs, to which it could only gain access by slow natural percolation through a great thickness of porous rock or earth. Under such circumstances, the powerful oxidizing influences of a porous and aërated soil are brought to bear upon the organic matter dissolved in the water. We have already shown (First Report *Mersey* and *Ribble* Basins, vol. 1. page 63; see also page 57 of the present Report) that, even under the artificial and far less favourable conditions of intermittent downward filtration, sewage itself becomes deprived of a very large proportion of the organic matter which it holds in solution. It was not, therefore, surprising to find that surface water, which is far less polluted than sewage by organic matter, should be

Part II. Classification.

General conclusions.

almost, or even quite, exhaustively purified from such matter, by the natural intermittent filtration which transforms it into spring or deep well water. Mere exposure to the air, however, even if accompanied by violent agitation, is comparatively powerless for the removal of polluting organic matter from water. (*See* page 136.)

Surface water draining from cultivated land is always more or less polluted with the organic matter of manure. Such water of course contributes very largely to rivers and streams which have already descended from their mountain or upland sources. Even when not contaminated by the actual admission into it of the sewage of towns and villages, it is not of suitable quality for domestic purposes, but when it is further polluted by excremental drainage, its use for drinking and cooking becomes fraught with great risk to health. Still more dangerous to health is the water drawn from shallow wells, no matter upon what geological formation they may be sunk, when they are situated, as is usually the case, near privies, drains, or cesspools. Many severe outbreaks of epidemic disease have been traced to the use of such water in villages and towns, and there is strong reason to believe, that sporadic attacks of typhoid fever often occur in isolated country houses from the same cause.

In respect of wholesomeness, palatability, and general fitness for drinking and cooking, our researches lead us to the following classification of waters in the order of their excellence and founded upon their respective sources :—

Wholesome	1. Spring water.	Very palatable.
	2. Deep well water.	
	3. Upland surface water.	Moderately palatable.
Suspicious.	4. Stored rain water.	
	5. Surface water from cultivated land.	Palatable.
Dangerous.	6. River water to which sewage gains access.	
	7. Shallow well water.	

We would further enforce this concrete result of our inquiries by urging that preference should always be given to spring and deep well water for purely domestic purposes, over even upland surface water. And we do this, not only on account of the much greater intrinsic chemical purity and palatability of these waters, but also because their physical qualities render them peculiarly valuable for domestic supply. They are almost invariably clear, colourless, transparent, and brilliant,—qualities which add greatly to their acceptability as beverages, whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge.

The foregoing remarks have reference exclusively to the use of water for drinking and cooking,—applications of paramount importance from a sanitary point of view;—but a large proportion of the water supplied for domestic purposes is used for washing, whilst in many towns considerable volumes are used in manufactories. For all these latter purposes it is of the utmost importance that the water should be soft,—a quality which is not always associated with wholesomeness and palatability. Classified according to softness, the waters from the various sources fall into the following order :—

1. Rain-water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river water.
5. Spring water.
6. Deep well water.
7. Shallow well water.

The interests of the laundress and of the manufacturer are thus evidently opposed to those of the householder; inasmuch as they lead to a preference for moderately palatable or even unwholesome water over that which is very palatable and wholesome. At page 205 we have shown how most of the hard waters from springs and deep wells can be easily and cheaply rendered soft, and the interests of the householder and manufacturer thus made identical. In Clark's process of softening water with lime, the sanitary authorities of towns have at their disposal a method of rendering hard water from springs or deep wells available for washing and manufacturing purposes, without diminishing either its palatability or its wholesomeness.

PART II. CLASSIFICATION.

General conclusions.

The foregoing classified analytical results also illustrate very fully the influence which the chief geological formations exert upon the water which comes into contact with them. They show, as might be expected, that the hardness of water is, *cæteris paribus*, dependent upon the chemical character of the soil or rock upon which the water falls or through which it percolates. Rocks and soils, which impart to water salts other than those of potash and soda, render it more or less hard; and as such hardening salts are almost invariably compounds of lime and magnesia with carbonic and sulphuric acids, it follows that Chalk, Limestone, Dolomite, and rocks containing selenite (sulphate of lime) are those which are almost exclusively instrumental in communicating hardness to water. The following are the chief British formations which yield, as a rule, soft water:—

1. Igneous.
2. Metamorphic.
3. Cambrian.
4. Silurian (non-calcareous).
5. Devonian (non-calcareous).
6. Millstone grit.
7. Non-calcareous rocks of the Coal-measures.
8. Lower Greensand.
9. London and Oxford Clay.
10. Bagshot Beds.
11. Non-calcareous Gravel.

On the other hand, the following geological formations almost invariably yield hard water:—

1. Calcareous Silurian.
2. Calcareous Devonian.
3. Mountain Limestone.
4. Calcareous rocks of the Coal-measures.
5. New Red Sandstone.
6. Conglomerate Sandstone.
7. Lias.
8. Oolites.
9. Upper Greensand
10. Chalk.

The influence of geological formation upon the palatability and wholesomeness of water, though not so palpable to the senses, is far from inconsiderable. In the case of surface water this influence is to a great extent masked, or indeed often altogether annulled, by superficial deposits of vegetable matters, such as peat, upon the rocks; and thus, except in respect of hardness and saline constituents, unpolluted surface waters from the most widely different geological formations vary but little in the proportions of organic matter which they contain, and consequently in their palatability and wholesomeness. But when the water percolates or soaks through great thicknesses of rock, its quality, when it subsequently appears as spring or deep well water, depends greatly upon the nature of the material through which it has passed. When the formation contains much soluble saline matter, the water becomes loaded with mineral impurities, as is frequently the case when it percolates through certain of the Carboniferous rocks, the Lias, and the Saliferous Marls. When the rock is much fissured, or permeated by caverns or passages, like the Mountain Limestone for instance, the effluent water differs but little from surface drainage, and retains most of the organic impurities with which it was originally charged. But when the rock is uniformly porous, or nearly so, like the Chalk, Oolite, Greensand, or New Red Sandstone, the organic matter, at first present in the water, is gradually oxidised and transformed into innocuous mineral compounds. In effecting this most desirable transformation, and thus rendering the water sparkling, colourless, palatable, and wholesome, the following water-bearing strata are the most efficient:—

1. Chalk.
2. Oolite.
3. Greensand.
4. Hastings Sand.
5. New Red and Conglomerate Sandstone.

This is seen from the following table, in which the average composition of unpolluted water from various sources is contrasted:— PART II. CLASSIFICATION.

Sea water.

AVERAGE COMPOSITION OF UNPOLLUTED POTABLE WATERS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

Class.	Division.	Section.	DESCRIPTION.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Number of samples analysed.
I.	—	—	RAIN WATER	2·95	·070	·015	·029	·003	·042	42	·22	—	—	·3	39
II.	—	—	UPLAND SURFACE WATERS.												
"	I.	—	FROM NON CALCAREOUS STRATA.												
"	"	I.	From Igneous Rocks	5·15	·278	·033	·001	·002	·035	0	1·13	·1	2·0	2·1	18
"	"	II.	From Metamorphic, Cambrian, Silurian, and Devonian Rocks.	5·12	·293	·024	·002	·006	·031	3	·92	·3	2·5	2·5	81
"	"	III.	From Yoredale and Millstone Grits and the Coal Measures.	8·75	·373	·037	·003	·010	·050	6	1·05	·4	4·3	4·7	47
"	"	IV.	From Lower London Tertiaries and Bagshot Beds.	8·40	·379	·048	·004	·007	·058	0	2·06	·3	3·5	3·8	3
"	II.	—	FROM CALCAREOUS STRATA.												
"	"	I.	From Calcareous portions of Silurian and Devonian Rocks.	13·71	·302	·026	0	·021	·047	77	1·20	1·2	7·4	8·6	3.
"	"	II.	From Mountain Limestone	17·07	·370	·047	·001	·011	·059	26	1·24	5·7	7·0	12·7	7
"	"	III.	From Calcareous portions of the Coal Measures.	22·79	·346	·037	·003	·016	·056	33	1·52	4·0	8·3	12·3	26
"	"	IV.	From the Lias, New Red Sandstone, Conglomerate Sandstone, and Magnesian Limestone.	18·80	·286	·042	·002	·010	·054	4	1·49	7·6	6·5	14·1	9
"	"	V.	From the Oolites	17·46	·326	·025	·004	·042	·070	130	1·55	6·6	5·8	12·4	1
V.	I.		DEEP WELL WATERS.												
"	"	I. & II.	In Devonian Rocks and Millstone Grit.	32·68	·068	·012	·005	·294	·310	2,671	2·70	8·8	8·6	17·4	7
"	"	III.	In the Coal Measures	83·10	·119	·034	·044	·207	·278	2,243	18·05	15·1	20·6	35·7	9
"	"	IV.	In Magnesian Limestone	61·14	·076	·030	0	1·426	1·456	13,937	4·31	16·9	26·9	43·8	3
"	"	V.	In New Red Sandstone	30·63	·036	·014	·003	·717	·734	6,895	2·94	7·4	10·5	17·9	28
"	"	VI.	In the Lias	70·98	·146	·027	·001	·389	·417	3,730	4·42	21·9	8·2	30·1	2
"	"	VII.	In the Oolites	33·60	·037	·010	·022	·625	·654	6,118	2·69	13·8	6·8	20·6	5
"	"	VIII.	In the Hastings Sand, Greensands, and Weald Clay.	45·20	·068	·014	·016	·196	·223	1,864	5·38	16·8	10·5	27·3	20
"	"	IX.	In the Chalk	36·88	·050	·017	·001	·610	·628	5,801	2·76	21·2	6·5	27·7	66
"	"	X.	In the Chalk below London Clay.	78·09	·093	·028	·048	·068	·135	797	15·02	9·7	8·7	18·4	13
"	"	XI.	In Thanet Sand and Drift	53·84	·113	·020	·072	·116	·202	1,517	6·32	14·4	7·6	22·0	4
VI.	I.	—	SPRING WATERS.												
"	—	I.	From Granite and Gneiss Rocks.	5·94	·042	·008	·001	·106	·115	846	1·69	·4	2·6	3·0	8
"	—	II.	From Silurian Rocks	12·33	·051	·014	·001	·178	·192	1,587	1·84	1·5	5·3	6·8	15
"	—	III.	From Devonian Rocks and Old Red Sandstone.	25·06	·054	·012	·001	·764	·777	7,339	3·85	4·8	7·2	12·0	22
"	—	IV.	From Mountain Limestone	32·06	·087	·010	·001	·224	·235	2,008	4·63	10·9	8·9	19·8	15
"	—	V. & VI.	From Yoredale and Millstone Grits and the Coal Measures.	21·91	·050	·014	·001	·393	·408	3,707	1·85	5·2	7·9	13·1	22
"	—	VII.	From Magnesian Limestone	66·52	·058	·038	·002	1·686	1·726	16,560	3·40	24·9	34·8	59·7	1
"	—	VIII.	From New Red Sandstone	28·69	·065	·017	·001	·330	·349	3,047	2·19	8·1	10·7	18·8	15
"	—	IX.	From the Lias	36·41	·073	·019	·001	·467	·487	4,406	2·48	21·3	8·8	30·1	7
"	—	X.	From the Oolites	30·33	·043	·011	·001	·402	·414	3,730	1·55	18·2	6·2	24·4	35
"	—	XI. & XII.	From the Hastings Sand and Greensands.	30·05	·053	·012	0	·326	·338	2,941	2·98	13·6	6·6	20·2	19
"	—	XIII.	From the Chalk	29·84	·044	·010	·001	·382	·392	3,511	2·45	18·1	5·5	23·6	30
"	—	XIV.	From Fluvio-marine, Drift, and Gravel.	61·32	·086	·019	·001	·354	·374	3,264	2·76	18·0	19·6	37·6	10

Note.—For the translation of these numbers into grains per gallon, see note to table on page 29.

SEA WATER.

The whole of the soluble ingredients, and a large proportion of the suspended matters contained in the water of rivers and streams, are all finally delivered into the sea, where, as scarcely any of these matters are volatile at common temperatures, they are left behind when the water containing them undergoes the process of spontaneous evaporation. Our analyses of rain-water, however, have demonstrated, that small proportional, but enormous

PART II. CLASSIFICATION. — Sea water.

aggregate, quantities of the saline constituents of sea water are conveyed back again to the land by the action of sea breezes. Every wave which breaks in foam throws into the atmosphere thousands of spherules of salt water; and these, presenting as they do very large surfaces in comparison with their masses, remain for a long time suspended in the air. If the latter be moist, they associate themselves with cloud or fog and fall as rain; if it be more or less dry, their watery portion evaporates, leaving solid residues of saline matter, which will obviously be in a still much finer state of division, and consequently capable of longer suspension in the atmosphere, than the original watery spherules from which the saline residues were derived. These minute particles of sea salt, which the spectroscope never fails to detect in the atmosphere of the British islands, either gradually settle down upon the surface of land or ocean, or are washed out of the air by falling rain. Nevertheless the result of the inflow of rivers, on the one hand, and the return to the land of solid saline matter, on the other, obviously leave a large balance of soluble matters in the ocean, the waters of which are enormously richer than are those of springs, streams and rivers, in soluble saline compounds. Even in respect of organic constituents, sea water generally contains much more than fresh water, although the latter may be considerably polluted. But the organic matter of polluted river water is dead and putrescible, whereas there is strong reason for believing, that nearly the whole of that present in sea water is organised and living.

In addition to numerous samples of sea water collected by ourselves near the shores of these islands, we have received others from Dr. W. B. Carpenter, F.R.S., who collected them, partly from the surface and partly from great depths, during the dredging expeditions made by Your Majesty's ship "Porcupine." The results of the analyses of all these samples are embodied in the following table:—

COMPOSITION OF SEA WATER.

RESULTS of ANALYSES expressed in parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Worthing, high water, at end of pier, Oct. 1867.	3984·0	·295	·294	·001	·038	·333	70	—	—	—	—	
Worthing, low water, 1 mile from shore, July 17, 1868.	3797·0	·994	·433	0	·029	·462	0	1948·5	—	—	—	
Worthing, two hours ebb, 1½ mile from shore, July 15, 1869.	3951·0	·191	·231	·005	·004	·239	0	1995·6	28·2	761·8	790·0	Temp. 17°·8 C.
Worthing, low water, 1 mile from shore, July 16, 1869.	3946·0	·194	·207	·002	·005	·214	0	1996·2	71·3	945·5	1016·8	Temp. 18°·1 C.
Hastings, high water, 1 mile from shore, April 13, 1868.	3815·0	·301	·218	·001	·056	·275	250	—	—	—	—	
Hastings, one hour before high water, 2 miles from shore, May 21, 1870.	3955·0	·291	·135	·005	·013	·152	0	2050·0	52·0	646·0	698·0	
Lat. 59° 56′ N., long. 6° 27′ W., surface.	4110·0	·264	·145	·007	·025	·176	0	2017·5	42·4	818·3	860·7	Temp. 11°·4 C.
Ditto ditto, bottom, 363 fathoms	4030·0	·136	·161	·004	·041	·205	120	2014·4	56·5	860·7	917·2	Temp. −0°·3 C.
Lat. 61° 21′ N., long. 3° 44′ W., surface.	4116·0	·170	·217	·005	·043	·264	150	1996·2	56·5	860·7	917·2	Temp. 9°·8 C.
Ditto ditto, bottom, 640 fathoms	3920·0	·217	·252	·008	·039	·298	140	1988·1	56·5	846·6	903·1	Temp. −1°·3 C.
Lat. 59° 34′ N., long. 7° 18′ W., surface.	4074·0	·647	·134	·022	·030	·182	160	2028·1	70·7	818·3	889·0	Temp. 12°·2 C.
Ditto ditto, bottom, 542 fathoms	4070·0	·331	·163	·022	·032	·213	180	2034·4	42·4	832·4	874·8	Temp. 6°·6 C.
Lat. 59′ 35′ N., long. 9° 11′ W., surface.	4036·0	·321	·098	·017	·056	·168	380	1987·5	98·9	804·2	903·1	Temp. 11°·4 C.
Ditto ditto, bottom, 767 fathoms	4132·0	·313	·096	·020	·061	·173	450	2026·9	84·8	818·3	903·1	Temp. 5°·2 C.
Mediterranean between Corsica and France, surface, May 15, 1870.	4288·5	·195	·088	0	·026	·114	0	2187·5	52·0	723·0	775·0	
Mid-channel between Arran and Ardrossan, July 25, 1870.	3712·8	·317	·144	·005	—	—	—	1943·7	13·0	646·0	659·0	
Aberystwith, 2 miles from shore, Oct. 5, 1872.	3243·5	·085	·074	·002	·020	·096	0	1630·0	15·5	559·5	575·0	Temp. 12° C.
Penzance, in Mount's Bay, Jan. 6, 1873.	3885·5	·264	·091	·001	·015	·107	0	1987·5	0	711·5	711·5	
Bridlington, from end of pier, Jan. 11, 1873.	3607·5	·212	·115	·001	·048	·164	170	1850·0	138·5	635·5	774·0	Temp. 7°·5 C.
Brighton, from end of new pier, Jan. 18, 1873.	3835·2	·261	·137	0	·034	·171	20	1962·5	7·5	666·0	673·5	
Eastbourne, 1 mile from shore, Feb. 22, 1873.	3747·5	·148	·095	·004	·046	·144	170	1937·5	46·0	688·5	734·5	Temp. 3° C. Slightly turbid.
Ramsgate, half mile from shore, after subsidence, March 2, 1873.	3587·5	·136	·133	·001	·026	·160	0	1893·7	15·5	650·5	666·0	Temp. 5° C.
Portland, at mouth of harbour, March 11, 1873.	3823·0	·116	·142	·001	·030	·173	0	2012·5	30·5	666·0	696·5	Temp. 7° C. Slightly turbid.
Average - - - -	3898·7	·278	·165	·006	·033	·204	103	1975·6	48·9	748·0	796·9	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART II. CLASSIFICATION. — Sea water.

From the foregoing numbers it is evident that the proportion of total solid impurity, nearly the whole of which consists of saline matters, varies considerably in the specimens collected in the different localities specified. It is highest in the Mediterranean; where the sea becomes somewhat concentrated by an evaporation, which appears to be more considerable in proportion to the afflux of fresh water than is the case in the Atlantic; and lowest near our own shores, where the sea is diluted by the rivers and streams which pour into it.

The proportion of organic elements varies between such wide limits in the different samples as to strongly suggest that much of the organic matter in sea water is in suspension and not in solution; and that this suspended organic matter consists of living organisms so minute and gelatinous as to pass readily through the best filters. It is only by such an assumption, that the variation in the proportion of organic elements from 1·427 part to ·401 part in 100,000 parts in the samples collected at different dates off Worthing can be satisfactorily explained. On July 17th, 1868, when the first-named proportion was found, the sea off Worthing was probably densely populated by minute gelatinous organisms, whereas on July 16th 1869, it was comparatively free from them. The lowest proportion of organic elements occurs in the sample collected off Aberystwith on the 5th October 1872, when only ·159 part of these elements was obtained from 100,000 parts of water. The *Rheidol*, the *Ystwith*, and the *Clarach* here pour their poisoned water from a very active lead-mining district into the Irish Channel. Although our sample was taken about two miles from the shore, the low proportion of saline matters and of chlorine show the presence of a very appreciable admixture of river water; and it is not improbable that this plumbiferous fresh water, which is said to injuriously affect the shore fishings at Aberystwith, may prove destructive to those minute and still more delicate organisms in sea water, which constitute an important part of the food of fish.

In every case the organic matter was highly nitrogenous, the proportion of nitrogen to carbon varying from N : C = 1 : 0·78 to N : C = 1 : 4·83 and averaging N : C = 1 : 1·83.

PART III.

Special Considerations.

Part III.
Specialities.

Alleged self-purification of polluted rivers.

The subjects considered under this division of the report include (1) the alleged self-purification of polluted rivers; (2) the propagation of epidemics by potable water; (3) the alleged influence of the hardness of water upon health; (4), the superiority of soft over hard water in cooking; (5), the softening of hard water; (6), the improvement of potable water by filtration; (7), the deterioration of potable water by transmission through mains and service pipes; and (8) the constant and intermittent systems of water supply.

I. ALLEGED SELF-PURIFICATION OF POLLUTED RIVERS.

It has been often asserted, but without proof (Report of Royal Commission on Water Supply, p. lxxix.), (1869) that the organic matter contained in sewage and other polluting liquids is rapidly oxidized during the flow of the river into which such liquids are discharged; and that if sewage be mixed with twenty times its volume of river water, the organic matter which it contains will be oxidised and utterly destroyed whilst the river is flowing "a dozen miles or so." We have made numerous observations and experiments upon this alleged destruction of sewage, and have already reported to Your Majesty upon some of them; but the subject is of such vital importance, in connexion with the supply of potable water from rivers, as to render it necessary that we should here give a complete history of our observations and experimental investigations.

During our inspections and inquiries in the basins of the *Mersey* and *Ribble* in the years 1868 and 1869 several favourable opportunities presented themselves for the investigation of this interesting problem.

The river *Mersey*, after receiving the drainage of many towns and manufactories above the Stretford Road bridge, flows thence thirteen miles to its junction with the *Irwell* without encountering any other material source of impurity, although its volume is somewhat augmented by unpolluted affluents. The river *Irwell*, after passing Manchester, falls over a weir at Throstlenest, and runs eleven miles to its junction with the *Mersey* without further material pollution, and with the addition of but very unimportant unpolluted affluents. Lastly, the river *Darwen*, which was, at that time, greatly polluted by the sewage of Over Darwen, Lower Darwen, and Blackburn, joins the *Blakewater* just below the latter town, and then flows thirteen miles to near its junction with the *Ribble* at Walton-le-Dale, without any further pollution, although its volume becomes more than doubled in this part of its course, by the accession of the river *Roddlesworth*, the *Alum House* brook, and numerous small affluents, all of which are unpolluted.

We took samples of the water of the rivers just indicated, viz.—1. the *Mersey* at Stretford Road bridge, and again just before its junction with the *Irwell*: 2. the *Irwell* just before it fell over the weir at Throstlenest, and again just above its junction with the *Mersey;* similar samples of this river being also taken in May and June following: 3. the *Darwen* one-third of a mile below its junction with the *Blakewater*, and again 50 yards above the bridge at Walton-le-Dale. The results of the analysis of these samples are contained in the following table:—

EFFECT OF FLOW ON POLLUTED RIVERS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	**Suspended Matters.**			Temperature of Water.
								Mineral.	**Organic.**	**Total.**	
* *Irwell* at Throstlenest weir, March 12, 1869.	44·6	**2·104**	**·248**	·230	0	·437	7·4	**1·84**	**·96**	**2·80**	6°·2 C.
* " at its junction with the *Mersey*, March 12, 1869.	43·1	**2·009**	**·304**	·338	0	·582	6·8	**·96**	**·48**	**1·44**	6°·8 C.

* Between the two points at which these samples were taken, the water of the *Irwell* is abundantly aërated by falling over six weirs a total height of 34½ feet; at each fall the river is covered with foam for several hundred yards below the weir.

EFFECT OF FLOW ON POLLUTED RIVERS—*continued*.

PART III. SPECIALITIES.

Alleged self purification of polluted rivers.

Description.	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Organic.	Total.	Temperature of Water.
Irwell at Throstlenest weir, May 13, 1869.	39·1	**2·156**	**·238**	·140	0	·353	4·9	**1·18**	**1·86**	**3·04**	12°·2 C.
" at its junction with the *Mersey*, May 13, 1869.	48·0	**2·374**	**·210**	·250	0	·416	6·4	**1·88**	**2·40**	**4·28**	13°·8 C.
" at Throstlenest weir, June 11, 1869, 8.30 a.m.	63·5	**2·134**	**·239**	·375	0	·548	13·0	**2·66**	**2·72**	**5·38**	17°·8 C.
" at its junction with the *Mersey*, June 11, 1869, 6.10 p.m.	61·5	**1·502**	**·241**	·418	0	·581	12·9	**2·28**	**1·88**	**4·16**	17°·8 C.
Mersey at Stretford Road bridge, March 12, 1869.	19·8	**·720**	**·095**	·066	·022	·171	2·3	**·94**	**·30**	**1·24**	4°·3 C.
" at its junction with the *Irwell*, March 12, 1869.	22·8	**·570**	**·078**	·048	·019	·132	2·5	**·84**	**·26**	**1·10**	4°·8 C.
Darwen after junction with *Blakewater*, March 10, 1869.	41·5	**2·127**	**·295**	·219	0	·475	3·6	**1·78**	**1·78**	**3·56**	10°·7 C.
" at Walton-le-Dale, March 10, 1869.	33·0	**1·289**	**·141**	·137	·045	·299	2·9	**·62**	**·18**	**·80**	6°·8 C.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These numbers must not be interpreted too strictly, since it is evident that the proportions of the different constituents of river waters, so highly polluted, as most of those experimented upon, must vary considerably from time to time at any given place in the stream. It is impossible to follow the same body of water for several miles down a stream, because different portions of the stream, in the same transverse section, move with different velocities; and therefore no body of water, included between two transverse sections of a river, can retain its identity whilst flowing down the stream. It is thus very improbable that the sample of water taken, for instance, from the *Irwell* at its junction with the *Mersey* had, at the time when it fell over the weir at Throstlenest, the exact composition exhibited by the sample taken at that weir. Again, the entrance of unpolluted water into the rivers between the places whence the samples were drawn, introduces another source of error which may be regarded as almost a vanishing quantity in the *Irwell*, considerable in the *Mersey*, but demanding correction in the *Darwen*, the volume of which was more than doubled by unpolluted affluents between the places of collection. Notwithstanding these complications, however, the above analytical results unmistakeably disclose the effect of a flow of between 11 and 13 miles upon the quality of a polluted river. They show, in the first place, that when the temperature does not exceed 17°·8 C. (64° Fahr.) such a flow produces but little effect upon the organic matter dissolved in the water. Making no correction for the unpolluted affluents of the *Irwell* and *Mersey*, —and taking the volume of the *Darwen* to be only doubled between the points where the samples were taken, by the accession of water containing the proportions of organic carbon and nitrogen present in the *Ribble* just before its junction with the foul water of the *Darwen*, viz., ·327 part organic carbon and ·026 part organic nitrogen in 100,000 parts,—we have the following reduction in these elements of organic matter in the five experiments:—

Description of Samples.	Reduction in 100,000 parts of Water. Organic Carbon.	Organic Nitrogen.	Per-centage Reduction of Organic Elements. Organic Carbon.	Organic Nitrogen.
Irwell after flow of 11 miles at temperature of 6°·2 to 6°·8 C.	·095	0	4·5	0
Irwell after flow of 11 miles at temperature of 12°·2 to 13°·3 C.	0	·028	0	11·8
Irwell after flow of 11 miles at temperature of 17°·8 C.	·632	0	29·6	0
Mersey after flow of 13 miles at temperature of 4°·3 to 4°·8 C.	·150	·017	20·8	17·9
Darwen after flow of 13 miles at temperature of 6°·8 to 10°·7 C.	0	·039	0	13·2

The rivers upon which the foregoing observations were made are notoriously much polluted by sewage and other refuse organic matters. So intense indeed is their pollution, that ordinary aquatic life is entirely banished from their waters. We deemed it therefore desirable, in order to complete this part of our investigations, to ascertain the effect of a

PART III. SPECIALITIES

Alleged self-purification of polluted rivers.

flow of some miles upon the water of a river less polluted, and in which animal and vegetable life still flourished. For this purpose we selected the *Thames* between Reading and Shiplake Paper Mill. Just below Reading, the *Thames* receives an important affluent,—the *Kennet*,—but it then flows about four miles without receiving any other affluent or pollution of importance. We collected samples of the water about a quarter of a mile below the junction of the *Kennet*, and again just above Shiplake Paper Mill, and submitted these samples to analysis with the following results :—

COMPARATIVE COMPOSITION OF THAMES WATER AT READING AND AT SHIPLAKE PAPER MILL.

Description.	Dissolved Matters.											Suspended Matters.		
	Total solid Impurity	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	**Mineral.**	**Organic.**	**Total.**
The *Thames* ¼ mile below junction with the *Kennet*, 2 p.m., May 31, 1873.	28·86	**·261**	**·071**	·007	·167	·244	1,410	1·70	15·8	6·9	22·7	**·42**	**·06**	**·48**
The *Thames* just above Shiplake Paper Mill, 5.48 p.m., May 31, 1873.	28·42	**·245**	**·068**	·007	·155	·229	1,290	1·70	15·9	7·4	23·3	**·14**	**·10**	**·24**

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

It is obvious that for a just comparison in such cases the samples must be collected with every care and precaution. We have had continual occasion to observe, that when an affluent joins a quietly flowing river, the tributary and main stream flow side by side for a long distance without admixture; we have thus seen the *Thames* and the *Kennet* after their junction, when the latter stream has been turbid and the former clear, flowing without any perceptible mingling for more than a quarter of a mile, and it is almost certain that these rivers do not get thoroughly mixed until they reach the weir and rapids at Sonning bridge, nearly two miles below their junction. Any sample taken from either shore between the point of junction and Sonning bridge would therefore certainly not represent the average composition of the whole stream, and it thus became necessary to take our higher sample in small fractions whilst we crossed the river in a boat. To secure a correct comparison, it was also necessary to make the interval between the two samples correspond approximately to the time of flow of the river between the two points at which they were taken. These precautions were duly observed, and moreover the trial was made on a bright sunny day at the end of May, when aquatic life had a maximum of activity. The analytical results embodied in the foregoing table show that even under these very favourable circumstances, the reduction in the proportion of organic matter was exceedingly small. So minute indeed that, even assuming it to go on at the same rate by night and day, in sunshine and gloom, it would require a like flow of seventy miles to destroy the organic matter present in the *Thames* after its junction with the *Kennet*. We know, however, that the removal of organic matter from the water would go on much more slowly in the shade, and would be almost arrested during the night; so that it would therefore be incorrect to assume that the river would clear itself of organic matter by a flow of seventy miles.

The mineral matters in suspension underwent a very considerable reduction in the still reaches of the river between Reading and Shiplake, but there was no corresponding subsidence of the lighter organic matters in suspension, indeed, the analyses show a slight increase in the proportion of these matters.

To test this point further, and in such a manner as to exclude the element of uncertainty introduced into the above experiments by the variability of the composition of the river waters at different times of the day, one volume of filtered London sewage was mixed with nine volumes of water. On analysis, the mixture was found to contain in 100,000 parts, ·267 part of organic carbon and ·081 part of organic nitrogen. It was then well agitated and freely exposed to the air and light every day by being syphoned in a slender stream from one vessel to another, falling each time through three feet of air. After 96 hours it still contained in 100,000 parts ·250 part of organic carbon and ·058 part of organic nitrogen; and even after 192 hours the undecomposed organic matter still contained ·2 part of organic carbon and ·054 part of organic nitrogen. The

Alleged self-purification of polluted rivers.

temperature of the air during this experiment was about 20° C. These results indicate approximately, the effect of oxidation which would be produced by the flow of a stream containing 10 per cent. of sewage for 96 and 192 miles respectively at the rate of one mile per hour. This effect may be thus expressed :—

Removal of Organic Constituents.	Reduction in 100,000 parts of Water.		Per-centage Reduction of Organic Elements.	
	Organic Carbon.	Organic Nitrogen.	Organic Carbon.	Organic Nitrogen.
In flow of 96 miles at rate of 1 mile per hour - -	·017	·023	6·4	28·4
In flow of 192 miles at rate of 1 mile per hour - -	·067	·027	25·1	33·8

Another similar series of experiments was made with a mixture of fresh human urine and the deep chalk well water supplied to London by the Kent Water Company, in the proportion of one gallon of urine to 3,077 gallons of water. The mixture was exposed to the air, and briskly agitated as before. A sample of it was submitted to analysis immediately after mixture, and samples were taken and analysed at almost daily intervals afterwards. The results of these analyses are embodied in the following table :—

EFFECT OF AËRATION UPON ORGANIC MATTER IN WATER.

———	Organic Carbon.	Organic Nitrogen.
Immediately after mixture, February 17, 1874 - -	·282	·243
" " 18 " - -	·298	·251
" " 19 " - -	·244	·255
" " 24 " - -	·225	·253
" " 25 " - -	·214	·259
" " 28 " - -	·214	·276

These results show that fresh urine when mixed with large volumes of water is, under atmospheric influences, still more permanent and indestructible than sewage.

Flowing at the rate of only one mile per hour in a river, the mixture experimented upon would travel over 264 miles before it would lose by oxidation 7 per cent. of its organic constituents.

Lest any error should have been introduced into these experiments by the abstraction of organic matter from the air itself during the long continued agitation of the water, we treated the Kent Company's water without any admixture of urine in exactly the same way, and submitted to analysis samples of it taken at the beginning and end of the experiments with the following results :—

COMPOSITION OF THE KENT COMPANY'S WATER BEFORE AND AFTER ELEVEN DAYS' AGITATION WITH AIR.

Kent Company's Water.	Organic Carbon.	Organic Nitrogen.
As drawn from main, Feb. 17, 1874 - - -	·054	·016
After agitation with air for 11 days - - - -	·056	·017

It is thus evident that the water abstracted but the merest traces of organic matter from the air.

An examination of the gases dissolved in water containing organic matter in solution still further confirms the results of the above experiments. The oxidation of the organic matter in water is effected chiefly, if not exclusively, by the atmospheric oxygen dissolved in the water; such dissolved oxygen being well known to be, chemically, much more active than the gaseous oxygen of the air. If, therefore, water contaminated with organic matter be perfectly excluded from the air in a carefully stoppered bottle, the gradual diminution in the amount of dissolved oxygen indicates exactly the progress in the oxidation of the organic matter.

We have made this experiment by mixing the Grand Junction Company's *Thames* water with 5 per cent. of fresh London sewage. The organic carbon, organic nitrogen, and dissolved oxygen were immediately determined in one portion of the mixture, and the remainder was then enclosed in a series of accurately stoppered bottles, which were exposed to diffused daylight and kept at a temperature of about 17° C. One of these was opened every 24 hours, except on an intervening Sunday, and the weight of dissolved oxygen

PART III. SPECIALITIES.

Alleged self-purification of polluted rivers.

contained in the enclosed water determined, by boiling off the dissolved gases in vacuo. The following results were obtained:—

Weight of Dissolved Oxygen in 100,000 parts of the Water.						
Immediately after Mixture.	After 24 Hours.	After 48 Hours.	After 96 Hours.	After 120 Hours.	After 144 Hours.	After 168 Hours.
·946	·803	·616	·315	·201	·060	·036

Immediately after mixture the sewage-contaminated water contained in 100,000 parts, 2·099 parts organic carbon and ·207 part organic nitrogen.

These numbers show that, even in warm weather, the oxidation of the animal organic matter in sewage takes place very slowly. Leaving altogether out of the question the oxidation of the hydrogen and nitrogen, and assuming that for the destruction of the organic matter, the carbon alone requires to be oxidized (3 parts by weight of carbon requiring for this purpose 8 parts of oxygen), then the per-centage of sewage destroyed in each of the above periods will be as follows:—

			Per-centage of Sewage destroyed.
1st	period of	24 hours	6·8
2nd	,,	24 ,,	8·9
3rd	,,	48 ,,	14·3
4th	,,	24 ,,	5·4
5th	,,	24 ,,	5·8
6th	,,	24 ,,	2·1
			43·3

Up to the end of the 6th day (or 5th period) the oxidation took place at a tolerably constant though somewhat diminishing rate; the amount of oxygen still left in solution had, however, then become so small as greatly to retard the rate during the next 24 hours, when the experiment was discontinued. Assuming, however, that if the polluted water had been constantly exposed to the air, a portion at least of the oxygen used would have been replaced; and assuming further that the oxidation proceeded during 168 hours at the maximum rate observed, then at the end of that time only 62·3 per cent. of the sewage would be oxidized.

It is thus evident from this experiment that, so far from sewage mixed with 20 times its volume of water being oxidised during a flow of 10 or 12 miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles, at the rate of one mile per hour, or after the lapse of a week. But even this result is arrived at by a series of assumptions which are greatly in favour of the efficiency of the oxidizing process. Thus, for instance, it is assumed that the 62·3 per cent. of sewage is thoroughly oxidised and converted into inoffensive inorganic matter; but the experiments showed that, in fact, no sewage whatever was so converted or destroyed even after the lapse of a week, since the amount of carbonic acid dissolved in the water remained constant during the whole period of the experiment; whilst, if the sewage had been converted into inorganic compounds, the carbonic acid, as one of these compounds, must have increased in quantity.

Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage or urine when these polluting liquids are mixed with fresh water and violently agitated in contact with air, or, finally, the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage; we are led in each case to the inevitable conclusion that the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidised. It will be safe to infer, however, from the above results that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.

These results confirm the opinion arrived at from theoretical considerations, and expressed by Sir Benjamin Brodie Bart., F.R.S., late Professor of Chemistry in the University of Oxford, in his evidence given before the former Rivers Pollution Commission (First Report, River *Thames*, Vol. II. (Minutes of Evidence), page 49. His evidence was to the following effect:—

"I should say that it is simply impossible that the oxidising power acting on sewage running in mixture with water over a distance of any length is sufficient to remove its noxious quality. Taking the case of Oxford: if the sewage of Oxford was, in its entirety, discharged into the river *Thames*, I

Part III. Specialities.

Alleged self-purification of polluted rivers.

should say that we could certainly not trust to the oxidising power to take away the noxious quality of the water before it reaches, say, Teddington. I presume that the sewage could only come in contact with oxygen from the oxygen contained in the water, and also from the oxygen on the surface of the water; and we are aware that ordinary oxygen does not exercise any rapidly oxidising power on organic matter. I believe that an infinitesimally small quantity of decaying matter is able to produce an injurious effect upon health. Therefore, if a large proportion of organic matter was removed by the process of oxidation, the quantity left might be quite sufficient to be injurious to health. With regard to the oxidation, we know that to destroy organic matter the most powerful oxidising agents are required; we must boil it with nitric acid and chloric acid and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time is absurd."

That the noxious qualities of polluted water are not removed by a flow of 10 or 12 miles is sufficiently evident, even to the senses, in the case of the three rivers upon which we experimented in the *Mersey* and *Ribble* basins. They were all very offensive at the termination of the flow; and the same condition of things in the case of the river *Bollin* contaminated with the drainage of Macclesfield, is testified to by Mr. James Wright, J.P., a riparian proprietor residing about six miles below Macclesfield, who says* :—

"The river which has been referred to runs through my land for about a mile and a quarter, and that is, I should think, within five or six miles of Macclesfield, but the river is most offensive even at that distance. It is as black as ink, and it is offensive, particularly in dry weather."

Messrs. Robert Greg & Co., of Handforth, also say of the same river* :—

"During the summer months in warm weather the smell or miasma from the river is bad, sometimes abominable. The whole of Macclesfield pours its sewage into this stream. This place is about eight miles from Macclesfield. The course of the stream would probably be more, say, 10 miles. In spite of this distance the water is generally utterly foul, and thick, slimy, and seething."

Although, however, the flow of a river has thus but little effect in purifying the water by the *oxidation* of the dissolved organic matters, it has a most material influence in the removal by *subsidence* of a large proportion of the suspended impurities, both organic and mineral, especially if the flow be sluggish in places. In passing through still pools, the turbid stream lets fall its load of grosser mechanically suspended particles, and thus the water becomes clearer, although the dissolved impurity remains nearly as great as ever. It is, doubtless, this clarification by subsidence which has led to the very general, but erroneous, belief in the rapid self-purifying power of running water. Our experiments upon the *Mersey*, and especially upon the more turbid *Irwell* and *Darwen*, show the great amelioration as regards turbidity which is effected during the flow of these rivers between the points already mentioned.

PURIFICATION OF THE IRWELL, MERSEY, AND DARWEN BY SUBSIDENCE.

Description.	Subsidence from 100,000 Parts of Water.			Per-centage Reduction of Matter in Suspension.		
	Mineral Matter.	Organic Matter.	Total Solid Matter.	Mineral.	Organic.	Total.
1. *Irwell*, after flow of 11 miles, Mar. 12, 1869	·88	·48	1·36	47·8	50·0	48·6
2. " " 11 " June 11, 1869	·38	·84	1·22	14·3	30·9	22·7
3. *Mersey* " 13 " Mar. 12, 1869	·10	·04	·14	10·6	13·3	11·3
4. *Darwen** " 13 " Mar. 10, 1869	·54	1·42	1·96	30·3	79·8	55·1

* Corrected as before for afflux of clean tributaries.

The *Irwell* deposits much of its suspended matter above Throstlenest weir, but gets rid of from one-third to one half of the remaining organic mud during its flow thence to the *Mersey*. The latter river being much less turbid, deposits but 13·3 per cent. of its suspended organic matters in a flow of 13 miles; whilst the *Darwen*, flowing much more rapidly, and having but few still pools, is nevertheless cleansed from no less than 79·8 per cent. of its suspended organic matters during its transit from Witton Park, Blackburn, to Walton-le-Dale. It must be remembered, however, that the mud so thrown down is only deposited, not removed or rendered innocuous. During floods it is stirred up and again becomes very offensive; and when the temperature of the water rises in summer, the sediment enters into active putrefaction, evolving nauseously smelling gases, which buoy up large flakes of the black mud, causing them to rise to the surface, and rendering the river horribly offensive to sight and smell, if not actually injurious to the health of the neighbouring inhabitants.

In his evidence before the Royal Commission on Water Supply (1869) (Minutes of Evidence, page 158), the Right Hon. Lyon Playfair, M.P., C.B., F.R.S., stated :—

"2681. (*Mr. Prestwich.*) Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and

* See 1st Report, Vol. II. (Minutes of Evidence), p. iii.

PART III. SPECIALITIES. — Propagation of epidemics.

what would be the effect of the presence of organic matter in such water?—The effect of the organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

"2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river, such as the *Thames* above London, the action of the aeration of the water would be in that case to destroy any moderate amount of organic matter, would it not?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination; by a chemical examination you can do so, but the presence of the most highly oxidised forms of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

"2683. Is it not considered that by the time the *Thames* water, with which London is now supplied, reaches the delivery pipes all organic matter is converted into the state of nitrates and nitrites?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not."

II.—ON THE PROPAGATION OF EPIDEMICS BY POTABLE WATER.

NUMEROUS researches, made by both physiologists and chemists, have led investigators to the conclusion that several, at least, of those diseases which are propagated in the manner of epidemics diffuse themselves by living germs or spores, which, finding a suitable *nidus* in the bodies of animals, there multiply and produce that specific disturbance of the normal vital functions, which characterises a disease of the zymotic class. It is indeed in consequence of the extensive prevalence of this view respecting the mode of propagation of such diseases that the term zymotic (from ζυμόω, I ferment) has come to be almost universally employed to designate them. This view is as yet far from being established upon a firm scientific basis; the germs or spores themselves have never yet been isolated or individually recognised, and it is obvious that until this has been done, all explanations of the propagation of disease founded upon this view belong to the region of theory. Nevertheless, this theory is better supported by the evidence of numerous facts and observations, than many convictions upon which it is necessary to act in ordinary life. Moreover its truth or falseness, leaves to a great extent untouched the sanitary teaching of the facts upon which it is founded; and the experience of the sequence of morbific phenomena, which such facts create, must not be ignored because this experience cannot be explained without recourse to theory. Be the theory true or false, it is a fact that cow-pox, sheep-pox, small-pox, hydrophobia, glanders, and syphilis, can be, with a very small per-centage of failures, propagated from individual to individual by means of an excessively small amount of organic matter.

The farthest advance towards a non-theoretical explanation of these phenomena has been made by M. Chauveau, who, in the year 1868, submitted the virus of vaccine matter, small-pox, sheep-pox and glanders, to a searching investigation, in order to discover whether the peculiar properties of these liquid poisons resided in their liquid or in their solid constituents; that is to say, whether the infectious matter of these poisons is in solution or in suspension in the serous fluid of which they are chiefly composed. He found that some of the solid constituents in suspension were so excessively minute in size as to pass through all filters, and that they were separated only very imperfectly by subsidence. The latter operation, however, permitted the complete deposition of the coarser organised particles (*leucocytes*), from the vaccine virus, when the latter was diluted with ten times its weight of water, but a fine granular material (*granulations élémentaires*) still remained suspended in the liquid, and M. Chauveau proved the decanted liquid to possess all its original infectious quality unimpaired. The question now presented itself,—would the infective power be still unimpaired if the remaining suspended particles, —the *granulations élémentaires*,—were also removed? To answer this question the decanted liquid was submitted to diffusion in distilled water; by which means the soluble constituents slowly passed into the distilled water and left the suspended granules behind. Infants, horses, and rabbits were inoculated with the liquid free from granulations, in every case without any result, whilst inoculation with the liquid containing the granules infected animals just as well as the original vaccine virus, thus proving that the power of infection resided in the suspended granules, which seemed to be organised, and not in the soluble, and consequently unorganised, constituents of the vaccine virus. M. Chauveau pushed his researches still further. If the suspended

Part III. Specialities. Propagation of epidemics.

granules be the poisonous agent, and if the morbific effects of inoculation depend upon the reproduction and multiplication of the organised granules in the bodies of the animals operated upon, mere dilution of the vaccine matter ought obviously to have little or no effect upon the virulence of the disease produced. It is true that inoculations with the very dilute lymph might be sometimes abortive, because the operator might fail to convey into the puncture a single living granule; if, however, only a single granule gained access to the wound, its infinite multiplication ought, if the zymotic theory be true, to produce, *cæteris paribus*, the same effect as that obtained with the concentrated lymph. But if, on the other hand, the infectious quality resided in the liquid portion of the lymph, then the gradual dilution of the latter might be expected to produce a corresponding diminution in the virulence of the disease caused by inoculation. The result of very numerous experiments of this kind upon infants, horses, and cows, showed that the per-centage of successful inoculations diminished with the dilution of the vaccine virus, although one successful result was obtained even after the lymph had been diluted with 150 times its weight in water. The most important result of these experiments was the demonstration, that in every case where the inoculation with the diluted lymph was successful, the disease had the same intensity and virulence as if the original concentrated lymph had been used. The dilution diminished the per-centage of attacks, but it left the virulence of the disease untouched. Similar experiments upon the virus of small-pox, of sheep-pox, and of glanders led to exactly similar results. The poisonous quality of all these humours was proved to reside in suspended and very minute organised particles, whilst the liquid in which these particles were suspended was found to be quite incapable of communicating the disease to animals innoculated with it. (Comptes Rendus de l'Academie des Sciences, tome lxvi. 1868, pp. 289, 317, and 359.) These remarkable and important results have since been confirmed by Dr. J. S. Burdon Sanderson, F.R.S., in connexion with the Medical Department of Your Majesty's Privy Council. (Twelfth Report of the Medical Officer of the Privy Council, 1869.)

In like manner, it is a fact that scarlatina, diphtheria, measles, and typhus fever, can be transmitted from diseased to healthy persons, not only without contact, but also without any *apparent* communication, the poisonous matters in these cases being presumably conveyed through the air from person to person. In the communication of these diseases, however, the conclusiveness of the fact is somewhat disturbed by the circumstance that a considerable per-centage of failures in the transference of the disease is observed, even when the persons, who remain uninfected, are exposed to infection under apparently precisely the same conditions as those to whom the disease is communicated.

Again, it is a fact that cholera and typhoid or enteric fever can be communicated from individual to individual; and the infectious matter of these diseases, which resides in the discharges from the stomach and bowels of the patients, is believed to be occasionally conveyed by air, but a great mass of experience renders its propagation through the medium of drinking-water almost certain. Here, however, again the continuity of the evidence is broken by the circumstance that a still more considerable per-centage of those who are equally exposed to the infection escape the disease. Nevertheless, we are of opinion, that the cases in which exposure to infected water has been followed by attack are sufficiently numerous and decisive to warrant the conclusion that water polluted by the discharges from the stomachs or bowels of cholera or typhoid patients can propagate these diseases. That such an unspeakably disgusting mode of infection is not only possible, but imminent, over a very large proportion of the inhabitants of Great Britain is conclusively proved by the numerous analyses of drinking water recorded in the preceding part of this report. So far from the horrible practice just indicated being exceptional, it is the rule. As the result of our inquiries into the polluted waters of this country we are compelled to state that it is a widely spread custom, both in towns and villages, to drink either the water of rivers into which the excrements of man are discharged, or the water from shallow wells which are largely fed by soakage from middens, sewers, or cesspools. Thus vast multitudes of the population are daily exposed to the risk of infection from typhoidal discharges, and periodically to that from cholera dejections. That this risk is not inconsiderable is abundantly proved by the following evidence, which we now adduce in confirmation of the statement, that cholera and typhoid fever are propagated through the medium of water polluted by human excremental discharges.

Propagation of Cholera by Water.

1. *London.*—London has suffered on four occasions from epidemics of Asiatic cholera which occurred in the years 1832, 1849, 1854, and 1866. The mortality in 1832

PART III. SPECIALITIES.

Propagation of cholera—London.

was undoubtedly great, but at that time there was no official registration of the causes of death; the number of deaths reported to the Privy Council, however, was 5,275, and as the population of London then amounted to only 1,681,641, the proportion of deaths to 10,000 of population was 31·4. In 1849 cholera killed in the metropolis 14,137 out of a population of 2,286,800, or 61·8 out of 10,000 people. In 1854, the population of London amounted to 2,504,198, and the number of lives destroyed was 10,738, or 42·9 per 10,000. In the year 1866, out of a population estimated at 3,037,991, cholera slew 5,596 persons, or 18·4 per 10,000. During the period from 1832 to 1866, the water supply underwent important changes. In 1832 a considerable part of London was supplied with water abstracted from the *Thames* and *Lee*, and the remainder from shallow wells. At that time the river waters within the metropolis could not have been nearly so much polluted as subsequently, owing partly to the smaller population upon their banks, but chiefly to the absence of an efficient system of sewerage in the metropolis. In 1849, the sources of water supply remained substantially the same, except that probably river water was more, and shallow well water less, used. But, in the meantime, the sewerage system had become fully developed in London, and the use of waterclosets had become almost universal. The excrements of nearly the whole population were thus rapidly conveyed into the *Thames*, the *Lee*, and the *Ravensbourne*, and these rivers became proportionately fouled before distribution throughout the metropolis. In fact, there was at this period the most perfect organization for the diffusion of the excremental discharges of the metropolis through the drinking water, and their speedy reconveyance to the inhabitants for daily consumption. It was also in this epidemic that London suffered most severely from cholera, the mortality from this disease having been nearly 62 per 10,000 of the population. Before the next visitation in 1854, a small portion of the water abstracted from the *Thames* within the metropolis had been replaced by a corresponding volume taken from the river above Teddington Lock, and consequently beyond the reach of the London sewage. The mortality from cholera in this visitation was 46 per 10,000 inhabitants. The next visitation of cholera occurred in 1866, when the whole of the foul water supply from the tidal *Thames* had been replaced by the less polluted water abstracted from the river above Teddington Lock. The Kent Water Company had abandoned the polluted *Ravensbourne*, and were supplying water pumped from deep wells in the chalk, but this water was not in 1866 wholly secured from admixture with the polluted water of the *Ravensbourne*. The East London Water Company had also improved its supply by removing its intake from Old Ford, where the River *Lee* was much fouled by sewage, to Lee Bridge, where the pollution was much less intense. This company, however, still reserved to itself the power, although it had not the legal right, of distributing foul unfiltered water from the reservoirs at Old Ford, and it made use of this power after the introduction of cholera into London in 1866. Nevertheless, a very large proportion of the water supplied in London in 1866, was very much less polluted by human excrements than that distributed in 1854. The mortality from cholera, in this last visitation, was only 5,596, or 18 per 10,000 of the population. Shortly summarised, the respective conditions of water supply and cholera mortality are as follow :—

—	Character of Water Supply as regards excremental Pollution.	Total Mortality from Cholera.	Mortality from Cholera per 10,000 of Population.
Epidemic of 1832 -	Polluted - -	5,275	31·4
„ 1849 -	Very much polluted -	14,137	61·8
„ 1854 -	Less polluted -	10,738	42·9
„ 1866 -	Much less polluted -	5,596	18·4

These are the results arrived at by the most general investigation of the subject. They show that in every epidemic the mortality varied directly with the intensity of the excremental pollution of the water drunk by the people; but the more detailed study of the statistics in those epidemics which permit of it, demonstrates much more conclusively this connexion between cholera mortality and the excremental pollution of water.

Reporting on the influence of the degree of sewage contamination of water upon the propagation of epidemic cholera, Dr. W. Farr, F.R.S., in a letter to the Registrar-General, printed in the quarterly return of the marriages, births, and deaths in England, during the quarter ending December 31st, 1854, showed by statistical tables that, in the cholera epidemic of 1849, the portion of the metropolitan population which was supplied by water taken from the *Thames* at Kew, suffered fatally from cholera to the extent of 8 in

Part III. Specialities. — Propagation of cholera—London.

10,000. Of every 10,000 people supplied with water taken from the river at Hammersmith, 17 died. Of the inhabitants of Belgravia, St. George's Hanover Square, Chelsea, and Westminster, supplied with water taken below Chelsea Hospital, 47 in 10,000 died; whilst the districts drawing their supply still lower down, viz., at Battersea and between Hungerford and Waterloo Bridges, where the river was still more foul, suffered to the extent of 163 deaths to 10,000 inhabitants. In the year 1854 (the next visit of epidemic cholera), the Southwark Water Company continued to get its water from the *Thames* at Battersea, close to one of the sewers, but the Lambeth Company had gone up to Teddington, beyond the range of the London sewage. In 1849, Bermondsey was supplied by the Southwark Company, and the deaths from cholera were 734, whilst in 1854 they were 829; the number of deaths was greater in 1854 than it had been in 1849, the foulness of the river at Battersea being presumably greater in 1854, than in 1849. In Lambeth, which was supplied partly by the Lambeth and partly by the Southwark Company, the deaths from cholera which were 1,618 in 1849 fell to 904 in 1854. In 26,000 houses supplied by the Lambeth Company, from Thames Ditton, the deaths were 294, whilst in 40,000 houses supplied by the Southwark Company, from Battersea, they were 2,284. In the houses supplied with comparatively pure water, the deaths from cholera were 40 per 10,000 of the inmates, whilst in those supplied with foul water, the deaths were 130 in 10,000. These houses were in the same district, the pipes of the two companies interlacing; it is therefore to be presumed that all were equally exposed to any other deleterious influences which affected the health of the district at that time, the quality of the water supplied by the two companies, constituting, so far as is known, the only difference in the conditions under which the population was placed.

In his evidence before the Royal Commission on Water Supply (1869), Mr. John Simon, F.R.S., the Medical Officer of Your Majesty's Most Honourable Privy Council, thus expresses his opinion on this subject. (Minutes of Evidence, p. 167):—

"There are dangerous qualities of water supply, with regard to which so far as I know (but I do not speak as a skilled chemist), chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect. It is, I think, a matter of absolute demonstration that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was the badness of the water supply then distributed to those districts of London. In the interval between the 1849 epidemic and the 1854 epidemic, one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river; and we at once lost a great part of the mortality on that side of the river. I have just said that in 1853–4, after the one company had improved the quality of its supply, the southern district of London showed a greatly diminished liability to cholera. But it was found that this great difference did not prevail uniformly through the south side of London, but was confined to those houses which were supplied by the improved water supply. There was still great mortality on the south side of the river, but this belonged exclusively to the houses which were still supplied with impure water. The details of this gigantic crucial experiment performed on half a million of people, are given in the report to which I have referred; this table extracted from it, gives a striking synopsis of the results:—

Death Rates per 1,000 of Living Population in two Epidemic Periods.		In Houses enumerated in 1854 as receiving their Water Supply	
		From the Lambeth Company.	From the Southwark and Vauxhall Company.
Cholera	1848–9	12·5	11·8
	1853–4	3·7	13·0
Diarrhœa	1848–9	2·9	2·7
	1853–4	2·1	3·3

"N.B.—Between the two epidemic periods the Lambeth Water Company had changed its source of supply.

"Now we come to another epidemic period. And now fortunately, both the companies which supply the south side of London have ceased to give foul water. Subject to some qualifications which I will state presently, they both give fairly good water, and now, in consequence, the cholera mortality in those parts of London, has been, comparatively speaking, insignificant. But, as is now a matter of notoriety, within the area of another water company in London, the population last year suffered very dreadfully from cholera; I refer to certain eastern parts of London. Cholera in high development was confined to those parts of London, and those parts of London were in the area of one water company. And what makes this case the more remarkable is, that not the whole area of that water company suffered; the water company gave two waters and the high cholera mortality was apparently restricted to those parts of London which received one of these two supplies, so to speak, to half the district of the East London Water Company. The source from which the company supplied this half of its district, was a source peculiarly exposed to contamination from a foul part of the river *Lee*. The contamination was sewage. Speaking broadly for the whole metropolis, the area of intense cholera in

PART III. SPECIALITIES.

Propagation of cholera—London.

1866 was almost exactly the area of this particular water supply, nearly, if not absolutely filling it, and scarcely, if at all reaching beyond it."

This outbreak of intense epidemic cholera in the water district supplied by the East London Company was closely investigated by Dr. W. Farr, F.R.S. and Dr. E. Frankland, F.R.S., for the Registrar-General; by Captain Tyler, R.E., for the Board of Trade; by Mr. J. Netten Radcliffe, for the Medical Department of Your Majesty's Most Honourable Privy Council, by the Rivers Pollution Commission appointed in 1865, and by others. These investigations conclusively proved that the illegal power, which we have already mentioned as at that time possessed by the East London Company, to supply foul and unfiltered water from their uncovered reservoirs at Old Ford, was exercised in the year 1866, once in March, once in the latter part of June, and once in the early part of July. As no precise record of this use of unfiltered water was kept by the company, and as the man in charge of the pumping engines at Old Ford had general orders to use it whenever the filtered water ran short, it is not improbable that recourse was had to the uncovered reservoirs more frequently than the man in charge of the engines at Old Ford was able to remember. It is, moreover, certain that this man was not warned of the danger of such a proceeding until the 1st of August, when the remarkable connection between this cholera explosion and the East London water was pointed out by the Registrar-General in his weekly return, which reached the engineer of the company and the public generally on that day. Be that as it may, however, we have it admitted by the man himself (See Second Report of the Rivers Commission, 1865,—River *Lee*), that early in July he did distribute this foul water over that part of the East London Company's district, which was supplied from Old Ford. This was the portion of their district which was the sole area of intense cholera in the metropolis, in 1866. In the words of Mr. John Simon "*the area of intense cholera in* 1866 *was almost exactly the* " *area of this particular water supply, nearly, if not absolutely, filling it and scarcely if* " *at all reaching beyond it.*"

A reference to the statistical records of the epidemic shows how close was the chronological connection, firstly, between the distribution of foul water by the East London Company *in the early part of July* and the outburst of the disease; and, secondly, between the warning given by the Registrar-General to the water company on the 1st of August and the subsidence of the epidemic. The following table, taken from Mr. Radcliffe's report, shows this connexion as well as the contemporaneous mortality in the rest of London:—

DAILY MORTALITY FROM CHOLERA IN THE EAST DISTRICTS AND REST OF THE METROPOLIS, FROM JULY 8TH TO SEPTEMBER 1ST, 1866.

Date.	East London, including West Ham.	Rest of London.	Date.	East London, including West Ham.	Rest of London.
July 8	0	1	August 5	119	24
„ 9	0	3	„ 6	115	15
„ 10	0	0	„ 7	84	18
„ 11	3	3	„ 8	93	22
„ 12	6	2	„ 9	91	11
„ 13	12	6	„ 10	72	7
„ 14	11	4	„ 11	67	9
„ 15	12	3	„ 12	71	15
„ 16	31	3	„ 13	44	13
„ 17	54	6	„ 14	38	7
„ 18	59	5	„ 15	50	20
„ 19	83	9	„ 16	44	15
„ 20	91	6	„ 17	38	13
„ 21	104	14	„ 18	39	12
„ 22	104	11	„ 19	24	6
„ 23	130	14	„ 20	31	10
„ 24	144	9	„ 21	24	9
„ 25	166	17	„ 22	25	12
„ 26	155	15	„ 23	30	3
„ 27	125	18	„ 24	20	9
„ 28	157	16	„ 25	11	13
„ 29	151	18	„ 26	23	11
„ 30	141	17	„ 27	21	9
„ 31	171	29	„ 28	15	8
*August 1	170	34	„ 29	23	13
			„ 30	10	12
August 2	155	24	„ 31	7	16
„ 3	114	18	September 1	8	15
„ 4	112	15			

* Date of warning given to the East London Water Company by the Registrar-General.

Part III. Specialities. — Propagation of cholera—London.

Not only was the filtered water supplied from Old Ford, thus polluted by the intentional admission of unfiltered soakage water from the uncovered reservoirs, but it was proved by Captain Tyler's inspection, that the reservoir in which the filtered water was stored, and from which it was pumped, was at all times exposed to the spontaneous percolation of excessively foul water from the surrounding porous sewage-sodden gravel, and from the neighbouring *Lee*, which was there little better than an open cesspool, receiving as it did the sewage of the large population inhabiting Old Ford, Bow, the greater portion of Bromley and part of Mile End. The river is here held up by locks, and a continuous stratum of gravel connected its bed, on the one hand with the uncovered reservoirs, and on the other with the covered reservoirs in which the filtered water was stored for distribution.

Thus the distribution, by the East London Company, of unfiltered water excessively polluted with sewage was conclusively proved to have occurred previous to and after the introduction of cholera into London. But the question now presents itself, was the sewage so distributed specially infected by the excrements of cholera patients? because if it was not so infected, the hygienic condition of the persons drinking that sewage would still not differ in respect of potable water, from that of many other communities who were then, as now, consuming sewage-tainted water. This question is thus answered by Mr. J. Netten Radcliffe in his before-mentioned report to the Medical Department of Your Majesty's Privy Council:—" Into the river *Lee*, cesspool and canal, at Bow Bridge, " about 600 yards below the northern uncovered reservoir, were poured on the 26th and " 27th June 1866, as shown in a previous section, the discharges of the first two patients " who died of epidemic cholera in the east districts. At the time the temperature was " excessive, and it promoted in the highest degree putrefactive changes in the canal, " which was in a peculiarly foul state from want of flushing. It is from the action of the " temperature, and its probable effect in promoting choleraic decomposition in the " excrementitious matter in the river, that I assign importance to the variations of " atmospheric heat described in the meteorological section.

" Moreover it is not to be forgotten that the sewage from the house in Archibald " Street, in which a death from choleraic diarrhœa occurred on the 12th June, would " pass into the *Lee* at a point about 200 feet distant from the northern uncovered " reservoir."

The evidence is conclusive as to the infection of the sewage, the access of the infected sewage to the service reservoir of the East London Water Company at Old Ford, and the distribution of the water so polluted exclusively, or nearly so, to the inhabitants of that district in the east of London, which suffered so severely from cholera in 1866, such distribution occurring immediately before the outbreak. The inference to be drawn from it is so irresistible, as to be scarcely affected by a few objections which have been raised against it, even if these had not been on the whole satisfactorily answered by Mr. Netten Radcliffe. (*See* Appendix to Ninth Report of the Medical Officer to Your Majesty's Most Honourable Privy Council, 1866, page 312.) In connexion with some of these objections we would here remark that whilst water is a very potent, it is not the sole, agent in the propagation of cholera. Wherever the defœcation arrangements of a town permit of excrementitious matters becoming dry, there will always be, during the prevalence of epidemic cholera, imminent danger of the propagation of the disease by excremental dust wafted through the air, and it is possible that in some of the cases of cholera in the eastern districts of London, in which the infection could not be traced to the consumption of the East London Company's water, it may have been thus communicated from the surrounding pest-smitten district.

The one essential condition for the propagation of cholera appears to be the conveyance of infected matter from the stomach or bowels of a cholera patient to the mouths of other persons, and it is obvious that this conveyance can be effected through a variety of media; but of these two only, air and water, from the universality of their use, and the common sources from which large communities derive them, are likely to be rapid carriers of the disease to masses of the population. In this country all investigations lead to the conclusion that water is by far the most frequent and effective carrier, although there are not wanting instances in which the infection was probably conveyed through the air. Thus the great outbreak at Merthyr Tydfil in 1849 was almost certainly due to atmospheric infection. At that period the town was rapidly growing from a mere village. Rows of cottages were built without any privy or water-closet accommodation, the unpaved streets were rendered passable by the spreading of cinders and ashes upon them, and we ascertained that it was the common practice for the inhabitants to throw all their excremental refuse upon these ashes in front of their houses. In this way the most favourable conditions for atmospheric propagation were

PART III. SPECIALITIES.

Propagation of cholera—London.

provided. A part, at least, of the outbreak of cholera in Liverpool in the year 1866 was probably due to the same cause. In the most miserable dwellings of the poor (since, to a great extent demolished thanks to the zeal of Dr. W. S. Trench, the Medical Officer of Health, and the late Mr. James Newlands, C.E., the Borough Engineer) the privies and ashpits were not unfrequently situated inside the houses; even two years later, we ourselves saw instances of this arrangement, and thus the excrements of the people were imminently liable to become dry, and to be dispersed as dust. This condition of defœcation, which is the exception in England, is the rule in several other European states, where the people live in houses divided into flats. In such houses the excrements discharged from the several floors are conveyed, by wooden or sheet-iron troughs or trunks, to a common midden at the base; there is usually a free circulation of air through these trunks, the outer air being drawn through them into the houses. The excrementitious matters, which soil these trunks from top to bottom, are thus extremely liable to become, from time to time, dry and capable of transport by the currents of air passing over them. Dr. Biermer, the Director of the Clinical Hospital, at Zürich, is of opinion that the outburst of cholera in that town in the year 1867 was directly traceable to this cause, and Dr. A. Fick, then Professor of Physiology in Zürich, has furnished us with information respecting this outbreak of which the following is a summary:—The introduction of the contagion into Zürich was susceptible of the clearest proof. The first case was that of a child brought to Zürich by its parents, who had suddenly fled from Rome through fear of cholera. This child was attacked on the journey, and died in an hotel in Zürich. The second case was that of the laundress who washed the child's linen. The third victim was a young man, who was accustomed to take his supper at this hotel. Afterwards several workmen in a dye-work, who were accustomed to visit the same hotel, were attacked. Then there arose a new focus of the disease in the large machinery works of Messrs. Escher, Wyss, and Co., from which the infection spread so widely that the origin of the single attacks could no longer be traced. After about thirty of the workmen in these works had been attacked, it was discovered that they had all used one particular privy in the manufactory. That privy was immediately closed, and from that day no fresh attack in Messrs. Escher and Co.'s works occurred.

These facts not only show the possibility of the diffusion of cholera poison through the air, but also sound a note of warning in reference to the dry methods of dealing with excrementitious matters recently, to some extent, brought into use in this country.

In a report on the cholera epidemics of London in 1849 and 1854, as affected by the consumption of impure water, addressed to the Right Hon. the President of the General Board of Health, by the Medical Officer of the Board, Mr. Simon makes the following remarks:—

"As often as Asiatic cholera had been epidemic in London, it had been observed to "prevail, with special severity, in certain registration districts on the south side of the "river, viz., in St. Saviour's, St. Olaves, and St. George's, Southwark, in Bermondsey, "Newington, Lambeth, Wandsworth, Camberwell, and Rotherhithe.

"It is to these nine districts that the inquiry was addressed, and they suggested "themselves as the best field for observation, not only because of their high epidemic "mortality, but because in them, if anywhere in London, there was to be gathered con-"clusive evidence for a verdict on the matter at issue; for a verdict which should "acquit or inculpate certain qualities of water supply, as bearing on the local prevalence "of cholera.

"Commonly, in attempting such inferences, the inquirer is baffled by difficulties, "which render exact conclusions impossible; for populations drinking different waters "will often be living in different circumstances of wealth, comfort, occupation, cleanli-"ness, soil, climate. But in the present case there was a singular freedom from such "sources of embarrassment. Throughout the investigated districts masses of similar "population were dwelling side by side; and the exterior influences which affected them "were, with a single exception, apparently identical.

"The one varying condition was the quality of water, as consumed in different house-"holds. For throughout those southern districts of London two great competing water "companies had in past times canvassed house by house for customers; their rival mains "were still branching within the same area, often running parallel in the same streets; "and during the late invasion of cholera (though now happily the difference has ceased) "these two systems of pipes were respectively charged with very different waters.

"If, during the epidemic prevalence of cholera, persons consuming pure water are "less liable to suffer the disease than persons consuming foul water, surely there might "be expected some striking difference between the death-rates of two populations respec-"tively drinking from the *Thames* at Ditton and the *Thames* at Battersea.

Propagation of cholera—London.

"And such were the sources of supply of the two companies referred to, *the Lambeth* "*Company* pumping from the higher part of the river, the *Southwark and Vauxhall* "*Company* from the lower; the former furnishing as good a water as any distributed in "London, while the latter was purveying perhaps the filthiest stuff ever drunk by a "civilized community.

"In the *Report of the Committee for Scientific Inquiries* the contrast of these waters "was shown. Microscopical and chemical observations were adduced, as proving the "almost incredible foulness of that supplied by the Southwark and Vauxhall Company; "how it was not only brackish with the influence of each tide, but contaminated with "the outscourings of the metropolis, swarming with infusorial life, and containing unmis-"takeable molecules of excrement.

"In reference to the comparison which had to be made, it is especially important to "observe that the tenantries of these two great companies were not set on different "parts of the South London area, each isolated from the other. On the contrary, the "two populations were, so to speak, mutually interfused. Of 31 sub-districts into which "the large space is divided, only eight were monopolised by a single water company; "while of the remaining 23, each was supplied, sometimes in equal proportion, by one "company and the other.

"It likewise deserves notice, that the materials for comparison were not on a small scale. "It was not village against village. The investigated districts comprise about a fifth "of the entire population of London. They contained in 1849 about 466,000 persons, "and in 1854 about 511,000.

"When at the latter period (after the termination of the cholera epidemic) the water "supply was investigated, nearly 25,000 houses could be shown to derive their water "supply from the Lambeth Company; nearly 40,000 from the Southwark and Vaux-"hall Company; while regarding the remainder (many supplied by pumps and wells) "no certain information could be got.

"Such were the materials for comparison, so like—except for the one unlikeness of "water supply—and at the same time so ample, as to promise unique facility for deter-"mining the matter at issue; and the very decisive results which have been obtained "justify the hope with which this laborious inquiry was commenced.

"In the 24,854 houses supplied by the Lambeth Company, comprising a population "of about 166,906 persons, there occurred 611 cholera deaths, being at the rate of 37 "to every 10,000 living. In the 39,726 houses supplied by the Southwark and Vauxhall "Company, comprising a population of about 268,171 persons, there occurred 3,476 "deaths, being at the rate of 130 to every 10,000 living.

"*The population drinking dirty water accordingly appears to have suffered* 3½ *times* "*as much mortality as the population drinking other water.*

"Further, if the number be reduced, by omitting from the comparison 11 sub-districts "which are almost monopolised by the Southwark and Vauxhall Company; so that "there remain 20 sub-districts, with a population of more than 365,000 persons, almost "equally supplied by the two companies; it is still found, nearly as before, *that the* "*consumers of the cleaner water suffered not a third as much as their neighbours.*

"Perhaps the real significance of these totals is best shown by an examination of the "details embodied in them; and for a convenient instance of this kind, there has been "prepared a table which illustrates, in respect of 45 streets, the method and materials "of comparison. In every one of these streets, the mains of the rival companies run "side by side, each supplying its own proportion of houses; so that, although in any "one street, the number of houses may be unequally divided between the companies, "the respective totals are equal—1,517 houses supplied by the Lambeth, 1,517 by the "Southwark and Vauxhall Company.

"Here then are 3,034 houses, with about 20,000 inmates, divisible as it were, into "two populations, each the exact counterpart of the other, except in the one particular "of water supply. *One of these populations lost* 57 *persons by cholera, the other* "*lost* 164.

"Hitherto it has been shown only that in the epidemic of 1853–4, a very large "population drinking foul water suffered from cholera more than three-fold as much as "a similar population drinking cleanly water.

"But this evidence is only a part of the case. It admits of being greatly strengthened "by a second group of facts, which the statistical tables exhibit. For the death registers "have been analysed with a view not only to the epidemic visitation of 1853–4, but also "to that of 1848–9. It was thought proper to see how far any discoverable influence "of foul water had been constant to both occasions; and this comparison is of singular "interest for our purpose, because the Lambeth Company, which in 1854 gave the

PART III. SPECIALITIES.

Propagation of cholera—London.

" superior water, was in 1848–9 purveying even a worse supply than that of the South-" wark and Vauxhall Company.

" It has already appeared that the tenantry of the Lambeth Company (a population " of 166,906 comprised in 24,854 houses) lost by the epidemic of 1853–4, 611 persons. " By the epidemic of 1848–9, in the same houses (or rather, in as many of them as " then existed) the deaths were 1,925.

" The earlier figures showed that this population suffered in 1853–4 not a third as much " as its neighbours: the present figures give the further fact—*that it suffered also not a* " *third as much as at the time of its unreformed water supply.*

" On the other hand, the Southwark and Vauxhall Company, which pumped an im-" pure water in 1848–9, pumped even a worse water in 1853–4;—worse because the " larger population and more extended drainage of London had given it a denser infusion " of sewage, and a more revolting unfitness for drink.

" Accordingly, in 1853–4, their tenantry suffered 3,476 deaths, against 2,880 registered " in 1848–9 for as many of the same houses as were then existing. In this large increase " half would probably be the utmost proportion for which new houses would account; " so that on this assumption, although the general metropolitan pressure of the epidemic " in 1853–4 was considerably lighter than in 1848–9, the houses supplied by the South-" wark and Vauxhall Company in the late epidemic *suffered probably* 10 *per cent. higher* " *mortality than the same houses in* 1848–9.

" In short (corrected, as far as possible, for difference of time) the comparison of the " two populations in the two epidemics stands thus:—*In the one population* (notwithstand-" ing a generally lighter invasion of the disease) *the cholera death-rate rose from* 118 " *to* 130; *in the other it fell from* 125 *to* 37.

" *And what was the only discoverable difference of condition between these two popula-* " *tions? The one had improved its water-supply to comparative excellence; the other* " *drank from even a filthier source than before.*

" To these facts may be added others not yet adverted to. In collecting the materials " for tabulation, it was thought necessary to extract from the register, not only the " entries of death by cholera, but likewise those of death by DIARRHŒA; and the latter " information has been tabulated in precisely the same manner as the former.

" In houses supplied in 1854 with water by the Lambeth Company, the death-rate " from diarrhœa per 10,000 of the population was 21; in houses supplied by the South-" wark and Vauxhall Company it was 33. Or, *the population drinking foul water* " *suffered* 57 *per cent. more diarrhœal mortality than the population drinking other* " *water.*

" And in comparing, with every possible correction, the respective sufferings of these " two populations in the two epidemics, we find that on the second occasion diarrhœa, " like cholera, pressed more heavily on the one population, though much more lightly on " the other. Among the tenantry of the Lambeth Company *the diarrhœal death-rate,* " *which in* 1853–4 *was* 21, *had in* 1848–9 *been* 29: among the tenantry of the South-" wark and Vauxhall Company, *this rate, which in* 1853–4 *was* 33, *had in* 1848–9 *been* " *only* 27.

" In some elements of these comparisons there may be trifling sources of error; but " none, I believe, which can modify—much less vitiate—the general result.

" Scarcely under any circumstances, indeed, are the physiological sciences susceptible " of greater certainty, than that which seems here to be justified.

" An experiment at which mankind would have shuddered if its full meaning could " have been prefigured to them, has been conducted during two epidemics of cholera on " 500,000 human beings. One half of this multitude was doomed in both epidemics to " drink the same fecalized water, and on both occasions to illustrate its fatal results; " while another section—freed in the second epidemic from that influence which had so " aggravated the first—was happily enabled to evince by a double contrast the compara-" tive immunity which a cleanlier beverage could give.

" By this experiment, it is rendered in the highest degree probable, that, *of the* 3,476 " *tenants of the Southwark and Vauxhall Company who died of cholera in* 1853–4, " *two-thirds would have escaped if their water-supply had been like their neighbours';* " and that, *of the much larger number—tenants of both companies—who died in* 1848–9, " *also two-thirds would have escaped, if the Metropolis Water Act of* 1852 *had but been* " *enacted a few years earlier.*

" The above conclusions rest on so large a basis of facts, that I venture to believe they " will be accepted as the final solution of any existing uncertainty as to the dangerous-" ness of putrefiable drinking water during visitations of epidemic cholera; and patho-" logists will probably admit that the definite proof of hurtfulness thus established in

PART III. SPECIALITIES.

Propagation of cholera—London.

" respect of that one disease, may in principle be extended to the doctrine of other " kindred affections.

" To many it may appear that such proof needs not to have been sought; for that no " reasonable person could ever seriously have doubted as to the hurtful tendency of the " water lately distributed by the Southwark and Vauxhall Company. Such reliance on " existing convictions would, however, have been misplaced. Not long ago, when there " was last a public hearing of this company, its Directors declared the water to be " 'unexceptionably good;' its Chairman, contending that the works were capable of dis- " tributing from the *Thames* at Battersea a supply 'inferior in no appreciable degree to " 'the stream in any part of its course,' remonstrated against any change of source as " 'a wholly uncalled for expenditure of capital.'

" But, while, on the above showing, it must be conceded that for scientific purposes " the definite information embodied in the following tables is of no superfluous kind, it " may perhaps be objected that the practical application is less obvious, and that the " inquiry has been instigated in a matter of past interest. For, since the epidemic of " 1853–4, the Southwark and Vauxhall Company, in obedience to the Metropolis Water " Act, has abandoned its former very objectionable source of supply, and for the last " few months has been distributing a water, nearly or quite identical in quality with that " here spoken of as furnished by the Lambeth Company.

" This is indeed a very satisfactory fact; which, if the final purpose of the investigation " had related only to persons suffering from that particular supply, would have superseded " all necessity for the present report.

" But the question is of larger scope. Whether water can securely be drunk from " rivers polluted by urban drainage, interests more or less every part of the country; " and whatever facts can terminate this doubt, bear upon every plan for the water supply " of a population, and upon every plan for the drainage of a town.

" Not even London can in this respect afford to consider itself safe against the danger " which seems to have been removed from it. Lower than Teddington Lock, indeed, the " *Thames* may not be used as a source of supply, but above that point there dwell beside " the river or its tributaries very considerable urban populations; and hitherto the " legislature has not provided against any pollution of refuse which these communities " may drain into the stream. At present, perhaps, the mischief is not great; the popula- " tion is scattered, the drainage incomplete; the admixture as compared with the volume " of the river, almost insignificant. But whatever at this moment may be the amount of " the evil, undoubtedly it tends day by day to increase; and that reform which the " Act of 1852 purported to accomplish, remains but imperfect and precarious, while those " river side populations exercise a right of sewerage into the drinking water of London.

" It is indeed indispensable for the healthiness of towns that house drainage should be " universally adopted, and that its currents should rapidly discharge themselves beyond " the inhabited area. But the advantages thus to be gained will suffer a serious counter- " poise, if they can be purchased only at the cost of making the sewerage outfall into " rivers, if the change must be from an unwholesome house to a polluted water source, " if that which would have been poison to inhale is to return as poison to drink.

" Between these alternatives, it is greatly to be feared lies the present choice of many " considerable populations. Town drainage has been executed of late years, with too " little recognition that its accomplishment, however successful, represents only part of a " great problem. From it there results the production, as it were, of a novel commodity; " valuable, if at the right time it can be at the right place, but otherwise valueless and " baneful; for in default of that market which only good organisation can create, the " nearest watercourse has to be fouled with what might enrich the fields. Even apart " from such new pollution, it rarely happens that rivers are first-rate sources of supply, " but they are often the easiest of application, and communities living along their course " will generally overlook the worse quality for the sake of the cheaper price. Often " therefore as town-drainage extends, successive populations a down the stream get worse " and worse water to drink, till the evil at length attains those large and dangerous " dimensions which, in respect of a single water-supply, it has been the object of this " investigation to trace."

The results of these gigantic experiments on the effects of water contaminated with choleraic sewage upon the lives of vast communities inhabiting large sections of the metropolis, are as conclusive as can be expected of experiments of such a nature; and it is much to be desired that even the claims of invested capital may not in future be allowed to impose upon the populations of this country any further tests of so cruel and disastrous a character. There are, however, not wanting other analogous experiments which, being upon a smaller scale, were perhaps more managable and consequently capable

Part III. Specialities.

Propagation of cholera—London.

of closer investigation. One of these occurred in the year 1854 in a circumscribed district around Golden Square, St. James's, Westminster. It was reported upon by the Committee for Scientific Inquiries appointed by the General Board of Health, and was still more minutely investigated by a committee, of which Dr. E. Lankester, F.R.S., was chairman, and of which Dr. Snow and the Rev. H. Whitehead were members. The district in which, on this occasion, an exceedingly intense outbreak of cholera occurred, is bounded on the north by Great Marlborough Street and Noel Street, on the east by Berwick Street and Walker's Court, on the south by Little Pulteney Street and Brewer Street, and on the west by Lower John Street, Golden Square, Upper John Street, and King Street. It includes thirty-one streets, twelve courts and one square. The population of this district at the census of 1851 was 42,272. All the houses in which cholera occurred, and also many other houses were inspected, and the inquiries were both careful and minute. The houses in the district, though old and inconvenient, were let at high rents and were decidedly not of a low class. During the month of August, cholera was prevalent in the locality, but only twenty-six cases were registered during that month in the sub-district of Berwick Street and Golden Square. On the morning of Friday the 1st of September, however, the disease broke out with fearful and fatal violence, and continued with little abatement until the morning of the 5th, when it began rapidly to decline. The centre of the pestilence was in the two blocks of houses bounded on the north by Broad Street, on the south by Silver Street and Pulteney Street, on the east by New Street, and on the west by Marshall Street. To this district an adjacent block to the east, bounded by Broad Street to the north, Berwick Street on the east, Maidenhead Court and Husband Street on the south, and New Street on the west, would have to be added, were it not that about two-thirds of it were occupied by a model lodging-house, a church, and Messrs. Huggins' brewery, which were entirely exempt from disease. The mortality on the immediate outskirts of this block in New Street and Husband Street was very great; in fact deaths occurred on every side of the model-lodging house except those portions of it fronting the church and brewery. One of the most important features in this memorable attack was its suddenness and the large number of individuals attacked simultaneously in different parts of the district. The epidemic attained its maximum intensity on the second, if not on the first, day of the outbreak, it then remained nearly stationary, and on the fifth day declined by about 50 per cent. The population of Broad Street was estimated at 860, of whom 90 died, besides 25 others who worked in Broad Street but died in other parts of London; of these latter two men and fourteen girls worked at a percussion-cap manufactory, No. 38, Broad Street. Throughout the surrounding neighbourhood the mortality was at about the same rate as in Broad Street. The total number of deaths in the three registration sub-districts, Golden Square, Berwick Street, and St. Anne, Soho, on the 1st and 2nd of September, including those of persons who had been removed to the hospitals and workhouses was 201; from 1st to 13th September, both inclusive, the deaths amounted to 569; from that to the 20th (which was the first day in the month on which no death took place) the number was 31, and up to the 30th only 10 more occurred; making the total number of deaths from cholera during the month of September in these limited districts 609. The Rev. H. Whitehead states that, "If "a person were to start from the western end of Broad Street, and after traversing its "whole length on the south side from west to east, to return as far as the brewery, and "then, going down Hopkins Street, along Husband Street, and up New Street, to end "by walking through Pulteney Court, he would pass successively forty-five houses of "which only six escaped without a death, and from three of these six no less than 18 "non-residents caught their deaths." Taking a more comprehensive view, the western half of Broad Street, which contained a public pump, was the centre of the infected district, and, starting from thence, a person walking at a moderate pace in any direction would have got beyond its limits in three minutes.

A special examination of the cesspool and drains belonging to the house, No. 40, Broad Street, immediately adjoining the pump just mentioned, proved conclusively that the contents of the former gained direct access into the well supplying the latter. About 78 hours before the great outburst a child was fatally attacked in this house with diarrhœa, and its dejections were poured into the drain which ran within 2 ft. 8 in. of the well. The following extract from the Report of the Cholera Inquiry Committee (*see* Appendix, No. 10) explains the chief reasons for connecting this pump with the virulent outbreak of cholera:—

"The contamination of the water in the well in Broad Street, by filtration from a cess-"pool during the time of the cholera outbreak, is rendered certain by the result of Mr. "York's investigations made in April; for the condition of matters then revealed must "have been of some duration. Nor is there anything wholly without parallel in these

Propagation of cholera—London.

" disclosures. Seventeen years ago this same cesspool was opened on suspicion of con-" taminating the well water, and the suspicion proved to be correct. Many years ago " closet-soil was found running down the sides of the well in Warwick Street; gas has " been detected in the Tichborne Street and Bridle Lane wells; and enormous quan-" tities of black-beetles were found in the well (since closed) in Marylebone Street.

" The gross impurity of the water from the pump in Broad Street being fully esta-" blished, it is equally true that it was in great repute through the neighbourhood for " drinking purposes. Its use indeed was very general, from choice on the part of some, " from necessity on that of others, as their own cisterns were foul, and the water in them " was liable to get heated and decomposed. It is remarkable that pump-water so impure " was so much liked; this might be partly explained by its low temperature, by the " quantity of carbonic acid contained in it, and by the saline matter preventing its " decomposition until after it had free access to the air; but evidence exists to show " that when so exposed for a few days it became offensive; even in a few hours it lost " its freshness.

" It was Dr. Snow who first endeavoured to trace out a relation which, from previous " researches in other quarters, he supposed might exist between the use of this well-" water and the cholera outbreak in the surrounding districts. The result of his laborious " inquiry was in favour of that supposition. Mr. Whitehead, entertaining at first adverse " views, ended his special investigation of Broad Street by a remarkable confirmation " of Dr. Snow's numerical results. For full particulars as to these two independent " investigations, reference must be made to their respective reports, which are inserted " hereafter. A careful perusal of them is here recommended." (*See* Appendix, No. 10.)

" It is shown by Dr. Snow—

" 1st. That the outbreak, properly so called, was principally confined to the area " about the Broad Street pump.

" 2nd. That 61 out of 73 persons who died during the first two days had been accus-" tomed to drink the pump-water either constantly or occasionally.

" 3rd. That the water was used in various other ways, and might so have been taken " in cases where its use in the ordinary way could not be distinctly traced.

" 4th. That in the workhouse, where the well water was not used, only five deaths " occurred, whereas 50 would have been a ratio proportionate to that of the neigh-" bourhood around.

" 5th. That in a factory employing 200 people, where the water was drunk daily, " 18 people died.

" 6th. That 70 men employed at the brewery in Broad Street never drank the water, " and escaped cholera.

" 7th. That in a number of individual instances which were particularly investigated, " the drinking of the water was followed by cholera; in one case, a lady living quite " away from the district, who had the water sent out to her, died after drinking it; her " niece also died under the same circumstances.

" 8th. That at any point decidedly nearer to another pump the mortality from cholera, " as a rule, ceased; and that, in an inquiry extending over 48 fatal attacks which took " place nearer to another pump, many apparent exceptions were found to be cases of " death in persons who really had a preference for the more distant Broad Street water.

" 9th. That in a particular street, containing 14 houses, the only four which escaped " without a death were those in which the Broad Street water was never drunk.

" 10th. That this water was used for drinking purposes only, and was used cold, a " statement which we may so far anticipate as to say is confirmed by the experience of " Mr. Whitehead, who met with but a single exception to this rule. From all these " several facts Dr. Snow is of opinion that, although the earlier cases of cholera and the " later cases were due to some other mode of diffusion, the outbreak between the 31st " August and the 10th September was attributable to the well water as the medium of " dissemination of the cholera poison. He believes, moreover, that the well water must " have been not merely generally contaminated by cesspool drainage, but specially with " the evacuations of a cholera patient."

" Mr. Whitehead's investigation of Broad Street shows,—

" 1st. That of the 90 fatal attacks among its resident population, 84 took place " between 31st August and 6th September, 56 between 31st August and 2nd Sep-" tember, and 50 on September 1st and 2nd.

" 2nd. That of the 90 deceased persons, 45 positively drank the water shortly before " illness; and that of only 13 altogether is it at all confidently said that they did not " drink it. Moreover, that of the above-mentioned 84, the non-use of the water is

PART III. SPECIALITIES.

Propagation of cholera—London.

"asserted of only 8; and of the 56 persons attacked between 31st August and 2nd "September, it is positively affirmed of only two that they did not drink this water.

"3rd. That undoubtedly of 100 persons residing in Broad Street who were attacked "with cholera or diarrhœa (including dead and surviving), 80 drank the water, whilst "20 are affirmed not to have drunk it; whereas out of 336 persons living in that street, "and who were not attacked with either disease, only 57 had drunk the water, whilst "279 had not.

"4th. That there is a great probability that the numerical proportions were even more "remarkable than this, all cases involved in any doubt having been rejected.

"5th. That in regard to the two factories situated next door to each other, both "equally well arranged in regard to other sanitary conditions, the workmen of one in "which the mortality was high had the water for drinking purposes, whilst those of the "other never drank it, and entirely escaped,—the former fact being strengthened by the "circumstance that the family of the proprietor never used the water, and did not suffer.

"6th. That in addition to the contrast pointed out by Dr. Snow as regards the "exemption from cholera on the part of the 70 men employed at the brewery where the "water was not drunk, and the amount of suffering amongst the 200 persons engaged "at a neighbouring factory where the water was drunk, a contrast even more remarkable "is found between the workmen of this brewery and those engaged in the closely "adjoining unfinished lodging-houses called Ingestre Buildings; for amongst these latter "the water was in use, and cholera proved fatal to 7 out of 35.

"7th. That of 97 people residing in 10 houses in which no attack occurred, 87 did "not drink the water at all, whilst the remainder did not drink it during the height of "the outbreak, or drank it either in small quantities or mixed with spirits.

"8th. That in a great number of particular instances the evidence of an injurious "influence exercised by the water becomes strengthened as the inquiry becomes more "strict and searching.

"9th. That the want of good sanitary arrangements in certain houses operated by "compelling the residents to resort to the pump for drinking water; and that, on the "contrary, in certain instances where the drains were in good order, the cisterns were "clean, and the inhabitants did not send to the pump.

"10th. That through the district generally the aged and infirm, when isolated, "escaped, not merely because they had more house accommodation, but because they "did not use the water, having no one to send for it.

"11th, and lastly. That on looking beyond Broad Street to certain cases at a distance "from the pump, a remarkable amount of evidence still presents itself in support of the "facts observed in its immediate vicinity." (*See* Appendix No. 10.)

The late Sir William Lawrence, F.R.S., Sergeant-surgeon to Your Majesty, described in the year 1854 a very remarkable and instructive instance of immunity from cholera enjoyed by two large institutions in the parish of St. George, Southwark, during the epidemics of 1832, 1849 and 1854, the water supplied to these institutions having been, since the year 1825, derived from artesian wells sunk upon the premises. These institutions were Bethlem Hospital and the "House of Occupations," containing about 700 persons inclusive of resident officers, attendants and servants. For some time after the hospital and adjoining house were settled in the parish of St. George, they were supplied by the Lambeth Waterworks Company. The water, which deposited an abundant muddy sediment, was of such bad quality as to be deemed unfit for use, the supply being also precarious and insufficient. The governors being determined to remedy this evil, caused artesian wells to be sunk on the premises, and all the water used in both establishments for every purpose was, from about the year 1825, derived from a boring carried to the depth of 220 feet. There was not a single case of cholera in the Hospital or House of Occupations during the severe epidemics of 1832, 1849 or 1854, although the immediately surrounding neighbourhood suffered severely, especially in the two later visitations. Before the last cholera epidemic in 1866, the inmates of Bethlem Hospital had been removed, moreover the water supply of the district having been greatly improved, the number of cases in the immediate neighbourhood were comparatively few. Sir W. Lawrence adds:—"It must, however, be observed "that there have been cases of diarrhœa in both institutions in each of the three "epidemics; and two or three have occurred in Bethlem within the last few days "(September 27th, 1854) with a severity of symptoms justly entitling them to be called "choleraic."

The immunity of Pentonville Prison from cholera, and the extinction of that disease in Millbank Prison in 1854, described at page 163, are similar remarkable instances illustrative of the dependence of cholera outbreaks upon water polluted by excrementitious matters.

Part III. Specialities. — Propagation of cholera in Manchester and Glasgow.

Another outburst of a still more intense character, but fortunately on a much smaller scale than that near Broad Street, was recorded by the late Dr. Gavin (Appendix B., to the Report of the General Board of Health on the Epidemic Cholera of 1848 and 1849) as having occurred in Windmill Square, Shoreditch, when one-half of the inhabitants perished. Windmill Square consisted of five houses inhabited by 22 persons of whom 11 died in a few days. The supply of water to these houses was from a pump drawing from a well originally 18 feet deep. After the formation of a neighbouring sewer the water disappeared from this well, and it was then sunk six feet deeper so as to carry it below the level of the sewer, by which an unfailing supply of water was secured. Near the centre of the small square a cesspool was dug to receive the surface drainage of the houses and to relieve the cesspools of their liquid contents. The water of the pump often smelled offensively, but the unfortunate inhabitants seem to have had no alternative source of water.

2. *Manchester and Salford.*—Until the year 1851 the inhabitants of Manchester and Salford obtained water partly from the *Irwell* and partly from shallow wells. The water from both sources was much polluted by human excrement. In the year 1851, the new supply of unpolluted upland surface water was introduced into these towns, and this supply has since been continued. In the four outbreaks of cholera, Manchester and Salford suffered in the following manner, as shown by the returns of the Registrar-General:—

MORTALITY FROM CHOLERA IN MANCHESTER AND SALFORD.

—	Polluted Water Period.		Pure Water Period.	
Year of cholera visitation - -	1832	1849	1854	1866
Total mortality in Manchester and Salford.	890	1,115	50	88

Thus, with a rapidly increasing population the total mortality from cholera was reduced, after the supply of unpolluted water to $\frac{1}{16}$th of its previous amount.

Bad as was the quality of the water supplied to Manchester by the waterworks company in 1849, that from shallow wells into which sewage percolated was much more fatal. Dr. John Sutherland in a report contained in Appendix A. to the report of the General Board of Health on the Epidemic Cholera of 1848 and 1849, states that while cholera was prevailing in Manchester, a sudden and violent outbreak of the disease took place in Hope Street, Salford.

Some of the houses in this street obtained water from a shallow well, receiving leakage from an obstructed sewer which passed within nine inches of the edge of it. Moreover, the water, in which the bedding of two persons who had died of cholera had been washed, had been thrown into a gutter which was believed to run into the well. The remaining houses were supplied with water either from other wells which were believed to be unpolluted, or from the waterworks. The results of a careful statistical inquiry into this outbreak by Mr. Currie, one of the acting medical officers of the union, demonstrated that the specially polluted pump water was used in 30, and the purer water in 60 houses. In the former there were 26 attacks of cholera and 25 deaths, whilst in the latter there was not even a single attack. In this case the virulence of the poison was highly remarkable; out of 26 persons who were attacked, only one escaped death.

3. *Glasgow.*—The history of cholera epidemics in this city affords equally conclusive evidence of the influence of potable water polluted with excrementitious matters upon the spread of the disease. Up to the year 1847, the water supplied to Glasgow was pumped from the *Clyde* and was polluted by the drainage of towns higher up the river, if not from the sewage of Glasgow itself. In the year 1847, a small portion of the polluted supply was substituted by unpolluted surface water from Gorbals, seven miles south of Glasgow. It was not, however, until the year 1859, that the magnificent supply of wholesome water from Loch Katrine finally displaced all polluted potable water from the city. The following table shows the mortality from cholera in the four epidemics.

MORTALITY FROM CHOLERA IN GLASGOW.

—	Polluted Water Period.			Pure Water Period.
Year of cholera epidemic - -	1832	1849	1854	1866
Total mortality in Glasgow - -	2,842	3,772	3,886	68
Mortality per 10,000 of population -	140	106	119	1·6

PART III. SPECIALITIES.

Propagation of cholera in Glasgow and Bristol.

A comparison of the columns in the foregoing table shows that the frightful rate of mortality from cholera, diminished greatly after the partial substitution in 1847 of the unpolluted water from Gorbals for the filthy beverage pumped from the Clyde, and that after the supply of the whole city with pure water in the year 1859 the rate of mortality from this disease descended to little more than $\frac{1}{100}$th of its amount in 1832. The evidence, as to the altered condition of Glasgow in 1866 with reference to cholera, is even more conclusive than it would have been if no cases had occurred in that year; because the 68 fatal cases constituted a sufficient nucleus for the outbreak of an epidemic under favourable conditions, whereas total exemption might be interpreted as showing that the zymotic poison never reached Glasgow.

4. *Paisley and Charlston.*—Paisley, and especially its suburb Charlston, have been severely attacked by cholera. The deaths in the epidemic of 1832 are not known, but in the subsequent visitations they were as follows:—

In 1849 - - - - -	182
In 1854 - - - - -	173
In 1866 - - - - -	7

In reference to these outbreaks, Dr. Daniel Richmond, the Medical Officer of Health for Paisley, gave evidence before us as follows (Fourth Report, Vol. II., page 282):—

"Q. 3,713. Have you any complaint to make of the water supply?—No; the water that we have in Paisley is of a very superior character, and there is an unlimited supply to the whole of the inhabitants. The supply is constant, and I regard that as one of the greatest blessings the people ever received.

"3,714. Is there any water used which is obtained from wells?—None. During the last epidemic of cholera, the wells were ordered to be entirely shut up.

"3,715. When did the last epidemic of cholera occur?—Four years ago. But I should say it was not epidemic in Paisley then. It was only threatened in 1866.

"3,716. Had you any cases of cholera then?—No; there was an alarm felt about it, but I had no fear of it, and I expressed that opinion before the Sanitary Committee that we should have no attack of cholera, and that the city of Glasgow would not have it.

"3,717. On what did you found that opinion?—Upon the unlimited supply of pure water that we had, and on the supply of pure water that Glasgow had obtained from Loch Katrine.

"3,718. Was your prediction fulfilled in both cases?—Yes.

"3,719. When had you cholera last in Paisley; was it in 1854?—In 1854.

"3,720. Had you an attack of cholera in 1849?—Yes, a very sharp attack.

"3,721. What was the state of the water supply in 1849?—In 1848 or 1849 the town was but partially supplied with water, and some of the large suburbs, such as Charlston, were not supplied with the town's water; Charlston was supplied with water from wells. There was one well that belonged to Baillie Smith, which supplied a large quadrangle of buildings; that well was at the bottom of an incline, surrounded by buildings on all sides except one. Those wells took a supply from the surface, they were surrounded by dung pits, and the wells imbibed the impurities of the dung pits. I took occasion to warn the people of the district not to use water from the wells, but to get the town's water. At that time the cholera raged to a very serious extent among 3,000 people, and it was a terrible sight to see the consternation, and to see the vans coming in to take away the dead, and painful to hear the people crying for doctors. I recommended the authorities to open pipes connected with the town's water, and to supply Charlston with pure water, and very soon after that was done the cholera disappeared from that district. There were two roads leading to that suburb, and along those two roads the water reached a certain point, and when you came to the last public well you moved into the region of cholera. Those wells were just like sentinels between the living and the dead. The result was this, that as soon as the pure town's water was introduced into the place there was an end of the cholera. There were some other districts in which the water from old wells was used. Mr. Sempel, the secretary to the Board of Health, had written to a landlord urging him to take in the town's water, but instead of doing that he said that he had a good well which he would repair, and he did so, and then it appeared that he had allowed the people to use the contaminated water. The result was that cholera broke out in that close, and that two deaths occurred from it. At the last threatened visitation of cholera in 1866, the Sanitary Committee took the precaution to remove all the handles from the pumps and they had the wells all shut up. There are none, therefore, now used in the town.

"3,722. Have they remained shut up ever since?—Yes.

"3,723. Do you think there is a direct connexion between the water supplied to a town and the propagation of cholera?—I believe that there is a very intimate connexion between the use of impure water and the propagation of cholera, and the proper antidote to that is a free and unrestricted supply of pure water.

"3,724. Did you learn at the time referred to whether there was a strong probability that excrementitious matters from persons actually suffering from cholera got into the wells?—I have no doubt that in Charlston that was the case, the statements of the people themselves were to that effect."

5. *Bristol.*—A violent outburst of cholera occurred in three adjacent courts in Bristol in the year 1849. Wellington Court, Wellington Buildings, and Gloucester Court, covered a piece of land 56 yards in length by 37 in breadth, and contained 66 dwellings. The houses were very small, and when the disease broke out were crowded with people. The supply of water for all the three courts was derived from one pump in Wellington Court, into which there had been an escape of drainage, either from the

sewer of the court which passed close to it, or from the burial ground. No fewer than 89 cases of cholera and 44 deaths occurred in these courts. (Report by Dr. Sutherland to the General Board of Health, 1850.)

PART III. SPECIALITIES. Propagation of cholera in Dumfries, Inverness, Sheffield.

6. *Dumfries and Maxwelltown.*—These towns are situated on opposite sides of the *Nith*, and in 1849 derived their water supply from the river below the outfalls of the sewers. The water was carted in barrels through the town and sold in small quantities at a high price. Cholera broke out here in November 1848, and out of a population of about 10,000 it was estimated that 269 died of the disease in little more than a month. (Report by Dr. Sutherland to the General Board of Health, 1850.)

7. *Hamilton.* — This town has not been passed over in any of the four cholera epidemics, but after a supply of unpolluted water in the year 1857, the mortality from the disease has become insignificant. The following are the data of the four epidemics:—

	1832.	1849.	1854.	1866.
Total attacks - - - - - -	111	440	86	2
Deaths - - - - - -	63	251	44	2
Deaths per 10,000 of the population - -	70	260	44	2

In his evidence before us, Dr. William Naismith, the medical officer of health for Hamilton, informed us that the town had been frequently and severely visited by cholera. In 1832 there were 111 cases and 63 deaths, the population being then about 9,000. There was a very severe epidemic of cholera in 1848–9, and the potable water was at that time obtained entirely from wells, a great many of which were near to middens and cesspools, and liable to infiltration. There were then 440 cases of cholera and 251 deaths, besides 754 cases of diarrhœa. Thus the cholera attacks were 44 per 1,000, and the deaths 26 per 1,000. In a population like that of London, this would be equal to 138,000 attacks and 78,000 deaths. The next cholera epidemic in Hamilton occurred in the year 1854, it was much milder. There were 86 attacks and 44 deaths, besides 128 cases of diarrhœa. In the year 1857 the new water supply was introduced. During the last cholera epidemic of 1866, only two fatal cases occurred in Hamilton. A few of the private wells were still in use in that year.

8. *Inverness.*—The cholera visited Inverness in April 1849. The houses attacked were situated on a flat gravelly piece of ground on the banks of the *Ness*. Sewers empty themselves into the river above these houses, and we have ourselves seen the diluted sewage following the bank of the river for several hundred yards, so that, although a vast volume of water flows seaward in the *Ness*, yet a highly polluted liquid would be obtained by the dipping of cans from the banks into the stream. In the year 1849, the people living on or near the banks of the river, obtained their water in this way.

9. *Bilston, near Wolverhampton.* — This town suffered severely from cholera in the year 1849. It had no drainage and no proper water supply. A brook ran through the town, which was little better than a common sewer, nevertheless the water was used for domestic purposes by the adjoining population. (Report by Dr. Sutherland to the General Board of Health, 1850.) In the epidemic of 1866, when a regular water supply had been provided, only a few cases of cholera occurred.

10. *Sheffield.*—During the epidemic of cholera in 1849, nearly the whole town and neighbouring villages were suddenly attacked by diarrhœa, but cholera proper was confined to a few localities close to the river banks. The mortality in Sheffield and Ecclesall was 150. One of the most prominent evils in the affected places, whether in Sheffield or the neighbourhood, was the state of the water which was either drawn from the river or from wells receiving sewage. This water under the microscope afforded indications of a large amount of animal and vegetable matter. In the year 1853, Sheffield and Ecclesall were largely supplied with unpolluted upland water from reservoirs in the *Loxley* and *Rivelin* valleys. In the subsequent cholera epidemics of 1854 and 1866, they lost only 141 and 24 inhabitants respectively by this disease. (Report by Dr. Sutherland 1850, and report to the Registrar-General on the cholera epidemic of 1866, by Dr. W. Farr, F.R.S.)

11. *Wigan.*—In the epidemic of 1849, cholera slew 348 persons. The water supply was then derived from shallow wells in close proximity to privies and drains. In 1866, surface water from a gathering ground a few miles from the town was distributed to the inhabitants, but some still used the old polluted wells, which were however closed as soon as the epidemic broke out. Only 58 persons died of cholera in 1866.

12. *Salisbury.*—In 1849 the cholera visited Salisbury with great severity, 165 deaths having occurred within three months amongst a population of about 9,300. At that time the subsoil of the city was soaked with moisture almost to the surface, and the sewage

Part III. Specialities.

Propagation of cholera in Southampton.

was discharged partly into small canals and partly into cesspools many of them very large, placed in porous subsoil often quite close to the wells, which were very shallow. The water supply was chiefly from those wells, but many cottagers took their water from the open channels, which thus at the same time served the twofold purpose of fountains and sewers. The well water, generally very bad, was, after heavy rains, stinking and coloured with cesspool filth. In 1854 a new water supply from a well 68 feet deep in the chalk was brought into the town. In the epidemic of that year 15 deaths from cholera occurred; but the new water had not been conveyed to all the houses, and after a careful investigation it was found that *all of these deaths without exception occurred in houses which had not yet been supplied with the new water.*

In the next cholera epidemic of 1866, when an abundant supply of good water (about 48 gallons per head per day) was furnished throughout the town, only one death from cholera occurred, and this was an imported case. A young man resident for some time near Southampton was there attacked with cholera, and brought thence to the house of his parents at Salisbury; he was then in the stage of collapse, fainted at the railway station, and lingered three or four days after his arrival at home. (Report on the Cholera Epidemic of 1866 in England. Supplement of the 29th annual report of the Registrar General of Births, Deaths, and Marriages in England.)

13. *Margate.*—On the 28th of August 1866, a virulent attack of cholera occurred at 13 Upper Marine Terrace, killing 6 out of 20 people in a few hours. The house was supplied with water from a well situated close to a cesspool. On the evening of the 26th of August a heavy thunderstorm visited the town, and an unusually large quantity of rain fell, the well water immediately became turbid and acquired a peculiar taste and smell. Nevertheless it was drunk rather copiously, both before and after being boiled, by all the persons attacked.

14. *Southampton.*—The introduction of cholera into this town in the year 1866 is ascribed by Dr. E. A. Parkes, F.R.S., Professor of Hygiène, in the Military Hospital at Netley, to the Peninsular and Oriental Steamship "Poonah," which arrived there on the 10th of June 1866. On the voyage home from Alexandria both crew and passengers enjoyed perfect health, until two days before arriving at Southampton, when a man died from cholera and several others became ill with severe diarrhœa. This outbreak was attributed to the drinking of foul water from a tank which was opened for the first time during the voyage on June 5th. The water seems to have been used chiefly, if not exclusively by the firemen, and the choleraic or diarrhœal affection occurred, with one exception, entirely among them. The water had a very foul taste and odour. On Friday the 8th of June, a fireman named Joseph Bachelor drank a very large quantity of this water; early the next morning he was taken ill with violent purging, vomiting and cramps, followed by coldness and pulselessness, and died in nine hours. He was buried at sea on Saturday. On the same day (June 9th) six or seven other firemen, and on the next day three or four more were affected with violent purging and some with vomiting as well. All the men who were ill had drunk the water, but it was not certain that all who drank the water became ill. No passengers were attacked and only one man of the crew. All these sick men landed in Southampton on Sunday and Monday (June 10th and 11th), and dispersed over the town. They were seen by several medical men who pronounced their disease to be the severest "choleraic diarrhœa." Edward Palmer, a fireman in the same watch as Bachelor, the man who died on board, was attacked at home, on the 10th or 11th with choleraic diarrhœa and died on the 15th. In the meantime, however, his child, aged 3 years, who slept in the same room with the father, was seized with true cholera, at 10 a.m. on the 13th and died at 4 p.m. on the same day. Professor Parkes considers that this incident proves that the disease caused by the foul water was really cholera, and that it was communicated by the father to the child while it was yet in the so called diarrhœal stage, and before the distinctive symptoms of cholera had come on. The source of the water which produced this mischief could not be distinctly traced, but cholera did not, so far as was known, exist at the time either at Gibraltar, Malta or Alexandria. The further spread of cholera in Southampton was both interesting and instructive, as it illustrated the possibility of the conveyance of infection by particles of liquid sewage carried through the air. The drainage from the western part of the town was raised by pumping, and was then discharged into the eastern sewers and passed to the outfall. Now just before the outbreak of cholera in the town, the pumping had been discontinued for some time, in order to permit of the cleansing of the sewers. The water supply was also at this time very deficient owing to alterations in the mains which were in progress. While this state of things continued, the sick men landed from the "Poonah," and some of them continued to suffer

from choleraic diarrhœa for six or eight days or nearly until the 20th of June, and the copious discharges from these eight or ten persons passed into the nearly stagnant sewers. In the beginning of July the pumping of the western shore sewer, into the outlet sewer was recommenced. The pumping station was near to the floating bridge in a tolerably good neighbourhood. The pumps were worked by a steam engine and were generally kept going day and night. Vast volumes of the filthy liquid were raised from the western sewers and discharged, in an agitated and frothy condition, down a channel open for some 8 or 9 feet, into the outlet sewer. The effluvium disengaged from this seething stream of sewage was overpowering. It spread all over the neighbourhood and was bitterly complained of in the adjacent houses, and there can be no doubt, from the well known behaviour of agitated and frothy liquids under these circumstances, that the air passing over this pumping station became charged, not merely with gases and vapours, but with veritable sewage in the shape of minute and invisible globules. The next cases of cholera in Southampton occurred in the clean airy houses near this pumping station. Attention was called to their probable source and on the 18th of July a closed iron pipe was substituted for the open conduit. From this day the number of cholera cases diminished, and on the 24th of July the worst of the epidemic was over. Altogether 107 persons perished in this outburst, besides 48 who died of diarrhœa. In 1849 the deaths from cholera were 240 and in 1854 they were 48. (Report on Cholera in Southampton, by Professor Parkes, F.R.S., published in the 9th Report of the Medical Officer to Your Majesty's Privy Council, page 244.)

PART III. SPECIALITIES.

Propagation of cholera in Carnarvon, Ivinghoe, &c.

15. *Carnarvon.* — A serious outbreak of cholera occurred in Carnarvon in the autumn of 1866. Out of a population of less than 9,000, no less than 60 persons perished in a month. The disease was not confined to any particular portion of the town, nor by any means limited to the very poorest people. That the condition of the water supply was such as to afford every facility for the diffusion of the cholera poison is evident from the following description by Dr. Seaton, one of the inspectors of the Medical Department of the Privy Council.

"The *quality* of the water may be judged from the sources; one of the chief of these is the river *Cadnant*, a brook which, coming down from the hills, receives, I am informed, the drainage of many farms and of part of the settlement of Bethel, *after which*, but before it enters Carnarvon, two water companies, the Vaynol Estate Company, and the Quellyn Company, take their chief supply from it and distribute it, mixed, I believe, in each case, with some water from springs, to the principal streets and houses of the town. That the water thus supplied, such as it is, undergoes no proper filtration, is clear from the fact that it oftentimes comes into the houses turbid. The water of these companies is not laid on to the courts and poorer streets; and a very large proportion of the inhabitants have to fetch all their water from springs, of which there are several in the town. But from the porous nature of the soil, and the position of the springs with regard to houses and privies, suspicion reasonably exists that they too are tainted."

16. *Ivinghoe, Bedfordshire.*—No deaths from cholera occurred in this village or its neighbourhood in 1854, but in 1866 a sharp and sudden outburst occurred in a small court inhabited by 26 persons, of whom 12 were attacked, and seven died. Only two other fatal cases occurred in the village or district, and one of those victims had been staying in the same court. All the deaths occurred within a fortnight. The water of the well supplying this court was discovered, at the time of the outbreak, to have been subject to a sudden irruption of foul and putrescent matter. As soon as water was obtained from another source, the epidemic quickly subsided. Eight of the nine victims were known to have drunk the polluted water. The immediate neighbours of the sufferers, apparently equally exposed to all other influences supposed to be favourable for the production of cholera, but who did not drink this polluted water, with only one exception, escaped its fatal power. (Communicated to the Registrar-General by P. H. Holland, Esq., M.R.C.S., Medical Inspector, Burial Acts Office. See Report on the Cholera Epidemic of 1866, in England, Supplement to the 29th Annual Report of the Registrar-General in England.)

17. *Theydon Bois, Essex.*—In the year 1865, a very instructive outbreak of cholera occurred here in a family of eleven members, including a visitor, maid servant, also a labourer and a boy assisting in the house but not sleeping there. The cause of the outbreak was carefully investigated by Mr. J. Netten Radcliffe, whose reports thereon are contained in the 8th and 9th Reports of the Medical Officer to the Privy Council, from which we extract the following:—

"The head of the family and his wife, after a fortnight's absence, had returned home from Weymouth by way of Southampton, cholera having appeared in the latter town eight days before. The day after reaching home the wife was seized with diarrhœa. The husband also suffered from more or less looseness of the bowels, left after an attack of vomiting and purging, which he had undergone about 36

PART III. SPECIALITIES.

Propagation of cholera in neighbourhood of Paignton, &c.

hours before leaving Weymouth. Both used a watercloset on the first floor, between the soil-pipe of which and the well supplying the house with drinking water there was free communication. The termination of the soil-pipe of the first-floor watercloset and the commencement of a sink drain, each lay within a yard of the mouth of the well. On opening the well indications of percolation through the brickwork nearest the sink, and a little distance below the level of the mouth, were at once perceived. On pouring water down the sink-drain a steady filtration at the suspected point soon commenced, showing that a communication existed between the sink-drain and the well. On removing the brickwork where the filtration occurred the soil at 2 feet 6 inches from the surface, and in the angle near the pump, was found to be saturated with drainage matter. But a careful examination failed to discover any leakage either from the sink-drain or the soil-pipe inside the walls. On prosecuting the search outside, however, it was discovered that the drain in which the soil-pipe terminated and the continuation of the sink-drain (the one drain having no communication with the other) were defective, and that a leakage took place from both. The escaped matters penetrated downwards along the outer wall of the house, passed beneath the foundation, saturated the earth in the angle between the pump and the well, and so reached the latter. Water having been poured down the watercloset, in ten minutes a portion had passed along this track and was dripping into the well. The soil-pipe from the watercloset was constructed of ordinary glazed stoneware, until it passed beyond the external wall of the house, when it was continued by common 6-inch unglazed butt pipes without sockets, and simply placed end to end. The leakage took place at the first joint between the glazed and unglazed pipes, and the porous material of the latter permitted free percolation of liquids. The water tainted with the diarrhœal discharges was used by the family, and the man and the boy mentioned, for five full days, during and subsequent to which several of the members were attacked with malignant cholera, in the following order:—

	Cholera attacks.
Water in use.	
"On the second day of the water's pollution - - - -	1
"On the fourth " " - - - -	2
"On the sixth " " - - - -	1
Water disused.	
"On the 11th from pollution and fifth after disuse - - -	2
"On the 12th from pollution and sixth after disuse - - -	3

"In addition, three cases occurred among individuals who had not consumed any of the water, but had been in communication with the sick; two members of the family (the oldest and the youngest daughter) and the visitor, although using the water as the rest of the family, escaped with slight gastric disturbance; and the youngest son, 12 years of age, did not suffer from any indisposition whatever. It was doubtful whether the gastric discomfort of the two daughters and the visitor arose from the water, or from the anxiety and trouble occasioned by the rapid series of attacks and deaths. For of the 12 cases, nine ended fatally, including the head of the family and his wife."

Thus, the outbreak of cholera at Theydon Bois, is one of the most important on record, because its history is so complete. Every step has been traced, the importation of the cholera poison, its transmission to the well water, its conveyance to the stomachs of the water drinkers, and its fatal action upon nine out of twelve individuals to whom it was administered.

18. *Goodrington, near Paignton, Devonshire.*—Here, in the epidemic of 1866, out of a population of 80 at most, six were attacked by cholera, and four died. The mortality being, therefore, at the rate of 500 per 10,000 inhabitants. The poison was introduced into the hamlet by a woman who returned from nursing her father, mother, and sister at Stoke Gabriel, where cholera prevailed. She was attacked and recovered; but a fortnight later two fatal cases occurred, viz. Mr. and Mrs. D——, for whom the woman's husband worked, and who had shown his wife great kindness during her illness. The water which they were in the habit of drinking was offensively polluted in consequence of drainage from the closet getting into the well. A fortnight later, Mrs. B——, who resided midway between the house of the first woman attacked, and that of Mr. and Mrs. D——, took the disease and died, also a man who worked for and occasionally drank the same water as the D——s. (Report to the Registrar-General by Charles Pridham, Esq., L.R.C.P. Ed.)

19. *Roundham, near Paignton.* — The first case, a fatal one, that occurred in this hamlet was that of a man who was frequently in the habit of visiting Brixham, where cholera was raging. The subsequent deaths (three in number) occurred to persons who were drinking water from a well which received the sewage from a completely choked drain in its vicinity. The sewage flowed through a bed of sand before it reached the well. From the day when this well was closed, no fresh case of cholera occurred. (Report to the Registrar-General by Charles Pridham, Esq., L.R.C.P. Ed.)

20. *Chulmleigh, Devon.* — The disease was confined principally to two or three families of farm labourers, of whom it killed eight, proving fatal in every case in a few hours. The epidemic only lasted a week. (Report on the Cholera Epidemic of 1866. Supplement to the 29th Annual Report of the Registrar-General for England.)

Propagation of cholera in Chester, Swansea.

Our analyses of the well waters used at Chulmleigh, given at page 72, show that the people of this village were, in 1868, in the habit of drinking shallow well water to which their own excrements gained free access.

21. *Chester.*—In the district including the borough of Chester, but excluding the sub-district of Tattenhall, and containing 60,666 inhabitants, 134 deaths from cholera occurred in 1866. The Registrar of the Chester Cathedral sub-district, furnished to the Registrar-General, the following particulars respecting the source of the water supplied to Chester.

"The whole of the borough is supplied by the Chester Waterworks Company with water taken from the river *Dee;* the river cannot perhaps be considered particularly pure at the best, inasmuch as it receives the sewage of Llangollen, Wrexham, Farndon, Holt, and a variety of smaller places before it reaches Chester; but unfortunately the part of the river from which the water is taken is further contaminated by being the receptacle of the sewage of the whole of the eastern half of the borough of Chester itself. This part of the river is formed into a sort of lake of about one mile in length by some 60 or 80 yards broad, bounded at the lower end by a stone causeway erected for the purpose of holding up the water to supply the mills, and at the upper end by the shallows of Broughton Ford; into the basin the drainage of the town is carried by at least four several sewers at different points, and in its depths lie the accumulated filth of generations, but from it is daily taken the whole supply of water for the city. It is only right to say that the Waterworks Company are now engaged in the construction of works to enable them to take the water from the long reach of the river below Heron's Bridge, where they would certainly escape the contamination of the Chester sewage and be able to deliver the water as pure as the condition of the upper river will allow."—(Report on the Cholera Epidemic of 1866. Supplement to the 29th Annual Report of the Registrar-General for England.)

Our analysis of the present water supply of Chester, given at page 46, shows that though it still contains a large proportion of organic matter, it exhibits no chemical evidence of previous sewage or animal contamination.

22. *Doncaster.*—This town was supplied with water in 1866 from the *Don,* after the latter received the sewage of Sheffield and Rotherham. Sporadic cases of cholera occurred in Sheffield from the beginning of July to the end of October. In Doncaster, a single death by cholera occurred in January, but the actual epidemic did not commence until July; it was most fatal in August and September, and it ceased on the 10th of November. Doncaster lost 36 persons by cholera, and 35 by diarrhœa.

23. *Ystradgunlais, near Neath.*—Many of the coal mining districts of South Wales, have suffered severely from all cholera epidemics, the pitmen being usually the victims. This is not improbably, owing to their drinking of the coal-pit waters, which are necessarily very liable to contamination with choleraic discharges when an epidemic is prevailing. Out of a population of 12,328, Ystradgunlais lost, in the year 1866, no less than 163 by cholera. In reference to the outbreak at Ystalyfera works, Mr. James Rogers, M.R.C.S., of Swansea, states:—

"The water supply was scanty in quantity, and very uncertain in quality, being 'little better than 'surface water percolating through shale tips, and the drainage of coal and mine seams and colliery 'workings; so scarce was the water in the works that it was a common practice with the men to 'drink largely of the canal water. *This water received the surface drainage of nearly all the houses in 'the village.*' The disease raged in nearly all the houses built close to and below the canal bank."—(Report on the Cholera Epidemic of 1866. Supplement to the 29th Annual Report of the Registrar General for England.)

24. *Swansea.*—In the year 1866, this town lost 326 persons by cholera out of a population of 14,553. The epidemic which prevailed chiefly in August and September, attacked all classes of operatives. Mr. Ebenezer Davies, M.R.C.S., the medical officer of health for Swansea, gives the following particulars relating to the water supply at that time:—

"The water supply of Swansea, before the completion of the last reservoir, was obtained from,—

"(*a.*) Brynmill reservoir, the first which supplied water to Swansea, and which latterly only supplied aportion of the town just above the sea level. Its water was derived: 1. From a spring rising within half a mile of the reservoir, and conveyed into it by a covered watercourse, and giving a daily supply, in dry weather of 32,000 gallons, and in winter of 104,000 gallons. 2. From three uncovered streams running through cultivated (principally meadow) land, with houses thinly scattered at a few points in the neighbourhood of their course, free from sewage contamination as far as known, but of course, like all open streams *liable to wilful or accidental fouling.* The great objection to this supply was that *after rain, surface water from gardens and roads, which the streams flowed under, was liable to get into the streams.* Daily supply in dry weather, 109,000 gallons, and as this supply was more than sufficient for the population of the district, the surveyor of the Board, long before cholera was expected had diverted stream No. 1 from the reservoir, and had taken it direct into the service pipe after leaving the reservoir. In this way the mass of water in the reservoir was only used *very occasionally to supplement* the supply from the spring if it fell short, and this reserve *was never turned into the town in July* 1866.

"(*b.*) Cwmdonkin reservoir. The supply is derived from: 1. An uncovered stream which rises in a market garden about a quarter of a mile from the reservoir, in dry weather affording a supply of

PART III. SPECIALITIES.

Propagation of cholera in Llanelly.

about 12,000 gallons daily, and in winter reaching 170,000 gallons. This supply passes through the garden of one other inhabited house. 2. A covered stream, rising in an abandoned coal level, which had been disused in consequence of the difficulty of getting rid of the water, and which was free from the possibility of contamination, and is still used. Average daily supply in dry weather, 43,000 gallons.

"(c.) The Velindre or new reservoir, commenced in 1862, and from which water was first brought into Swansea in 1863. It is formed by an embankment across the valley through which the river supplying it runs. This river is fed by springs rising in a gathering ground of mountain about 1,900 acres in extent, and at a level of about 450 to 800 feet above the sea. The soil of the gathering ground is almost entirely uncultivated, affording pasturage to mountain sheep and a few cattle. There are four or five small holdings on the mountain tenanted by cotter farmers, who, besides keeping sheep, grow perhaps enough corn to supply their own households. This reservoir for storage is about seven miles to the north of Swansea; the top water 408 feet above mean-tide level. The service reservoir is on the hill above Morriston (in the sub-district of Llangafelach), 291 feet above tide level. After supplying that part of Morriston lying within the borough boundary, it enters the town of Swansea at its highest point, the north-eastern end, and supplying in its course this part of the town, passes through it and empties itself into the Cwmdonkin (b) reservoir at the western extremity of Swansea.

"It may be thought that as there was more than one water supply, there might have been a difference in purity; the streams supplying the old reservoirs were for a great part of their course uncovered and in the neighbourhood of inhabited houses, and *as there was just a possibility of sewage contamination*, and as it was very important that the water supply of the town should be above suspicion, the Board, at my suggestion, cut off entirely, on 28th July 1866, the water supply from the old sources, and thenceforward it was wholly drawn from the new reservoir, which was absolutely free from the risk of sewage contamination."—(Report on the Cholera Epidemic of 1866. Supplement to the 29th Annual Report of the Registrar-General for England, page 246.)

It will be seen from the above account that the supply of suspicious water to Swansea was continued up to the 28th of July, or five days after the explosion on the 23rd of July, "when cholera appeared simultaneously in parts of the town widely separately from each "other." The possibility that the chief outbreak of the disease was caused by the distribution of cholera poison in the water supply, is thus established, and it is not clear from Mr. Davies' description whether the water of the Cwmdonkin reservoir was or was not used after the 28th of July. If it was used the poison might have been distributed after the 28th of July. It is remarkable, that "in the third division of the borough "lying within the parish of Llansamlet, cholera was only slightly felt,—12 deaths in an "estimated population of 3,500; *water supply incomplete*, and drainage very imperfect."

25. *Llanelly.*—In this district, which includes, besides Llanelly, Loughor, Pembrey, Llannon, Llwynhendy, Felin Foel, Morlais, Pontyberem, and Penygar, and contains an aggregate population of 27,979, the mortality from cholera in 1866 was 228, besides 49 from diarrhœa. The epidemic prevailed from July to October inclusive. Dr. Thomas, the medical officer of the Llanelly district, furnished the following particulars respecting the water supply:—

"The water supply in Loughor borough at the time of the cholera epidemic was from two wells, one within a few yards of several privies, which must have in some measure drained into it, the other in close proximity to a burial ground.

"At Llwynhendy the water supply was also from two wells and a colliery pump, in neither of which could I find any source of impurity.

"At Felin Foel the people obtained their water from the river in part, and partly from a well and a small running stream. The two former were suspected of being contaminated.

"The Wern, New Dock, and the Custom House Bank, were supplied from the town reservoir, which is very insufficient for the supply of the town, and open to pollution from four cottages with 22 inhabitants without a privy to either, but having a pigsty each, overhanging the little stream that supplies the reservoir, as well as from a farmyard.

"In Pembrey parish the disease was very much scattered, Pembrey proper escaping. The water supply was chiefly from small wells, some of them open to grave suspicion of being contaminated.

"At Morlais, where the complaint prevailed most severely in this district, the water was got from a small running stream largely polluted.

"In Llannon parish the disease was also very much scattered, the village escaping. The water supply here also was obtained from small wells, most of which would appear to be removed from any source of impurity, except at Ponteberen, where the water was had from the river and from the canal, both of which sources were bad.

"There was a general scarcity of water through the district during the greater portion of the time that cholera prevailed.

"The only special causes present in all the localities were decomposing animal and vegetable matters, the evacuations of men and animals, polluting the air and the water too. To the neglect of a systematic and thorough removal of these manures into the earth, particularly the excrements of man, I am disposed to attribute the heavy epidemic of cholera that visited this place, and to the same causes the common presence of typhoid fever over the whole district.

"The river water was suspected as a cause in the attacks at Felin Foel, as well as at Penygar, a small place containing about 50 inhabitants, who also up to this time had used the river water; and to prevent the people using it, several cart-loads of lime were thrown into it above the village; whether from this circumstance or not I cannot say, but the attacks sensibly decreased in number and severity immediately thereon."—(Report on the Cholera Epidemic of 1866. Supplement to the 29th Annual Report of the Registrar-General for England, page 248.)

Part III. Specialities

Propagation of cholera in Calcutta.

26. *Calcutta.*—Even in the natural home of cholera where the disease is believed to be endemic, observant men are beginning to find out how important is the part played by water in the propagation of the disease. Until May 1870, this city was supplied with water pumped from the river, and polluted by human excrements. Up to that time, the mortality from cholera in Calcutta averaged during 30 years, 3,867 per annum, and in 1866, it amounted to 6,826. In May 1870, a supply of purer water was brought to the city, and generally used, but even in November 1872, it had not yet been introduced into the bye-lanes of Calcutta. Nevertheless, whilst the supply of better water was still imperfect, the mortality from cholera fell to 1,560 in the year 1870, to 790 in 1871, to 1,068 in 1872, and to 1,134 in 1873. The following statements on this subject were communicated to the Indian Medical Gazette (Vol. VIII., Nos. 2 and 3, 1873, and Vol. IX., No. 3, 1874), by Dr. C. Macnamara, surgeon to the Native Hospital, and the Ophthalmic Hospital, Calcutta.

"I would observe that the year 1872, unlike 1871, has been characterised as a season in which epidemic cholera of a virulent type has been disseminated throughout the length and breadth of Bengal. It cannot therefore be argued, as it was in 1871, that the decline of cholera in Calcutta had nothing to do with the improved water-supply, because the inhabitants of the place had been spared from the ravages of the disease in common with the people of the neighbourhood. In answer to this argument I can only refer to the records of cholera in Calcutta, and remark that in 1871, the first year in which the new waterworks came into operation, the death-rate from cholera in Calcutta was one-half of what it is reported to have been during the most favourable season, throughout a series of 27 years, preceding 1871."

"We know that not only has cholera been very destructive over the greater part of Bengal during the year 1872, but it has been terribly rife on several occasions during the past 12 months in the suburbs, and among the river population of Calcutta; nevertheless, the death-rate from cholera reported as having occurred in Calcutta, which also includes much of the river and suburban population, is lower this year than it has ever been before, excepting last season. It is impossible to argue that this result is due to the disease having been in abeyance throughout Bengal, for any such assertion would be contrary to facts, but, as I shall subsequently attempt to show, the actual number of deaths from cholera in the town of Calcutta has been lower than the figures given below represent, and, moreover, it is only the inhabitants of the town who could have been influenced by the improved water supply, because the people in the suburbs of Calcutta, and those living on the river, still consume water from other sources than that distributed by our municipal authorities; the waterworks not extending beyond the precincts of the town; and even in Calcutta many of the bye-lanes are still beyond the reach of our municipal waterworks, for, as late as November 1872, the Chairman moved a resolution at a meeting of the Calcutta justices to the effect that the Lieutenant-Governor be applied to for a loan to cover 'the 'cost of extension of the waterworks into the bye-lanes of this city.'"

"I would also invite those interested in this subject to examine into the circumstances of the European troops residing in Fort William, Calcutta, with reference to the influence which a pure water supply has had in reducing cholera among our soldiers. The rise and fall of the ground water, and the condition of the weather cannot materially have differed during the past 15 years; the barracks in which the men live, and the food they consume have undergone no great changes since 1866. If we refer, however, to the medical reports of the British troops in India, we find that for 10 years prior to 1866 the death-rate from cholera among the men in the fort, amounted on an average to no less than 26 per annum. In 1866 the old wells in Fort William were closed, the troops were no longer supplied with drinking water through the medium of a bheestee's *mussack* filled from the wells in the place; all this was changed, and the soldiers were 'entirely supplied with water for 'all purposes from the two tanks at the foot of the glacis. The tanks are large, and well kept and 'guarded. Between the tanks is a masonry cistern, which is opened with sluice gates and can be 'connected with both, or either tank; but before entering the cistern, the water has to pass through a 'considerable thickness of sand and broken bricks. From this cistern the water is raised by means 'of a pump worked by a steam engine to a cistern on the ramparts, and thence it is distributed to 'stand pipes placed about the fort.' This supply of pure water was introduced into the fort in 1866. During the year 1867 two men died of cholera in Fort William; in 1868 there were five deaths from this disease; in 1869 no deaths at all took place among the European troops from cholera; in 1870 two deaths were reported; in 1871 there were no deaths from cholera; and in 1872 one death from this disease occurred; so that, as I have above stated, prior to the introduction of the improved water-supply into Fort William, the regiment living there lost on an average 26 men every year from cholera, but subsequently to the pure supply of water being introduced into the fort, they have only lost two men per annum from this disease."

"Lastly, we may refer to the influence which a pure supply of water has had in protecting emigrants proceeding from this port. Dr. J. G. Grant has very kindly supplied me with the following information on the subject:—It seems that during the past 20 years, cholera has appeared year after year among the coolies on emigrant ships proceeding from this to the Mauritius. The same remark applies to emigrants sailing from Calcutta for the West Indies: as many as 25 to 30 deaths from cholera not unfrequently being reported among a batch of some 300 emigrants during the voyage. In August 1870, strict orders were issued by Government that emigrant vessels were to be supplied with no other water than that drawn from the Calcutta Municipal works, and from that time to the end of 1871, out of 17 emigrant ships leaving this port, in one vessel only has cholera occurred."

"The experience of the past year (1873) affords me another opportunity of drawing the attention of the profession to the circumstances of cholera in Calcutta, with reference to our improved water-supply; and, as time goes on the interest of this question seems to increase rather than diminish; for each succeeding year demonstrates with greater precision the fact, that the death rate from cholera

PART III.
SPECIALITIES.

Propagation of cholera in Calcutta.

among the inhabitants of this town has sensibly decreased since we have been supplied with pure drinking water. Facts of this description must, I think, ultimately overcome the prejudices of those who are disposed to ignore the water theory of cholera, as they will most certainly cheer others on to renewed confidence in their endeavours to stay the progress of this fearful disease among the inhabitants of India and Europe; for it must happen that, as the communication with India and Persia increases, Russia and the countries to the West will find themselves constantly subject to the importation of the disease from the East, until cholera becomes endemic not only in Europe but in America and other parts of the world. In truth, this time is not so far distant as some would have us believe. The distinct and well-marked intervals of the cessation of cholera from among the inhabitants of countries lying beyond its endemic area are becoming gradually less defined; authorities are even now disputing as to when the cholera lately spreading over Europe from the East commenced, the fact being that Persia and the countries bordering on the Black Sea are being impregnated with the disease to such an extent that they will ultimately form endemic foci of cholera to Western Europe, in the same way as the inhabitants of Bengal have not only kept the plague alive here, but the disease overflowing its endemic limits has from time to time extended its dire influence far and wide over the whole of the civilized world.

The municipal water-works for the town of Calcutta were opened in January 1870, and from that date until January 1874 there have been 2,992 deaths recorded from cholera in Calcutta. We are unable to compare the mortality of these three years with the corresponding years of 1860, 1850, and 1840, because the records of 1861–2–3 are not to be found, but if we compare the mortality from cholera in Calcutta during the last three years, with that which existed in 1845, 1855, 1865, and the three following years, we find that the death-rate from this disease has been, for—

	1845–46–47	1855–56–57	1865–66–67 and	1870–71–72
Death-rate	15,461	12,162	14,072	2,992

It may be argued that the year 1873 was similar to 1871, in that the inhabitants of Calcutta were spared from the ravages of cholera in common with the neighbouring population; it is of course possible that such may have been the case, but the same remark cannot apply to the season of 1872, which was characterized as a year in which virulent epidemic cholera was disseminated throughout the length and breadth of Bengal; and so far as I know we have not the slighest statistical evidence at our command, on which to base the idea that the suburban population of Calcutta were more exempt from cholera than usual in 1871 and 1873. As far as my own personal observation extends, I can only assert that, during the last three years, I have frequently been called in consultation to see patients suffering from cholera in Entally, Bhowanipore, and Kidderpore, (the principal suburbs of Calcutta,) but during the whole of that time I have not been asked to attend a single case of the disease among the middle and upper classes of the native population residing in Calcutta. Prior to 1870, although I was less known among the native community than at present, I used frequently to be sent for, and often several times a day, to see cholera patients in the native quarter of the city.

But it may be argued that deaths do take place from cholera in Calcutta, the hospital returns alone make this fact quite certain; no doubt such is the case, but it must be remembered that our enormous river and suburban population derive little or no benefit from our improved water-supply; these people drink the river and tank water as heretofore, but they come for treatment to our Calcutta hospitals, in fact there is no other place for them to go to; and if they die in hospital their deaths are re-recorded as taking place in Calcutta, and consequently, so far as the question of the improved water-supply bears on cholera, these outside instances of the disease raise the death-rate from cholera in the town far beyond the limits which the place is really responsible for.

The figures printed in antique type indicate the number of deaths in Calcutta since the opening of the water-works."

STATEMENT of DEATHS from CHOLERA, reported by the Municipal Authorities as having occurred in the town of CALCUTTA from 1866 to 1873.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1866 - -	509	826	1,193	736	616	885	552	491	371	236	203	208	6,826*
1867 - -	161	142	292	343	330	257	108	126	92	149	243	140	2,268
1868 - -	252	205	694	591	860	174	97	395	188	350	405	352	4,178
1869 - -	264	428	760	746	698	331	78	53	41	57	78	58	3,592
1870 - -	171	259	257	381	**165**	**118**	**50**	**40**	**30**	**37**	**22**	**30**	1,560
1871 - -	**54**	**97**	**50**	**85**	**30**	**24**	**25**	**38**	**70**	**81**	**128**	**108**	**790**
1872 - -	**80**	**81**	**64**	**67**	**65**	**55**	**71**	**79**	**61**	**86**	**178**	**237**	**1,068**
1873 - -	**128**	**187**	**220**	**163**	**152**	**93**	**59**	**31**	**26**	**24**	**28**	**21**	**1,134**

* The highest rate of mortality from cholera reported in Calcutta for a series of thirty years. The average number of deaths from cholera for thirty years was 3,867 per annum, as follows:—

1841 - -	5,177	1851 - -	4,374	1865 - -	5,076
1842 - -	6,545	1852 - -	4,189	1866 - -	6,826
1843 - -	3,739	1853 - -	5,632	1867 - -	2,268
1844 - -	5,811	1854 - -	3,082	1868 - -	4,178
1845 - -	6,240	1855 - -	3,744	1869 - -	3,592
1846 - -	6,427	1856 - -	4,540	1870 - -	1,560
1847 - -	3,041	1857 - -	3,838	1871 - -	790
1848 - -	2,502	1858 - -	5,195	1872 - -	1,068
1849 - -	3,867	1859 - -	4,676	1873 - -	1,134
1850 - -	3,348	1860 - -	6,553		

PART III. SPECIALITIES.

Propagation of typhoid fever in London.

During the year 1863	there were	708	cases of cholera treated in our Calcutta hospitals.			
,, 1864	,,	1,147	,,	,,	,,	
,, 1865	,,	943	,,	,,	,,	
,, 1866	,,	1,628	,,	,,	,,	
,, 1867	,,	628	,,	,,	,,	
,, 1868	,,	1,044	,,	,,	,,	
,, 1869	,,	894	,,	,,	,,	
,, 1870	,,	465	,,	,,	,,	
,, 1871	,,	179	,,	,,	,,	
,, 1872	,,	226	,,	,,	,,	

PROPAGATION OF TYPHOID FEVER BY WATER.

TYPHOID fever is endemic in this country, and slays on the average, in England and Wales alone, about 15,000 persons annually out of a population of 22,712,000. In this disease, the proportion of deaths to attacks is much smaller than in cholera; nevertheless, the aggregate mortality from fever, including typhus and simple continued fever, is much higher, whilst the amount of suffering corresponding to a given mortality must be very much greater. The poison of typhoid fever, like that of cholera, exists in the evacuations of persons suffering from the disease, and its conveyance, from infected to healthy persons, requires conditions analogous to those which propagate Asiatic cholera. Outbreaks of typhoid fever are continually occurring in various localities in England, and many of them have been made the subjects of special inquiry by the Inspectors of the Medical Department of Your Majesty's Privy Council and by others. In a great majority of cases these inquiries have resulted in establishing the fact that water polluted by sewage, if not by typhoid sewage, had been consumed by the individuals attacked. We select the following cases for illustration :—

1. *London.* — The great unhealthiness of Millbank Prison was for a number of years a cause of great anxiety, and many measures were resorted to for its improvement, but in vain. Typhoid fever was especially fatal. At length in the year 1854 the supply of the prison with water pumped from the *Thames* as it flowed past the prison was discontinued, and the water raised from the artesian well in Trafalgar Square was substituted for it. Immediately on the introduction of the new supply, the health of the prisoners improved, and from that date up to April 1872, a period of 18 years, there have been only three deaths from typhoid fever. The following most instructive report by Surgeon-Major A. C. C. De Renzy, now Sanitary Commissioner in the Punjab, appeared in the "Lancet" of 8th June 1872 :—

"*On the Extinction of Typhoid Fever in the Millbank Prison by the disuse of Thames water.*—The Millbank Prison was first opened for the reception of convicts in 1816. It is built on the cellular system, each convict having a cell to himself of a cubic capacity of about 900 feet. The number of convicts confined there has ranged from about 600 in the earlier years of occupation to upwards of 1,200. For very many years the prison had a bad reputation for unhealthiness. Its inmates from the first suffered a very high rate of mortality; phthisis being the disease most productive of casualties, but epidemics of typhoid fever, diarrhœa, and dysentery were of frequent occurrence. Of the four epidemics of cholera that have visited England, the first three, viz. :—those of 1833, 1849, and 1853–5, were very fatal in the prison. In the fourth epidemic, that of 1866, the convicts entirely escaped. In the month of August 1854, the health of the convicts began to exhibit a very marked improvement, which has continued up to the present time. Typhoid fever has become extinct, and diarrhœa and dysentery have ceased for many years to appear as causes of death. Nor has the disappearance of these diseases been followed by the appearance of other causes of death. From the year 1862 to the present time not a single convict has contracted typhoid in the prison. There were only three cases of the disease altogether treated in that interval; but the patients had the disease upon them at the time of admission to the prison. One of these three cases was admitted and proved fatal in 1865. For the next six years there was not a single case of typhoid in the prison. The other two cases were admitted recently from another prison and are now convalescent.

"From August 1854 to April this year, a period of nearly 18 years, there have been only three deaths altogether from typhoid, viz., one in 1855, one in 1860, and one in 1865. As already stated, the last case was an imported one. In the same period of 18 years there has been only one death from dysentery and diarrhœa.

"A change in the health of the prison so sudden, so marked and permanent, is of great interest in relation to some moot questions in preventive medicine; for our knowledge of the circumstances under which the change occurred is so full and precise that we can hardly err in attributing it to its true cause. In preventive medicine it is hardly possible to exaggerate the value of an accurate precise knowledge of the mode in which zymotic diseases spread; for without such light our preventive measures must be empirical, roundabout, and unnecessarily costly.

"But it will be well to state, in more detail, the grounds of the assertion that the health of the prisoners has undergone a radical change since 1854. I shall then discuss the cause of the change. The extent and reality of this change will be established by information taken from the reports of two Select Committees of the House of Commons that were appointed to investigate the cause of the

PART III.
SPECIALITIES.

Propagation of typhoid fever in London.

sickness in 1822, 23, 24, and by quotations of the opinions of the medical officers of the prison as recorded in their official reports and by official statistics of sickness and mortality.

"From the report of the Select Committee of 1823 I find that for some time previous to 1822 the convicts had been subject to an intestinal flux, which the medical officer supposed to be due to overfeeding and insufficient exercise. In consultation with Sir James McGrigor, the head of the Army Medical Department, the managing committee of the prison adopted a reduced dietary. Three months after the introduction of the reduced dietary a great epidemic of diarrhœa, dysentery, and fever, accompanied with symptoms of scurvy, began. There were nearly 500 convicts sick at one time, out of 880. The opinions of the College of Physicians and of Sir Henry Halford, Sir Gilbert Blane, Drs. Roget and Latham, and other eminent medical men, were taken as to the cause of the epidemic. With the exception of Sir James McGrigor, they were all agreed in thinking that the main cause of the sickness was attributable to the new dietary being insufficiently nutritious, subsidiary causes being the depressing influences incidental to protracted imprisonment on the solitary system, insufficient exercise, defective ventilation, cold, and possibly some influence peculiar to the locality. But, although the diet was improved, a very large amount of sickness continued to prevail; and even convicts who had not been on the reduced diet at all, who were admitted after its abolition, contracted the diarrhœa and fever peculiar to the place. These circumstances led to the opinion that the disease was contagious, and measures of prevention were taken accordingly. Sir Humphrey Davey was requested to report on the ventilation of the prison, and Faraday was employed to disinfect it; and every suggestion that the science of the day could offer was availed of. There is no precise information to show when or how the epidemic came to an end, and for many years the sanitary records are extremely meagre, but there is enough to show that the prison continued unhealthy. In 1833 the convicts suffered very severely from cholera. In the Prison Report for 1839 the Inspectors of Prisons are quoted as saying that 'these circumstances lead us to regard the situation of the prison as decidedly unhealthy.' In 1841 the late Dr. Baly was appointed to the medical charge of the prison, and at his recommendation great alterations were made in the discipline of the prison, and from that time the data available for judging of its sanitary condition are much more ample. In the year 1842 there was a great epidemic of dysentery and fever. At one time there were 110 cases in the infirmary, nearly all being dysentery and fever. In 1847 there was much continued fever—'in the fifteen months ending 31st March 1849, there was a great increase of sickness and unprecedented mortality,' fever and cholera being very fatal. The death-rate for 1849 was 82·23 per 1,000. In 1853 and 1854 there were again epidemics of fever and cholera, attended with much mortality. We have now reached the turning point in the history of the prison. In 1855, notwithstanding the occurrence of five deaths from cholera, the death-rate sank to 11·3 per 1,000. From that year up to 1870, the highest death-rate was 19·3; it was as low as 3·92 per 1,000, and in nine years out of the sixteen it was under 12 per 1,000.

"The following table shows, in a concise form, the sanitary state of the prison since 1843:—

Date.	Number of Prisoners received.	Average Daily Number.	Deaths per 1,000.	Date.	Number of Prisoners received.	Average Daily Number.	Deaths per 1,000.
1843	1,961	741	18	1857	2,497	1,109	11
1844	4,102	906	18	1858	2,306	1,068	8
1845	3,523	990	15	1859	2,234	993	5
1846	3,657	998	13	1860	2,386	1,003	8
1847	2,762	1,151	28	1861	2,496	984	9
1848	3,141	1,373	53	1862	2,859	1,018	3
1849	3,047	1,053	82	1863	2,584	1,013	10
1850	2,247	1,154	23	1864	2,015	985	18
1851	2,570	1,091	18	1865	1,851	898	14
1852	2,351	1,202	30	1866	1,608	918	13
1853	1,599	1,038	28	1867	1,889	942	18
1854	1,513	752	69	1868	1,502	935	10
1855	—	967	11	1869	1,333	1,011	13
1856	2,640	928	19	1870	925	712	15

"In studying these statistics, it should be remembered that the death-rate of a year depends to a considerable extent on the state of health of the convicts admitted in that time.

"In the ten years from 1845 to 1854 there were 57 deaths recorded under the head of typhoid, or 5·7 per annum, and there was no year without a death from typhoid. In the eighteen years from 1855 to 1872 there were altogether three deaths from typhoid, and in fifteen years of the period there was no typhoid death at all. In the twelve years from 1843 to 1854, inclusive, the death rate was 33 per 1,000. In the sixteen years from 1855 to 1870 it was only 12 per 1,000.

"The reality, extent, and permanence of the change in the health of the prison being thus clearly established, it remains to investigate the cause of this change. The following enumeration of possible causes will probably be considered sufficiently comprehensive as a basis of discussion; viz., improvements in (1) drainage, (2) ventilation, (3) diet, (4) clothing, (5) discipline, (6) water supply. The observations I have to offer on each of these heads will, I think, prove to demonstration that the cessation of typhoid in the prison was in no degree whatever due to any changes under the first five heads and that it was due solely and exclusively to the change in the water supply.

"*Drainage.*—As regards drainage, two improvements have occurred. The prison was formerly surrounded by a wet ditch which communicated with the *Thames*, and which was believed to render the site damp. The ditch, however, was filled up many years ago, and has not existed within the memory of the present generation; and as fever prevailed in the prison with great intensity from time to time for at least a quarter of a century after the ditch was filled up, we may eliminate this cause as

Propagation of typhoid fever in London.

utterly unconnected with the cessation of the disease. Indeed, the health of the prison appeared to be steadily deteriorating for some 10 or 12 years before the sudden improvement in 1854. The other improvement in drainage was the connexion of the main sewer of the prison with the intercepting sewer of London. This change occurred in 1869; but as the fever had become extinct years before this cause came into operation, we may eliminate it, too, as irrelevant. A few further remarks on the drainage may be of interest. The prison formerly drained direct into the *Thames*, and the mouth of the sewer, being under the level of high-water mark, was furnished with a sluice to prevent flooding of the drains. Thus the sewage of the prison was kept stagnant in the drains every day for several hours. Occasionally, too, when a fall of rain happened to coincide with an unusually high tide, the basement of the prison was flooded, and the sewer gases forced out into the prison corridors. The drains are well constructed, but, owing to the low position of the prison on the banks of the river, they had very little fall, so that silt accumulates in them rapidly, and they have to be opened out constantly to be cleansed. It appears, too, that the drains have no ventilation whatever. At present they form a long blind end in connexion with the main sewer of London, and I am informed there is no communication of any sort between the general atmosphere and the prison main drain in the interval between its connexion with the London sewer and the prison waterclosets. The waterclosets, too, on the day of my inspection of the prison were by no means free from offensive smell, and appeared to be insufficiently ventilated. I do not mention these facts for the purpose of contending that typhoid is never caused by bad drainage, but the case appears to show conclusively that perfect immunity from typhoid may co-exist with very indifferent drainage. Some eminent authorities have lately described the water-removal of excreta as necessarily involving serious danger to the public health by favouring the propagation of typhoid, diarrhœa, scarlatina, &c. The facts here recorded may help to moderate such fears. Before leaving the subject of drainage, I would mention that there is not a particle of evidence for supposing that the extinction of typhoid in Millbank was in any way connected with a change in the 'ground-water.' Prof. Pettenkofer's hypothesis is demonstrably inapplicable in this case.

" *Ventilation.*—As regards ventilation there is little to be said. It is substantially the same as it was when the prison was unhealthy—the same as it was left nearly fifty years ago by Sir Humphry Davy, under whose advice the arrangements for ventilation were carried out. A complaint, indeed, occurs in Dr. Baly's report for 1849, p. 12, 'of the prison courts being surrounded on all sides by the buildings, so that the body of air within them, which supplies the cells and wards, is changed with difficulty; and this evil has within the last few years been aggravated by the erection of a long and continuous range of higher houses on the south-west and western sides of the prison, by which the access of the most frequently prevailing winds to the prison is greatly impeded.' As this impediment to the ventilation, *quantum valeat*, is common to the two states of the prison, it may be eliminated as irrelevant.

" *Dietary.*—The dietary was altered in 1864, but as typhoid had ceased nine years previously there can be no casual relation between the two events. The nutritive value of the diet was reduced and the solid food allowed per week was reduced from 306 to 284 oz. Long experience proves that the new diet is sufficient to maintain health, but there is no reason to believe that its adoption has made zymotic disease less prevalent.

" *Clothing.*—There has been no change in the clothing.

" *Discipline.*—The discipline was somewhat changed in 1864 in a sense not favourable to health. While the prison was unhealthy, the medical officers thought it dangerous to the health of the convicts to carry out the solitary system with the strictness enforced in other prisons, and they recommended that the cell-doors should be left open a few hours each day. But in 1864 the prison had been healthy for so many years that orders were given to have the cell-doors closed all day, as in other prisons, and the practice has been kept up ever since.

" *Water supply.*—The water-supply was changed on the 10th of August, 1854. Up to that date the prison had been supplied with water pumped from the *Thames* as it flows by the institution, and purified by filtration. The new source of supply was the artesian well in Trafalgar Square. The change was carried into effect in the midst of the cholera epidemic which so severely visited London that year, and the prison was suffering from cholera at the time. Six days after the change the disease suddenly ceased, and a marked improvement took place in the health of the prison. From the date of the introduction of the new water supply up to April of the present year—a period of nearly nineteen years—there have been only three deaths from typhoid—viz., one in 1855, one in 1860, and one in 1865. Of these the last occurred in a convict who was suffering from the disease at the time of his admission. In the first part of 1854, and before the change of water-supply, there had been three deaths from fever and two from diarrhœa. In the nineteen years since the change of water-supply there has been only one death from diarrhœa and dysentery. It is thus shown conclusively that the disappearance of typhoid coincides exactly with the disuse of *Thames* water, and as this change occurred whilst in all other respects the sanitary condition of the prison remained unaltered, there can be no doubt the two events were not coincidences only; there must have been a causal relation between them. In further confirmation of this conclusion, I would mention that in the twenty-one years for which we have mortuary statistics for the Pentonville Prison, there has not been a single death from typhoid in that institution. There have been only three deaths from diseases of the bowels, of which all were contracted before the patients were imprisoned. The Pentonville Prison drew its water-supply exclusively, until very recently, from a deep well in the chalk. It has been singularly free from epidemics of every kind and remarkably healthy, its death-rate rarely exceeding 6 per 1,000. It has never suffered from cholera, though three epidemics of that disease have visited London since the prison was established in 1843.

" The exact study of the causation of diseases among a free population is beset with great difficulties, owing to the infinite variety of conditions under which the diseases occur; so that it is impossible to eliminate the inert accompaniments from the causal accompaniments. But, in the case of Millbank, the conditions are so few, and the facts so definite and well authenticated, that the process is easy. The history of the institution, in the last fifty years, may be regarded as a great physiological investigation, in which the effects of filtered *Thames* water upon the human constitution have been determined with almost the precision of a chemical experiment. It is instructive, as an illustration of the difficulty

PART III. SPECIALITIES.

Propagation of typhoid fever in London.

of discovering the true cause of sickness, to note that, of all the many distinguished physicians and men of science who were consulted from time to time about Millbank, no one appears for the first thirty years of its existence to have had a suspicion that the water-supply was in any degree answerable for the epidemics of fever, diarrhœa, and dysentery that visited the institution so frequently. During the inquiry conducted for many months by the two Select Committees of the House of Commons in 1823 and 1824, the state of the water-supply was not once mentioned. The earliest mention of any suspicion of the water-supply is found in the report of the Directors of Convict Prisons for 1852. At page 123, Dr. Baly says: 'It was determined to put to the test of experiment an opinion more than once 'mooted respecting the cause, not only of the cholera, but also of the other kinds of bowel complaint 'which, in a mitigated degree, are almost constantly present in the Millbank Prison. It had been 'suggested, namely, that these diseases are produced by the *Thames* water, which the prisoners 'drink; and although for some years this water has been well filtered within the prison and freed from 'all obvious impurity, it was still possible that matters in solution in it produced a deleterious effect.' It is evident from his later reports that this opinion had little weight with Dr. Baly, but, notwithstanding, he strongly recommended that it should be put to the test of experiment. His own opinion, which appears to have been shared by every physician who was consulted about the prison, was expressed as follows in his report for 1849, and repeated in several later reports:—'The causes of the 'general liability of the prisoners to fever,' he says, 'appear to be the low site of the prison, the 'proximity of low and ill-drained ground, open sewers and manufactories which fill the air with 'impurities, the construction of the building which impedes the free circulation of air through it, and 'the proneness to suffer from general causes of disease which is produced by the state of imprison-'ment.' Dr. Baly was evidently surprised at the remarkable results that followed the introduction of a pure water-supply in August 1854. He could not believe that the sudden cessation of cholera that followed in six days was due to the change of water-supply, but the continued healthiness of the prison in after years gradually shook his scepticism, though some traces of it remain apparent to the last. In his report for 1855, he writes: 'One of the special tests of the health of Millbank Prison is 'the degree of prevalence of diarrhœa, and there have been fewer complaints on account of this 'disease than in former years. This improvement in the health of the establishment began towards 'the close of 1854. It followed quickly upon the substitution of the artesian well water for the *Thames* 'water, and it is, most probably, in great part due to the greater purity of the water at present in use. 'It may be hoped, therefore, that this improved health of the establishment will at all events to some 'extent be permanent. But it is not to be expected that the convicts in Millbank Prison will suffer 'as little from diarrhœa, dysentery, and fever, as the convicts in prisons differently situated.'* In his report for 1856 a further advance of opinion appears. He says: 'I have again to report that the 'health of the prison is satisfactory, and that those diseases which have hitherto appeared to be 'inseparably connected with locality have been less frequent. These favourable results are, I believe, 'attributable in great part to the purity of the water with which the prisoners are now supplied. I 'have, therefore, a strong hope that they will be permanent.' It may here be stated that Dr. Baly mentions no other cause to which the improvement in the health of the prison could be attributed.

"Dr. Guy, who succeeded Dr. Baly in the medical charge of the prison, expresses his surprise that although the Thames was unusually offensive in 1859, the prison was unprecedently free from sickness. In 1862 Dr. Guy reports that 'the male convict population are at least as healthy as any other population with which it can be compared, and that the female convict population suffers but little by comparison with the population out of doors.' In 1871 the present able medical officer, Mr. Gover, reports that 'the prisoners have continued to be free from every form of disease which could call the sanitary arrangements into question, as free as if the prison occupied the healthiest site in the kingdom.' These extracts show very strikingly the permanence and the thoroughness of the change which has taken place in the health of the prison.

"The sanitary history of Millbank appears to me to warrant the following conclusions:—

"1. That the extinction of typhoid fever, and other diseases of the same class, is quite within the range of practicability.

"2. That the extinction of one class of zymotic diseases is not necessarily followed by zymotic diseases of a different class. For example: it is supposed that the increased prevalence of scarlatina and measles of late years is due to the partial displacement of small-pox by vaccination. The case of Millbank shows that it is practicable to protect a community against every kind of zymotic disease. Ignorance of sanitary science is the great obstacle to the extension of this protection to the free population.

"3. That since some of the ablest physicians in London failed for many years to detect the true cause of the unhealthiness of Millbank Prison, and assigned causes for it which later experience has found to be unconnected with it, the probability is that a similar error is frequently made elsewhere, and that the prevalence of some zymotic diseases is ascribed to locality, malaria, heat, cold, variations of temperature, moral depression, and other intangible influences which would be entirely removed by the general disuse of impure water.

"4. That as it required long years of observation to establish the noxious influence of *Thames* water in Millbank, even when well filtered, under conditions very favourable for detection, we should be cautious in accepting the opinion, based on the results of chemical analysis, that the use of that water by the population of London is free from danger.

"5. That the vital statistics of prisons, carefully kept and tabulated, would be of the greatest value as data for the investigation of the causes of disease. Those now published by the Directors of Convict Prisons are excellent."

2. *Terling*, *Essex*.—In the autumn of 1867 a severe outbreak of typhoid fever occurred in this village, and by order of Your Majesty's most Honourable Privy Council, Dr. R. Thorne Thorne was instructed to proceed to the spot in order to examine into the causes

* The experience of eighteen years shows how groundless this apprehension was.

PART III. SPECIALITIES.

Propagation of typhoid fever in Terling.

and nature of the disease. Out of 900 inhabitants, fully 300 were attacked, chiefly within a period of two months, and 41 of the number died. The village, consisting principally of labourers' cottages, is situated on the gently sloping banks of the rivulet *Ter*, an affluent of the *Blackwater*. The bed of this rivulet is clay, which on both sides of the stream is covered by a plateau of gravel and occasional layers of sand, and on this the village is built. Dr. Thorne reports that "at Terling all the nuisances which are generally "associated with outbreaks of typhoid fever exist in great and unusual abundance, and "all that is necessary to produce contamination of air, soil, and water is to be found "throughout the village. The cottages are literally surrounded by every species of "nuisance that it is possible to conceive; slops and ashes are thrown down on the "unpaved yards and gardens; manure heaps, cesspools, and masses of decaying vege-"table matter lie round about. The privies, none of which have a properly constructed "tank for the reception of fœcal matter, are in many instances in a most dilapidated "state, and owing to their being frequently constructed of wood, the back is in part "broken away, and the contents either lie in masses on the ground, or else are collected "in large holes which have been dug out for that purpose. Surrounding one cottage, "and within a circumference of 20 feet of it, I found one pigstye, three manure heaps, "two cesspools, and a privy, the contents of which extended about 12 feet down an "adjoining field."

The first case of typhoid fever, in the outbreak now under consideration, occurred on 13th November to a young woman who had recently returned from Somersetshire, and who, in common with her father and mother, procured all her drinking water from the river which flows by the side of their house (Lord Rayleigh's dairy). "The water, "which has a very dirty appearance, is collected at the foot of a few steps leading from "a yard down to the stream. Three feet from this spot, a pipe which conveys all the "drainage from the yard and the wash-house, empties itself into the river, and 12 yards "lower down the stream is the privy which belongs to the dairy, the entire contents of "which fall into the water. On making inquiries, I found from those who lived here, "that at times, owing to the scarcity of water, the river at this spot is in nearly a "stagnant condition, and the water must therefore under these circumstances become "well saturated with fœcal matter, to say nothing of the surface drainage. But in "addition to this, the dairy lies at the extreme south of the village, and since the stream "flows towards it, the contents of several ditches which I saw passing from privies to "the water's edge, must be washed past the very spot where these persons collect "their drinking water. It becomes a question whether this young woman could have "imported the fever from Somersetshire, and whether the diarrhœa which occurred "immediately after her arrival at Terling was not a part of the disease which, after "apparently subsiding, manifested itself again three weeks afterwards; she, however, "had certainly not to her knowledge been amongst persons who were suffering from "any disease at all. It is also possible that her fever may have been brought on "through drinking contaminated water, although the mother of the patient assured me "that it was always boiled before any one used it."

It is thus uncertain whether or not the disease was on this occasion introduced into the village by this young woman, or whether the specific poison had lain dormant there during the two or three months which appear to have elapsed since the last known case occurred in Terling; but three weeks later, viz., on the 4th December, the disease broke out with alarming violence. "During the following 10 days 30 fresh cases were "seen, but on the 15th, 16th, and 17th by far the largest number were attacked, "22, 19, and 12 cases occurring respectively on those days. After this, though the "daily number of fresh cases was by no means so large, still a steady increase took "place. The villagers were everywhere alarmed, for owing to the many inter-"marriages every one had several relatives attacked, some dangerously so. As yet, "however, only one death had taken place, namely on December 14th; but when the "third week of the epidemic had arrived a steady and gradually increasing death-rate "commenced, and on the 30th, 12 of the patients had died, and others were dying. "Terling was now completely panic-stricken. Women with tears flowing down their "cheeks called from their cottage doors for help, and every one seemed to dread the "prevailing disease. No class of persons was exempt; the rich, the well fed and clad, "were attacked in common with the poor and destitute. At Lord Rayleigh's residence "10 cases had occurred, the vicar's house was a seat of the epidemic, and from one end "of the village to the other the disease seemed to be almost evenly spread.

"Age and sex seemed to present remarkable peculiarities; thus, out of 145 cases "whose ages I was enabled to obtain, 79 were children under 14 years of age, and of "the remaining 66, 50 were females, leaving only 16 males, whose ages exceeded 14

PART III. SPECIALITIES.

Propagation of typhoid fever in Terling.

" years, out of the entire number attacked. This I believe to be accounted for by the " fact that the men and the majority of the boys over 14 years of age spend the greater " portion of their time away from home, labouring in the fields, and that they princi- " pally drink beer, whereas the women and children are left at home, and procure a " considerable portion of their beverage from the wells, the children drinking directly " from them much more frequently than the women, owing to the latter consuming a " good deal of tea, in making which the water is of course boiled."

The epidemic was preceded by a drought, and was coincident with a rise of water in the wells consequent on heavy rainfall. When the state of the water-supply in Terling is considered it is easily understood how the filth collected at the surface of the soil would be rapidly washed down to the water-level of the shallow wells. These wells are thus described:—" In the central part of the village, each cottage, or " each group of two or three, has its own well, and if the ground is at all undulating, it " is invariably placed at the lowest point. These wells which are all sunk in the gravel, " are as a rule uncovered, and are merely lined with bricks placed loosely one above " another, without any cement or plaster; their depth, which varies from about 5 feet to " 40 feet, agrees with the increase in the rise of the ground. On a higher level than " these wells and everywhere surrounding them, lie the various nuisances just enume- " rated, and when we remember the loose and porous nature of the soil, and the ease " with which it admits of the percolation of fluids, the closeness of such sources of con- " tamination to the cottagers' drinking water is seen to be fraught with the greatest " danger. Some of the cottages lying in the outskirts of the village have no wells, and " those who reside in them are therefore compelled to fetch their drinking water from " ponds in the adjoining fields. All the drainage from the field ditches, and at times " from the roadsides runs into them, the cattle frequent them, and in summer they are, " to use the expression of a resident, 'nothing better than stinking pools.' "

In proof of the connexion between the rise of water in the wells and the attack of the disease, the following instances are cited:—" In one of the most populous parts of " the village stands a row of five cottages, ill-constructed and badly ventilated; they " are built of wood, and are called the Old Workhouse Row. Behind them stand " some pigstyes and accumulations of refuse; ashes and slops of every description are " evidently thrown into the yard in front, which is unpaved, and the ground has every " appearance of being sodden with filth. In this yard is an uncovered well, for the use " of those who inhabit the row. At cottage No. 1 there has been one case of typhoid " fever; at No. 2, one case and one death; at No. 3, two cases and one death; at " No. 4, three cases, and at No. 5 two cases. The water in the well I ascertained had " very gradually sunk during the summer, and after having remained empty for about " two months, during which time all those living here procured their water from a " neighbouring well, bearing the name of 'Middleditch's well,' it rose again towards the " end of November. A woman living in the first cottage was delivered of a child on " the 19th of November, and she experienced considerable inconvenience owing to there " being no water at hand with which her linen could be washed. Exactly one week after " the birth of her infant, that is to say, on the 26th of November, water was again found " in the well, it was immediately procured for the use of her house, and it was also on " that day used for drinking purposes. The first case of fever in this row occurred in " this woman's family on the 6th of December, 10 days after the rising of the surface " water; or, in other words, the period which elapsed between that event and the out- " break of the disease corresponds to what is generally admitted to be about the period " of incubation for typhoid fever. On the 9th of December, two more cases occurred " in this same block of cottages, another on December the 12th, and three more on the " 15th. At first sight the connexions between these latter cases and the rise of the " water seems to be less distinct, but on inquiring more minutely into the matter, I ascer- " tained that in all the other cottages, although the water was used for scouring the floors " from the first, yet, owing to its not having its normal bright and clear appearance, all " the drinking water was brought up from Middleditch's well for several days longer, " but the exact number of days I was in no instance able to ascertain.

" Another instance in every respect similar to this one is that of two cottages occupied " by families named Steele and Game, close to the Old Workhouse Row; their common " well having been empty for three weeks, they also sought their water from Middle- " ditch's. Several cases of typhoid fever have occurred here, and though perfectly " accurate dates could not be ascertained, the disease had evidently broken out about a " fortnight after they were first able to procure water on their own premises. Standing " again close to the Old Workhouse Row, and at right angles to it are four cottages, in " the first of which six have been affected, in the second there has been one case in the

Part III. Specialities. Propagation of typhoid fever in Terling.

" third two cases, and in the fourth two cases. These cottages have gardens behind " them, at the end of which are situated three privies, one stands alone, and its entire " contents are collected in a huge hole behind it in an adjoining field, the other two " stand together and empty their contents on to the same field. Into one of these a " very large amount of soapsuds and water is daily thrown from a wash-house, these " become mixed with the fœcal matter, and the whole runs in a large mass, which sub- " sequently divides into several streams for about 20 yards down the field which slopes " towards the river. This portion of the field is so saturated with fœcal matter as to be " converted into a foul swamp, which I found it impossible to walk across. Three " yards from the margin of this flow of filth and at a very much lower level, is the well " referred to as 'Middleditch's.' It is about 5 feet deep, and owing to its very low " situation it is never known to be empty. This well supplies the four cottages just " mentioned, and it is impossible that it can be otherwise than seriously contaminated " by the fœcal matter running from the above-named privies, indeed from its position " it is evident that the water supplying it must pass through the very ground into which " the filth sinks, and hence it becomes in plain terms a filtrate of human excrement.

" The question now arises, was the contaminated state of this water during the period " of scarcity, the cause of the fever in the Old Workhouse Row, and in the cottages " occupied by Steele and Game? This may fairly be answered in the negative, first, " because none of the cases occurred during or immediately after the period in which it " was used by those living in these places; and, secondly, because the first symptoms of " the disease corresponded with the time at which they all discontinued using it, owing " to their being able to procure water from their own wells. But the outbreak in the " four cottages at right angles to the Old Workhouse Row has still to be accounted for. " Now, although I was unable to get distinct proof that any change had occurred in the " height of the water in Middleditch's well, we may conclude that it did not form an " exception to the general rule everywhere else observed, and the propriety of this con- " clusion is confirmed by the fact that in the case of a well called 'Lines' well,' which " is situated on even a slightly lower level than Middleditch's, and like it never known " to be empty, the fall and the rise of the water were observed to take place, although " not to so considerable an extent as in wells which were placed on higher ground.

" In another part of the village are two cottages, the first of which is occupied by a " family named Aves, and there I saw five well-marked cases of typhoid fever; in the " second I saw one. About 10 feet from these cottages and in a garden belonging to " them is situated the well; 20 feet from this well is a deep cesspool loosely lined with " bricks, which contains the drainage from the privies of an adjoining large house, and " within 12 feet of it a privy which pours its contents into a second cesspool. The " water in the well I was informed had been exceedingly low, especially about the 20th " November. The woman from whom I derived this information, and who lives in the " first-named cottage was taken ill a few days after this date and was unable to leave " the house for an entire week. Almost the first time she ventured out she went to " the well, and she remembers being surprised that the amount of water in it had so " greatly increased during her short illness. This visit to the well, took place about " the 29th of November, but my informant not being able to speak with perfect accuracy, " it may have occurred one day prior to, or subsequent to that date. The first case of " typhoid fever in her cottage was that of her daughter Susan Aves, who was attacked " on the 16th December, and whom I saw apparently in a dying condition; four others " occurred soon after.

" One more instance also tends to the same conclusion. A family named Edwards " live in a cottage near the river, and two of their number were suffering from typhoid " fever at the time of my visit. Their well is placed in a garden by the side of their " house. From this well which is at about the lowest point, the ground gradually rises " in almost every direction and within 26 feet of it there are two manure heaps with a " cesspool between them, and three privies, two of which belong to some neighbour- " ing cottages. Behind each of these privies is a hole in the ground for the reception " of its contents; this receptacle in the case of the central one is of an enormous " magnitude, measuring about 12 feet broad, by 15 feet long, and so crammed is it " with fœcal matter that its contents have been poured a few feet down an incline " and have there burrowed out a second cesspool nearly 12 feet long by 8 in breadth. " In addition to the above-named nuisances a pigstye is also placed near the well though " on a slightly lower level. This well which has been referred to as 'Lines' well,' " and which is about 5 feet deep, is lined with bricks simply placed one above another " and the edges of these bricks have a blackened appearance. It lies very low, and " consequently is never empty, but it is evident that the height of the water in it has

PART III. SPECIALITIES.

Propagation of typhoid fever in Terling.

"participated in the change everywhere else observed; for when speaking of its appear-
"ance being turbid, I was informed that this was due to the well having recently been
"suddenly filled. No one could give me the exact date of this occurrence, but I
"ascertained that it took place at about the same time that it was observed in the other
"wells in the village.

"One more example is worthy of detail, owing to the fact that the spot which was
"attacked was an almost isolated one, the patients also were all living surrounded by
"comfort and plenty, and apparently placed under the most perfect hygienic conditions.
"Ten cases of typhoid fever have occurred at Terling Place which is situated on an
"estate lying at the extreme south of the village. Here as elsewhere the severity of
"the disease has been very great, four of the patients having suffered seriously from
"hæmorrhage from the bowels and three have died. All of those affected were servants
"residing in the establishment, and although they occasionally frequented the village, in
"no instance could I ascertain that they had drunk any water from the wells. The
"portion of Lord Rayleigh's residence occupied by the servants is a wing almost
"entirely detached from the house only communicating with it by a small door. In
"endeavouring to ascertain the cause of the disease here, I naturally turned my
"attention to this part of the building. At the end of a long passage stands a pump
"the water from which is only used by one member of the household, with the exception
"of the servants. This pump is supplied from a well 40 feet deep, which is situated in
"a courtyard at the end of the servants' wing, and the pipe which passes from the well
"to the pump crosses a brick drain leading from two water closets. This pipe which
"is a leaden one I found to be perfectly sound throughout. The drain was then opened
"and on examining it, it was evident that the mortar which was used to cement the
"bricks together was almost destroyed, and at the side of the drain which was nearest
"the well, a leakage had evidently taken place into the surrounding ground, which had
"a fœcal odour. Nine feet from this drain and about midway between it and the well
"is a bricked cesspool or tank which ought only to receive the dirty water from the
"scullery, the waste water from the pump, and the rain from a portion of the roof. On
"opening it, however, I was struck as was also a servant who accompanied me, with the
"fact that the odour was most distinctly of a fœcal character. The distance from the
"drain to the well is 18 feet, and the soil here as elsewhere is loose gravel and easily
"allows of the passage of contaminating matters. This well might have become fouled
"either directly by the leakage from the drain or indirectly by the passage of the foul
"fluids first into the cesspool, which is not water-tight, and then from it on to the well.
"One point worthy of remark is that the outbreak at Terling Place occurred simultane-
"ously with that throughout the village, and we may fairly assume that the water in
"the well here had risen at the same time with that in the other wells, although owing
"to its being a covered one this fact had escaped observation. I would however state
"that a very bad odour had been noticed to rise up the waste pipe leading from the
"pump to the tank in the yard; this for some weeks had been complained of in the
"servants' wing, and by some residing here was considered to be the cause of the fever.
"The leakage from the drain into the tank could easily have given rise to this
"odour."

"During my visit I carefully examined every well throughout the village, and I found
"that with very few exceptions they were all so placed that the water they contained
"could easily become contaminated. Two of those which were placed under exceptional
"circumstances deserve notice *because they supply with water the only two large groups*
"*of cottages in which none of the inmates have suffered from the disease.*"

The water from three of the polluted wells was examined by the late Dr. W. Allen Miller, F.R.S., at the time of the outbreak; his analysis shows the following proportions of previous sewage contamination in 100,000 parts of the water:—

Middleditch's well - - - - -	24,850
Lines' well - - - - - -	9,160
Terling Place well - - - - -	10,980

3. *Chichester.*—This city had for five years been severely visited by typhoid and low fevers, when Dr. Edward C. Seaton was, in May 1865, instructed by Your Majesty's Privy Council to make inquiry into its sanitary state. He reported that the position of the city is excellent. Standing at the termination of a gentle descent from the South Down Hills, on the widest part of the long plain which extends from Brighton to Portsmouth, it is freely open to currents of air on every side. It is built on a thick bed of gravel, beneath which, at a depth of some 20 feet or more from the surface, is an impervious stratum of London clay. Of the drainage and drinking water Dr. Seaton

Propagation of typhoid fever in Chichester.

thus speaks :—"There is no system of drainage in Chichester, and there is no extraneous "water supply. The *Lavant Course*, a stream which only runs at times, entering the city "at the north-east, does not traverse it, but skirts the walls on the east and south, leaving "the city at the south-west. It receives the surface and sink drainage of the houses "built along its course, and may receive other things which ought not to enter it. "Anyhow, it is frequently very offensive, and in summer when the water is low is little "better than a fœtid open ditch. No drinking water is taken out of it. The sink "drainage of all the houses not built along its course, and the watercloset drainage and "privy drainage of all houses is into cesspools. These are nothing more than so many "holes in the porous soil, walled generally by brick and mortar, the liquid that flows "into them being either absorbed by the ground beneath, or overflowing and running "into the soil nearer the surface. Out of other deeper holes in this porous soil all the "drinking-water is taken, these wells being so constructed that any fluid stuff may "percolate into them laterally. The whole city is thus riddled with holes, the deeper "holes or wells being frequently within a few feet of the shallower holes or cesspools. "Under such circumstances the frequent contamination of the drinking water is "inevitable. Even where the wells were 15 yards from any cesspool or privy, I had "evidence of such pollution in several instances; in one case there was the clearest "evidence of contamination having taken place from a cesspool at a distance of 20 or 30 "yards. It was in Somers Town that the water was generally the worst. In many houses "it stank at times, and became unusable. But in every part of the city, in the North, the "South, the East, and the West streets, and in the North Pallant, I had evidence that in "some houses the water at times became offensive. The water from the public pump in "North Street had been offensive last summer. In one house in East Street, in which "the well was within three yards of the privy cesspool, the water often after heavy rain "was unusable. In another house in the same street, where the well was 12 yards from "a very large cesspool which received the closet drainage, the occupant was obliged "after heavy rains to send away for water, and never at any time thought it prudent to "drink the water of his own well without first boiling it. Some of the inhabitants had "been obliged to abandon wells from their liability to pollution, and to sink fresh wells.

"Whenever pollution went to the extent of making the water stink, the inhabitants, it "need scarcely be said, had recource to other sources of supply for their drinking-water; "but when the gross and obvious indication of contamination which the smell affords "had passed away, or when the pollution had not gone to the extent of making the "water actually offensive, they generally drank it, though they might not think it very "good, rather than have the trouble of sending away. The water which I collected "from Mrs. Barnett's pump in George Street, which Professor Miller states to be unfit "for domestic consumption, had a peculiar but not an offensive smell, and had been "drunk for the seven months she had resided in the house; at times, however, she said "it had been offensive. The water from Mr. Reade's pump in South Street had, some "weeks before I collected it, been offensive, so that he was obliged to send elsewhere; "but he had resumed the use of it as soon as he could, and no doubt had been drinking "a great deal of sewage, for even now, when it was quite bright, and unobjectionable to "taste, Professor Miller finds evidence of its having been contaminated. The water in "the house in which the 16 cases of fever had occurred had not, so far as could be "recollected, ever been actually offensive, but it had always a saltish sweet taste, and "had not been a pleasant water.

"The conditions under which the water became offensive were (1) when the wells "were low, the solution of sewage being then most concentrated, and (2) when heavy "rain, by overflowing or by soakage sent a lot of cesspool stuff direct into the wells. "The water I collected and sent for analysis was taken when the wells were full and "the weather was dry; it was said to be at its very best. In many of the houses "which I made inquiry, the water was not only bright and good to taste now, but had "not at any time, so far as I could learn, given evidence of contamination.

"In most of the houses I visited in which fever had prevailed, I found that the water "had been polluted, and saw the conditions under which this had taken place. In one "house in Somers Town, in which there had been several cases and a death from fever, "the well and cesspool were within three feet of each other; in another, in which fever "or some other form of sickness was constantly prevailing, the well was in close "proximity to seven cesspools."

It is thus evident that the city of Chichester presented all the conditions favourable for the propagation of the typhoid poison through the medium of water.

4. *Salisbury.*—During the period 1844–52, Salisbury was supplied with water from wells about 8 or 10 feet deep, in which the water stood within 2 or 3 feet of the

Propagation of typhoid fever in Tottenham.

surface. These wells were generally situated close to cesspits which frequently overflowed, and their liquid contents at all times soaked away into the surrounding porous stratum from which the wells were fed. The annual mortality from typhoid fever during this period of nine years averaged $7\frac{1}{2}$ per 10,000 inhabitants. In 1853 public waterworks and drainage works were commenced and were nearly completed in 1856. The water was obtained from a well 68 feet deep, sunk into the chalk and connected with a tunnel 70 feet long, and was supplied on the constant system at the rate of about 40 gallons per head per day. During the eight years, 1857–64, the average annual mortality from typhoid fever was only $1\frac{3}{4}$ per 10,000 inhabitants.

5. *Buglawton near Congleton.*—There had frequently been sporadic cases of typhoid fever in this village, but at the beginning of 1866 a violent outbreak of the disease occurred. We are indebted to the report of Dr. Buchanan to the Medical Officer of the Privy Council for the chief facts embodied in the following remarks:—In a population estimated at 1,150 no less than 150 cases, of which 14 were fatal, occurred. The first case was that of a young woman who lived in a house adjacent to a well 15 feet deep, known as Scragg's, from which a large number of persons in the neighbourhood derived their supply of water. This well is described as being surrounded by privies at about 30 paces off, and Dr. Miller's analysis of a sample of the water collected on 20th April 1866 showed evidence of 15,145 parts of previous sewage or animal contamination in 100,000 parts of the water. In other words, this well water had contained as much privy stuff as would be communicated by the addition of 15 gallons of strong sewage to 85 gallons of pure water. Although the outbreak of fever was not confined to the immediate neighbourhood of this well, still it was a focus around which a great number of severe attacks were clustered; moreover it deserves to be mentioned that young persons, and especially young females, that is water-drinkers, were the chief sufferers. Thus of the fatal cases only two were over 25 years of age, and only three were males. Around Scragg's well there were 87 attacks and five deaths. It is easy to perceive how a typhoid focus thus established must, by the washing of dirty linen, by visits to the houses of the sick, accompanied in some cases by the drinking of the infected water, occasion the spread of the disease to other parts of the village. The disease was of a severe type, having a very long duration and a considerable tendency to relapse. There is no public water supply in Buglawton, besides shallow wells such as the one just described; most families get water for washing and other domestic purposes from the *Dane* at points adjacent to, or immediately below, the discharge of sewage into it. It is stated, however, that this water is seldom used for drinking except by some persons in Dane Row, abutting on the river. In this row, however, there were eight attacks of typhoid fever in six houses.

6. *Tottenham.*—From the year 1862, and probably earlier, many cases of fever had occurred at Page Green, a detached hamlet in the parish of Tottenham, but in the years 1864 and 1865 a severe outbreak occurred affecting about 100 persons. This continued prevalence of typhoid caused an inquiry to be made by Dr. Seaton on behalf of the Medical Department of the Privy Council, from whose report we extract the following:— "This continued prevalence of typhoid directed my inquiry, as a matter of course, in "the first instance to the sources of supply of drinking water. Many of the houses at "Page Green derive their supply from surface wells, others are supplied from the "waterworks of the Local Board of Health; none of the 56 houses at which I made "inquiry had on the premises a supply from both sources. Inquiry as to the effect this "difference in the source of water supply had had on the incidence of the fever gave "the following results:—

Source of Water Supply.	Number of Houses visited.	Number of these Houses in which *a Case or Cases* of Fever had occurred.	Number of these Houses in which *more than a single* Case of Fever had occurred.	Number of these Houses in which *there had been a succession* of Cases of Fever or Diarrhœa.	*Approximate* Total Number of Cases of Fever, including persistent Diarrhœa.
Surface wells - -	24	19	17	13	80
Local Board Waterworks -	34*	10*	4	2	22
Totals - -	58	29	21	15	102

* "Two houses are included, referred to in a former note, which I did not visit as the occupants had gone away, but in each of which there had been a case of fever."

"The difference was so striking* as to lead at once to the further inquiry whether, in "the houses supplied by the Local Board in which fever had prevailed, the inhabitants "had really taken all their drinking water from the Board's supply, or whether they "might not have derived at least some share of it from their neighbour's surface wells. "I found that the occupants of six of these houses—*including all the four which had* "*had more than a single case of fever*—from dislike of the Board's water, or from the "irregularity with which they were supplied, very frequently borrowed water from their "neighbour's wells;† at three of the houses, from removal of the families in which the "fever case had occurred, I could get no information on this point; at the remaining "house, in which there had been last autumn a case of mild typhoid in a child, the "water drunk was, so far as could be ascertained, exclusively that of the Local Board. "Excepting these last four cases (concerning three of which no information on the "subject could be got), it is established that in every case of fever which has occurred "at Page Green the supply of drinking water had been wholly or in part, and in the "immense majority of cases wholly, from the surface wells.

Part III. Specialities. — Propagation of typhoid fever in Tottenham.

"These wells are very shallow, about seven or eight feet deep, sunk in porous gravel. "The water they yield is said to be generally bright and pleasant, and is evidently a "favourite water with the people. Some selected for analysis from a well in a row of "houses called Caines Terrace, in which fever had particularly prevailed, was very "popular; and the inhabitants although allowing that it was not *always* so good and "pleasant as at the present time, seemed surprised at the notion of there being anything "injurious in it, and amused at its being analysed. But the liability of these wells to "surface and sewage contamination had been manifested in some of the houses on "various occasions, by the water becoming unpleasant to taste and smell after heavy "rains or from matters thrown down sinks; and it was well illustrated, at the time of "this inquiry, at a house in the Markfield Road, where some carbolic acid, which had "been thrown down the yard sink, was distinctly smelt in water pumped from the well "in my presence. It should be stated that the houses at Page Green (except three) "have not cesspools, but waterclosets communicating with the sewers of the Local Board; "but in those houses which derive their water supply from wells there are no means of "flushing except by pails of water poured down occasionally.

"Specimens of water from the wells at No. 1, Cambrian Cottages, in the Markfield "Road, and at No. 5, Caines Terrace, in the Stamford Road, were submitted to Pro- "fessor Miller for analysis, and both of them unreservedly condemned by him. Of the "first he reports, 'It is somewhat turbid, hard, and contains a very unusal proportion of "'ammonia, as well as a notable amount of organic matter. Some sewer drainage most "'probably finds access to this well. It is quite unfit for use for dietetic purposes.' Of "the latter he says, 'It is a very hard water, and it continues so after boiling. It con- "'tains nitrates and a considerable amount of organic matter. Its aeration is very "'defective. I should recommend its immediate discontinuance as a beverage.'

"The way in which people go on unconsciously imbibing fever and diarrhœa from "such wells as these is so aptly illustrated by the occurrences at Caines Terrace, that I "must be permitted to give in brief detail the results of my inquiry at the five houses of "which the terrace consists, all deriving their water from two or three surface wells. In "the one (No. 5) from which the water was taken for analysis, Mr. Gaffney has lived "for three years; his family, consisting of four, had all diarrhœa soon after they came, "and in Nov. 1864,—Jan. 1865, the son and daughter had marked and severe typhoid; "the son narrowly escaped dying of it; they were attended by Dr. May. In the next "house (No. 4), supplied by the same well as Gaffney's, in Dec. 1864, Mrs. Greenwood, "the then occupant, was attacked with typhoid, and was attended by Dr. Pool; in May "1865, the present occupant, Mrs. Slark, came; she, her son, and her daughter (the "only permanent inmates), had diarrhœa immediately on their coming; the lodgers "whom she receives have, each as they came, successively had diarrhœa, and some of "them have had also low fever. Mrs. Barnes has lived in the next house (No. 3) for "two years; they are four in family, and for the first six months of their residence they

* "It would have been still greater if time had permitted me to visit the remainder of the houses (above 30), "all of which I had reason to believe had been free from fever, and nearly, but not quite, all of which were "supplied with water by the Local Board."

† "The water supplied by the Local Board of Health was complained of by several of the inhabitants as being hard, turbid, and red. The turbidity and redness were only noticed when the water first came on, the supply, though professedly constant, being really intermittent, and were no doubt due to rust in the pipes; but considerable hardness, as analysis by Prof. Miller showed, existed even after boiling. The irregularity and uncertainty of supply were universally complained of, and the truth of the complaint was admitted by the Local Board, who, however, had taken steps to increase their resources."

PART III. SPECIALITIES.

Propagation of typhoid fever in Guildford.

"had nothing but fever and diarrhœa; lately they have began to take lodgers, they have "had two sets, and each set has had diarrhœa. The two remaining houses are occupied "by families who have only resided for seven weeks, but in each of these houses there "was fever last year. Of the present occupants, the family residing in one of them, five "in number, have all suffered from diarrhœa since they came; the family residing in the "other, three in number, have not suffered in any way, *but this family boil first all the* "*water which they use for drinking*. Mrs. Slark informed me that many of the neigh-"bours who were supplied by the Local Board came begging water from her well. And "I found that the occupants of two houses so supplied close by—the only two houses "supplied by the Local Board in which there had been *succession of cases* of fever and "diarrhœa, viz., Graham's and Bartholomew's—had very frequently borrowed water "from this well.

"The story of Caine's Terrace is repeated in a row of three houses in the Markfield "Road supplied by one well, in all which houses typhoid fever had prevailed at the end "of 1864 and early part of 1865, and in two of which very nearly, if not quite, all the "occupants (12 in number) had had that disease, one of them dying of it; in other "houses in the Markfield Road; and in both the houses standing together near the "railway. In one of these latter not only have there been four cases of fever in the "family, who have now and for the last two and a half years been in occupation, but "other cases of fever had been attended by Dr. Pool before their occupancy.

"Upon the grounds I have stated the conclusion appears to me irresistible that the "fever and illness at Page Green have been mainly kept up by the use of impure surface "water for drinking, and I deem it a matter of the most urgent necessity that the "surface wells should at once be closed."

7. *Guildford*.—Sporadic cases of typhoid fever are not uncommon in Guildford, but in September 1867 a severe outbreak of this disease occurred. During the first 28 days of August there were about 10 cases scattered about in the town, then so large an accession occurred that within the next 33 days there were no less than 250 attacks, of which 150 occurred in a fortnight. These attacks, especially in the first fortnight, occurred within an area which nearly coincided with a particular section of the public water supply, and thus a strong suspicion arose that the water distributed to this particular area was the cause of the disease, and this suspicion, to use the words of the Medical Officer of the Privy Council, "eventually became a certainty." It was shown that about 10 days before the outbreak 330 out of the 1,675 houses in Guildford had *exceptionally* received their water from a service reservoir which had been filled from a new well sunk in the lowest part of the town and close to several sewers, the brickwork of which was so defective as to allow the sewage to flow into the well. "The persons "residing in or frequenting these 330 houses constituted the part of the population on "which the epidemic influence had almost exclusively fallen."

The following account of this outbreak is extracted from Dr. Buchanan's report contained in the Tenth Report of the Medical Officer of the Privy Council, 1867, page 34:—"Guildford is placed on the side of a hill of chalk, where it is cut through "by the valley of the *Wey*. The northern, and more level part of the town, which "extends into the parish of Stoke, is on a bed of Lower London Tertiaries overlying "the chalk. This bed is of somewhat marly sand, and has a maximum thickness of "15–20 feet. But it is with the larger portion of the town, built immediately on "chalk, that this report is most concerned.

"The chalk furnishes a perfect natural drainage for the town. Cesspools sunk into "it keep themselves dry, and are commonly so inoffensive that they are not emptied for "many years together. The water-line in the chalk is of course much below the sur-"face of the higher part of the town; at the lower parts, water is easily reached at a "level a little above that of the river surface; into the river considerable springs from "the chalk constantly pour. The water-level under the town undergoes no appreciable "fluctuations, either from changes of season or artificial influences.

"There is no recognised system of closet drainage in Guildford, but cesspools into "the chalk are almost universal. Shallow sewers receive surface water from most of "the streets and slops from the houses, and in some of these sewers, more or less night "soil—chiefly the liquid portions of it—is discharged. This is without the consent of "the authorities, as the sewers were never constructed for such a purpose.

"The water supply of Guildford is derived partly from the public waterworks, which "are fed by two wells sunk some 20 feet into the chalk at the lowest part of the town; "an old well from which water is raised by the power of an adjacent watermill; and a

Part III. Specialities.

Propagation of typhoid fever in Guildford.

" new well from which, from April to July inclusive in the present year, water was " distributed to the higher parts of the town by engine power. But of the 1,675 houses " (1867) of Guildford, only 928 are supplied from these sources, the remaining 747 " obtaining their water from private wells and some few from the river.

" The population of Guildford in 1861 was 8,032, in 1,514 houses. The population " is now estimated at 9,000, and the number of houses is 1,675. There is some sub- " letting of houses, but very little serious crowding in the town. The occupations of " the people are various, agricultural and manufacturing, but offer nothing to note in the " present report.

" § II. Typhoid fever not unfrequently prevails in Guildford and the neighbouring " villages. The district of Guildford stands second highest amongst extra-metropolitan " registration districts of Surrey for its death-rate from fevers, but the best local opinion " ascribes this circumstance to the frequency of fever in other parts of the district rather " than in Guildford itself. In the present summer, cases of typhoid had occurred from " time to time in various neighbouring villages, and some few in the town before the " time of the outbreak under question. During the first four weeks of August about " 10 cases of fever appear to have occurred in the town, six of them being reported by " one practitioner.

" In the last three days of August cases of typhoid fever came under treatment in " Spital Street and Pannell's Terrace, high-lying and usually very healthy parts of the " town. In the first two days of September a few others came under observation, and " on September 3rd and 4th a surprisingly large number of people sent for medical " assistance and were found to be suffering under the same fever. In the first 10 days " of the month a total of some 150 cases had come under treatment, and this number " had increased to 264 by the end of September.* A singular circumstance soon forced " itself on attention in connexion with this outbreak. Whereas the few cases that had " previously happened in Guildford had been scattered through the poorer low-lying " parts of the town, this sudden outbreak was restricted with almost absolute precision " to the high levels; well-to-do people were affected as much as the poor; streets in " various quarters of the town were affected; the best-kept houses were invaded as " much as dirty ones. Except the coincidence with high level, there was nothing " approaching uniformity in the distribution of the epidemic.†

" The outbreak reached its greatest intensity before the middle of September, and " thenceforth declined pretty rapidly; meanwhile a very few cases were occurring at " other parts of the town. At the time of inquiry only a few new patients were coming " under observation, and these were increasing in number in parts of the town that had " not been affected by the first explosion.

" Looking carefully for any condition that might coincide in distribution with the " fever, it was soon seen that drainage could have played no direct part in the result, " inasmuch as there is no system of sewers in the town, and the parts affected were " those whose natural drainage is the best. Other suggestions having been put aside as " not meeting the broad facts of the case, only one condition was to be discovered " generally coincident in distribution with the outbreak, and that was the *high service* " *of the town water-supply.*

" More particular inquiry was then made as to the source from which each affected " house procured its drinking water, and it turns out that all the houses *first* attacked at " the beginning of September were supplied with water from the high service. A few " exceptions to the absoluteness of this rule were in school children and others who, " living in houses not supplied by high-service water, spent the hours of the day in " houses that got their supply from the high service. In the latter part of September " new attacks had been less exclusively distributed to such houses.

" Of the total number of 264 cases of fever that have occurred in Guildford in August " and September, 177 have been in the 330 houses that derive their water from the high- " service mains; only 30 have occurred in the 598 houses that are on the low service, and " 57 cases in the 747 houses that take no water from the public works. Even these " figures show an incidence of the fever on the high-service houses ten times as great as " on the low service; but this does not express the true limitation of the outbreak. If

* " The mortality of the fever cannot yet be stated. Only three cases had been fatal at the end of September. Some other persons who were then ill have died while this report has been in preparation. Evidently the death-rate will turn out to be very low, a fact of interest in connexion with the transitory operation of the apparent cause of the fever."

† " The parts affected by the outbreak are all on chalk. Sporadic fever has shown no preference for the chalk, rather for the more level and lower lying Tertiary parts of the town."

PART III. SPECIALITIES.

Propagation of typhoid fever in Guildford.

"the few sporadic cases occurring before August 28th, and those that did not occur "until the end of September, when the disease was getting more diffused, be excluded, "there remain not more than two or three dozen cases (out of the 150 that occurred "between August 28 and September 10) in houses that did not get high-service water. "And if deduction be made of the school children above mentioned, there remain less "than a dozen persons attacked in this fortnight who had not had daily and hourly "access to the water of the high service. The experience of all the medical men has "been combined in this conclusion; but the practice of the Surrey County Hospital may "be quoted in illustration. Careful inquiry by the resident medical officer showed that "of 39 cases coming under treatment there between September 3 and October 1 (he had "seen no fever for weeks before) 26 lived in houses supplied by high-service water, four "in houses supplied by low-service water, and nine in houses that got water from their "own wells. But of these last 13, 10 were children, who in August went to schools "supplied by the high-service water. Two of the other three cases did not come under "treatment till October 1, and the third was on September 20th at a village three "miles off.*

"The coincidence of the fever outbreak with the area of high-service water-supply "being thus strongly marked, and the cause of the disease having evidently come into "operation about the middle of August, it was at first sight perplexing to be told that "since the beginning of August identically the same water had been delivered to both "the high and the low service districts of the town. The engine which pumped water "from the new well to the high-service mains and to the high-service reservoir had "broken down on August 1st, and from that date no water had been pumped from the new "well, but the high-service mains had been charged by the water-wheel in connexion "with the low-service, and the water to both services had been that of the old well.

"On further investigation, however, it was found that some water from the new well, "raised on or before August 1st, had been stored in the new high-service reservoir, and "that on August 17th, the water-wheel being on that day under repair, this stored "water was distributed to the high-service houses of the town. It was distributed on "no other day and to no other houses. These 330 houses, therefore, on which the fever "almost exclusively fell had received a different water from the other houses of the "town, viz., water from the new well, stored up from August 1st, and delivered on "August 17th. The statement may be repeated that no other condition could be "found, on careful and detailed inquiry, at all coincident with the outbreak of fever."

The water was submitted to analysis by the late Dr. W. Allen Miller, F.R.S., and the results he obtained show that each 100 gallons of it had been polluted with an amount of animal matter equal to that contained in $7\frac{1}{4}$ gallons of London sewage.

Under date December 21st 1867 Mr. Taylor, one of the Poor Law Medical Officers of the town, wrote to Dr. Buchanan as follows:—

"I take upon myself to inform you that your suspicions as to the percolation of sewage matters into the new well have been now rendered almost certain. The engineers employed in the repairs of the steam engine noticed some exudation in the wall of the engine-house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine-house. The sewer was found leaking in various places and the soil between it and the wall of the engine-house was saturated with sewage of which as much appeared to run outside as inside the sewer. This was found to be an old fashioned 12-inch drain, constructed with red unglazed gutter tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the

* "Mr. Taylor had had 60 cases of typhoid, little or none before September 3rd. His earlier cases were all in houses supplied by high-service water. In all 43 of the cases had been in houses so supplied; 7 had been in houses on the low service, and these included 4 children who went to school in the high-service district; 8 were in houses with wells, and of these persons 5 went to school or were employed where high-service water was in use; two cases were beyond the town in persons who had worked in houses similarly supplied. Very similar distributions had occurred in the practice of Dr. Stedman, Dr. Morton, Mr. Eager, Mr. Butter, and Mr. Schollick, and the outbreak in the practice of each of these gentlemen had occurred about the same day, and was at first wholly in houses supplied with high-service water, scarcely any cases of the fever having been previously under their care. The most numerous cases of scattered fever had been in the practice of Messrs. Sells and Wilson, probably from the circumstance of their holding a poor-law appointment in an unwholesome district. Their experience, though not identical in form with the rest, is wholly confirmatory of the above conclusions. In the first 28 days of August they had no case of fever in houses supplied by the high service, one in a house supplied by the low service, three in houses of the town supplied from wells, and five cases in the surrounding country. In the 17 days, August 28th to September 14th, the number of attacks among their patients whose houses are on the high service was 22, in houses on the low service 3, in houses with wells 9, and in country parts 6. In the 16 days, September 15th to September 30th, the new attacks in high-service houses had diminished to 14, but those in houses supplied by low service had risen to 6, those in houses with wells to 10, and those in the country districts to 8."

soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark coloured fœtid slush had to be dug out and removed in baskets, making the men vomit who were employed in the work."

Propagation of typhoid fever in Southampton and Clifton.

In order that the full significance of the leakage of sewage into the engine-house may be understood, it is necessary to add that the well itself was situated beneath the floor of the engine-house. This well has now been abandoned, and another has been sunk on an island in the *Wey*, quite out of the reach of direct leakage from sewers. (*See* analysis on page 88.)

8. *Southampton.*—In his evidence before the Royal Commission on Water Supply (1869), Dr. E. A. Parkes, F.R.S., Professor of Military Hygiène in the Army Medical School at Netley, says:—

"I have got a good deal of evidence together as to diseases which may be communicated by water, not only to the troops, but among the civil population. I have made a list of diseases, all of which are occasionally communicated by means of water, not solely communicated by water. For example, typhoid fevers, of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me arising from water impregnated with typhoid sewage, or possibly with simple sewage. When I speak of typhoid sewage, I mean sewage from persons suffering from typhoid fever.

"Can you detect that after its mixture with water?—Not by any chemical re-agents.

"But under the microscope have you the means of detecting it?—No, there is no possibility of determining the particular substance which causes the fever in other persons. We only know the effect produced upon other persons, and no doubt it is from that cause.

"How did you ascertain that those outbreaks were due to water impregnated with typhoid sewage? —On account of the cases immediately following that impregnation with typhoid sewage. I do not wish to deny that simple sewage might produce the same disease, but that is a question still undecided.

"Have you the means of tracing the discharge of that sort of sewage into the water, and the results following in fever?—Yes.

"Have you obtained many confirmatory results from that observation?—There have been altogether a considerable number of cases now placed upon record by different writers of such an effect following the passing of typhoid sewage, or, possibly, of simple sewage into drinking water. We had a case in the neighbourhood of Southampton only this last year, in a young ladies' school, where a drain pipe passed within three feet of the well; at the point nearest the well the soft ground below the drain pipe had given way, and the pipe had sunk, and the sewage passed into the water of the well. Immediately following that was an outbreak of typhoid fever, which affected something like 80 per cent. of the population, that is to say, 18 or 19 persons were affected out of a population of 24 or 26; there were several deaths, and many of them very severe cases. In that case it was impossible to prove whether or not it had been typhoid sewage passing into the well; but the impregnation of the water with sewage was certain and coincident at that time; and that, coupled with several cases of the kind, seems to show that the outbreak of the fever is owing to the impregnation of the water with sewage."

9. *Clifton, Bristol.*—In the autumn of 1847 a sudden and alarming outbreak of fever occurred in Richmond Terrace, Clifton, of which the following account is given by Dr. William Budd, F.R.S., of Bristol, whose painstaking and persevering researches have in a great degree contributed to establish accurate knowledge of the propagation of typhoid fever through the agency of air and water. (Typhoid fever: its nature, mode of spreading, and prevention. By William Budd, M.D., F.R.S. Longmans Green and Co. 1873):—

"The terrace in question is built somewhat in the form of a horse-shoe, and consists of thirty-four houses of a good class, occupied by persons in a genteel rank of life. At the end of the terrace there is a pump, from which, at that date, the inhabitants of thirteen houses drew their drinking water. In the latter end of September it became evident that this water was tainted with sewage. The fact first made itself known by a characteristic taste and smell in the water, and was afterwards further verified by an examination of the well and discovery of the actual leakage. Early in October, typhoid fever broke out nearly at once *in all the thirteen houses in which the tainted water had been drunk.* In almost every house of the thirteen, two or three persons were laid up, and in some a much larger number. Amongst others, the case of a school for young ladies was very striking. The first to suffer in the school was the lady of the house. She was taken ill on the first Monday in the month. Four of her pupils were seized on the following day; and before the end of the week, the mistress, six school-girls, and two maid-servants, were all in bed with the same fever. In the beginning of the week following, two more were added to the list. Three children who were sent home on the first outbreak of the disorder, and three others who remained at the school, were the only persons who escaped.

"The houses in which the same specific fever thus simultaneously broke out on so large a scale were many of them far apart in the length of the terrace, and their inmates were, for the most part, not in the habit of personal intercourse. The other families on the terrace, *living side by side with these*, continued all the while to be perfectly free from fever. The only important circumstance in which those who suffered so severely differed from these who did not suffer at all, was that the former had drunk of the tainted well, and the latter had not.

"Only a few doors from the school already mentioned there was another girls' school, with about the same number of pupils. In all that related to their internal economy the two schools were exactly alike; but while, in the one, eleven persons out of seventeen were struck down with fever, in the other there was not a single case. The one was supplied with drinking-water from the poisoned well, and

Propagation of typhoid fever in Cowbridge.

the other from an entirely different source. The circumstances gave to the contrast, here, all the force of an experiment. In complex questions it is not often, indeed, that even experiment yields results so clear and precise.

"Amongst the sufferers at Richmond Terrace were nine servants, who were removed to the Bristol Infirmary soon after being attacked. To make the case complete, I have only to add, that all nine presented, in full development, the diagnostic marks of this species of fever. Two of the number, who were my own patients, offered perfectly typical specimens of the disorder. In two others, who died, the small intestine was crowded with the ulcerations which are characteristic of the disease."

10. *Cowbridge.*—In the month of November 1853, two public balls were held on two successive nights at the chief inn of the small town of Cowbridge in Wales. About 140 persons from different parts of the principality and also from Gloucester, Somerset, and other distant counties attended these balls. A violent outbreak of typhoid fever occurred amongst these persons after their dispersal to their various homes. We extract the following account of this and of another case from the description of Dr. W. Budd, F.R.S. (Typhoid fever: its nature, mode of spreading, and prevention. Longmans Green and Co. 1873.)

"Almost immediately afterwards, a number of these persons were seized with typhoid fever, and as many as eight died of it. Among the sufferers there was a considerable proportion who had never been in one another's company, except in the Cowbridge ball-room. It is clear, therefore, that they had in some way contracted the fever there; and that the typhoid poison was present at this hostel in no common degree of force and intensity. It is not recorded that fever was specially prevalent at the time in the neighbourhood; and, with the exception of one or two persons who lived in the house, those who attended the balls appear to have been alone attacked.

"An occurrence so painfully striking, and in all ways so remarkable as this, naturally attracted great attention at the time, and an inquiry was held, with a view to discover the cause of the calamity. The only sanitary defect elicited by this inquiry, in explanation of so terrible an outbreak, consisted in the fact that 'the supper room was merely a temporary transformation of a loft over a seven-stabled 'stable,' and that the passage between it and the ball-room was partly built over a large tank which collected the water from the roof of the house.

"About fifteen months after this outbreak occurred I was called to Cowbridge to a case of typhoid fever which had come down by direct lineal succession from one of the original sufferers; and I took the opportunity of ascertaining, as well as I could, both from the people of the hotel and from the medical man consulted on the occasion, the leading circumstances of it.

"First, in order came the all important fact, which had not been disclosed to the gentleman who originally reported on the outbreak, that there had been a case of typhoid fever in the hotel immediately before the balls were held.

"The disease occurred in the person of a gentleman visiting the hotel, and who was laid up there for some time with it. A day or two before the balls, although not yet fully convalescent, he left the house on account of the approaching festivities.

"As none of the ball-goers had been in the presence of the sick man, it was obvious that they did not contract the fever from direct personal infection. There was no reason to believe that the infection was communicated through the air, as no offensive smell in the ball-room, or, indeed, anywhere in the house, was noticed by the guests. From this and other considerations I was led to infer that drinking-water was the most probable vehicle of it.

"A visit to the courtyard of the hotel left in my mind no doubt that this was the true view of the case. The cesspool and drain, which I was informed had received the bulk of the diarrhœal discharges from the fever patient, was at the time of the outbreak so near to the well, that, under the conditions of soil and locality, percolation from one to the other was almost inevitable.* I further learnt, from persons who were present at the balls, that, as usual on such occasions, many drinks—lemonade among others—were largely supplied there and freely drunk.

"This much, then, was sure,—that a considerable number of the persons who attended the balls drank freely water from a well in close proximity to a receptacle which, for a considerable time, had received the specific excreta from the diseased intestine of a fever patient.

"The main facts established, there are one or two collateral points almost equally deserving attention, which it may be well to note at once.

"The first is the very large proportion in which the guests were infected. Of the persons who attended the balls, there is reason to believe that from forty to fifty suffered—a truly remarkable proportion when it is borne in mind that many probably drank no water at all, or only water that had been boiled."†

The second "point has come to my knowledge subsequently to the visit at which I learnt most of the particulars hitherto given. In the course of the nineteen years which have since elapsed, I have been consulted, professionally, by eight persons who caught fever at these balls. From them I learnt that the one peculiarity which distinguished their illness was the extreme shortness of the time which intervened between the reception of the infection and the actual development of the fever. In four days, all eight had already taken to their beds, two were laid up on the second day,

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* "Some months after the occurrence of this great calamity, the sanitary defects of the hotel were investigated and remedied; and, as regards these important conditions, the hotel is now, I believe, thoroughly well appointed."

† "Of the inmates of the hotel itself, the landlady had fever severely, and some other members of the household had, I believe, slighter attacks. But I do not possess any evidence to enable me to give, with precision the number of local sufferers."

PART III. SPECIALITIES.

Propagation of typhoid fever in Winterton.

and two others were seized with violent vomiting and purging the day after the balls, and went straight into the fever from that time. Indeed so rapidly, in many, did the illness supervene, that the outbreak, at first, was supposed to be not one of fever at all, but the result of common chemical poisoning.

"I have observed a like shortness of incubation in many other cases of typhoid from drinking infected well-water, and believe it to be due to the high degree of concentration of the poison, which must result from its being cast out into a medium of fixed and limited amount.

"As regards this point, however, everything must depend upon the nature of the communication between the cesspool or drain, and the well. Where the communication is large and direct, the succession of events is rapid; but where it is by gradual percolation through strata of some depth, a considerable time may elapse after the poison is discharged before it can again reach the human stomach. A heavy fall of rain sometimes appears to be the determining incident.

"It seems probable, also, that a suddenly increased draught upon the water of a well, by causing a correlative inflow from surrounding tainted strata, may also hasten the result."

11. *Winterton, Lincolnshire.*—This small town which enjoys a healthy situation and an excellent system of sewerage, strikingly exemplifies the futility of good natural position and of attention to drainage, if the access of fœcal matters to the water supply be not rigidly prevented. In consequence of an epidemic of typhoid fever extending over several years, Dr. R. Thorne Thorne was sent down to Winterton by the Medical Department of the Privy Council to inquire into the cause and extent of the disease. From his report we extract the following particulars:—

"Winterton is a small market town, situated on a gentle slope in the northern part of " the county of Lincoln, about two miles south of the *Humber*. It consists mainly of " one street, called the High Street, running directly from east to west, but at the " western extremity houses are also collected around an open space originally occupied " by a pond, and round two sides of the churchyard. The town, which is on high " ground, is situated on a stratum of oolitic limestone, which is very porous, and easily " admits of the percolation of fluids. Above this substratum lies a clay marly soil.

"In 1861 the population was 1,780, and since that date it has not increased beyond " about 1,800.

"The town is under the government of a local board, the only other officials being the " clerk to the board, and a labouring man who holds the appointment of town surveyor " and inspector of nuisances. Its situation on a slope gives great natural advantages " to Winterton as regards sewage, and within the last few years a very effectual main " drainage has been laid through the town. Into this drain a running stream has been " diverted, and thus a continual flow of water is kept up nearly throughout its whole " length. Two outfalls carry the drainage into a brook running parallel with, and out- " side the town; this discharges itself into an artificial piece of water called Sir Row- " land's Drain, which in its turn runs directly northwards, and joins the *Ancholme* river, " just before this stream empties itself into the *Humber*. All the openings from the " street gutters into the drains are well constructed and properly trapped, and with the " exception of one of the outfalls which have just been mentioned, the whole system " works efficiently. The town consists almost entirely of cottages, which are, with few " exceptions, well built of brick or of limestone. Absolute poverty is but little known " there, for though about nine-tenths of the population consist of the labouring classes, " yet these, when in health, almost all earn good wages; intemperance also is rare, so " that neither of these causes can be said to be at work in predisposing the inhabitants " to disease. Ague was, up to 30 years ago, very prevalent in the district, but since the " neighbourhood has been properly drained no cases have occurred.

"Winterton is at present (April 1867) suffering from a widely spread epidemic of typhoid " fever. This disease, according to Mr. Bennett, has never been entirely absent from the " town for nearly seven years, but during the last two or three years only has it affected " so large a number of the population as to give rise to public anxiety. The epidemic is " now principally confined to the east end of the town, where it has attacked the poorest " class of the inhabitants, but during the past year almost all the cases occurred at the " west end, in the houses adjoining the churchyard. These houses are 35 in number, " and Mr. Bennett's books show that from June 1865 to June 1866, out of 145 persons " residing in them 100 suffered from fever, of whom 17 died. The upper classes and " the tradesmen have not been exempt from the fever, but at the time of my visit none " but the labouring classes were suffering from it.

"From Mr. Bennett's position as union medical officer, almost all these patients are " under his care, and by his permission I visited with him all those who were now under " treatment. The number I thus saw was 49, all of whom exhibited the various symptoms " of typhoid fever, including the rash and the bowel affection, with the exception of a " few, whose cases were of too recent a date for the eruption to have exhibited itself,

PART III. SPECIALITIES.

Propagation of typhoid fever in Winterton.

" and a few more who were progressing towards convalescence, but who had evidently " suffered from some acute febrile disease. In addition to these cases there were six " under Mr. Sadler's treatment, making a total of 55 cases. Notwithstanding this large " number, the mortality has been small, six cases only having terminated fatally since " the 1st of January this year. This is to be accounted for by the fact that at the " present time the disease is in by far the majority of instances of a mild type; indeed, " I saw several patients sitting up, who had well-marked rose spots about them, and " were suffering from diarrhœa at the time of my visit.

"The epidemic prevalence of fever in Winterton is undoubtedly to be ascribed to the " disgraceful state of the privies, cesspools, ashpits, and wells. With the exception of " about six houses, where waterclosets have been constructed, all the cottages are " provided with privies, which are generally built of brick, and have an aperture at the " side or back, through which they can be cleaned out. This aperture I found open in " almost all instances, and the result of this is that the contents of at least half the " privies in the town run out into the gardens, soak into the earth, and penetrate in many " instances into the wells, besides producing the most offensive odour. In addition to " this many of the tenants either throw their refuse and slops, including urine, into the " yards outside their doors, or else they improvise a receptacle by digging in the ground " close to the aperture in the privy wall. The fæcal matter pours into it, and they then " add to their previous list of nuisances that of an open cesspool. In some instances ash- " pits have been built, but these are uncovered, and since urine and the bowel discharges " of typhoid patients are thrown into them, in addition to other refuse, they are but little " better than open privies. All these sources of fæcal fermentation are situated as a rule " close to the houses, and in some instances within a few feet of the back doors, and just " under the windows. The wells are also in their immediate neighbourhood, and many " of the inhabitants informed me that their water was so bad that they had been com- " pelled to discontinue drinking it. In one instance I found the space between two " pigstyes entirely occupied by a well three feet in diameter. Fever is present in the " house to which this well is attached, but since the occupants do not use it, the " necessarily contaminated condition of the water cannot be considered to bear upon " the disease. Given, the existence of typhoid fever in a town, it is hardly possible to " conceive of conditions more favourable for its spread than those existing in Winterton.

"The record of a few cases differing in no essential points from all those I visited, will " exhibit something of the evidence on which this statement is based.

"A group of four cottages, the property of Mr. Dale of Appleby, stand in the High " Street; their back doors all opening into one common yard 14 feet wide. In front of " the third house, and within 5 feet of the windows, is an open untrapped drain, which " communicates with the main sewer, but owing to this communication being defective " a large quantity of stinking fluid, which partly consists of urine, has accumulated there. " Within 8 feet of this is the pump, from which a waste pipe runs into the drain; but " when the drain does not properly empty itself, that is to say, when it is in the condi- " tion in which I found it, the fluid regurgitates up towards the pump. The well which " supplies all these four cottages with water lies 2 feet to the west of the pump, at the " foot of two steps leading into the gardens behind the cottages; these gardens being " raised above the yard, and sloping towards it. *Close by these steps and overhanging " the well, is an open ashpit, on which the bowel discharges of typhoid patients are " thrown*, in addition to filth and almost every description of decomposing matter, which " it is possible to conceive. A few feet higher up the garden, and within 6 or 7 feet of " the well, are two pigstyes. Immediately behind these, and raised slightly above them, " are three privies and one cesspool; two of the former are filled with night soil nearly " up to the seats, the remaining one is less full because it empties itself into the open " cesspool. The pestilential odour in the neighbourhood of this group of nuisances it " would be almost impossible to describe; suffice it to say, that on pointing them out to " the inspector of nuisances, that official, as on several other occasions, politely begged " to be excused from approaching them any nearer. *In short, we have within a circuit " of about* 14 *feet round this well one open drain, one open ashpit, two pigstyes, three " privies, and one open cesspool, all of which, with the exception of the drain, are raised " to a height varying from* 1 *foot* 6 *to* 3 *feet above it, and situated on a loose porous soil*

"As a result of this I found that in cottage No. 1, where three persons live, two " have had fever, of whom I saw one, viz., Joseph Hewson, a labourer, who was " evidently recovering from some acute febrile affection. No. 2 was empty, but I " ascertained that up to eight weeks ago, four persons resided there. The neighbours " told me that 'they were always ill,' and Mr. Bennett stated that one of them had died " of fever. No. 3. Here seven persons live, all of whom have had fever. In this house I

" found in a small room 12 feet × 8 feet and 7 feet high, Henry Driffell, bricklayer, " ætat 32, lying in a semi-comatose condition on a mattrass saturated with urine and " fæcal matter to such an extent that the ammoniacal and fæcal emanations were abso- " lutely pungent, and I was compelled to go to the window, which I found closed, and " open it, in order to breathe some fresh air. Covering the patient were a blanket and " a sheet, also saturated with his discharges. The nurse who had been provided by the " parish was so exhausted by continually watching him day and night, that she was no " longer able to move him, and if she had been she stated that it would be useless, as " she could obtain for him no change of linen. . . . . . In another room lay this " man's wife, who was also attended by the same nurse. In No. 4, four persons live. " I examined them and found them all free from disease. They informed me that " they had never been ill.

PART III. SPECIALITIES. Propagation of typhoid fever in Wicken Bonant.

" *On continuing my inquiry I ascertained that the inmates of cottages Nos.* 1, 2, *and* 3 " *where the epidemic has been so rife, all of them drink the water from the well just* " *described; those living in No.* 4, *and who have always enjoyed good health not liking* " *the taste of it, have drawn their water from a neighbour's well.*

" Nothing could point much more conclusively to the contaminated state of this water " and on examining it I found it to be of a light brown colour and disagreeable taste, " and to yield a considerable deposit after standing for a few hours. Under the micro- " scope it exhibits a large quantity of organic matter, both animal and vegetable, as well " as infusoria and animals of a low type."

12. *In Wicken Bonant, Essex.*—In this small village the inhabitants became, in the autumn of 1869, conspicuously poisoned by drinking water polluted by the discharges from the bowels of a typhoid patient. Dr. Buchanan was deputed by the Medical Department of the Privy Council to investigate this case, and the following particulars are extracted from his report, which is printed in the Twelfth Report of the Medical Officer of the Privy Council, 1869:—

" Wicken Bonant is a parish in the north-west corner of Essex, in the union of Saffron " Walden. Most of the houses lie along an east and west street, which slopes down- " wards to the east, and has higher ground on either side of it. The nature of the ground " will be considered along with the water supply. Through the village, from west to " east, runs a brook channel, now (Nov. 22) dry in most of its course along the street, " but in wet seasons running with water.

" The population of the parish in 1861 was 173, but now 206 inhabitants may be " enumerated. There are 40 houses in the parish, 38 of which are occupied. . . . The " houses are mostly cottages of three or four rooms. A few of them are overcrowded by " large families, and some smell close and unwholesome through dirtiness and want of " ventilation. Each house is provided with its privy of the usual village type, but now " found somewhat less offensive than such places generally. This is partly due to " many of them having been recently cleaned out, but also to the porousness of the soil " in which the privy pit, without any lining, is dug. There is no rule about emptying " these pits, but the manure is taken from them when the cottagers want it. As the " liquid part of their contents soaks away, these pits do not rapidly fill, and one was seen " that was said not to have been emptied for 11 years. Two houses only have water- " closets and sewers, the Rectory and the 'Brick House,' the sewers discharging into the " brook. From the Rectory sewer nothing is seen to issue, solid matters being inter- " cepted in a brick chamber, and liquid matters appearing to be absorbed into the ground. " From the Brick House sewer, liquid is seen to come, and the brook channel, below the " outlet of the sewer, is a long pool of blackish sewage, of which more will presently " have to be said.

" The water supply of the village is partly from the 'parish well,' used by the inhabi- " tants of 19 houses; partly from private wells which supply the other 21 houses. The " wells are sunk through a varying amount of gravel into the chalk, and are mostly " bricked or cemented in their upper parts. The level of the water below the surface " ranges (chiefly, it appears, according to the level of the surface where the well is " situated) from 20 to 35 feet; but of course this level would vary materially according " to the wetness or dryness of the season. Water is drawn from the parish well, and " from most of the others, by bucket and chain. The parish well, situated by the road- " side, is four or five paces from the brook channel, and it has been observed that after " heavy rains, and when the brook is flowing, the water of this well is discoloured. The " brook channel hereabouts is now empty, and looks clean. The Rectory sewer enters the " brook below the point nearest to the well, but the Brick House sewer enters it about " 250 yards above this point. A few weeks before the present inquiry, a new well had " been dug, at the cost of the gentleman who owns the greater part of the village, at the

PART III. SPECIALITIES.

Propagation of typhoid fever in Wicken Bonant.

" west or higher end of the village street, at a place where there is a very thin covering " to the chalk. The water of this well stands at something more than 30 feet from the " surface, and is as yet distinctly milky from chalk.

" The soil of the village, and its relation to the water supply, have been specially " investigated for the purposes of this report by Mr. W. H. Penning, of the Geological " Survey, whose statement is as follows :—

" The village is situated in a valley that is cut through the boulder clay and scooped " out of the gravel beneath. At the very lowest point, viz., the channel of the brook, " the gravel has been entirely removed, and the rain-wash rests directly on the chalk.

" This gravel is about 20 feet thick; it is coarse at the top, finer and more sandy " towards the bottom. It contains patches of sand, and has a very irregular base of " sandy clay, plastic and impervious.

" At the upper or west end of the village, water is constantly running, in a strong " stream, along the brook, but after receiving the sewage from a drain it disappears " near where the road and the brook cross. The channel through the village is thus " left dry for the greater part of the year, the water being absorbed by the lower or " sandy portion of the gravel at the spot indicated. It appears to be carried along, " beneath the surface, by the gravel to its eastern extremity at the lower end of the " village, where water is again found in the brook. The base of sandy clay, although " irregular, is probably persistent, and prevents the downward percolation of the water. " The dryness of the channel through the length of the village, and the reappearance of " water at the lower end, show that the water having once entered the gravel is kept " therein for that distance, either by slight difference of level, or by the coating of " rain-wash from the clay-covered hills.

" The parish well is sunk through (and evidently derives its water from) this sandy " portion of the gravel, thus intercepting in its course water into which, within a distance " of 250 yards, sewage matter has been discharged.

" There is evidently direct communication, by fissure in the chalk, or otherwise, " between the now dry channel and the parish well, as in times of flood, when the " channel is full, the water in the well rises to a corresponding height, and becomes " cloudy in appearance.

" It will be seen presently that the dates when water flowed in the brook, about the " middle of the year, are of importance to the inquiry. No record of the facts has been " kept at Wicken, and the only inference that can be drawn respecting the probable time " and duration of the flow from considerations of rainfall and of the physical features of " the place, is, that for some weeks after the great falls of rain in May, the brook would " in spite of the dry weather of early June be visibly running; and it happens that the " date of June 14th can be fixed upon as one day when there was water in the brook, " for it then interfered with the work of some labourers in its channel. The water was " then no doubt falling in the soil.

" After that time there was water here and there in the brook. But the parts of the " brook now dry have not latterly run with water, and the brook is now, as before " mentioned, dry in almost all its course through the village.

" The fever which has prevailed in Wicken Bonant has been typhoid.

" There had been none of this fever in the village for a long time before the present " epidemic, which began among the villagers in July, two occurrences of it, which will " have to be presently considered in more detail, having anticipated the general out- " break. The epidemic has continued up to the time of visit, has affected in all 45 " persons, and has caused four deaths. The earlier cases appear to have been somewhat " more serious than the later ones.*

" Of the 45 cases, five have occurred among the 118 people who get their water from " private wells. Two of these five, however, had been lodging in houses supplied by " the public well, and two others of the five are, at the time of visit, of new occurrence, " and their nature is still somewhat uncertain.* Thus only one positive case occurred in " four months among the 118 persons who drank water from private wells. The re- " maining 40 (or adding two of the above patients, 42) cases occurred among 88 persons " who had no source of water-supply except the parish well, some of them, however, " occasionally taking water, when it could be had, from the brook. There were thus, " among persons getting water from private wells, less than 3 per cent. attacked by " fever; among persons getting water from the parish well, over 46 per cent. attacked. " No other general difference, except the source of water-supply, can be observed " between the families which suffered and those which did not suffer from the fever.

* " P.S.—Dec. 31. Between Nov. 22 and the end of the year, 19 fresh cases of fever and two deaths have occurred."

PART III. SPECIALITIES.

Propagation of typhoid fever in Wicken Bonant.

"The earliest cases of fever among the villagers were in a dirty cottage standing near "to the brook channel, at a spot some 35 yards above the parish well. In this cottage "a family named Clark, consisting of eight people, live, and seven of them have been "attacked. The first case (but the second of the two earliest occurrences above "reserved) began on June 24th in one of the Clark boys. His mother was the next "person who got the disease in the village, and she fell ill on July 25th, from which "time cases have occurred at weekly or shorter intervals.

"*The privy of Clark's house stands almost on the edge of the water channel at a "point* 35 *yards above the parish well. The boy had plentiful diarrhœa, and his stools "were thrown without previous disinfection into this privy.*

"Ten days before the boy's attack there was water along the brook course, and "during his illness there must have been plenty of water in the gravel, if not (at the "part of the brook near Clark's cottage) above ground.

"At the beginning of July, while Clark's stools were constantly being thrown into the "privy, the soil water was falling, and stagnant pools of water were to be seen here "and there in the brook. *As there is communication between the brook and the parish "well some of the little water remaining in the former, and mixed with typhoid stool, "must have gone into the well and have been drawn upon by those who derived their "supply therefrom.*

"A month after Clark's attack the drinkers of this well water began to be numerously "affected with fever, commencing with other residents in the same house with him, "while the drinkers of water from other wells all (with one apparent exception) escape "fever for four months, up to the time of inquiry, when there begins to appear some "indication of extension by other means. There can be no doubt that the epidemic "prevalence of the disease was caused by Clark's stools getting, with their specific "poison unchanged, into the parish well."

Some interesting cases of the propagation of typhoid fever by water have been investigated in Germany and Switzerland. (*See* Appendix No. 4, p. 463.) One of these cases deserves very serious consideration, because it goes far to demonstrate the insufficiency of filtration for the separation of the typhoid poison from water.

These records of the poisoning of communities and families by the discharges from the stomachs and bowels of cholera and typhoid patients are obviously less strictly conclusive than corresponding instances in which men have succumbed after swallowing arsenic or strychnine, because in the former case the specific poison has not been chemically or microscopically recognised, whilst in the latter, the noxious agent can be traced throughout its entire course, and everywhere chemically identified. Nevertheless, after a careful consideration of all the facts accessible to us, we are of opinion that the existence of specific poisons capable of producing cholera and typhoid fever is attested by evidence so abundant and strong as to be practically irresistible. The poison of each of these diseases is contained in the discharges from the intestinal canal, and in typhoid fever it appears to be present in a yellow matter which is secreted from an ulcerous eruption in the bowels of the patient. Both this and the cholera poison may be disseminated, firstly by water, either as suspended matter in such an excessively fine state of division as to pass easily through ordinary sand or domestic filters; and, secondly, by air, either in the form of dust or as the fine spray of liquids containing the poisonous matter. Through either of these two necessaries of life the zymotic germs of both diseases may thus be conveyed into the stomachs of large communities; but their effect will be determined, firstly, by the power of the individuals to resist the poison, and, secondly, by the degree of dilution of that poison. It is further exceedingly probable that a very attenuated poison will suffice to infect persons who are very susceptible of the disease, whilst on the other hand, even a very concentrated poison may fail to tell upon a person endowed with extraordinary powers of resistance; such a power, for instance, as is conferred, in the case of typhoid fever, by a previous attack of the disease. The history of a large number of outbreaks of both diseases shows that, where the poison was concentrated, the disease manifested itself suddenly, that is to say, with short incubation, and in these cases a large per-centage of individuals exposed to it were attacked.

Besides the local charging of the atmosphere in houses, courtyards, or streets with the specific poisons of these diseases, it is more than probable that during the prevalence of intense epidemics, the general mass of air extending over large areas becomes sufficiently impregnated with the poisonous particles, in the form of dust, to infect very susceptible people, who then, under favourable conditions for the propagation of the diseases, form new foci of attack.

PART III. SPECIALITIES.

Influence of hard water on health.

Throughout these investigations, in which we have now been engaged for upwards of six years, we have again and again been strongly impressed with the vital importance of the principle of dilution in arresting the ravages of epidemic disease. Diffuse the zymotic poisons through vast volumes of air or water, and their power to injure has either disappeared or dwindled to insignificance. Thorough ventilation of houses and of sewers, and large dilution of sewage, together with water supply not only immaculate but abundant—these are the principal conditions which everywhere root out epidemic disease. Indeed, if this were not so, the diffusion of zymotic poisons through the air could not fail to affect the whole human race, breathing as it does a common atmosphere, which is continually being transferred from kingdom to kingdom and from continent to continent.

We have restricted the above remarks to two zymotic diseases, but evidence is not wanting to show that other scourges, such as dysentery and diarrhœa, are probably propagated by water which has received the excrements of patients suffering from those diseases. It is humiliating to reflect on the vast amount of premature death and misery which is thus carelessly permitted to exist in the midst of a civilised community. In England and Wales alone the average yearly number of deaths from zymotic poisons is 120,000, representing a total number of cases of more or less intense suffering which is certainly not over-estimated at 1,200,000. But even this enormous number only includes the persons actually poisoned, it takes no cognisance of the misery of families reduced to pauperism or worse, by the death or long illness of those upon whom they are dependent for support. We have heard excuses for the continuation of this frightful mortality on the ground that these diseases attack and carry off the weakly and unhealthy portion of the population, and thus improve the general strength and vigour of the race. We have been unable to find any confirmation of this theory, so far, at least, as the two diseases of which we are especially writing are concerned. There appears to be no connexion whatever between weakness of constitution and susceptibility to cholera and typhoid fever, the robust and the delicate—the prince and the peasant—are alike the victims of these poisons; and there is not as yet any satisfactory proof even that the per-centage of fatal cases in those attacked is greater amongst the weak than it is amongst the strong. The means for preventing much of this death and torture are now well known, and capable of practical application. Their neglect really signifies the destruction of the people by parasitic organisms which we have the means, but not the will, to exterminate; and it will not much longer be regarded as involving less national disgrace than would attach to the annual loss and mutilation of vast numbers of our population by beasts of prey which we were too apathetic to destroy.

III.—ON THE ALLEGED INFLUENCE OF THE HARDNESS OF WATER UPON HEALTH.

The question of the comparative wholesomeness of soft and hard waters has for many years past received the attention of the highest medical and chemical authorities. The general result appears to be that whilst, on the one hand, opinions have differed considerably as to the wholesomeness of hard water, on the other there has been, and now is, an almost complete unanimity as to the wholesomeness of soft water. In their report on the water supply of the Metropolis by the General Board of Health, presented to Parliament in 1850, the following evidence on this subject is adduced:—Dr. John Sutherland, speaking of the water at that time supplied to Liverpool, and which was of about the same hardness as the water at present supplied to London from the *Thames*, says:

"Having lived for a number of years in Liverpool, a town which has a supply of very hard water for domestic use, my attention has for a length of time been called to the fact that the continued use of this water has a somewhat peculiar effect on the digestive functions in certain susceptible constitutions. There are so many local causes of disease in the town, which may be left behind by going to other more favourable localities, that it is not very easy to state positively how much injury may be done by the quality of the water alone; but after some experience and observation, both in myself and others, I arrived at conclusions which I frequently expressed several years ago, and which nothing has since occurred to alter, and these are, that in the class of constitutions referred to, the hard water tends to produce visceral obstructions; that it diminishes the natural secretions, produces a constipated or irregular state of the bowels, and consequently deranges the health. I have repeatedly known these complaints to vanish on leaving the town, and to re-appear immediately on returning to it, and it was such repeated occurrences which fixed my attention on the hard selenitic water of the new red sandstone as the probable cause, as I believe it to be, of these affections."

The late Dr. Todd Thomson states in his work on the domestic management of the sick-room:

"The best and the most universal drink for the sick is *water*; but the qualities of water differ, according to the source whence it is procured. The fewer foreign ingredients it holds in solution, the greater

Part III, Specialities.

Influence of hard water on health.

are its diluent properties; thence, either distilled water, or rain or river water filtered, are the only kinds proper for the use of the sick-room. Hard water under whatever name it is found, whether as spring water, or pump water, or well water, should be excluded."

The Board of Health state (Report on the Supply of Water to the Metropolis, 1850, page 54) that "Apparatus for the distillation of water having been proposed to be intro- " duced on board the French navy to obviate the possible failure of water stores, the " Minister of Marine appointed several medical commissions to give distilled water " to the men and observe the effects upon them. The trials were made separately " and the results were reported to be uniformly favourable."

Dr. Leech of Glasgow, with reference to the Gorbals Gravitation Waterworks of that city, states:

"My attention has been called to the bearing of the question of pure soft water supply on the public health. The Gorbals water is very soft and pure. The new supply has been introduced about two years, but in consequence of the bad water supply which existed before the new water was introduced, my attention, as well as that of my medical brethren, was directed to the question for a long time previously. The comparative value of the new soft supply over the old hard supply has been matter of discussion at the Glasgow Southern Medical Society, of which I was president two years. It was the unanimous opinion of the medical profession, that great benefits of a sanitary kind had followed on the substitution of the soft water, on the principle of constant supply. It has been observed that since this change, urinary diseases have become less frequent, especially those attended by the deposition of gravel. So far as experience has gone, my own opinion is, that dyspeptic complaints have become diminished in number."

In commenting upon this evidence, the Commissioners express the following opinion: —"On the whole, from much evidence of the same tenor as that we have cited, we " cannot doubt that the presence of lime and other mineral matter deteriorates the " wholesomeness and value of water for the purposes of drinking."

The Commissioners appointed by Your Majesty's Principal Secretary of State, Home Department, 1851, to investigate the quality of the water available for the supply of the metropolis, whilst strongly recommending on other grounds soft water for the supply of towns, admit that "it may be safely stated that no sufficient grounds exist " for believing that the mineral contents of the water supplied to London are injurious " to health. No reasonable doubt, indeed, can be entertained of its salubrity. " . . . . An aërated water is manufactured and safely consumed to some " extent which contains 92 grains of carbonate of lime to the gallon, instead of " 12 or 14 grains, as in Thames water. The portion of lime and magnesian salts in the " water drunk must indeed be greatly exceeded in general, by the quantity of the same " salts which enters the system in solid food. The only observations, from which an " interference of the lime in water, in deranging the processes of digestion and assimila- " tion in susceptible constitutions, has been conjecturally inferred, have been made upon " waters containing much sulphate of lime and magnesia, as the Brighton shallow well- " water, or the hard selenitic water of the New Red Sandstone, and have no force as " applied to the Thames and its kindred waters, as the earths exist in these principally " in the form of carbonate."

The Royal Commission on Water Supply (1869) took a good deal of evidence upon this subject from engineers and others, as well as from medical men and chemists. We confine our extracts to the evidence of the last two classes of witnesses. Professor John Thomas Way said:

"1458. (*The Duke of Richmond, Chairman.*) Do you consider that water, which is, as you say, 2 or 3 degrees, much more healthy or more economical?—It is more economical. It is exceedingly doubtful whether it is more healthy, because people are in the habit of drinking waters of 17 or 18 degrees of hardness, without any apparent injury to health; indeed, they are the most beautiful waters as drinking waters. The waters that are the brightest and the most liked are the hard waters, the chalk waters.

"1459. Have you analysed any of the waters in the northern part of Scotland?—No, not to my knowledge; not of late years at all events. I think that the question of the effect of hard waters upon health is quite an open one. There is no reason to believe that chalk water is injurious, except, I believe, in some instances, such as in the introduction of goitre. There are cases I believe in the valley of the Thames in which hard water is said to produce that effect; but the advantage of soft water for domestic use is very obvious, both in comfort, and also in economy, and for cooking purposes. . .

"1460. If you had your choice to provide a large community with water, and you were able to get with equal ease hard water or soft, you would prefer the soft water?—Undoubtedly. I should go further than that, and say that water that is hard ought to be softened if it is possible to soften it.

"1461. (*Mr. Prestwich.*) Do you mean for general purposes, excepting the question of health?—No, I do not attach anything one way or the other to the question of health, that is to say, where the hardness is in moderation, where carbonate of lime is the hardening ingredient; but where you have water with 80 or 90 grains of sulphate of lime in a gallon, as you sometimes have, that is another question entirely."

Dr. Henry Letheby, then Medical Officer of Health to the Corporation of the City of London, says:

"There is a table to which I would wish to direct the attention of the Commission. I have classified in this table the composition of the water supplied to most of the towns in England, giving an account

PART III. SPECIALITIES.

Influence of hard water on health.

of the appearance of the water when it is examined in a long glass tube; next the quantity of solid matter contained in a gallon; next, the amount of organic matter; then, the oxygen required to oxidise the organic matter, then the ammonia, then the hardness, and then the population of each of those towns, and lastly, the mortality per 1,000. The object of this is to ascertain whether there is any relation whatever between the mortality of a district and the quality of its water supply, and you will find at the bottom, under the line, that where the water supplied to the towns is over 10 degrees of hardness, which I look upon as on the side of a hardness, the mortality is only 22·2 per 1,000 of the population, whereas in all the towns with soft water, that is with water under 10 degrees of hardness, the mortality is 26 per 1,000, and with the metropolitan water it is 23 per 1,000. I do not pretend to say that the quality of this water has had anything to do with the mortality, but there is this important fact, which comes from the examination of the table, that certainly soft water does not improve the health of the people, and that many of those towns are very comparable. I take Sheffield and Birmingham to be very comparable with regard to the character of the inhabitants, but look at the mortality in the two places. Birmingham has nearly the hardest water that we have in England, and Sheffield has one of the softest waters, nevertheless, the mortality of Birmingham is only 24 in the 1,000, whereas you will find that the mortality of Sheffield is 26·2 per 1,000. I do not mean to say that the water has anything to do with it, but it shows that there is no evidence of soft water so benefitting the health of the people as to reduce the death rate.

"3919. From your large experience, you would scarcely be prepared to say that the mere question of the supply of good or bad water would actually in itself determine the mortality of a place; there are other circumstances, are there not, which must be taken into account?—Yes, certainly.

"3920. For example, take the condition of Glasgow, where they have an unexceptional water, yet where there is a lack of all other sanitary arrangements, drainage of the town, and so on, that might of themselves be a sufficient cause for the increased mortality there?—Yes, and it is one of the largest, —27 per 1,000 is the mortality of Glasgow.

"3921. (*Sir B. Phillips.*) The smallest amount of mortality in this table appears to be at Croydon? —Yes, and it is a hard water that they have at Croydon.

"3922. Was there not a serious outbreak of fever there some time ago?—That was before the water supply. That was at the time when they began the drainage by pipe-drains, and in consequence of the bad ventilation of those drains the gases were all forced into the houses of the people, and a tremendous fever broke out. I have had occasion twice to inquire into the outbreak of fever at Croydon, and I have no doubt it was traceable to that. The pipe drainage system is a system which, unless perfectly carried out and the ventilation is good, is so tight that the gases cannot get out, and they therefore force their way through the valves of the waterclosets and get into the houses, and an outbreak of fever ensues.

"3923. (*Sir John Thwaites, Chairman.*) The best proof of that is, that immediately the alteration took place you found an improvement in the public health?—Yes.

"3924. (*Mr. Harrison.*) In Sheffield is not the average of age less in consequence of the knife-grinding that is carried on there?—That may be so.

"3925. (*Mr. Prestwich.*) This return appears to be made up to 1861, what was your reason for that?—In every instance the waters which they are taking now were taken in each of those towns in the year 1861, but I am not able to say what the population of those towns at the present time is, nor what the death-rate is. I am obliged to take the only reliable information I can get, namely, the mortality returns as well as the population in 1861, for they are the only ones that are accessible, but all those towns had the same water in 1861.

"3931. Apart from the question of organic contamination, about which there can be no doubt, have you any evidence with respect to which is the best water for drinking purposes, soft or hard water?—A moderately hard water is best.

"3932. Have you any evidence bearing upon that?—Yes, I have. I have evidence derived from my own inquiries, and my own experience, and the evidence of the continental commissions which have been appointed to inquire into the best supply for the large cities of the continent. I will take the case of Paris. The commission appointed a few years ago had opportunities of gathering water from granite districts, and from millstone grit districts, I believe, as well as from hard chalk water districts; and upon investigating the facts of the case very carefully, the French commission concluded that the evidence went to show that the men were finer grown, and that less conscripts were refused on the ground of insufficient stature or something of that kind, in the hard water districts than in the soft water districts; and after much consideration of the subject, they recommended the municipality of Paris to take a water which is almost identically the same as the water of London. Very recently I have received from the Government of Vienna the report of a commission appointed to investigate the distribution of water in Vienna, and there again they have abandoned soft water, and have taken to a moderately hard water for two reasons, first, that the evidence goes to show that the men are better formed, that the bones are stronger and better formed, and that there is better health in moderately hard water districts than there is in soft water districts, and, secondly, that the public prejudices against water tainted with peaty matter are so great that a large city should never draw its supply from a soft water district.

"3933. (*Sir John Thwaites, Chairman.*) Lime is not necessary in water to supply bone, is it?—You cannot say that it is not, probably there is no evidence to show that it is, but there is no evidence certainly to the contrary. Our bones must be made of lime. It is true that milk and the common articles of diet contain generally speaking enough lime to form the young tissues in that respect, but you cannot say how much a hard water or the lime of a moderately hard water contributes to it. And if we are to be guided by what may be termed the Providential evidences with respect to it, four-fifths at least of the earth's surface being calcareous districts, that is to say, districts supplying hard water, one would think that if it had been the case that soft water was better than hard, we should have had it more abundantly distributed to us than it is. There are notions abroad that hard waters have a tendency to produce gravel, but I have investigated that subject, and there is not an instance of gravel or any surgical affection of the same kind that I can trace to hard water. My own opinion is,

Influence of hard water on health.

that water of between 10 and 15 degrees of hardness is in every respect the most proper water for the supply of a city. In the case of large manufacturing towns, where the water is used to a very large extent in steam-engines, and for bleaching and dyeing purposes for which soft water is required, that would affect my conclusions; but in large cities such as London, Paris, Vienna, or Berlin, I have no doubt in my own mind that water of between 10 and 15 degrees of hardness is the proper water, provided that upon being boiled it would be reduced to about four degrees of hardness. It is five degrees of hardness in any kitchen boiler that you like to take it from in London, and that is sufficiently soft for tea, for washing purposes, and for everything that may be required in ordinary domestic use. And in addition to that the water is agreeable, it is almost always colourless, bright, sparkling, and agreeable to the palate, and as far as I know may contribute something towards the nourishment of the tissues.

"3934. In expressing those opinions your view would be clearly against the notion of going any distance to obtain a supply of water to the metropolis?—I would not only not go to a great distance, but I would say that if soft water were next door to you, if the Thames itself were soft water like that which is proposed to be supplied to London from the lakes, and there were found in the chalk of the neighbourhood a harder water like that which we are now using, I should unquestionably advise the harder water to be taken.

"3935. Even at additional cost?—Yes, even if the soft were close to you, and if the hard water would cost more. I call it hard merely comparatively. I mean waters that would range from about 10 degrees to about 15 or 16. Beyond that it becomes too hard, particularly if it is a selenitic hardness, if it is sulphate of lime in place of carbonate of lime, under such circumstances it becomes objectionable.

"3936. (*Mr. Harrison.*) Taking it that the average of the hardness of the waters of the Thames companies is only 13·3°, that quite comes within your limits?—It does, and I am of opinion from a large experience of the matter, not only from chemically analyzing the water, but from observing the effect of it upon the public health, that there is hardly a city in Europe so well supplied with water, either as regards quantity or quality, as the city of London.

"3937. You would not consider it necessary, according to your view, to apply Dr. Clark's process to this water?—I should not, for I think it would be injurious. If the water were softened by Clark's process, it is not only an expensive process, and as far as I know a very difficult process to carry out on a large scale, for I know of no instance in which more than half a million gallons a day have been softened, but apart from all that the softening process renders the water very liable to attack lead. It did so at Plumstead to such a degree that they were obliged to replace, I believe, the whole of the cisterns, or nearly so, at Plumstead, at the cost of the Local Board. The carbonate of lime that was in the water was thrown down in the pipes by a process of crystallization afterwards, so as to block up the pipes for miles in length. Whenever there is a bend in a pipe it offers a little hindrance to the movement of the water, and the particles as it were strike together, and the carbonate of lime begins to be deposited directly. I have seen pipes become almost entirely shut up with it a long distance from the works.

"3942. (*Sir B. Phillips.*) Supposing that water could be brought from the lakes and delivered to London at the same cost as the water is now supplied from the Lea and from the Thames, do you think it would be desirable to avail ourselves of such a supply?—I have already said that if we had next door to us instead of at the lakes of Cumberland soft water, and we had the water supplied by our rivers flowing from the chalk districts, I would recommend without hesitation the use of the hard water in preference to the soft water. I have had occasion to examine and analyse very carefully the waters that are flowing from Loch Katrine into Glasgow, and I know the quantity of carbonate of lime that is taken up by those waters in their flow along the channel from the Loch to the city of Glasgow. It amounts to about 500 tons of carbonate of lime are taken up from that channel every year; what will be the end of it in the course of years I do not know. All that carbonate of lime comes, I daresay, from the mortar that joins the stones together, and one would think that it would bring the whole thing to pieces at last."

The last statement of this witness must refer to a period soon after the opening of the aqueduct. There has been no such action going on during the past six years. We have analysed the water as it leaves Loch Katrine and as it is delivered in Glasgow, and the degree of hardness, or rather of softness, is identical at both places. Professor Gustav Bischof's monthly analyses, given at page 347, show that the hardness of the water as delivered in Glasgow rarely exceeds 1° and is sometimes only 0°·1. Taking the daily supply of Glasgow at 26,000,000 gallons there would, at the last-named degree of hardness, be only 42 tons of carbonate of lime thus annually carried into Glasgow.

Mr. John Simon, F.R.S., Medical Officer to the Privy Council, gave evidence as follows (Minutes of Evidence, page 168):

"2777. (*Sir J. Thwaites.*) Has your attention been directed to the quality of the water in London for drinking purposes, as to the effect upon the health of the inhabitants, as compared with water of a softer and purer character?—I have no evidence upon that subject. I think that, practically, the only very important sanitary question as regards the quality of the water supply to London is the question of organic admixture. I do not think that the question of a few grains of lime in a gallon of water can be regarded as a very important sanitary question.

"2778. Then, in your judgment, the presence of lime, or two or three degrees of hardness in the water, would not be a matter of much consideration, supposing the water were free from organic impurities?—Quite so, as regards the public health.

"2779. For drinking purposes, probably a little hardness in the water would add to its life and pleasantness to the taste?—I would not quite say that. I have found soft waters, or, at all events, hard water artificially softened, very agreeable.

"2790. Speaking generally, if you had the choice of soft water compared with water of seven or eight degrees of hardness, you would elect the soft water for general manufacturing and drinking

PART III. SPECIALITIES.

Influence of hard water on health.

purposes?—As regards many manufacturing uses, I believe it to be commonly conceded that soft water has very great advantages. As regards drinking purposes, I am not sure of any important difference, but am inclined to prefer the soft water.

"2791. (*Mr. Prestwich.*) Do you know of any experiments which have been made with regard to the use of soft water and hard water upon health?—If by hard water is meant such water as we have in London, I am not aware of any facts of the smallest value showing difference of effect between such water and soft water.

"2792. It has been stated that there are certain classes of diseases more prevalent in districts where hard water is used than in others, for example, diseases of the bladder and the stone; can you give us any evidence on that point?—I do not think there is any evidence that is worth a rush upon that subject.

"2794. (*The Duke of Richmond, Chairman.*) Is it true that diseases of the bladder prevail very much in Norfolk?—It has been said so, and of course there have been many explanations, among which Norfolk dumplings hold a chief place; but when that assertion became current, Norwich had a famous lithotomist. It is possible that his reputation, by attracting sufferers into temporary residence in the district, or perhaps his zeal in discovering cases of stone, may have given the district a fictitiously lithogenous character.

"2835. (*Mr. Harrison.*) Having at your door a soft water or hard water, you would give a decided preference to soft water, taking all questions of economy and health into account?—An overwhelming preference with regard to economy, about that there can be no doubt. And as regards health, my bias is in favour of soft water; but I cannot say that I think the case established against hard water (*i.e.* against hard water of such comparatively few degrees of chalk hardness or carbonate of lime hardness as you have in the London water) that it acts injuriously on health. It is different, of course, when you come to certain other hardnesses of water; but I do not think that the hardness, for instance, of the New River Company's water can be considered detrimental to health."

The Right Hon. Lyon Playfair, C.B., M.P., F.R.S., late Professor of Chemistry in the University of Edinburgh, speaking of *Thames* water, said (Minutes of Evidence, page 156):

"It is not so hard a water as is supplied to many places, but it is decidedly hard water.

"2645. (*The Duke of Richmond, Chairman.*) Could you mention the degrees of hardness?—I can only do so from memory. It averaged from 13 to 14 degrees on Clark's scale.

"2646. What is your opinion first of all, as to the effect upon the general health of the population, and, in the second place commercially, in the use of hard water, compared with soft water?—As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health, but it is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. . . .

"2647. I gather from your statement, also, that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes, it is a curious thing that one never washes one's hands *in* a basin with hard water; where the water is hard you take a small quantity of it in the hand itself, and rub the soap until it forms a lather in the small quantity of water that is in the hand, and you merely use the water in the basin to rinse off that which you have employed in cleaning the hands; but with soft water you use the whole mass of water for detergence, and therefore it is much more effective.

"2648. And it is thereby more conducive to health?—Yes, a more thorough cleansing takes place.

"2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

"2658. (*Mr. Harrison.*) Looking at the sanitary question again as regards general health, you appear to divide that question into the water which is used for drinking and that which is used for personal washing?—Yes. I should have explained that in extreme cases I would consider a hard water injurious to health, but in ordinary cases, such as the Thames water, I do not think it injurious to health, if there are no other impurities in the water than the mere differences in the amount of carbonate of lime.

"2659. Suppposing that you had a choice between a hard water, such as is now supplied from the basin of the *Thames*, supposing it to be free from the impurities of sewage and otherwise, and a pure soft water, which should you give the preference, with regard to the question of drinking or its use for culinary purposes?—Undoubtedly to the soft water. In all cases I strongly recommend towns not to accept hard water. Within the last three or fous weeks I have been consulted with regard to supporting a bill in Parliament for a water supply to a town, and I refused to support it because it had a water with 20 degrees of hardness.

"2660. You do not consider that hardness is positively injurious to health, do you?—In some cases hard water might prove injurious, as in calculous affections and in dyspepsia; still, generally a tolerably hard water may be taken without much inconvenience; but water of 20 degrees of hardness is very hard water, and I should much prefer even for purposes of health that it should be softer.

"2661. Taking the water which comes from the springs in the chalk, do you consider that water generally to be prejudicial to health?—No, not prejudicial to health, except in the circumstances which I have mentioned.

"2662. Taking the other side of the question, as to the advantages from cleanliness, both with regard to personal cleanliness and washing from the use of soft water, that you look upon as a matter of considerable importance?—Of very great importance.

"2663. And you think that it is decidedly conducive to the health of a town, especially amongst the lower orders of the people?—I think it is of very great importance indeed.

"2672. (*Mr. Prestwich.*) Are you aware of any disadvantages arising to health from the use of soft water?—The only question involved is, that where it is distributed upon the intermittent system of supply, and the pipes are alternately full and empty, soft water may act upon the lead of the pipes, but if the pipes are always full, and the supply is not on the intermittent system, there is very little risk, or I may say, almost no risk from that cause.

PART III. SPECIALITIES. — Influence of hard water on health.

"2673. In any of the towns that are supplied with soft water, such as Glasgow, or the towns in the Midland counties supplied with water off the millstone grit, have any instances of the deleterious effects of lead come before you?—I have never seen any instances where the softness of the water produced the evil if the distribution were rightly made. I have seen individual instances of lead poisoning equally with hard water where there has been an intermittent system of supply, but the theoretical danger at all events is more common with soft water.

"2674. With the constant system of supply, you consider that there would be no more risk in the use of soft than of hard water?—Precisely so.

"2691. Are you aware of any experiments which have been made with regard to the advantages of the use of either hard water or soft water for drinking purposes?—I can only rely upon the experiences of large towns where they have been supplied with hard water, and the supply has been suddenly changed to soft water; of course I do not know of the reverse instances where soft water has been suddenly changed to hard, but in the former cases I never saw any deterioration of health.

"2692. Do the returns of the mortality of the towns now supplied with soft water show any improvement in consequence of the use of soft water?—I might mention such towns as Liverpool, for instance, where there has been a very large improvement in the health; but the introduction of soft water was only one of many hygienic improvements which took place at the same time, therefore, the proportion which should be attributed to that is difficult to distinguish from the others.

"2693. That, probably, would be the case in almost all instances where a new water supply has been introduced?—It is; for a new and enlarged supply of water generally arises when a population has become awakened to the necessity of hygienic improvements generally.

"2696. You are aware probably that in a decision recently arrived at with regard to the supply of water to Paris, preference was given to waters of a moderate degree of hardness over those of the *Mowan* and the *Loire*?—Yes.

"2697. Are you aware of any cause for that preference?—I do not attach nearly so much importance to any hygienic decisions in France as I would to our larger experience in this country, for I think that we are far in advance in our knowledge of the hygeine of cities than they are in France; and I do not think that the experience in this country justifies the selection of water of any amount of hardness if you can get soft water. The only fear of danger is as to the use of lead pipes, but the experience of Glasgow, where it was very much apprehended at one time, has shown that there is no practical danger where the pipes are always filled. There has not been a single case where it has been found, as far as I have heard, that any danger has arisen from the soft Loch Katrine water flowing through the pipes.

"2711. (*Sir J. Thwaites.*) You state, do you not, that water of 20 degrees of hardness would be injurious to health?—I have no direct experience that it is injurious to health, but I should not employ it habitually in my family; I do not think it is a suitable water with which to supply a town.

"2712. Can you fix upon a degree of hardness which in your judgment would be safe?—If I were selecting for a town, and could get it, I would prefer a water of not above three or four degrees of hardness, and I would dislike waters that are higher.

"2713. Take the *Thames* water for example, when you get a mean of 13 or 14 degrees of hardness out of 40 tests are you of opinion that that water would be injurious to health?—I would not say that it would be injurious to health, I think it would not; but I believe it is a misfortune that a large metropolis like this is supplied with a water so hard.

"2714. You think that it would be worth a considerable sacrifice to obtain water of a less degree of hardness?—I think it would, and it would cover a great outlay to obtain water of a less degree of hardness. I think it is a pity that London cannot be supplied with soft water on account of its greater effect in detergence, and for industrial purposes.

"2715. Do you mean on the score of heath?—On the score of health, the more hardness I do not think would be injurious, at least, I have no evidence to show that it is injurious. I am not a medical man, and would therefore speak with diffidence on this part of the inquiry.

"2716. (*Mr. Prestwich.*) Do not some medical men consider that the presence of carbonate of lime in drinking water is rather desirable than otherwise for health?—I have seen evidence given in cases of water supply, not only that it was desirable for health, but that it was absolutely necessary for the formation of the bones. But that showed a lamentable want of chemical knowledge, because the lime required in food does not come from the water but from the solid articles of food taken, and I do not think that the lime in water has any influence on the processes of healthy nutrition.

"2717. (*The Duke of Richmond, Chairman.*) What is the quality of the water in the Cumberland and Westmorland district, and in the Highlands of Scotland?—It is generally soft where it comes from mountainous districts.

"2718. Is there much lime in it?—No, very little generally, but I am not very familiar with the Cumberland district.

"2719. The population are generally fine grown people, are they not?—Yes, our Highlanders are not generally supposed to be deficient in bone or muscle."

Dr. Edmund A. Parkes, F.R.S., Professor of Military Hygiene in the Army Medical School at Netley, gave the following evidence. (Minutes of Evidence, page 195):

"3124. (*Sir J. Thwaites, Chairman.*) Have you had any means of forming a judgment as to the value of hard water as compared with soft water for drinking purposes?—With regard to the effect upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime and sulphate of magnesia waters, the carbonate of lime waters appear in some cases cer-

PART III. SPECIALITIES.

Influence of hard water on health.

tainly, to produce some effect upon health; for instance, dyspepsia, and they do not agree with some class of persons, whereas to others they appear to be quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease, calculus or anything of that kind, but at the same time persons do sometimes suffer from indigestion.

"3125. What degree of hardness would, in your judgment, be a safe water, taking an average constitution; some people will live in spite of difficulties; their resistive force being such that nothing seems to affect them, but my question has reference to an average constitution?—I do not think with regard to pure chalk water that there is any evidence that a moderate amount of carbonate of lime in the water does any harm, certainly not on the large scale; in some individuals it produces indigestion.

"3126. Would 16 or 20 degrees of hardness be prejudicial?—I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons, but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned; but I should draw a marked distinction between that and the hardness arising from sulphate of lime or sulphate of magnesia or chloride of calcium, which would certainly disagree in much smaller quantities; so that the goodness of water for drinking purposes, I would estimate according to its permanent hardness rather than according to its temporary hardness.

"3127. Are you acquainted with the waters that are supplied to the metropolis by the several water companies?—Yes, I know them very well.

"3128. Take the Southwark and Vauxhall Company for example, the total hardness of their water is 17·7?—Yes, but I do not know how much of that is permanent. The table of Dr. Frankland does not enable me to see how much is permanent. The total hardness merely is put down, and the other ingredients that are stated do not allow me to tell how much of that is permanent, but I suppose that it would be four or five degrees.

"3129. (*Col. Harness.*) How do you distinguish between permanent and temporary hardness?—Simply by boiling; permanent hardness is that which remains after boiling. Supposing we have a water containing carbonate of lime, sulphate of lime, and magnesian salts, the hardness after boiling will consist of a certain portion of carbonate of lime, two grains per gallon held in solution, and the remainder of the hardness arises from the sulphate of lime, the sulphate of magnesia, and the chloride of calcium. That we call permanent hardness, which we cannot break down by boiling, and that water is certainly worse than the carbonate of lime waters, which lose a great part of their hardness by boiling. Consequently, many persons living on carbonate of lime waters, for instance, at Chatham and such places, take comparatively but little carbonate of lime, because they take the water in tea, and lose a great deal of the carbonate of lime; even after standing the water loses a great deal of the carbonate of lime, so that in tea they would take it tolerably free from carbonate of lime; that would be different from water of permanent hardness.

"3134. (*Sir J. Thwaites, Chairman.*) But supposing the water was equal in purity and free from organic matter, does the question of simple hardness or softness enter into the consideration of those whose special duty it is to care for the troops with regard to the kind of water that they should use?—In all cases we would prefer a soft water if it were possible to obtain it; and if the water were permanently hard, to a large extent that water would be reported upon unfavourably, and better water as regards that property would be procured if it were possible.

"3135. Do they resort to any means of softening the water where they are unable to obtain soft water?—In one instance it is done, at the Herbert Hospital at Woolwich, where they employ Clark's process to soften the water. In that case it is carbonate of lime water, and it is softened to some extent before it is distributed in the hospital. I believe that that is the only instance in the army.

"3136. (*Col. Harness.*) Did they do anything with the Chatham water?—No, the Chatham water is very pure chalk water containing scarcely a trace of sulphate of lime, but a large quantity of carbonate of lime, 16 or 17 grains.

"3137. (*Sir J. Thwaites, Chairman.*) Speaking generally, you are of opinion that the mere presence of carbonate of lime of 15 degrees of hardness would not be injurious to health?—With 15 or 16 degrees of carbonate of lime hardness I should say that it would be hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees if possible. At the same time I should wish to state that one would prefer water free from even that, if it were possible to get it.

"3138. For all other sanitary purposes I presume there can be no question that soft water would be preferable?—No question at all.

"3201. (*Mr. Prestwich.*) The greater part of the troops, I presume, in this country are located in districts where the water is of a moderate degree of hardness; for instance, Dover, Portsmouth, Southampton, Plymouth, and the greater part of Ireland?—Yes, and at Chatham. At Southampton we have no troops, and at Aldershot the troops are upon soft water. At Chichester the water is hard, and at Colchester it is hard. For the most part they are chalk waters.

"3202. Have you known instances of any ill effects from the use of such waters?—Not of the good chalk waters.

"3203. Have you known any instances where troops have been located in districts where they have been using water of a moderate degree of hardness, and have suffered when they have been removed to a district where the water was soft?—I have never seen any reports of that kind.

"3204. Are there troops located at Aberdeen?—There is only a small number at Aberdeen, except when the Queen is in the Highlands.

"3205. You have no means of knowing the effects of the use of such waters?—No.

"3207. (*Mr. Prestwich.*) You have mentioned the case of Woolwich, where they use Clark's process for softening water, does not that arise from the circumstance that the waters there are unusually hard, and are derived from wells, the water of which is of a greater degree of hardness than is furnished by the waters in the chalk districts?—Yes, it is hard water, and the water having to be supplied to the hospital, and it being considered to be of importance to have pure water for the patients, I believe that

Influence of hard water on health.

that was the chief consideration which led to the use of that process, but the water is very hard which is derived from the wells there.

"3212. Are you aware whether a certain quantity of carbonate of lime may not in many cases be rather beneficial than otherwise to health?—I think that is again very doubtful. The fact is, that almost all kinds of food contain enough lime for the supply of the body, and the quantity of carbonate of lime supplied in water might no doubt be applied to the wants of the system, but I can hardly think that it would be necessary, that is to say, I do not think it should be an argument for the supply of chalk water that lime is thereby supplied.

"3213. Some of the authorities both in this country and in France have been of opinion, have they not, that the presence of lime was rather beneficial than otherwise?—Yes, several have been of that opinion, but some of the chief arguments have been derived from the feeding of pigs, for example, by a French chemist, and it has been shown that his calculations have hardly borne that idea out. He supposed that the lime supplied in the water was really applied in the nutrition of the pig, but it was shown that enough lime was passing in the food to give all the lime that was really wanted.

"3214. Provided it was not kept upon some particular food in which a certain quantity of lime was present?—Quite so.

"3215. But apart from the use of lime for the formation of bone, I presume that the presence of lime as a slight alkali is combined with the carbonic acid in the water. Do you attach any importance to that?—I should not attach any importance one way or the other perhaps to it. There are certain persons who are not able to take carbonate of lime water from its producing in them constipation and dyspepsia, but they are a small minority.

"3216. And that would hardly arise in the case of a population which has been accustomed to the use of such water?—I should think not.

"3217. I see that one disorder which you mention is calculi; have you been able to trace that back to the use of water?—In Germany especially there is a very strong opinion in certain parts that the phosphate of lime calculi and calculi generally are more common in districts where the inhabitants use very hard waters, but in this country the evidence is so far negative; but we have not many districts supplied with limestone waters or the magnesian limestone waters, most of our lime waters are chalk waters, and so far, I think in this country there is no evidence of there being a greater amount of calculi than in other districts not supplied with this water, but in Germany, and perhaps in France, the evidence is stronger that the use of some of the lime waters may have an influence in the production of some of the calculi.

"3218. Would that be in the case of water of an ordinary degree of hardness, or of an excessive degree of hardness arising from the chalk or from the presence of sulphates?—I believe especially from the large amount of hardness arising in most cases from the mixture of chalk and of sulphates, at least it is so in most of those waters."

Sir Benjamin Brodie, Bart., then Professor of Chemistry at Oxford, gave the following evidence (Minutes of Evidence, page 434):

"7023. (*Mr. Prestwich.*) Have you any reason to suppose that the use of soft or hard water as a drinking water produces any difference of effect upon health?—I cannot say I have reason to think so.

"7024. Have you reason to suppose that the health of a district is independent of that?—I have no reason to think it to be dependent upon it.

"7025. Is there not a want of direct experiment upon that subject?—Oxford is a place where the spring water is extremely hard, and injuriously hard for every purpose, but I never heard that it had been made out that Oxford was liable to any particular class of complaint from that reason. If it were so, I think it would have been discovered, but perhaps some physician from the infirmary might tell you to the contrary."

Professor William Odling, M.A., M.B., F.R.S., then Professor of Chemistry at St. Bartholomew's Hospital, gave the following evidence (Minutes of Evidence, page 354):

"6439. (*Sir J. Thwaites.*) On the score of health, do you make any distinction between soft and hard water?—I do not think there are any facts which enable one to give a positive opinion. Some gentlemen who have considered the subject entertain very strong opinions both ways; but I do not know any facts upon which one can speak positively.

"6478. (*Mr. Prestwich.*) What is your opinion with regard to the presence of carbonate of lime?—For mere drinking purposes I do not consider it a matter of any disadvantage at all."

The late Professor William Allen Miller, M.D., F.R.S., Professor of Chemistry in King's College, gave evidence as follows (Minutes of Evidence, page 436):

"7054. (*Sir J. Thwaites, Chairman.*) Then as to the effect of soft water as compared with hard water on the health, apart from cleansing purposes, would the use of soft water promote the health of the inhabitants to a greater degree than the use of hard water?—Any precise observations are difficult to obtain, but I think, so far as observation goes, it is a matter of indifference whether it is hard or soft water.

"7055. When you use the term 'hard,' you mean, of course, an ordinary and not an extreme degree of hardness?—Yes.

"7056. Would 10 degrees of hardness in your judgment be injurious?—Not merely as hardness; it depends upon the quality of the hardness. Chalk waters, I consider, are waters which are perfectly wholesome, but waters which have a similar degree of hardness from sulphate of lime, there appears to be some reason to believe, are found occasionally to disagree with persons. Still there are waters which are supplied to large populations containing sulphate of lime, and very hard sulphate of lime waters. For instance, the population of Wolverhampton and Birmingham are supplied with water of this kind. It is certainly objectionable, but what I was going to say was, that the evidence in that

PART III. SPECIALITIES.

Influence of hard water on health.

case is that there is no sensible injury to health directly traceable to the water as far as observations go. I believe, generally speaking, the impression is, that the hardness caused by sulphates of lime and magnesia is more likely to produce certain slight derangements than the use of chalk waters of a similar degree of hardness.

"7057. You would have no doubt that water of something like 15 to 20 degrees of hardness might be used for domestic purposes?—I should not think there was the slightest reason to suppose that any injury would result from such water.

"7058. Then you attach no value for drinking purposes to soft water over hard?—From long habit I should certainly prefer hard water for drinking purposes to soft water.

"7095. (*Mr. Prestwich.*) Are not a very large proportion of the waters consumed in this country, or in any other country, flowing as they do over calcareous formations principally, hard waters?—Yes, they are.

"7096. And the proportion of soft water used is comparatively small?—The Scotch waters are many of them very soft, and some of the waters in Cumberland are soft. Whitehaven, and several large towns, are supplied with soft water now, but in the south of the island the water supply is generally hard.

"7124. Have you formed any opinion yourself as to the comparative value of a supply of water of a moderate degree of hardness to a town, or of a soft water supply?—I should say that for drinking purposes a hard water is preferable, and it is liable to a less frequent change than a soft water. The principal objection which appears to me to arise, in the case of a soft water, is that it is liable to peaty discoloration, which makes it at times very disagreeable for drinking purposes, and it is also more liable to absorb organic impurities, but as far as economical applications are concerned there is no doubt that there is economy in the use of soft water. I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always, in our chalk districts, a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents. That seems to me to be one of the serious practical inconveniences from hard water which I do not think has been prominently touched upon.

"7125. No inhabitant of London can be unacquainted with that inconvenience?—No doubt they are, and I suppose they feel the inconvenience to some extent. At the same time I should prefer, merely looking at it as an abstract question, water of a moderate degree of hardness for drinking. I must say that for domestic use, soft water is preferable on account of its economy, but for dietetic purposes I think hard water has the preference.

"7126. Do you know of any experiments bearing directly upon that question with regard to the effect upon health?—No, I have no observations upon that point. Having always lived in a hard water district I certainly prefer it for drinking purposes, but I believe persons who live in soft water districts are equally favourable to the use of soft water."

Dr. Robert Angus Smith, F.R.S., Chief Inspector of Alkali Works, gave the following evidence (Minutes of Evidence, page 453):

"7260. (*Mr. Prestwich.*) Have you been able to form any opinion as to the effect upon health of the use of soft water or hard water?—I do not think there is good evidence upon that point. I have heard of horses losing their appearance when they used hard water, and of persons of my own acquaintance who got indigestion by coming into hard water districts; but then I must say that those cases are somewhat balanced by people being rather disagreeably affected on going to soft water districts, and especially some of the hilly districts of the north.

"7261. That depends a good deal, I presume, upon the previous habits of people?—Yes, I do not think that there is a great deal of evidence on either point. I do not think it is fair, in fact, to take the appearance of the population as any criterion, if we did so, we might find some arguments in favour of soft water. I should think that the tallest people in Great Britain are to be met with in soft water districts; for instance, in Cumberland, and probably in Aberdeen. I may say that the tallest people I have seen in Great Britain are in Aberdeen, which is a very soft water district.

"7262. (*Sir B. Phillips.*) Are they the most muscular?—They are powerful people. At the same time, if we take the death-rates from the Registrar General's reports, we find that the smallest number of deaths occur upon the other side of Scotland, in the western district, where also there is soft water; perhaps that shows that the water has nothing to do with the matter."

Dr. William Farr, F.R.S., Superintendent of the Statistical Department of the General Register Office, gave evidence as follows (Minutes of Evidence, page 176):

"2883. (*Sir J. Thwaites.*) Has your attention been directed at all to the question of hard or soft water, and their effect upon the human system?—I have often thought it most important to endeavour to determine the effect of hard and soft water on health, but at present I am not satisfied that we are able to state the precise effect of hard and soft water upon health. I heard a gentleman here mention that stone had been said to be prevalent in chalk countries, and I know that a paper was written on the subject, and published in the transactions of the Royal Society, showing that there were more stone cases and cases of lithotomy in Norfolk than in some other counties: but there was no registration of the cause of death at that time; the means of registration were very imperfect, so that I do not feel that we are at present able to say what is the precise effect which lime and other substances of that sort have upon health. I think the subject ought to be investigated.

"2884. Do you think there really are more cases of stone in Norfolk than in other counties?—I am not satisfied that the fact is established.

"2928. (*Mr. Harrison.*) A change of water, as is well known, has an effect upon people. For instance, on changing from a soft water to a hard water, going into a limestone district where the water comes from the magnesian limestone, many people are made ill for a time?—Yes, and that has an effect on animals also, no doubt. I remember going over John Day's training establishment at a time when he had some hundred horses training. His establishment was situated on the chalk where the water was hard, and when I asked him about the water that the horses drink, he said that he gave them nothing but rain water, that they would not drink the hard water, and he found that a perfectly pure water suited the horses best. I do not know what other trainers do. The character of the water no doubt has a great influence on the strength and health and vigour of man, and I do not think that we have yet determined the precise effect of hard water on the human constitution."

PART III. SPECIALITIES.

Influence of hard water on health.

The following evidence was adduced before us:

Dr. Francis Ogston, Medical Officer of Health of Aberdeen, gave evidence as follows (4th Report of Rivers Pollution Commission (1868), Vol. II., page 180):

"128. (*Dr. Frankland.*) Do you, or not, approve of soft water as a domestic supply to a population? —I have always had a good opportunity of judging, and I am positive that soft water is preferable to hard water. Hard water generally produces bowel complaints, principally diarrhœa. I have never observed any deposit of lead in the supply pipes of Aberdeen; it does collect occasionally."

Dr. George C. Pirie, M.D., Medical Officer of Health for Dundee, gave evidence as follows (4th Report of Rivers Pollution Commission (1868), Vol. II., page 183):

"272. (*Dr. Frankland.*) Have you noticed that the prevalence of stone in the bladder in Dundee has diminished with the change in the water supply, and has there been a marked decrease since soft water was more used in Dundee?—Those cases have been much fewer than before the introduction of the present water supply. Stone in the bladder was a very common ailment in Dundee, and operations were frequently performed, but during the past 10 years I have not been aware of more than two or three cases in Dundee in which there have been operations.

"273. Do you attribute the former prevalence of this disease to any particular constituents in the water supplied?—I cannot explain it in any other way than that the water, before the people used the present supply, was well-water, which contained more lime and more salts, and therefore gave rise to stone in the bladder.

"274. Is it consistent with your experience that hard water has a tendency to produce stone in the bladder?—I believe so.

"275. Generally speaking, would you recommend for the domestic supply of a population hard or soft water?—Soft water."

Mr. John Hume, Medical Officer of Health of Jedburgh, gave evidence as follows (4th Report of the Rivers Pollution Commission (1868), Vol. II., page 195):

"737. (*Dr. Frankland.*) What is your opinion about hard and soft water?—I think moderately hard water is the best.

"738. Do you object to soft water on the ground that there is not enough of lime in it?—Yes.

"739. Do you consider that that is a valid objection to it?—I think so.

"740. You prefer hard water?—Yes.

"741. Have you ever known cases of stone in the bladder to arise from the use of very hard water? —Not in Jedburgh.

"742. Elsewhere?—No."

Mr. D. Macleod, Medical Officer of Health of Hawick, gave the following evidence (4th Report of the Rivers Pollution Commission (1868), Vol. II., page 198):

"888. (*Dr. Frankland.*) Do you consider that the hardness of the water has anything to do with the healthiness of the population who use it?—I do not know; but we generally consider that, for general household purposes, moderately soft water is the healthiest water to use.

"889. Have you met with any cases of stone in the bladder?—I have known a great many cases in Hawick.

"890. Notwithstanding the softness of the water?—Yes.

"891. Was the water that was used before a harder water?—Yes."

Mr. Stephen Edward Piper, F.R.C.S., Medical Officer of Health for Darlington, gave evidence as follows (3rd Report of the Rivers Pollution Commission (1868), Vol. II., page 252):

"253. (*Dr. Frankland.*) Do you consider the quality of the water at present supplied to Darlington good?—Yes, it is most excellent. There is no better water for domestic purpose, and it is excellent water for drinking purposes, so much so, that many persons who formerly drank the pump water, and complained of dyspepsia, drink the other water which is less hard.

"254. Are you in favour of soft water for the supply of towns?—Yes, certainly.

"255. You do not consider it necessary that there should be a large quantity of lime in it?—I do not."

Dr. William J. Gairdner, M.D., Professor of Practice of Medicine in the University of Glasgow, and Medical Officer of Health for that city, gave evidence as follows (4th Report of the Rivers Pollution Commission (1868), Vol. II., page 253):

"2694. (*Dr. Frankland.*) Of course amongst the possible causes of the high mortality in Glasgow, you cannot put the quality of the water supply; or what is your opinion of that?—My opinion is that the water supply of Glasgow is unexceptionable.

"2695. An opinion has been expressed that very soft water is a bad thing, do you concur in that?— I think there is no foundation for that at all."

PART III. SPECIALITIES.

Influence of hard water on health.

Dr. H. Anderson, the provost of Selkirk, who is also Medical Officer of Health for the burgh, said in his evidence before us (4th Report, Vol. II., Part III., 805–831):

"Which do you consider best for the supply of a town for domestic purposes, soft water or hard?—I think, on the whole, soft water is best for all purposes generally, if the water is pure.

"Have you observed that the use of very soft water has done any injury to health?—Not at all."

It will be seen from the foregoing evidence that whilst there is considerable difference of opinion as to the salubrity or otherwise of hard waters, there is almost absolute unanimity as regards the wholesomeness of soft water. It is true that Dr. Letheby, late Medical Officer of Health for London, adduces a statistical table which indicates a higher rate of mortality in those towns which are supplied with soft water, but the wide differences in respect of other important sanitary conditions restrains him from drawing the inference that the softness of the water is the cause of the higher rate of mortality. He says, "I do not pretend to say that the quality of this water has had anything to do "with the mortality." And again, in comparing the mortality of Birmingham, where hard water is used, with that of Sheffield, to which soft water is supplied, he says, "I do not mean to say that the water has anything to do with it." We entirely agree with Dr. Letheby that the mere question of the supply of soft or hard water to a town cannot in itself determine the mortality of that town, or even affect it in an important degree; but to test this point further, and to gain a much broader basis of statistical facts than that laid before the Royal Commission on Water Supply, we have embodied the results of our inquiries in the following tables, which contrast the mortality in towns using very soft water with that which obtains in (1st) towns which are supplied with moderately hard water, and (2nd) towns the inhabitants of which drink hard or very hard water.

TABLE I.

TOWNS SUPPLIED WITH WATER NOT EXCEEDING 5° OF HARDNESS.

—	Population, 1871.	Mortality per 1,000 per Annum.	—	Population, 1871.	Mortality per 1,000 per Annum.
ENGLAND			Scotland—*cont.*		
Batley, Yorkshire	20,871	25·0	Dumbarton	11,423	26·5
Bolton, Lancashire	82,854	28·6	Glasgow	547,538	31·1*
Bury, "	41,344	25·6	Greenock	57,821	33·6
Canterbury	20,962	24·5†	Inverness	14,510	25·2
Halifax, Yorkshire	65,124	29·5	Johnstone	7,538	26·4
Kendal	13,446	21·6	Lanark	5,099	26·8
Manchester	351,189	32·0*	Paisley	48,257	28·5
Plymouth	68,758	23·3†	Peebles	2,631	24·6
Salford	124,801	28·6*	Perth	25,606	25·4
Sheffield	239,946	27·5*	Pollokshaws	8,921	24·9
Swansea	51,702	23·2†	Port Glasgow	10,823	28·1
			Selkirk	4,640	22·6
SCOTLAND.			Stirling	14,279	26·1
Aberdeen	88,189	24·3	Average	73,366	29·1
Blairgowrie	5,252	27·5			

N.B.—In this and the following tables the numbers to which * is attached are from the Registrar-General's Annual Reports, and are corrected by him for increase of population; those to which † is attached are also from the Registrar-General's Reports, but calculated on the mean population for 1861 and 1871; all others are from returns supplied to us by the authorities of the towns themselves. The mortality is calculated in most cases on the average of ten years. In some instances the data were wanting for an average extending over so long a period, but in no case does it extend over a less period than five years.

Influence of hard water on health.

TABLE II.

TOWNS SUPPLIED WITH WATER OF MORE THAN 5°, BUT NOT EXCEEDING 10° OF HARDNESS.

—	Population, 1871.	Mortality per 1000 per Annum.	—	Population, 1871.	Mortality per 1000 per Annum.
ENGLAND.			England—*cont.*		
Accrington	21,788	30·3	Rochdale	44,559	24·3†
Birkenhead	65,971	24·0†	Stockport	53,014	32·0
Blackburn	76,339	25·4			
Bradford, Yorkshire	145,830	26·0*	SCOTLAND.		
Carlisle	31,049	24·1†			
Chorley	16,864	24·5	Airdrie	15,671	23·8
Exeter	34,652	25·5†	Alloa	9,362	26·9
Hastings	29,291	20·4†	Dundee	119,141	29·0
Huddersfield	70,253	23·0	Edinburgh	197,581	26·3*
Leeds	259,212	28·5*	Galashiels	10,312	23·4
Liverpool	493,405	34·0*	Hamilton	11,498	24·4
Macclesfield	35,450	26·8	Hawick	11,356	25·0
Merthyr Tydfil	97,020	25·1†	Kilmarnock	23,709	26·0
Oldham	82,629	26·7†			
Preston	85,427	28·0†	Average	81,655	28·3

TABLE III.

TOWNS SUPPLIED WITH WATER OF MORE THAN 10° OF HARDNESS.

—	Population, 1871.	Mortality per 1000 per Annum.	—	Population, 1871.	Mortality per 1000 per Annum.
ENGLAND AND WALES.			England and Wales—*cont.*		
Ashton-under-Lyne	31,984	28·3			
Bath	52,557	22·2†	Portsmouth	113,569	21·5*
Berwick-on-Tweed	13,282	22·3	Reading	32,324	22·4†
Birmingham	343,787	24·4*	Southampton	53,741	23·8†
Brighton	90,011	22·6†	Stockton-on-Tees	27,738	25·6
Bristol	182,552	23·9*	Stoke-upon-Trent	130,985	27·9†
Bury St. Edmunds	14,928	24·5†	Stroud	38,610	20·9†
Cambridge	30,078	22·1†	Sunderland	98,242	26·3*
Cardiff	39,536	21·3†	Tranmere	16,143	18·8
Cheltenham	44,519	19·2†	Trowbridge	11,508	23·2
Colchester	26,343	21·3†	Wakefield	28,069	24·4
Croydon	71,319	19·9†	Warrington	32,083	27·3
Darlington	27,729	22·3†	Whittlesey	7,002	20·8†
Dover	28,506	19·7†	Wigan	39,110	32·1
Durham	14,406	23·7	Witney	2,976	18·9
Exeter	34,652	25·5†	Wolverhampton	68,291	25·9*
Frome	9,752	22·7	York	43,796	23·5†
Horbury	3,977	25·0			
Hull	121,892	25·2*	SCOTLAND.		
Ipswich	42,947	22·3†	Arbroath	20,169	24·1
Kidderminster	19,473	21·2†	Ayr	17,954	24·6
Leicester	95,220	27·0*	Brechin	7,959	25·7
Lynn	16,562	22·8†	Cupar	5,105	22·5
Maidstone	26,196	23·4†	Forfar	11,131	27·4
Middlesborough	39,563	18·3	Jedburgh	3,321	21·4
Newcastle-on-Tyne	128,443	29·3*	Kelso	4,564	26·3
Newtown (Montgomery.)	5,744	24·7	Kirkintilloch	6,139	24·0
Northampton	41,168	25·5†	Leith	44,721	24·9
Northwich	1,244	21·0	Linlithgow	3,690	24·9
Norwich	80,386	24·4*	Montrose	14,608	23·4
Nottingham	86,621	24·2*	Musselburgh	7,517	28·2
Oxford	31,404	21·9†	Average	44,797	24·3

From Table I. it follows that amongst an aggregate population of 1,933,524 living in 26 towns, and drinking water not exceeding 5° of hardness, the average annual rate of

PART III. SPECIALITIES.

Influence of hard water on health.

mortality per 1,000 persons living was 29·1. Table II. shows that amongst an aggregate population of 2,041,383 living in 25 towns, and drinking water of more than 5°, but not exceeding 10° of hardness, the average annual rate of mortality per 1,000 persons living was 28·3. Table III. shows that amongst an aggregate population of 2,687,846 living in 60 towns, and drinking water exceeding 10° of hardness, the average annual rate of mortality per 1,000 persons living was 24·3. Lastly amongst an aggregate population of 3,254,260 living in London, and drinking water varying from 16° to 32° of hardness, the average annual rate of mortality per 1,000 persons living was 24·6.

These statistical data may be thus summarised:—

No. of Cities and Towns.	Average population of each Town.	Hardness of Water.	Average rate of Mortality per 1,000 per Annum.
26	73,366	Not exceeding 5°.	29·1
25	81,655	Above 5° but not exceeding 10°.	28·3
60	44,797	Above 10°.	24·3
London.	3,254,260	From 16° to 32°.	24·6

These results would, taken without further investigation, lead to the conclusion that very hard waters are the most wholesome, whilst soft water and water of moderate hardness are comparatively unwholesome. It is obvious, however, that such comparisons as those presented by the foregoing tables are altogether fallacious; for, even on the assumption that hard and soft waters differ in their salubrity, the effect of such difference upon the populations of the towns enumerated must be entirely masked by the much wider disparity in other essential sanitary conditions which exist in towns so dissimilar in situation, in actual and average population, and in mode of defœcation. With regard to the last named most important sanitary condition, for instance, out of 26 towns supplied with soft water and enumerated in Table I. there are only three in which the pestiferous midden system is not in full operation, out of 25 towns supplied with moderately hard water, there are again only three in which the water-closet system is predominant, whilst amongst the 60 towns, the inhabitants of which drink hard water, there are no less than 30 in which, on the water-closet system, the excrements of the population are at once washed out of the town.

The comparatively high death rate of Bolton, Glasgow, Manchester, and Greenock is owing, not to the soft water which is supplied to their inhabitants, but to the density of the population, the masses of excrement in middens and cesspools in constant and close proximity to the houses, and to the lack of care which, in manufacturing towns, is often suffered by young children. And, again the low death rate of such towns as Croydon, Middlesborough, and Tranmere must be attributed, in a considerable degree, not to the circumstance that their inhabitants drink hard water, but to the fact that they are growing rapidly by the immigration of adults, whereas other towns on this list are increasing naturally by additions to the infant population.

The gross disparity involved in the foregoing tables is not diminished by grouping the towns compared under three heads, viz.:—1. Seaport towns, 2. Inland manufacturing towns, and 3. Inland non-manufacturing towns, as in the following tables:—

COMPARATIVE MORTALITY IN SEAPORT TOWNS.

TABLE I.

MORTALITY IN SEAPORT TOWNS SUPPLIED WITH SOFT WATER.

—	Population, 1871.	Mortality per 1,000 per Annum.
Aberdeen - - - - - - - -	88,189	24·3
Glasgow - - - - - - - -	547,538	31·1*
Greenock - - - - - - - -	57,821	33·6
Plymouth - - - - - - - -	68,758	23·3†
Swansea - - - - - - - -	51,702	23·2†
Average - - - - -	162,801	29·4

Part III. Specialities.

Influence of hard water on health.

TABLE II.

Mortality in Seaport Towns supplied with Moderately Hard Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Birkenhead - - - - - - - -	65,971	24·0†
Dundee - - - - - - - -	119,141	29·0
Liverpool - - - - - - - -	493,405	34·0*
Average - - - - - -	226,172	32·1

TABLE III.

Mortality in Seaport Towns supplied with Hard Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Bristol - - - - - - - -	182,552	23·9*
Hull - - - - - - - -	121,892	25·2*
Newcastle-on-Tyne - - - - - - - -	128,443	29·3*
Portsmouth - - - - - - - -	113,569	21·5*
Southampton - - - - - - - -	53,741	23·8†
Sunderland - - - - - - - -	98,242	26·3*
Average - - - - - -	116,406	25·1

This comparison shows that in an aggregate population of 814,008, residing in five large seaport towns, and drinking soft water, the average annual death-rate per 1,000 persons living was 29·4; whilst amongst an aggregate population of 678,517, living in three large seaport towns, and consuming moderately hard water, the average mortality per annum was no less than 32·1 per 1,000; and in a population of 698,439, living in six large seaport towns supplied with hard water, it was 25·1 per 1,000 per annum. This comparison would lead to the conclusion that moderately hard water is the most unwholesome, which is obviously absurd. Indeed these averages, varying as they do altogether independently of their water supply, plainly have no bearing whatever on the effect of the hard or soft water upon the health of the towns to which they refer. That is determined by altogether different causes. Thus, Greenock has a death rate of 32·6 in the thousand, and Plymouth, a town of nearly the same population, has a death rate of only 23·3 in the thousand, notwithstanding that in both cases a soft water is supplied to the inhabitants. The difference in the density of population is here probably sufficient to account for so great a contrast, there being in the former town only 2,183 houses for a population of 59,785, or one house for every 28 people. A contrast even greater exists between Birkenhead and Liverpool, both supplied with moderately hard water; the former a new town upon a recent site, with wide and open streets, has a death rate of 24 per thousand; the latter, an old and densely populated town, whose site long since saturated with much that is injurious to health, is occupied, to a large extent in certain districts, by poor Irish families, living thickly huddled together in mean streets, has a death rate of no less than 34 per thousand.

Comparative Mortality in Inland Manufacturing Towns.

TABLE I.

Mortality in Inland Manufacturing Towns supplied with Soft Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Bolton, Lancashire - - - - - - - -	82,853	28·6
Halifax - - - - - - - -	65,510	29·5
Manchester - - - - - - - -	351,189	32·0*
Salford - - - - - - - -	124,801	28·6*
Sheffield - - - - - - - -	239,946	27·5*
Average - - - - - -	172,860	29·7

Part III.
Specialities.

Influence of hard water on health.

TABLE II.

Mortality in Inland Manufacturing Towns supplied with Moderately Hard Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Blackburn	76,339	25·4
Bradford, Yorkshire	145,830	26·0*
Huddersfield	70,253	23·0
Leeds	259,212	28·5*
Merthyr Tydfil	97,020	25·1†
Oldham	82,629	25·7†
Preston	85,427	28·0†
Stockport	53,014	32·0
Average	108,715	26·9

TABLE III.

Mortality in Inland Manufacturing Towns supplied with Hard Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Birmingham	348,787	24·4*
Leicester	95,220	27·0*
Nottingham	86,621	24·2*
Stoke-upon-Trent	130,985	27·9†
Wolverhampton	68,291	25·9*
Average	144,981	25·5

Thus amongst an aggregate population of 864,299, living in five large inland manufacturing towns, and drinking soft water, the average annual death-rate per 1,000 persons living was 29·7; and amongst an aggregate population of 869,724, living in eight large inland manufacturing towns, and consuming moderately hard water, the average mortality per annum was 26·9 per 1,000; whilst in an aggregate population of 724,904, living in five large inland manufacturing towns, supplied with hard water, the average annual rate of mortality was 25·5 per 1,000.

Comparative Mortality in Inland Non-manufacturing Towns.

TABLE I.

Mortality in Inland Non-manufacturing Towns supplied with Soft Water.

—	Population, 1871.	Mortality per 1,000 per Annum.
Canterbury	20,962	24·5†
Blairgowrie	5,252	27·5
Johnstone	7,538	26·4
Lanark	5,099	26·8
Peebles	2,631	24·6
Perth	25,606	25·4
Selkirk	4,640	22·6
Stirling	14,279	26·1
Average	10,751	25·4

Influence of hard water on health.

TABLE II.

MORTALITY IN INLAND NON-MANUFACTURING TOWNS SUPPLIED WITH MODERATELY HARD WATER.

—	Population, 1871.	Mortality per 1,000 per Annum.
Carlisle	31,049	24·1†
Alloa	9,362	26·9
Edinburgh	197,581	26·3*
Hamilton	11,498	24 4
Average	62,372	26·0

TABLE III.

MORTALITY IN INLAND NON-MANUFACTURING TOWNS SUPPLIED WITH HARD WATER.

—	Population, 1871.	Mortality per 1,000 per Annum.
Bath	52,557	22·2†
Bury St. Edmunds	14,928	24·5†
Durham	14,406	23·7
Arbroath	20,169	24·1
Brechin	7,959	25·7
Cupar	5,105	22·5
Forfar	11,131	27·4
Kelso	4,564	26·3
Linlithgow	3,690	24·9
Montrose	14,608	23·4
Cambridge	30,078	22·1†
Croydon	71,319	19·9†
Exeter	34,652	25·5†
Ipswich	42,947	22·3†
Maidstone	26,196	23·4†
Northampton	41,168	25·5†
Norwich	80,386	24·4*
Oxford	31,404	21·9†
Reading	32,324	22·4†
York	43,796	23·5†
Average	29,169	23·2

The last three tables show that in an aggregate population of 86,007, living in eight inland non-manufacturing towns, and consuming soft water, the average annual death-rate per 1,000 persons living was 25·4; in an aggregate population of 249,490, living in four non-manufacturing inland towns, and drinking moderately hard water, the average mortality was 26 per 1,000; and amongst a population of 583,387, living in 20 such towns supplied with hard water, the average mortality per annum was 23·2 per 1,000.

Even when the grosser inconsistencies of comparison are removed, these tables still lead to a result which cannot be regarded as trustworthy, and it is quite obvious that even amongst the members of each of the three classes of towns just enumerated, the conditions of salubrity, other than wholesome water, vary between wide limits. Thus of the 12 towns consuming soft and moderately hard water, there is only one (Canterbury) in which the watercloset system prevails, whereas amongst the 20 towns supplied with hard water there are no less than 11 in which the excrements are immediately removed by water. Indeed, amongst such conditions there are unquestionably several, the influence of which upon the death-rate is at least equal in importance to that of a supply of wholesome water; such, for instance, as sufficiency of air-space and ventilation in the interior of houses, purity of external air, and cleanly habits of the people. The lack of any one

PART III. SPECIALTIES.

Influence of hard water on health.

of these conditions almost renders nugatory the attainment of the remainder. Thus if the people are crowded together in badly ventilated rooms, we have everywhere the strongest evidence that they suffer frightfully from epidemics of typhus, typhoid and scarlet fevers; the same result follows if sewer gases gain access to the interiors of houses through untrapped drains, or if the external air is polluted and poisoned by reeking middens and foul streams. And lastly, the enjoyment of all other conditions of health may almost go for nothing if the people are dirty in their habits and ignorant of the commonest precautions against the propagation of disease.

These conditions of salubrity vary so much in each of the classes of towns amongst which we have instituted the foregoing comparisons, as to render the discovery of the influence (if any) of hard and soft water upon the health of the people utterly hopeless, and these statistical tables do little more than expose the absurdity of such attempts. There is, however, another class of towns or registration districts which are comparatively free from such disturbing causes, and amongst the members of which a comparison of this kind may, perhaps, be made with a better prospect of a trustworthy result. These are the watering places or sanitariums of the country. Here the interests of the local authorities are so entirely identified with the maintenance of a character for salubrity, as to cause a much more stringent and effective application of remedies for sanitary defects than that which obtains elsewhere; and we have therefore prepared the following tables, contrasting those towns and districts of this class which consume soft water with others to which moderately hard and hard water respectively are supplied.

COMPARATIVE MORTALITY IN THE DISTRICTS CONTAINING SOME OF THE PRINCIPAL ENGLISH WATERING PLACES.

TABLE I.

MORTALITY IN THE DISTRICTS SUPPLIED WITH SOFT WATER.

—	Population, 1871.	Mortality per 1,000 per Annum for the Years 1861–70.
Buxton including Ashborne, Bakewell, Chapel-en-le-Frith and Matlock - - - - - - -	65,961	20·6
Kendal including Windermere, Ambleside, and Bowness -	39,941	18·5
Malvern, including Upton-on-Severn - - -	23,373	19·6
Newton Abbot, including Dawlish, Torquay, and East and West Teignmouth - - - - - -	68,210	19·6
Tunbridge Wells, including Tunbridge - - -	44,664	18·4
Average - - - - -	48,430	19·5

TABLE II.

MORTALITY IN THE DISTRICTS SUPPLIED WITH MODERATELY HARD WATER.

—	Population, 1871.	Mortality per 1,000 per Annum for the Years 1861–70.
Aberystwith - - - - - - - -	27,441	19·6
Barnstaple, including Ilfracombe - - - - -	37,358	18·8
Hastings - - - - - - - -	35,640	19·7
Average - - - - -	33,480	19·2

TABLE III.

MORTALITY IN THE DISTRICTS SUPPLIED WITH HARD WATER.

Part III. Specialities.

Superiority of soft water in cooking.

—	Population, 1871.	Mortality per 1,000 per Annum for the Years 1861–70.
Bath	69,585	22·1
Brighton	90,013	22·0
Cheltenham	53,159	19·3
Clifton, including part of Bristol	128,034	21·5
Dover	35,020	20·0
Eastbourne	15,703	17·0
Isle of Wight	66,165	17·2
Leamington, including Warwick	48,845	20·6
Ramsgate, including Margate	42,134	20·5
Scarborough	36,556	22·3
Weymouth, including Melcombe Regis	31,261	17·2
Worthing, including Arundel and Littlehampton	21,563	18·2
Average	53,170	20·4

The towns and districts compared in the foregoing tables, though still varying in their death-rates, are more nearly equal in sanitary condition than those previously contrasted. In an aggregate population of 242,149, living in five towns and districts, and drinking soft water, the annual rate of mortality averaged 19·5 per 1,000; and amongst an aggregate population of 100,439, living in three towns and districts, and consuming moderately hard water, the annual death-rate was 19·2 per 1,000; whilst in an aggregate population of 638,038, living in 12 towns and districts supplied with hard water, the average mortality was at the rate of 20·4 per 1,000 per annum.

Thus, where the chief sanitary conditions prevail with tolerable uniformity, the rate of mortality is practically uninfluenced by the softness or hardness of the water supplied to the different towns, and the average rate of mortality in the different water divisions varies far less than the actual mortality in the different towns of the same division.

We are therefore of opinion that, whilst waters of excessive hardness may be productive of calculous and perhaps other diseases, soft and hard waters, if equally free from deleterious organic substances, are equally wholesome.

IV.—ON THE SUPERIORITY OF SOFT OVER HARD WATER IN COOKING.

The superiority of soft water in the laundry, partly owing to its greater power of dissolving either filthy matters or those adhesive substances by which they cling, is experienced also in the kitchen, where this power of solution on the part of water is a property of great importance. In the extraction of the soluble parts of such materials as are submitted to boiling, or to simmering at a high temperature, soft water has an acknowledged superiority over hard water,—a superiority which, as it economises the material on which it operates, has a distinct money value. In the extraction of tea from the leaf as well as in the extraction of juices from meat in the preparation of soups, a smaller quantity of the material thus suffices for the production of an extract of a given strength; and as the process is not only more effectual but more easy, time and fuel are also saved.

The same truth obtains in the experience of the brewer, who prefers a soft water for the rapid and effectual extraction of the saccharine matter of malt in the preparation of his wort; or who employs a hard water when he desires to prevent the too easy solution and extraction of the colouring matter of malt—a permanently hard water being thus needed in the manufacture of pale ale. Even in the cooking of meat and vegetables, where it is not the extract but the solid food that is the desired result, it is alleged by experienced witnesses that the result is more satisfactory—sometimes, as in the case of vegetables, in respect of the subsequent appearance of the cooked food—when soft water is used.

The following testimony on these points is quoted from the minutes of evidence taken before the General Board of Health in the year 1850.

PART III. SPECIALITIES.

Superiority of soft water in cooking.

Monsieur Soyer gave the following evidence:—

"You are known to the Commissioners from your writings on cookery; and you have doubtless had occasion to try the qualities of different waters for cooking and culinary purposes; you have probably used *Thames* water?—Yes, I have; when I first became cook to the Reform Club we occupied Gwydyr House, which was then supplied with *Thames* water.

"What was your experience of it?—That it was very hard and inconvenient; it had sometimes a disagreeable taste; this, however, we found was occasioned by the cistern, which we remedied; it was, however, at all times very hard.

"What was the effect of the hardness in cooking?—That we were in many processes obliged to use potass or soda for the water, to soften it.

"What were the processes?—First, in boiling cabbage, greens, spinach, asparagus, hard water gives them a yellow tinge, especially in French beans; hard water shrivels greens and peas, and will be more particularly noticed in French beans; the process of boiling is also longer.

"That requires more fuel?—Certainly.

"What would be the difference in time?—With dry vegetables certainly one-fourth more.

"How is it with potatoes?—I do not think it acts so much upon potatoes, but still it has an influence upon all sorts of vegetables. I do not see the same effects however upon roots generally, as upon leaves generally; the effects are very powerful.

"What do you find to be the effect of hard water upon the animal foods?—Upon salt beef the hard water is not so good, it does not open the pores of the meat so freely as soft water. On fresh meat it likewise has a prejudicial effect, but not equal to that on vegetables. It has the effect of making very white meat whiter than the soft water; upon all delicate things it has however a more marked effect—for example, in making beef-tea, chicken or veal broth, or upon lamb; and the more delicate a substance is, the greater is the influence of a hard water upon it. A hard water as it were compresses the pores whilst a soft water dilates them and the succulent matter which they contain. It makes them more nutritious. The evil of hard water is more visible in small quantities, such as broth or beef-tea.

"Then it will be the more prejudicial or expensive in domestic cookery, which must be in small quantities?—Exactly so; in the larger operations, where there is much boiling, the boiling itself, and for a long time, reduces the hardness. In the small quantities requisite for invalids and delicate persons the disadvantages are the most experienced. When I used *Thames* water at Gwydyr House, I have had quantities boiled in order to soften it, and have then let it get cool and kept it ready for use for the smaller operations.

"What is the effect of hard water upon bread?—I have not had practical experience in bread-making; but there is not the least doubt that soft water is of the greatest importance as making the best bread. This is exemplified in Paris, where the water is hard, and where that bread, which is made in imitation of Gonness bread, though made with the same flour and by the same bakers, never equals that made at the place itself, where the water is soft. I am informed that part of the water at Glasgow is very soft, and that the Scotch bakers from thence, when they first come to London, cannot understand why the bread does not rise so well as in Glasgow, even though they make use of the same yeast and flour. It is well known that the addition of a small quantity of bi-carbonate of magnesia in the water renders bread lighter and whiter.

"What is your experience in respect to tea?—The hard water is injurious in deteriorating the flavour; it also requires more tea to give an equal strength. There can be no doubt that the softer water is of very great importance, we have found it so with the water used at the Reform Club, which is Artesian well water.

"In respect to coffee, what is your experience?—Hard water produces a similar effect, but not quite so powerful.

"From these experiments, and your extensive knowledge, will you state the general results as to the relative power of the hardest and the softest water in making tea?—I should say that whilst with the hard water three cups might be made, with the soft water about five might be made.

"What extra expenditure of tea then would the use of the *Thames* water incur in making tea?—Nearly one-third.

"That is on all the tea consumed in the metropolis?—Yes, I have no doubt of it.

"Do you consider that the action of water in tea is a fair test and representative of its action on meat and vegetables in general, in all the delicate processes of cookery? Yes, I do, and I have proved it in the following way. I have taken the solution of 16°, and compared it with the water from the well of the Reform Club. First, with vegetables, that is carrots, turnips, and onions, cut into small pieces of about one inch long and an eighth of an inch square, such as are used in Jullienne soup, placed in two saucepans, with the same quantity of water, and on the same gas-stove: those cooked in the Reform water were quickly done, and the flavour of the vegetables in the water; whilst those cooked in the solution never became tender, nor did the flavour go into the water. Secondly, with potatoes, I cut a peeled potato into two, and boiled them at the same time in the above waters; the difference was easily distinguishable, that which was boiled in the hard water being harder but at the same time whiter. Thirdly, in extracting the juice or gravy from meat; the soft water does so quickly and well, but the hard water, instead of opening the meat, seems to draw it closer together, and to solidify the gluten, and I believe that the true flavour of the meat cannot be extracted by hard water. In boiling of salt meat less salt is extracted when boiled in hard water, and at the same time the meat is not so tender as when boiled in soft water. Soft water evaporates one-third faster than hard water. I should in every way give the preference to soft water, but, at the same time, if very tender meat is required to boil very white, hard water should be used."

Mr. Philip H. Holland, M.R.C.S., Medical Inspector, Burial Acts Office, gave the following evidence:—

"Have you tried the difference of hard and soft water for cooking?—I have not made any accurate experiments except as to tea-making. I find that the water softened by means of oxalate of ammonia extracts the strength of tea almost twice as well as when hard. I had tea made with equal quantities of the leaf and equal quantities of boiling water, with and without oxalate of ammonia. The infusion made with water softened by the oxalate was strongly and better flavoured, and had to be diluted with the addition of 80 per cent. of hot water to bring it down to the strength of the other. It follows, therefore, that with the oxalate 10 parts of tea go as far as 18 without it.

On softening hard water.

"Does that saving pay for the expense ?—Over and over again ; my tea costs me about 1*s.* a week ; If I can save eight parts out of 18, I can have as strong and better flavoured tea for less than 7*d.* a week, being a saving equal to half the water rate. It is not easy, however, to get these savings effected regularly, it is apt to be forgotten, and cannot well be left to the servants. It would be far better to have a water originally soft, if it were procurable."

Professor Clark, of Aberdeen, gave the following evidence :—

"My health has, heretofore, prevented me from making any more than merely preliminary experiments. From these it appeared that hard water was very unfit for the purpose of infusing tea. In making use of a series of waters at 4°, 8°, 12°, 16°, of hardness, the strength of the infusion, as manifested by the depth of colour produced, was evidently in a series, such that each infusion could be sensibly distinguished from the one next to it, above or below, the hardest water giving the least depth of colour, and the softest water the greatest. At 4° of hardness, the infusion was transparent with no sensible muddiness ; at 6° the transparency of the infusion began to be injured; at 12° there was a distinct muddiness; at 16° this muddiness had become very decided, and above 16° it was disgusting. No such muddiness appeared with any of the waters after pouring off the first infusion and making a second. With regard again to depth of colour, it is very worthy of remark, that whereas the greatest depth was observed in the first infusion in the softest water, and the least depth in the hardest; now, in the second infusion, the same thing was observed again, with this difference, that in the harder waters, the depth of colour was proportionally still less; not only absolutely less, as might be expected, but relatively less. In making these experiments, about half an ounce of tea was made use of with a pint of boiling water, so that you will understand the result if you suppose in each of two similar teapots, half an ounce of tea to be put, and over each a pint of boiling water, but in the one case at 4° hardness, and in the other case at 16°; the infusion at 4° will turn out much stronger than the infusion at 16°; the infusion at 4° will be transparent ; the infusion at 16° will be offensively muddy. But supposing you pour off the first infusion and make a second infusion, then the second infusion at 4° will be a little weaker in colour than the first infusion at 4°, while the second infusion at 16° will be of a still proportionally weaker colour than the first infusion at 16°. In short, hard water is bad for a first infusion, still worse for a second. The only way of making an infusion of tea with waters at 8°, 12°, or 16°, equally strong with an infusion by water at 4°, is to increase in each case materially the quantity of tea infused. Sub-carbonate of soda in crystals may be made use of in very small quantities in order to soften the water and make it fitter for the purpose of infusing tea; it produces this effect by decomposing the earthy salts present; but if made use of in any proportion above what will exactly decompose the earthy salts present, the excess may, indeed, deepen the colour of the infusion by dissolving some coloured vegetable extract such as pure water would not dissolve, but it will infallibly injure the fine flavour of the tea to all persons not accustomed to the taste of soda in their tea."

Evidence on this subject was given before the Royal Commission on Water Supply (1869). The greater economy in the household from the use of a soft water was generally admitted, but as in the case of the *Thames* water the hardness arises mainly from the presence of the bicarbonate of lime, which is deposited on boiling, the objection to the use of hard water for culinary purposes, which was principally insisted on, is the manner in which deposits take place from it in kettles and boilers.

The late Professor W. A. Miller, M.D., F.R.S., said :—

"I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always in a chalk district a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents ; that seems to me to be one of the serious practical inconveniences from hard water."

V. ON THE SOFTENING OF HARD WATER.

We have already discussed the causes and the evils of hardness in water used for domestic purposes (*see* page 21 and 201) ; such hard water may be softened by any one of the following processes :—

By distillation.
By carbonate of soda.
By boiling.
By lime.

Of these processes the first and second are the most effective, but, owing to their expense, they are not applicable on the large scale. The third and fourth are efficient

PART III. SPECIALITIES. — On softening hard water.

only with certain classes of waters which are rendered hard by the presence of the bicarbonates of lime, magnesia, or iron. The fourth is, however, a very cheap process and is easily applicable to the vast volumes of water which are supplied to large cities, provided the hardening ingredients are of the character just mentioned.

The Softening of Water by Distillation.

By distillation, water is completely separated from all fixed saline matters, and, consequently, from all hardening matters, with which it may be contaminated. Distilled water, however, has a vapid and unpleasant taste, owing partly to deficient aëration and partly to the presence of traces of volatile organic matter. These evils are best remedied by filtering the distilled water through animal charcoal. The process is too costly to be employed for the softening of water used in washing, but the expense by no means imposes an insuperable barrier to its employment for the manufacture of a pure and soft water for dietetic purposes. It is in fact so employed, and we believe with entire success, for the preparation of potable water from sea water in Your Majesty's navy. For such purposes this method is invaluable, not merely for the supply of soft water, but for the total suppression of all risk of infection through the agency of water. Thus ships on unhealthy stations would entirely close one of the two great gateways through which disease is communicated (*see* page 140); and it is well worthy of consideration, whether bodies of troops attacked with cholera, fever, or dysentery could not in many cases be supplied in this way with water, which, even in the most unhealthy districts, would then be absolutely powerless to propagate disease.

The Softening of Water by Carbonate of Soda.

We have already explained (*see* page 21), that the hardness of water is almost exclusively caused by the presence, in solution, of the bicarbonates and sulphates of lime and magnesia. These salts are all decomposed by carbonate of soda, slowly in the cold but rapidly when the water is hot, insoluble carbonates of lime and magnesia being deposited or precipitated as a fine mud, whilst soluble bicarbonate and sulphate of soda are formed.

This process is only applicable on a comparatively small scale, and to water which is to be used for washing, since the water acquires an unpleasant taste of the soda salts introduced. Hard water must be softened before it can be rendered available for the laundress. Indeed the first action of soap upon hard water is to render the latter softer at the expense of the soap which is thereby destroyed or rendered useless for cleansing, and it is necessary to add sufficient soap to completely soften the water before efficient washing can commence. Each degree of hardness (*see* page 21), requires the destruction of 12 lbs. of the best hard soap by 10,000 gallons of the water when used for washing. Thus 10 gallons of water of the hardness of *Thames* water (about 20 degrees) cause the waste of nearly a quarter of a pound of soap when it is used for washing. Now good hard soap costs about 2*l.* 6*s.* 6*d.* per cwt., whilst carbonate of soda (commonly called soda or washing soda) costs only 12*s.* 2*d.* per cwt. But the cost of softening water by soap instead of soda is relatively much higher than appears from this comparison because to obtain a softening effect equal to that produced by 1 cwt. of soda, it is necessary to use more than 4¼ cwts. of soap. Hence there is great economy in softening the water with soda before soap is applied, and this operation is commonly practised in the laundry.

The Softening of Water by Boiling.

That portion of the hardness of water which is due to the bicarbonate of lime, magnesia, or iron is corrected by boiling the water for half an hour. During ebullition, the soluble bicarbonates are decomposed into carbonic acid, which is expelled as gas, and the normal carbonates of lime, magnesia, or iron which are insoluble; they render the water muddy, but they are no longer capable of decomposing soap. The operation is both troublesome and expensive, and as already explained at page 22, is not efficiently performed in ordinary kitchen boilers where water is heated for culinary and other purposes. To raise the temperature of 1,000 gallons of water to the boiling point and to maintain it in ebullition for half an hour would require the expenditure of at least 2½ cwt. of coal, and as performed in the wasteful apparatus used in households, at least double that amount of fuel would be expended, costing about 7*s.* 6*d.* The softening by soap, Clark's process for softening hard water.

to the same extent, of 1,000 gallons of *Thames* water as delivered in London, would cost about 9*s.*, consequently softening by boiling is not much less expensive than softening by soap.

THE SOFTENING OF WATER BY LIME.

The economy which carbonate of soda exhibits in comparison with soap, as a softening agent, is far surpassed by that which results from the use of lime for this purpose. The latter material costs only about 8*d.* per cwt., and this weight of lime will do the work of 20¼ cwts. of soap in softening hard water. To soften a quantity of hard water which requires 1 cwt. of lime the following would be the weight and cost of the three alternative materials:—

	£	*s.*	*d.*
1 cwt. quicklime - - - -	0	0	8
4¾ cwts. carbonate of soda - - -	2	17	9
20¼ cwts. soap - - - -	47	1	8

There is thus an enormous economy in the use of lime, and in the discovery of this process the late Dr. Clark, Professor of Chemistry in the University of Aberdeen, conferred a valuable boon upon the inhabitants of many hard-water districts. Dr. Clark's patent right has expired, and the public are therefore free to use this cheap and simple method of rendering hard water suitable for washing and cleansing purposes. The process is, however, only applicable to water which owes its hardness, entirely or chiefly, to the carbonates of lime and magnesia (*temporary hardness*). Water which is hardened by sulphate of lime or sulphate of magnesia (*permanent hardness*), cannot be thus softened, but any water which softens by boiling for half an hour, will be softened to an equal extent by this method. The hard water derived from Chalk, Limestone, or Oolite districts, is generally well adapted for it.

The following is Dr. Clark's own account of the process ("Journal of the Society of Arts," 16th May 1856):—

"In order to explain how the invention operates, it will be necessary to glance at the chemical composition and some of the chemical properties of chalk; for, while chalk makes up the great bulk of the matter to be separated, chalk also contains the ingredient that brings about the separation. The invention is a chemical one for expelling chalk by chalk. Chalk, then, consists, for every 1 pound of 16 ounces, of lime 9 ounces, carbonic acid 7 ounces.

"The 9 ounces of lime may be obtained apart by burning the chalk, as in a lime-kiln. The 9 ounces of burnt lime may be dissolved in any quantity of water, not less than 40 gallons. The solution would be called lime-water. During the burning of the chalk to convert it into lime the 7 ounces of carbonic acid are driven off. This acid, when uncombined, is naturally volatile and mild; it is the same substance that forms what has been called soda-water, when dissolved in water under pressure.

"Now, so very sparingly soluble in water is chalk by itself, that probably upwards of 5,000 gallons would be necessary to dissolve 1 pound of 16 ounces; but by combining 1 pound of chalk in water with 7 ounces additional of carbonic acid, that is to say, as much more carbonic acid as the chalk itself contains, the chalk becomes readily soluble in water, and, when so dissolved, is called bicarbonate of lime. If the quantity of water containing the 1 pound of chalk with 7 ounces additional of carbonic acid were 400 gallons, the solution would be a water of the same hardness as well water from the chalk strata, and not sensibly different in other respects.

"Thus it appears that 1 pound of chalk, scarcely soluble at all in water, may be rendered soluble in it by either of two distinct chemical changes, soluble by being deprived entirely of its carbonic acid, when it was capable of changing water into lime water, and soluble by combining with a second dose of carbonic acid, making up bicarbonate of lime.

"Now, if a solution of the 9 ounces of burnt lime, forming lime water, and another solution of the 1 pound of chalk and the 7 ounces of carbonic acid, forming bicarbonate of lime, be mixed together, they will so act upon each other as to restore the 2 pounds of chalk, which will, after the mixture, subside, leaving a bright water above. This water will be free from bicarbonate of lime, free from burnt lime and free from chalk, except a very little, which we keep out of account at present for the sake of simplicity in this explanation. The following table will show what occurs when this mutual action takes place:—

AGENTS.		PRODUCTS.	
Bicarbonate of lime in 400 gallons - - -	Chalk - 16 oz.	= 16 oz. of chalk	=2 lbs.
	with		
	Carbonic acid 7 oz.	= 16 oz. of chalk	
Burnt lime in 40 gallons of limewater	- 9 oz.		

"A small residuum of the chalk always remains not separated by the process. Of 17½ grains, for instance, contained in a gallon of water, only 16 grains would be deposited, and 1 grains would remain. In other words, water with 17½ degrees of hardness arising from chalk, can be reduced to 1½ degrees, but not lower.

"These explanations will make it easy to comprehend the successive parts of the softening process.

PART III. SPECIALITIES.

Clark's process for softening hard water.

"Supposing it was a moderate quantity of well-water from the chalk strata around the metropolis that we had to soften, say 400 gallons. This quantity, as has already been explained, would contain 1 pound of chalk, and would fill a vessel 4 feet square by 4 feet deep.

"We would take 9 ounces of burnt lime made from soft upper chalk, we first slack it into a hydrate, by adding a little water. When this is done we would put the slacked lime into the vessel where we intend to soften, then gradually add some of the water in order to form lime water. For this purpose at least 40 gallons are necessary, but we may add water gradually till we have added thrice as much as this; afterwards we may add the water more freely, taking care to mix intimately the water and the lime water or lime. Or we might previously form saturated lime water, which is very easy to form, and then make use of this lime water instead of lime, putting in the lime water first and adding the water to be softened. The proportion in this case would be one bulk of lime water to 10 bulks of the hard water.

"It is of importance that the lime or lime water, that is, the softening ingredient, be put into the vessel first, and the hard water gradually added, because there is thus an excess of lime present up to the very close of the process, and this circumstance is found to render the precipitation of the carbonate of lime produced in the process more easy.

"But what you will wish to know now is, by what mark is the conductor of the process to find out when there is enough of water to take up the last of the excess of lime, so as to be enough but no more.

"This is done by what has been called the silver test, the only test necessary to the operator after the process is fairly set a-going. This test is a solution of nitrate of silver in twice distilled water, in the proportion of an ounce per pint. In making use of the silver test with ordinary waters, we get a white precipitate; but if the water have in it a notable excess of lime water, there is a light reddish brown precipitate produced; but if the excess be very slight, we only get a feeble yellow precipitate. The way we make use of the test is to let two or three drops of it fall on the bottom of a white tea-cup; then add the water somewhat slowly, then if there be the slightest excess of lime, a yellow colour will show itself."

This process of softening received the careful attention of the Commissioners appointed by the Secretary of State for the Home Department in 1851 to investigate the quality of the water available for the supply of the metropolis. The Commissioners were the late Thomas Graham, Esq. F.R.S., Professor of Chemistry at University College and subsequently Master of the Mint; the late W. A. Miller, Esq., M.D., F.R.S., Professor of Chemistry in King's College, London; and Dr. A. W. Hofmann, F.R.S., at that time Professor of Chemistry in the Royal College of Chemistry, and now Professor of Chemistry in the University of Berlin. They reported as follows upon Clark's process:—"Other "means of improvement of the present supply have been brought before us, and engaged "much of our attention, namely, the removal of carbonate of lime from water with a portion "of the organic and colouring matter by adding to it a proper quantity of caustic lime, "as proposed by Professor Clark, either in the form of lime water or of the dry hydrate "of lime.* Carbonate of lime being held in solution by the free carbonic acid gas "dissolved in water is precipitated by boiling which expels the gas as already stated, "and may be precipitated by removing the same gas in any other way. Accordingly "caustic lime when added to hard water in sufficient quantity to neutralize the "carbonic acid removes the solvent, and becoming at the same time carbonate of "lime must precipitate together with that originally in solution. The operation of this "process was first witnessed by us at the Mayfield Print Works in Lancashire, where "300,000 gallons of water are submitted to it daily at a trifling expense and with little "trouble, but more for the purpose of discoloration than softening. A careful series of "experiments made in the laboratory left no doubt on our minds that the means of con-"ducting this process are certain in their results, and sufficiently simple to be left to "the execution of a workman of ordinary intelligence. The precipitation of the car-"bonate of lime was terminated within 24 hours, and the water if free from turbidity "before the liming continued in that state, but if originally turbid it remains so, and "requires filtration besides the liming to make it clear. The New River and *Thames* "waters were softened in this way to an average of about $3\frac{1}{2}$ degrees of hardness, or to "a lower point than by an hour's boiling."

"More important trials of this process upon the large scale were afterwards witnessed "by us at the Chelsea Waterworks, which were conducted under the immediate super-"intendence of Mr. James Simpson, Junr., the resident engineer. The usual supply "of water pumped up from the river was run into the first reservoir in company with "a small stream of milk of lime flowing from a wooden cistern, in which the powder of "slaked lime was mixed with water and kept in suspension by stirring. The inter-"mingled streams passed on into one of the great settling reservoirs to the extent of "from 3,000,000 to 4,000,000 gallons which is nearly a day's supply. The only pre-"caution taken to insure the absence of any excess of caustic lime, consisted in testing "the water in the settling reservoir by a drop of nitrate of silver, which shows if the "quantity of lime required has been exceeded by the brown colour of the precipitate

* Repertory of Patent Inventions, October 1841.

" then formed. After subsiding generally for 24 hours or longer the water was finally " passed through the ordinary sand filters before being distributed. The degree of " hardness before and after the softening process in five such experiments was reported " to us by Mr. Simpson as follows, with the appended remarks.

PART III. SPECIALITIES.

Clark's process for softening hard water.

THAMES WATER AT THE CHELSEA WATERWORKS.

1851.	Degrees of Hardness. Before Liming.	Degrees of Hardness. After Liming.	Remarks.
February 24 - -	14·0	4·5	The river was in good condition. The mixing was completed in 10 hours.
March 1 - - -	14·1	3·75	The river was in good condition. The mixing in 9¾ hours.
March 18 - - -	10·5	5·0	The river in flood. The flood tinge retained after liming.
March 22 - - -	11·6	4·8	Recovering from flood. Yellow flood tinge not removed.
April 17 - - -	15·5	3·6	River in an average condition.

" The conclusions which were come to both by the engineer and ourselves, from these " experiments, in which the operation had not the advantage of the efficient means of " mixing, which might be introduced where it was permanently adopted, were that the " process falls easily into the routine operations of waterworks, and is not attended with " any peculiar difficulty on the large scale, and that the softening of *Thames* water " in its ordinary condition by this process, to a point under four degrees of hardness, is " perfectly practicable.

" The water of the experiment of the 17th of April was analysed before and after the " softening operation. The whole fixed constituents contained in one gallon of water " were found to be reduced from 24·07 to 8·31 grains, and the organic matter from " 2·50 to 1·60 grains. At the same time that the quantity of lime salt present (con- " sidering it all as carbonate), was reduced from 13·65 to 2·63 grains. The softened " water was clear and bright, had acquired no odour nor taste from the process, and " could not be distinguished in its sensible qualities from pure spring water of equal " softness."

" The average cost of the application of the process in the five experiments was " 1*l.* 6*s.* 2*d.* for one million gallons of water, of which almost exactly one third was for " labour, and two thirds for lime, the latter costing 1*s.* per cwt. Mr. Simpson believes, " however, that it may be reduced, and that 20*s.* for one million gallons would be a more " proper general estimate. The influence which this addition to the cost might have " upon the price of water, may be gathered from the following returns lately made to " the General Board of Health, of the present cost to each water company for one " million gallons of water:—

	£	s.	d.
New River - - - - - -	9	17	4
East London - - - - - -	6	7	7½
Southwark - - - - - -	5	9	4
West Middlesex - - - - -	16	9	7
Lambeth - - - - - -	15	0	6½
Chelsea - - - - - -	19	10	4½
Grand Junction - - - - -	9	14	6¼
Kent - - - - - -	17	2	10¼
Hampstead - - - - - -	22	5	7¾
Average (about) - -	10	10	9¾

" The average charge of the companies is, by the same return, about sixpence for " 1,000 gallons, or 25*l.* for one million gallons. The softening process would, therefore, " add about 10 per cent. to the original cost of the water, or four per cent. to the " price charged to the consumers.

" *Thames* water appeared always to be divested of a certain quantity of both organic " and colouring matter by this process, so that its purifying influence greatly exceeds " that of sand filtration. It cannot, however, be expected to exhaust the whole organic

PART III. SPECIALITIES.

Clark's process for softening hard water.

"matter, and might therefore leave certain soluble sewerage products untouched. Moreover, it does not supersede the necessity for sand filtration; for the subsidence of the precipitated chalk, and the spontaneous clearing of the water by rest, after the liming, appear only to be complete when the water has been filtered beforehand, or is so bright as not to require filtration. The suspended chalk may, however, be always removed by sand filtration, and being highly crystalline and granular, it does not choke up or act injuriously upon filters. The experience of eight months at Mayfield was quite decisive, that sand filters are not injured by superadding the lime process, but only require to be more frequently cleansed from the greater deposit on their surface.

"The high degree of hardness of the chalk spring waters is also greatly redeemed by their peculiar adaptation to the softening process. The Batchworth spring was thus reduced to 2·6 degrees of hardness, when lime-water was used, and to 2·8 degrees by means of the solid hydrate of lime; the Redbourn spring to 2·5 and 2·6 degrees. Such is the degree of softness, therefore, at which this supply is attainable. From the extreme purity of the water the precipitated chalk falls entirely colourless, and, indeed, from its finely levigated condition might be sold as whitening. The precipitation appeared to be completed within twelve hours, and was so perfect that no filtration of the water was necessary. The water retained all its original brightness and transparency, and acquired no flavour or other property by which it could be distinguished from the equally soft waters supplied by nature. The experience obtained by us of this softened water as a beverage for some weeks was confirmatory of the statements that the palate becomes gradually reconciled to the impression of a soft and pure water.

"It is a valuable property of the chalk spring water, that in practice it may be softened fully or partially with the same facility, or to any degree desired; the precipitate falling quickly and completely in every case, and leaving the supernatent water clear and colourless.

"The chalk spring water is not naturally a soft water. In this respect it is inferior to the present supply in one sense, being one fourth harder; but it will be remembered that the hardness of both is principally of the temporary kind, and that, after boiling, the advantage is with the spring water. It is, however, in the facility and completeness of the removal of this hardness, that the superiority of the spring over the river water is most apparent. The softening operation by the use of lime is applicable in all seasons to the spring water, which, indeed, adapts itself with singular felicity to that process, the carbonate of lime always precipitating with rapidity, and so completely as not to create a necessity for filtration. The chalk spring waters can thus be commanded with certainty, under three degrees of hardness, which is probably the extreme limit attainable anywhere in England for a great supply. The lower price of lime in the chalk districts, and the reduction of the labour of mixing, must also bring the cost of the process considerably within the estimate formed at the Chelsea Works, and would not, we believe, form a greater addition than a sum equal to two per cent. upon the present price of water. This is without allowing anything to be obtained in return for the precipitated chalk, which would have some market value."

"The chalk spring water after being softened is an extremely pure water. It appears to be considerably superior even to the soft water from the streams of the Surrey sands. The chalk water alone is uniform in its excellence at all times, the sources of it lying beyond the influence of weather or season. In the judgment of the Commissioners, this softened chalk water is entitled, from its chemical quality, to a preference over all others for the future supply of the metropolis. It is no longer possible to disregard the chemical means of removing hardness, or to represent them as impracticable on a great scale; they place the question of water-supply upon an entirely new footing."

This report was written twenty-three years ago. In the meantime, a knowledge of the elements of chemistry has been spreading among engineers and others, and the practicability of this valuable process upon a large scale can now be no longer doubted.

We have ourselves seen it carried out upon such a scale, 1st, at the works of the Chiltern Hills Spring Water Company, near Tring; 2nd, at the works of the Caterham Spring Water Company; and 3rd, at the works of the Canterbury Water Company. At the works near Tring the water is raised from a well, and bore holes sunk into the chalk to the depth of 507 feet, but the bottom of the lowest borehole is 153 feet above ordnance datum. The water stands in the well between 473 feet and 511 feet above ordnance datum. Here 230,000 gallons of hard water are daily softened by the addition of 18,400 gallons of lime-water at a cost of about 27*s.* per million gallons, including lime and labour.

Clark's process for softening **hard water.**

The following table shows the composition of this water before and after softening :—

Composition of Tring Water before and after Softening.

Description.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
Tring water supply from Chiltern Water Company before softening	28·60	·036	·010	26·3
Ditto after softening	8·18	·041	·008	3·2

Thus the total solid impurity was reduced from 28·6 parts per 100,000 parts of water, to 8·18 parts per 100,000; the proportion of organic elements (organic carbon and nitrogen) which was very small in the original water, remained practically unaltered, whilst the hardness was reduced from 26°·3 to 3°·2. The water, originally very hard, was rendered very soft and suitable for washing and cleansing, whilst its brilliancy, transparency, and palatability were not in the least impaired.

At the Caterham Waterworks, the water is pumped from a well in the chalk with a borehole into the greensand, attaining a total depth of 490 feet. The water stands in the well at 340 feet from the surface, and the curb of the well is 709 feet above ordnance datum. Here 100,000 gallons of hard water are daily softened by the addition of about 10,000 gallons of lime-water, at a cost of 27*s.* per million gallons, including lime and labour. 700,000 gallons could be daily raised and treated if required. The samples which we took before and after softening yielded, on analysis, the following results :—

Composition of Caterham Water before and after Softening.

Description.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
Caterham water supply before softening	27·68	·028	·009	21·2
Ditto after softening	8·80	·015	·003	4·4

These results show that the lime process reduced the proportion of total solid impurity from 27·68 parts to 8·8 parts per 100,000, the organic elements (organic carbon and organic nitrogen) from ·037 part to ·018 part per 100,000, and the hardness from 21°·2 to 4°·4. Both the original and the softened water were beautifully brilliant and palatable, and we found by repeated trials that it was impossible, by taste or appearance, to distinguish the one from the other.

At the Canterbury Waterworks there are two bore-holes, 24 inches internal diameter, and 11 feet from centre to centre, sunk 490 feet into the chalk. Both bore-holes are lined to a depth of 36 feet, with cast-iron tubes; 110,000 gallons of hard water are raised per day and softened by the addition of 11,000 gallons of lime water at an expense of 27*s.* per million gallons, including lime and labour. We collected and analysed samples of the water before and after softening with the following results :—

Composition of Canterbury Water before and after Softening.

Description.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
Canterbury water supply before softening	33·60	·012	·012	26·3
Ditto after softening	11·94	0	0	4·9

The numbers in the foregoing table show that the proportion of total solid impurity was, in this case, reduced from 33·6 parts to 11·94 parts per 100,000 parts of water, every trace of organic matter was removed and the hardness was reduced from 26°·3 to 4°·9. The softened water was clear, brilliant, and palatable.

All the three works just described were designed and constructed by Mr. Samuel Collett Homersham, M. Inst. C.E., who has had upwards of twenty years' experience of Clark's process. As the result of this experience he states in his Report to the Chairman and Directors of the Canterbury Gas and Water Company, page 19, that :—

"Spring water, when softened, may be kept in open reservoirs exposed to the air, light, and sun without becoming covered on its surface with vegetation as the hard water does which issues from a chalk spring; for such water, though naturally free from organic matter, has a source of contamination within itself. When exposed to air, light, and sun, more especially in warm weather, the duplicate

PART III. SPECIALITIES.

Clark's process for softening hard water.

dose of carbonic acid that keeps the chalk dissolved gives rise to masses of vegetation that float in the water. Such masses (confervæ) soon grow, soon become corrupt, soon give forth an offensive marshy odour, and become the habitat of animalcules and other living organisms which permeate and contaminate the water. The softened water having had the bicarbonate of lime precipated in the form of chalk, the cause of these impurities (the carbonic acid) is taken away and the water, as already stated, may be kept in open reservoirs free from such contamination.'

In his evidence before the Royal Commission on Water Supply, Mr. Homersham says (Minutes of Evidence, page 406):—

"I have specially directed my attention to procuring spring water from the chalk; that spring water from the chalk being softened by Dr. Clark's process before it is supplied to the consumers.

"6764. Can you shortly state to us the process of Dr. Clark for softening water, and then the steps which you have taken to apply it, and where and what has been the result?—The process is simply putting a certain quantity of water saturated with lime into a reservoir. If the reservoir holds 900,000 gallons of water in the first instance you put in the bottom of the reservoir 100,000 gallons of saturated lime water, and then add to this 100,000 gallons of lime water 800,000 gallons of spring water; I say spring water because it is essential for the process that it should be a clear spring water; a river water is not adapted for being softened by the process.

"6765. Are we to understand that the lime water which you apply is in bulk as one to nine?—Yes, one eighth to one ninth in round numbers. Sometimes it is a little more and sometimes a little less, according to the quality of the water, but as a rule about one ninth is the average quantity required. The reservoir is then filled up with spring water, say eight ninths of it, and the water as it is sent in to fill up the reservoir is sent in at a low point through three or four small apertures at a considerable velocity so as to mix the lime water and the spring water intimately together. When the reservoir is filled the water is allowed to stand something like five or six hours, a sufficient length of time for the carbonate of lime that is formed by putting the lime water to the spring water to be deposited, and the water then becomes perfectly clear. The water when clear is either lowered into a reservoir situated below the reservoir in which it is softened, or, if the water has to be delivered at a higher level, it is pumped up to a reservoir at a higher level for the supply of the consumers.

"6766. What time is occupied in mixing the lime water one ninth in bulk with the water in the reservoir?—To give a practical illustration; at the last works which I recently made in the Chiltern Hills we soften in one reservoir 100,000 gallons of water. The lime water is put in in half an hour, and the hard water is filled up in about three hours, making three hours and a half, and at the end of six or seven hours after that the water is clear and ready to lower down into the reservoir below, so that altogether the softening in one reservoir takes some nine or ten hours. If the quantity be 1,000,000 or 10,000,000 gallons it is just the same, supposing your engine power to be as adequate to pump the larger quantity of water as it would to pump the smaller quantity.

"6767. Will you now state where you have applied this process, and with what success?—The process has been applied at various works. It was applied at the Plumstead works, which were opened, in 1854, and the process was in operation there for seven years and gave great satisfaction.

"6768. Is it in operation now?—Not at the Plumstead works; it was in operation there till 1861, when the works were sold to the Kent Water Company, and immediately upon the Kent Water Company purchasing the works they ceased to soften the water. It was not because the process did not answer, and it was very much against the wish of the consumers who were supplied with the softened water, but they did as a matter of fact cease to soften immediately they purchased the works. The Plumstead Works were made, I should say, in opposition to the Kent Water Company, and they were in operation for seven years in opposition to them. They were then sold to the Kent Water Company, and when the Kent Water Company got possession of them, and not before, the softening process was abandoned.

"6769. Are you informed as to the motives of the Kent Water Company in giving up this process? —No, it is impossible for me to be certain as to their motives. I know the engineer of the Kent Water Company, Mr. Morris, very well, and I understood at the time that they gave up the process simply because they did not choose to apply it through their whole district. The Kent Company supply a very large district independent of the district which they supplied when they bought the Plumstead Company, and they gave up softening, but of course I cannot tell with certainty what may have been their motive.

"6770. What was the volume of water operated upon at Plumstead?—At Plumstead, latterly, we operated upon just about 1,000,000 gallons a day. I think from 900,000 to 1,000,000 gallons. In summer we frequently softened as much as 1,000,000 gallons.

"6771. What was the size of your reservoirs?—There were three reservoirs there, each holding 220,000 gallons, independent of the room below for the deposit. We could soften in each reservoir about 220,000 gallons, the reservoir holding about 250,000 or 260,000 gallons, the extra room being required to allow the carbonate of lime to deposit at the bottom of the reservoir.

"6772. If your reservoir accommodation did not exceed 660,000 gallons, it would take you 15 hours to soften that quantity would it not?—I will explain the process. Here are plans and sections of the three Plumstead reservoirs (*producing the same*). The spring water is pumped into a reservoir, the lime water being at the bottom of the reservoir. In this first work at Plumstead we used cream of lime instead of lime water; in all other works which I have made we use lime water. We made cream of lime the same as lime is slaked for whiting the ceiling; the cream of lime was forced by means of a cylinder among the water as the water was pumped up from the well; the lime mixed with the water, and then passed through what we call an agitator or a mixing apparatus (*producing a section*). The cream of lime and water, at the rate of about 1,000 gallons per minute, was forced together through a pipe, enlarged for a short distance, and having four plates with small holes in it. The cream of lime with the water went through the holes at a higher velocity than it did in the body of the pipe. Then it went on through another such agitator, and so into three agitators. The water then passed by means of a pipe into a catch reservoir, and any bit of flint or any small matter that might have mixed with the lime fell to the bottom of this catch reservoir. The water then proceeded on to another agitator, and finally went into the depositing reservoir.

Part III. Specialities.

Clark's process for softening hard water.

"6773. That process of dealing with a certain quantity of water, mixing it with one-ninth its bulk of lime water, agitating the water, and passing it into the reservoir, occupies about 10 hours, does it not?—The filling of the first reservoir occupies about three hours and a half, and as soon as that is filled the second reservoir is filled.

"6774. Then from the commencement of the operation, having your plant all ready, mixing your lime and then passing it into this pipe and through the agitator, so as thoroughly to mix it with the large body of water, and allowing the deposit to take place, and passing it into the reservoir, it occupies how many hours?—As soon as we had filled the first reservoir, and while we were filling the first reservoir we were intent on pumping the softened water from the second reservoir into the service reservoir, which was situated on Plumstead Common at an elevation of 170 or 180 feet above the works, and by the time the No. 1 reservoir was filled No. 2 reservoir was empty. We then filled up No. 2 reservoir, and at the same time emptied No. 3 reservoir, and by the time No. 2 reservoir was filled No. 3 reservoir was empty, and by the time No. 3 reservoir was filled No. 1 reservoir was emptied, and ready to fill again.

"6775. Those three reservoirs were found sufficient for dealing with 1,000,000 gallons?—Rather more than 1,000,000 gallons, but practically they supplied about 1,000,000 gallons a day of 24 hours.

"6776. Supposing you had to deal with a larger body of water, are those reservoirs of a size that you would use, or would you increase the size of the reservoirs to adapt them to the larger quantity?—If I were dealing with 8,000,000 or 10,000,000 or 12,000,000 gallons of water a day, I should certainly have an additional number of those reservoirs, or reservoirs of larger capacity.

"6777. Would you multiply the reservoirs or increase their capacity?—I should increase their capacity; in the first instance I should make them very much larger, and the engine power would also be very much more powerful, but we should fill them relatively in the same time.

"6778. Still keeping to the works at Plumstead, where you had experience for seven years, can you tell us what the cost of the application of this system of softening was?—Yes, I can tell it quite accurately. The total cost of the construction of those three depositing reservoirs, the lime apparatus, and the whole complete, was under 3,800*l.*, including the connexion with the pipes, the agitators, and so on.

"6779. Do you mean that that was the cost of all the arrangements necessary for your softening process?—Yes, except in this, that we pumped the water from a well about 150 feet deep to the bottom of the well, and if we had supplied the water in its normal condition, in its hard state, to the consumer we should only have had one set of pumps, and should have pumped the water direct from the well to the service reservoir upon Plumstead Common, and that would have saved us some little expense in the first cost. To soften the water we had two sets of pumps. We had one set of pumps at the well which pumped the water into the softening reservoirs, and we had another set of pumps to pump the water from the softening reservoirs to the service reservoirs, from which it was supplied to the consumers, and as nearly as I can say that might have cost an extra sum of 500*l.* or 600*l.*

"6780. That would be 600*l.* added to 3,800*l.*?—Yes, including the extra pump work.

"6781. Is that an inclusive sum, or are there any other items of cost?—No, I think that is fairly the cost at those works. You will observe that the softening reservoirs are not covered. Now from my experience at those works I have never made any other works with softening reservoirs uncovered, and I should not recommend the water to be softened in uncovered reservoirs. It is quite as practicable to soften in uncovered reservoirs as it is to filter in uncovered reservoirs, but pure spring water is of a very delicate character, and in hot weather many sorts of things settle upon the top of the water.

"6782. What would be the cost of covering reservoirs of this size?—Those reservoirs would probably cost another 1,000*l.* additional to cover.

"6783. Then, about 5,500*l.* would be the total cost?—Yes, I should say if you calculate it at 6,000*l.* per 1,000,000 gallons, that would be the outside estimate for the structural works. I may also add with regard to filtering river water, that the structural works would have cost as much as those reservoirs, and as far as the pumping goes, you must take the water from the river and pump up your water after it has been filtered.

"6784. Will you direct your attention to the cost of working and the current expenses?—The current expenses at Plumstead were about 1*l.* 7*s.* per 1,000,000 gallons for the cost of the lime and the labour, that is to say, the cost of the lime was about 1*l.* per 1,000,000 gallons, and the labour about 7*s.*, making about 1*l.* 7*s.* as the cost of the lime and the labour per 1,000,000 gallons.

"6785. But there are other expenses besides the labour and lime, are there not?—I think not; the pumping is included, because, although we pump from the well into the softening reservoir, and then we pump from the reservoir into the service reservoir, yet the total lift is no more. We raise water from the well, say 130 or 140 feet into the softening reservoir, and then we raise it from the reservoirs another 150 or 160 feet into a service reservoir situated on Plumstead Common, but if not softened we should have had to raise it at once 300 feet.

"6786. You move your agitator by means of steam, do you not?—Yes, but that is a very small matter. I think that the 1*l.* 7*s.* would quite include it, it is nothing of any consequence.

"6787. Have you been able to form an opinion as to the application of this system to 1,000,000 gallons, or its application to a very much larger volume of water?—If you take spring water, which, as I have said before, is essential to the success of this process, you may apply it to any amount of water. It is much easier to apply it to 100,000,000 gallons a day than it would be to 1,000,000 gallons a day, inasmuch as the adjustment of the exact quantity of lime to the water is much more easily accomplished on a very large scale than on a small scale.

"6788. Taking the supply to the metropolis as 100,000,000 gallons a day, have you formed any idea as to the cost of the works which would be suitable for dealing with so large an amount of water?—Taking 6,000*l.*, which I am sure is an outside estimate for the works to soften 1,000,000 gallons, of course it would be 600,000*l.* for the whole metropolis at 100,000,000 gallons a day.

"6789. What would be the area which you would require to carry out this system?—I should certainly say less than one-third of an acre, or perhaps say about one-third of an acre. Of course that

PART III. SPECIALITIES. — Clark's process for softening hard water.

is for 1,000,000 gallons, and that would be 3,000,000 gallons to the acre, or about 33 acres for 100,000,000.

"6790. Have you calculated the cost of applying this system to the whole of the supply of London?—The cost would not be more than what I have given; on a large scale probably you may do it more cheaply rather than less cheaply, so that you may take 600,000*l.* as the cost of the structural works; the cost of lime and labour per 1,000,000 gallons would be 1*l.* 7*s.*

"6791. Mr. Morris was examined here as a witness, and he states with reference to Dr. Clark's process at Plumstead that he took possession of the Plumstead works, where the process had been going on for some years, but he says:—'We did not carry it on; we found the whole thing so 'imperfect and so utterly not to be depended upon that we were obliged to abandon it?'—I would say in answer to that, residing as I did at Shooter's Hill at the time those works were under my charge, and having my attention specially directed to the works, which, as I said, was for a period of seven years, that immediately the works came into the possession of the Kent Company they ceased to soften by that process, and they had no experience with it at all. Mr. Morris did not carry on the softening process for one hour, and therefore it is not correct for him to say that the process was troublesome and that that was the reason he abandoned it.

"6792. He says here that all the leaden cisterns in the district of Plumstead were found to be seriously affected and some of them perfectly destroyed?—That is altogether erroneous. The softened water has far less action upon the lead than the unsoftened water; softened water in fact has no action at all upon lead, and the unsoftened water may have a very slight action. I hold in my hand a report by the late Dr. Clark and by Dr. Smith, who both examined this point very carefully indeed, and this evidence of Dr. Clark's and Dr. Smith's was confirmed by Dr. Stenhouse, by Dr. Lankester, Mr. Dugald Campbell, and some other equally eminent men. What they state is this:—'In order to ascertain 'whether the softened spring water would take up any dangerous quantity of metal from leaden pipes 'or cisterns, we kept this water in contact with lead under precisely the same circumstances as four 'other waters that were not known from experience to have produced upon the consumers any ill effects 'from lead. The contact was continued long enough to permit a considerable action by some of the 'waters. Of those tried, the water that had most action on lead was the filtered water of the river 'Dee, as supplied to the inhabitants of Aberdeen. This water, which is about half the hardness of 'the softened Watford water, and contains about half the saline matter, took up one-tenth of a grain 'of lead per gallon. The next degree of action on lead was found in the *Thames* water; one specimen 'from the West Middlesex Company's water, another from the Lambeth Company's water, derived 'by them from Thames Ditton. There was no perceptible difference in the action of these waters 'upon lead. Each took up about a half of the preceding water, or one-twentieth of a grain per 'gallon. Next in its action on lead was the New River water, which took up two-thirds of what the '*Thames* water took up, or one-thirtieth of a grain per gallon. Tried in precisely the same way as 'the *Dee*, the *Thames*, and the New River waters, the softened Watford waters showed to our tests no 'action on lead, although those tests would have detected in the water much less than one-hundredth 'of a grain per gallon.' I may state practically that I made the works as I said for the supply of Castle Howard with softened water, which have been in operation for a great many years. The water is pumped by a water-wheel for the supply of Castle Howard through a lead pipe, which is laid all the way up from the works, which are something like half a mile distant to the castle, and the cistern itself is lined with lead. It is a very large cistern, perhaps half as large as this room, and there has not been the slightest action either upon the lead pipes or upon the cistern. I was at the works a very short time ago, indeed within the last fortnight, and there is not the slightest action upon the cistern or upon the pipe. The late Earl of Carlisle, who took a great interest in the softening process (and it was through him that it was adopted at Castle Howard) had the water constantly examined when the works were first in operation to see if there was any action upon the lead by the water, so that nobody might be injured at the castle.

"6793. Can you point us to any other place where this system has been applied to any considerable quantity of water?—The works where they are applied I can give you in order. There was the Castle Howard Waterworks, opened in 1858. Then there were the Caterham Waterworks.

"6794. Of the latter I believe you have no experience at present?—They have been in operation ever since 1861, so that we have seven years' experience at Caterham, and we have added within the last 12 months 20 miles of pipe to that district.

"6795. What is the amount which you supply from those works?—We supply Caterham, Godstone, Bletchingley, Nutfield, and Red Hill, a district containing a population of 24,000 persons.

"6796. What quantity are you supplying now?—I do not know the exact quantity at the present time, but only last autumn our pipes were extended into Red Hill, and the works have been in use for the supply of Caterham and Warlingham, and a large district around, ever since 1861. I do not know the exact quantity that we are softening per day. There we have no complaints, and in fact I may say positively that there is no action of that water upon lead. I have a report by Mr. Campbell, who has analysed that water most particularly for its action upon lead, and in it he states:—'The action 'of the softened water was tried in a very severe manner, by exposing it for six days to bright scraped 'lead and likewise to ordinary lead, such as in pipes and cisterns, only in each experiment the surface 'of lead exposed was very much larger indeed than would occur in practice; and on testing the water 'afterwards by the most delicate tests, I was unable to detect a trace of that metal in either case, so 'that this water may be said practically to have no action whatever upon lead, which is not the case 'even with many hard waters, although their action is generally slight, and scarcely what may be 'termed of a deleterious nature.' We have practically supplied it to cisterns in Caterham lined with lead, and we find not the slighest action upon lead by that water.

"6797. But you have made no calculation at all, have you, as to the cost of the works for dealing with the whole water supply of the metropolis, or as to the annual charge for working the system?—I have already said 600,000*l.* would be the cost of the structural works, and that 1*l.* 7*s.* per 1,000,000 gallons would be the cost of softening the water; it might be rather less upon a larger scale.

"6798. Are you sanguine as to the applicability of this system to the whole supply of the metropolis?—Certainly, there is no more reason why water should not be softened than that it should not

Part III. Specialities. — Clark's process for softening hard water.

be filtered, it is easier to soften water; I have had a great deal of experience in filtering water, and a great deal of experience in softening water.

"6799. What do you do with the spent lime?—I have brought some of the deposit to show the Commission. We put in half a ton of lime and we take out in return 3½ tons of whiting, the most beautiful whiting you can possibly imagine. If you put it under a microscope you will perceive that it forms beautiful octohedral crystals perfectly white, and it is well adapted for cleaning metals, making soda-water, and most of the purposes to which ordinary whiting is applied; and if the process is applied in covered reservoirs, and proper care is taken with the whiting, I have no doubt that it will pay a very large proportion of the expense of the softening process itself.

"6799*a*. Have you had it analysed?—Yes, I have had it analysed, and I have the analysis of it here. This (*producing a specimen*) is some whiting taken within the last day or two from the Chiltern Hill works. That is made not with cream of lime, but with lime water.

"6800. Then it has been no source of expense to you, but rather of profit to utilise this product?—I should say that the commercial value of that whiting is about 15*s.* or 16*s.* a ton, and I calculate that the value of the whiting would be equal to the whole cost of softening the water. Here is the analysis of the whiting by Mr. Campbell:—

"'I beg leave to report to you the results of my analysis of a specimen marked "The Caterham " Spring Water Company whiting or precipitated chalk obtained in softening the water by Dr. Clark's " process, December 10th, 1863."

In 100 parts.

Moisture	5·39
Silica	1·09
Oxide of iron, alumina, and phosphoric acid	0·94
Carbonic acid	40·39
Lime	49·40
Magnesia	1·50
Potash	0·49
Soda	0·74
Loss	0·06
	100·00

It was submitted to low redness for some hours, but without any loss of weight, thus showing that it contained no organic matter; but besides this test the gas was passed for hours through proper solutions, to test for organic matters, but without exhibiting the slightest trace. This, together with the high per-centage of carbonic acid which it yields, would render it, I think, especially valuable for the manufacture of gaseous drinks.'

"6801. (*Mr. Prestwich.*) What do you consider to be the value of this whiting?—I consider it worth from 15*s.* to 16*s.* a ton. We have never sold it for so much, because it has never been worth our while to collect it in a proper manner, and put it before the public for sale. At Plumstead we used to sell the whiting for about 7*s.* a ton, but it was used by brickmakers. There was a great demand at Plumstead at the time those works were in operation for chalk to mix with brick earth for making bricks, and we used to get rid of it without drying it, men came and fetched it away at 7*s.* a ton, and that about paid for the lime. For every ton of lime that we put in we took out 3½ tons, or rather more than that, of this whiting. Say that the lime cost us 1*l.* a ton, we sold this for about 7*s.* a ton, three times that is 21*s.*, and there was the additional half a ton, so that we got a little more, in point of fact, for the deposit than we paid for the lime that we put in the water.

"6802. Do you find a sale for it in those other localities where it is applied?—We shall do so. The Chiltern Hills works we have only just opened, and I have no doubt that we shall put up a proper apparatus there to dry the whiting. Whiting should be dry and clean, but it did not matter to the brickmakers whether it was clean or a little dirty; but from inquiries which I have made I am satisfied that properly treated it is worth certainly from 15*s.* to 16*s.* a ton.

"6803. Do the waters of those five localities present any considerable difference?—There is a considerable difference in the qualities of the waters. At Castle Howard the original hardness of the water is 22·1 degrees, and it contains in solid contents per gallon 28·4 grains. The water softens down to 4·3 degrees, and the solid contents in the water are 10·75 grains. At the Caterham works the original hardness of the water is 18·74 degrees, and the solid contents per gallon 26·84 grains. The degrees of hardness when softened are 3·5, and the solid contents 9·84 grains. At the Herbert Hospital, where I should say the water is supplied by the Kent Company from their wells, the original degree of hardness is 22, and the solid contents per gallon 29·48, and when softened it softens down to 7½, and the solid contents per gallon to 15·1. At the Chiltern Hills the original hardness of the water was 13·25, and the solid contents in grains per gallon 21·6, and the water when softened was 2·2 degrees, less than 2¼, and the solid contents per gallon 8·24 grains.

"6804. Then the result in different localities is different?—The result is different with different quality of waters; but when you get what I term the pure chalk water, the water got where the chalk is not covered with London clay, or interfered with by any superficial deposit, the quality of the water from the chalk is almost uniform, whether you take it at Hull, at Great Grimsby, or Bridlington, or Tring, or Watford, or Brighton, or any place where the chalk is not covered by a superficial deposit of London clay or plastic clay, you find the water almost of one uniform quality; sometimes it will contain one or two or three or four, more or less, grains of bicarbonate of lime, but that is the only difference that you find in the quality of the water.

"6805. I am aware that there is no great difference in the quality of the water in different parts of the chalk, but my question was with reference to the result which you obtained after subjecting the water to your process?—After subjecting the water to the process my experience is that where the chalk has not been covered by London clay or by plastic clays, it almost always comes down to from 3½ to 2½ degrees of hardness. In the district south of London, if you take the North Downs, which supply the Croydon and Caterham Works, and so on, it softens down to 3½ degrees; the Chiltern Hills

PART III. SPECIALITIES.

Clark's process for softening hard water.

water softens down to 2¼ degrees; the water taken at Watford or St. Albans, or Redbourn, or Tring, softens from 22 down to 2·6 degrees.

"6806. The Caterham Waterworks are on the lower chalk, are they not?—The fact is that at Caterham we go through something like 130 or 140 feet of gravel or more before we come to the chalk at all; they are on the top of a hill. We are 700 feet above the level of the sea, and we go through the chalk into the upper greensand. I for this purpose call the upper greensand anything lying above the galt clay chalk; probably geologists would call it the upper greensand. A great deal of our supply does come from the upper greensand; half of it comes from the chalk, and a large portion from a borehole that we have made into the upper greensand; we rather avoid going through the gault.

"6825. (*Sir John Thwaites.*) Applying your principle of action at Plumstead to the cost of the application of the system if applied to the metropolis, assuming only 100,000,000 gallons per diem, I find that it will cost, in round figures, 80,000*l.* a year?—That is, I suppose, provided you have nothing in return for your deposit. The actual cost is 600,000*l.* for structural works, and if you take that at four per cent. it would be more like 24,000*l.* If you take 600,000*l.* at 10 per cent. it would be 60,000*l.*, and at five per cent. it would be 30,000*l.* In your calculation you do not take anything into account for the value of the deposited chalk or whiting. The whiting, as I said, at Plumstead, paid for the lime. Without drying it, or giving ourselves any further trouble than letting it go into a sort of receptacle to get somewhat hard, we sold it and it was carted away for brickmaking at 7*s.* per ton. If it was properly dried I am satisfied it would pay the whole expense, including the interest of the capital for constructing the reservoirs."

We are of opinion that the estimate of the cost of softening 1,000,000 gallons of chalk water given by Mr. Homersham in the above evidence is too high, because he employs, unnecessarily as we think, "flare lime" a very expensive kind of quicklime. We estimate the cost of softening 1,000,000 gallons of chalk water having a temporary hardness of 20° to be as follows:—

	s.	*d.*
16 cwt. lime at 1*l.* per ton - - -	16	0
Labour - - - - -	7	0
	23	0

It is impossible to say how much of this expense would be recouped by the sale of whiting of which about 2½ tons would be produced from the above quantity of water. One half of this could be re-burnt and then used for softening another million gallons of water. Whiting is worth about 15*s.* per ton, and, taking into consideration the cost of drying the deposit so as to convert it into marketable whiting, we consider that at least 10*s.* nett could be realized from 2½ tons of the material. This would reduce the cost of softening to 13*s.* per million gallons. As the lowest charge to consumers of water in London is 6*d.* per 1,000 gallons, or 25*l.* per 1,000,000 gallons, the addition for softening would thus only amount to 2 per cent. upon the lowest charge.

Besides witnessing the operation on a large scale at Tring, Canterbury, and Caterham, we have made many trials on a smaller scale. For household purposes the process may be carried out upon the metropolitan water supply as follows:—To soften 700 gallons of the water, supplied by the Chelsea, West Middlesex, Southwark, Grand Junction, Lambeth, New River, or East London Company, slake thoroughly 18 oz. of quicklime (chalk lime is best) in a pailful of water, stir up the milk of lime thus produced, and pour it immediately into a cistern containing at least 50 gallons of the water to be softened, taking care to leave in the pail any heavy sediment that may have settled to the bottom in the few seconds that intervened between the stirring and pouring. Fill the pail again with water and stir and pour as before. The remainder of the 700 gallons of water must then be added, or allowed to run into the cistern from the supply pipe. If the rush of the water thus added does not thoroughly mix the contents of the cistern, this must be accomplished by stirring with a suitable wooden paddle. The water will now appear very milky, owing to the precipitation of the chalk which it previously contained in solution, together with an equal quantity of chalk which is formed from the quicklime added. After standing for three hours, the water will be sufficiently clear to use for washing, but to render it clear enough for drinking at least 12 hours' settlement is required. Before softening, *Thames* water has generally a brownish yellow tint when viewed in a cistern four or five feet deep, this is owing to the presence of coloured organic matter in solution, but after being softened and settled, it displays the blue green tint of pure water, and resembles the *Rhone* as it emerges from the lake of Geneva, the water of which has, in fact, been deprived of its organic colouring matter in a perfectly analogous manner, viz., by agitation with the mud of the glaciers of the *Rhone* and Zermat valleys. The chalk mud precipitated from *Thames* water by milk of lime performs the same functions as the glacier mud of Switzerland in removing coloured organic impurity from water.

The water supplied to London by the Kent Company being considerably harder than the *Thames* and *Lee* water delivered by the other metropolitan companies, 700 gallons of it require 21 oz. of quicklime for the softening operation.

Such were the proportions of lime required to soften those waters at the time our experiments were made, but as their hardness is subject to some variation at different seasons, it is necessary, in order to produce at all times the maximum softness, to vary the proportions of lime in a corresponding degree. A very simple chemical test enables the operator to do this. A solution of nitrate of silver strikes a yellow or brownish yellow colour, when it is added to water which contains even a very minute trace of uncombined lime. During the final running of the water into the cistern as above described, a dessert spoonful of the milky water should be from time to time taken from cistern and put into a white teacup containing a couple of drops of the nitrate of silver solution, if a brownish coloration be produced the slaked lime is still in great excess and more hard water must be admitted, but if the tint produced be a very faint yellow only just visible, the proper proportion of lime to hard water has been attained and the inflow of the latter must be stopped.

PART III. SPECIALITIES.

Clark's process for softening hard water.

We have, in this way, experimented upon the water of the *Thames* as delivered in London by the Grand Junction Company, upon that of the *Lee* as delivered by the New River Company and upon the water from deep wells in the Chalk as supplied to metropolitan consumers by the Kent Water Company. The following analytical table shows the chemical composition of these waters before and after the softening operation :—

COMPOSITION OF METROPOLITAN WATERS BEFORE AND AFTER SOFTENING WITH LIME.

DESCRIPTION.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
THAMES WATER.				
Grand Junction Company's water, 1st June 1870 - - -	23·98	·144	·018	18·8
Ditto after Clark's process, 19th June 1870 - - -	9·26	—	—	8·8
Grand Junction Company's water, 13th July 1870 - - -	23·02	·123	·023	17·6
Ditto after Clark's process, 11th July 1870 - - -	10·00	·080	·022	3·6
Grand Junction Company's water, 10th October 1870 - -	24·72	·102	·014	21·8
Ditto after Clark's process, 12th October 1870 - - -	9·26	·066	·019	3·4
Grand Junction Company's water, 7th November 1870 - -	28·10	·134	·024	20·3
Ditto after Clark's process, 14th November 1870 - - -	11·64	·127	·027	5·0
Grand Junction Company's water, 8th December 1870 - -	28·84	·166	·024	20·6
Ditto after Clark's process, 8th December 1870 - - -	14·10	·118	·021	4·9
Grand Junction Company's water, 16th January 1871 - -	30·24	·177	·042	21·8
Ditto after Clark's process, 16th January 1871 - - -	13·84	·153	·019	5·4
Grand Junction Company's water, 8th February 1871 - -	31·70	·241	·040	21·2
Ditto after Clark's process, 9th February 1871 - - -	16·58	·178	·021	7·0
Grand Junction Company's water, 10th March 1871 - - -	29·56	·145	·016	22·4
Ditto after Clark's process, 10th March 1871 - - -	13·70	·114	·021	5·7
Grand Junction Company's water, 15th April 1871 - - -	26·22	·109	·022	20·6
Ditto after Clark's process, 15th April 1871 - - -	12·18	·080	·013	4·6
Grand Junction Company's water, 9th May 1871 - - -	28·26	·248	·033	20·6
Ditto after Clark's process, 9th May 1871 - - -	14·34	·181	·033	6·7
LEE WATER.				
New River Company's water, 14th February 1871 - - -	30·60	·135	·018	22·4
Ditto after Clark's process, 14th February 1871 - - -	13·76	·100	·011	6·0
WATER FROM DEEP WELLS IN THE CHALK.				
Kent Company's water, 16th January 1871 - - - -	40·42	·045	·014	29·1
Ditto after Clark's process, 16th January 1871 - - -	19·00	·044	·016	7·0

It will be seen from the above table that Clark's method is equally efficacious in softening all three kinds of water, indeed the water of the *Thames* and *Lee* is chiefly Chalk spring water similar to that delivered by the Kent Company but soiled by filthy impurities. Besides softening *Thames* and *Lee* water, however, the treatment with lime also removes from them a considerable proportion of organic impurities, as is seen by an inspection of the columns headed "organic carbon" and "organic nitrogen" in the above table. The results would, in this respect, have been still better, had not the conditions of the experiments upon the *Thames* water necessitated the exposure of the softened water, in a cistern on the roof of a house, to all the impurities of a London atmosphere for 24 hours.

PART III. SPECIALITIES.

Clark's process for softening hard water.

Not only would the application of this simple and inexpensive process to the metropolitan water supply ensure the annual saving of a vast amount of soap now wasted in London, but there are many other British towns in which a corresponding advantage would be secured, as is seen from the following table which exhibits in collateral columns the hardness of the water supplied to 87 British towns and the hardness which would remain after softening by lime:—

NAME OF TOWN.	Hardness. Before softening.	Hardness. After softening.	NAME OF TOWN.	Hardness. Before softening.	Hardness. After softening.
ENGLAND.			ENGLAND—*cont.*		
Banbury	24·1	10·5	Newport, Isle of Wight	29·4	6·0
Basingstoke	25·1	6·1	Northampton	10·3	1·7
Bath	24·2	6·7	Norwich	23·7	4·6
Bedford	40·8	11·5	Nottingham	26·2	11·3
Boston, Lincolnshire	14·4	3·8	Oxford	25·4	6·9
Braintree	14·0	6·3	Plumstead	30·6	13·8
Bridlington, Yorkshire	23·9	5·0	Portsmouth	23·3	7·4
Brighton	21·2	6·4	Ramsgate	26·3	5·9
Bristol	24·5	5·9	Reading	22·8	2·4
Bury St. Edmunds	30·0	7·4	Romford	27·5	5·4
Cambridge	25·1	9·6	Ryde	20·6	7·1
*Canterbury	26·3	4·9	Salisbury	23·6	4·2
*Caterham	21·2	4·4	Sandgate	29·7	8·9
Cheltenham	15·1	6·0	Sevenoaks	19·4	5·7
Colchester	25·7	13·0	Sheerness	16·3	1·4
Coventry	25·1	9·4	Shortlands	23·9	4·6
Crayford	25·7	5·4	Sittingborne	27·5	4·4
Croydon	22·0	9·1	Southampton	24·5	6·1
Deal	23·6	5·4	Stockton-on-Tees	12·3	3·6
Dorchester	23·6	5·3	Stoke Row	25·4	3·5
Dover	23·6	5·0	Stonehouse	19·4	7·6
Durham	25·0	13·4	Streatley	24·2	3·4
Eastbourne	20·9	7·1	Stroud	32·5	6·3
Eton	25·4	9·4	Sudbury, Suffolk	35·5	5·3
Folkestone	32·2	7·7	Swanage	42·8	23·3
Gloucester	19·6	3·6	*Tring	26·3	3·2
Gosport	14·9	7·9	Trowbridge	57·1	29·7
Grantham	23·6	6·5	Tunbridge	22·1	7·0
Great Grimsby	20·6	6·3	Ventnor	26·3	4·6
Guildford	21·5	7·0	Wakefield	13·5	5·8
Haydon Village	45·7	13·4	Watford	28·8	4·6
Hertford	26·0	4·6	Weymouth	20·6	4·4
Hexham	14·6	5·9	Winchester	23·0	6·0
Hull	25·4	5·4	Windsor	25·4	9·4
Ilminster	43·5	17·4	Witham	28·2	7·0
Ipswich	28·2	10·4	Wolverhampton	29·7	10·3
Leamington	27·5	11·6	Worthing	24·7	8·3
Leicester	24·8	9·0	Yeovil	20·9	6·1
Lewes	22·7	4·6			
Lichfield	21·8	9·7	SCOTLAND.		
London	21·8	5·5			
Lynn Regis	16·9	5·9	Granton	27·5	12·6
Maidstone	27·9	7·1	Jedburgh	19·6	6·9
Malpas, Cheshire	34·3	17·7	Linlithgow	18·3	5·9
Middlesborough	12·3	3·6	Berwick-on-Tweed	19·4	7·1

* In these towns the softened water is already actually supplied to consumers.

VI. ON THE IMPROVEMENT OF POTABLE WATER BY FILTRATION.

The improvement of the quality of drinking water by filtration has scarcely received so much attention as it deserves. That the objectionable qualities of impure water can be mitigated we have frequently had occasion to observe. Indeed the purest of natural waters owe their brilliant condition, and comparative freedom from that most objectionable of impurities—organic matter—to the exhaustive natural filtration which they undergo, in their passage from the foul surface of the earth to springs and deep wells. There is a great difference between this perfect process and the filtration through a couple of feet of sand, which is practised by water companies drawing their supplies from polluted rivers; nevertheless evidence is not wanting to show that even this slight treatment is attended with a marked beneficial result; the improvement being due chiefly to the removal of impurities in suspension, but partly also to the oxidation and removal of organic matters in solution.

The following table contains the results of our investigations into the effects of sand filtration, as practised on the large scale by water companies, upon the quality of potable water :—

COMPOSITION OF WATER BEFORE AND AFTER FILTRATION THROUGH SAND.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Liverpool Water Supply. Rivington Pike water before filtration, June 4, 1869 - - -	8·48	**·243**	**·031**	·004	0	·034	**0**	1·53	·1	3·6	3·7	Slightly turbid.
Ditto after filtration, June 4, 1869 -	9·66	**·210**	**·029**	·002	0	·031	**0**	1·53	·3	3·7	4·0	Clear.
The *Wear* above Durham as it entered the Waterworks, Oct. 5, 1870 - - - - -	49·56	**·166**	**·030**	·010	0	·038	**0**	4·60	11·8	10·9	22·2	Slightly turbid.
Ditto after filtration, Oct. 5, 1870 -	54·50	**·082**	**·020**	0	·041	·061	**90**	4·85	11·6	13·4	25·0	Do.
The *Tees* above Middlesborough, as taken into the Stockton and Middlesborough Waterworks, Oct. 6, 1870. - - - - -	17·92	**·183**	**·020**	0	0	·020	**0**	·95	10·4	3·0	13·4	Do.
Ditto after filtration, Oct. 6, 1870 -	17·24	**·180**	**·013**	·001	0	·014	**0**	·90	8·6	3·7	12·3	Clear.
New River Company's water at Stoke Newington, before filtration, Jan. 25, 1873 - -	31·98	**·350**	**·084**	·004	·310	·397	**2,810**	1·70	16·4	6·6	23·0	Turbid.
Ditto after filtration, Jan. 25, 1873	30·16	**·246**	**·042**	0	·810	·352	**2,780**	1·65	16·4	6·6	28·0	Clear.
New River Company's water at New River Head, before filtration, Jan. 27, 1873 - -	31·96	**·330**	**·061**	·004	·339	·403	**3,100**	1·70	16·9	7·3	24·2	Turbid.
Ditto after filtration, Jan. 27, 1873	31·56	**·242**	**·043**	0	·334	·377	**3,020**	1·70	15·9	7·7	23·6	Clear.
The *Thames* at Hampton, at intake of London Water Companies, Jan. 31, 1873 - - - -	32·00	**·321**	**·063**	·001	·317	·381	**2,860**	1·80	15·0	8·3	23·3	Turbid.
Ditto after filtration by Southwark Water Company at Hampton, Jan. 31, 1873 - - - -	31·56	**·273**	**·042**	0	·286	·328	**2,540**	1·80	17·7	5·6	23·3	Very slightly turbid.
Thames water after subsidence and before filtration at Chelsea Company's Works, Thames Ditton, Jan. 31, 1873 - - - -	31·36	**·325**	**·046**	·003	·312	·360	**2,820**	1·75	18·3	5·6	23·9	Turbid.
Ditto after filtration, Jan. 31, 1873	31·10	**·258**	**·032**	0	·307	·339	**2,750**	1·70	17·0	5·7	22·7	Clear.
Thames water after subsidence and before filtration at Lambeth Company's Works, Thames Ditton, Jan. 31, 1873 - - - -	32·96	**·273**	**·067**	·004	·348	·418	**3,190**	1·80	18·5	5·1	23·6	Slightly turbid.
Ditto after filtration, Jan. 31, 1873	32·74	**·258**	**·038**	·001	·361	·400	**3,300**	1·80	17·9	5·7	23·6	Clear.
Thames water after subsidence and before filtration at Grand Junction Company's Works, Feb. 3, 1873 - - - - -	31·42	**·262**	**·042**	·004	·356	·401	**3,270**	1·75	18·9	4·7	23·6	Slightly turbid.
Ditto after filtration, Feb. 3, 1873 -	30·68	**·231**	**·032**	·001	·345	·378	**3,140**	1·70	17·6	5·7	23·3	Clear.
Thames water after subsidence and before filtration at the Southwark Company's Works, Battersea, Feb. 5, 1873 - - - -	31·80	**·239**	**·047**	·005	·348	·399	**3,200**	1·80	18·3	5·3	23·6	Slightly turbid.
Ditto after filtration, Feb. 5, 1873 -	30·90	**·226**	**·035**	·001	·315	·351	**2,840**	1·80	18·6	5·6	24·2	Clear.
Thames water after subsidence and before filtration at the West Middlesex Company's Works, Barnes, Feb. 7, 1873 - - - -	31·22	**·209**	**·071**	·005	·329	·404	**3,010**	1·80	15·4	7·9	23·3	Slightly turbid.
Ditto after filtration, Feb. 7, 1873 -	30·56	**·198**	**·043**	·001	·335	·379	**3,040**	1·80	14·7	7·4	22·1	Clear.
The water of the *Lee* after subsidence and before filtration, at the East London Company's Works, Feb. 1, 1873 - - - -	34·68	**·363**	**·082**	·004	·311	·396	**2,820**	1·95	16·6	7·0	23·6	Turbid.
Ditto after filtration, Feb. 1, 1873 -	84·70	**·305**	**·041**	·001	·314	·356	**2,830**	1·90	17·1	7·1	24·2	Clear.

The foregoing analytical results prove conclusively that sand filtration, as carried out at waterworks, not only clarifies the water by removing suspended impurities, but also diminishes appreciably the proportion of organic matter in solution (organic carbon and organic nitrogen) to an extent dependent upon the thickness of the filtering medium and the rate at which the water passes through that medium.

The Rivington Pike water supplied to Liverpool is thus perceptibly improved, although its total solid impurity and hardness are at the same time slightly increased. This increase is obviously due to solution of the sand and fragments of millstone grit composing the filter beds; but the very slight deterioration thus produced scarcely detracts from the substantial improvement effected. To ascertain the amount and nature of the organic matter thus removed by mere adhesion to the substance of the filter we submitted to analysis two portions of sand, one of which had just been taken

PART III. SPECIALITIES.

Improvement of water by filtration.

from a filter bed, whilst the other consisted of a portion of the same sand which had been just washed and made ready for use again. 100,000 parts of the sand contained:—

	Organic Matter.	Organic Carbon.	Organic Nitrogen.
As removed from filter-bed - - - -	1,523·40	314·160	38·674
After washing - - - - - - - -	804·41	94·921	16·973

It cannot be doubted that a small amount of organic matter undergoes oxidation and destruction during the passage of the water through the sand, but independently of this it appears, from the above analytical numbers, that one ton of dry sand washed after previous use, is capable of removing from water and retaining 16·1 lbs. of peaty matter.

We also submitted to analysis a sample of the filth washed from the sand which had been used by the West Middlesex Water Company, for the filtration of *Thames* water and found it to contain organic and mineral matter in the following proportions:—

Organic Matters - - - - - - - -	22·21
Mineral Matters - - - - - - - -	77·79
	100·00

The best result, as regards the removal of organic matter, recorded in the foregoing table is that obtained by the Durham Waterworks Company. By using unusually deep filters, this company reduced the proportion of organic elements from ·196 part to ·102 part per 100,000 parts of water. The clarification however of this water was not quite satisfactory. Clarification and removal of organic matters from solution depend upon somewhat different conditions of filtration. The slower the rate of filtration the greater will be the clarification and also, *cæteris paribus*, the purification from organic matter; but the latter depends still more upon the frequency of the cleansing of the sand. Amongst the Metropolitan water companies whose supplies require to be filtered, the rate of filtration has varied between wide limits. The New River and West Middlesex companies have long used the slowest rates, and these are the only London Companies which have almost invariably supplied bright, clear, and efficiently filtered water during the last six years. The East London Company also now filters at a very slow rate, and the water it sends out is very rarely turbid; the Grand Junction and Southwark Companies have employed much quicker rates of filtration and the water which they distributed to consumers was consequently occasionally turbid, whilst the Chelsea and Lambeth Companies who passed the greatest volume per hour through a given area of their filter beds, also most frequently delivered turbid water.

The following table records the rate of filtration and the frequency of turbidity in the case of each of the metropolitan water companies:—

THAMES AND LEE WATER. COMPARATIVE EFFICIENCY OF DIFFERENT RATES OF FILTRATION DURING THE YEARS 1868 TO 1873 INCLUSIVE.

NAME OF COMPANY.	Maximum rate of Filtration expressed in inches per hour.	Number of Monthly Occasions when			
		Clear.	Slightly turbid.	Turbid.	Very turbid.
THAMES.					
Chelsea - - - - - - -	7·27	49	15	5	6
West Middlesex - - - - - -	4·71	75	0	0	0
Southwark and Vauxhall - - - - -	6·00	41	24	5	4
Grand Junction - - - - - -	6·97	55	14	7	0
Lambeth - - - - - - -	12·00	42	11	12	10
LEE.					
New River - - - - - - -	5·00	70	4	0	0
East London - - - - - - -	8·85	51	18	3	2

Whenever towns have the misfortune to be supplied with water from rivers polluted by sewage, efficient filtration should always be stringently insisted on. The filter here supplies to the consumer, in some slight degree, the safety which the wire gauze surrounding his lamp affords to the miner. If we consent to the admixture of infected excrements with our drinking water, we ought at least to insist that this protection, such as it is, should not fail for a single hour. We have already explained at page 144 the frightful results which occurred in the East of London, in the cholera epidemic of 1866, from, probably, not more than a single hour's suspension of filtration.

Filtration on the large scale is rarely performed with uniform efficiency, and the water delivered in towns is therefore frequently submitted to domestic filtration through sand and other materials. Filtration upon a small scale may, if carefully performed, be rendered much more efficient, than the waterworks process as at present most frequently conducted; but we are bound to say that domestic filtration, when left to the care of average servants, not only entirely fails to purify the water, but actually often renders it more impure than before. No other result than this can be expected if we consider the work which the domestic filter is called upon to do. A small volume of the filtering material is crammed into the smallest possible space and then for months or even years, water, more or less polluted, is passed through it until the pores become so clogged with filth as to refuse the transmission of more liquid. Long before this happens, however, the accumulation of putrescent organic matter, upon and within the filtering material, furnishes a favourable nest for the development of minute worms and other disgusting organisms, which not unfrequently pervade the filtered water; whilst the proportion of organic matter in the effluent water is often considerably greater than that present before filtration. It cannot be too widely known that, as a rule, domestic filters constructed with sand, or sand and wood charcoal, are nearly useless after the lapse of four months and are positively deleterious after the lapse of a year. In such filters, the material ought to be renewed every four months if the filter be much used.

PART III. SPECIALITIES. Improvement of water by filtration.

Of all materials for domestic filtration with which we have experimented, we find animal charcoal and spongy iron to be the most effective in the removal of organic matter from the water. We are not prepared to say that these are the only materials in actual use which are efficient: they are, however, the only successful ones amongst those with which we have had the opportunity of making satisfactory trials.

Animal charcoal is manufactured by heating bones to redness in closed iron retorts. After cooling, the bone-charcoal is crushed to a granular condition resembling coarse sawdust. As it is important not to clog this charcoal unnecessarily with the suspended matters which are capable of spontaneous subsidence from water, the filter is usually placed in a cistern or other vessel in such a manner as to cause the water to pass upwards through the charcoal.

We have experimented with a domestic filter of this construction through which the whole of the water supplying a family of nine persons passed. Samples of the water before and after filtration were collected from time to time and submitted to analysis with the following results:—

COMPOSITION OF WATER BEFORE AND AFTER FILTRATION THROUGH ANIMAL CHARCOAL.
RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved matters.								
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	**Total Hardness.**
New River Company's water, unfiltered, Nov. 19, 1867.	25·20	**·104**	—	·001	·187	—	**1560**	—	**18·5**
New River Company's water, filtered (filter had been in use six months), Nov. 19, 1867.	24·80	**·075**	—	·001	·176	—	**1450**	—	**18·6**
Grand Junction Company's water, unfiltered, May 15, 1870.	24·60	**·129**	**·023**	0	·188	·211	**1560**	1·60	**19·4**
Grand Junction Company's water, filtered through fresh animal charcoal, May 15, 1870.	19·40	**·029**	**·007**	·018	·194	·212	**1730**	1·60	**15·2**
Grand Junction Company's water unfiltered, May 1, 1874.	25·94	**·164**	**·030**	·002	·062	·094	**320**	1·90	**19·7**
Grand Junction Company's water filtered through animal charcoal,* May 1, 1874.	25·10	**·010**	**·002**	·002	·125	·129	**950**	1·90	**19·1**

* In this case the filter had been in use for eleven months, but *the drinking water only* of the family had passed through it.

These analyses prove that filtration through *fresh* animal charcoal removes not only a large proportion of the organic matter present in water, but also a not inconsiderable amount of mineral saline matters. Thus the Grand Junction Company's water lost in one experiment when the whole water of the household was passed through it, about three fourths of its organic matter and about one fourth of its hardness; whilst in another trial, when the drinking water only of the family was filtered, there remained only one-sixteenth of the original proportion of organic matter even after the charcoal had been in use for eleven months. The removal of mineral constituents, and the consequent softening of the water ceases in about a fortnight, but the withdrawal of organic matter still continues, though to a greatly diminished extent, when the filter is

PART III. SPECIALITIES.

Improvement of water by filtration.

much used, even after the lapse of six months. It is necessary therefore to renew the animal charcoal in these filters after the lapse of not more than six months when they are used for the cleansing of the New River Company's water, and when the whole household water is filtered through them; but if the drinking water only be filtered a much less frequent renewal is required. *Thames* water as supplied by five of the eight London Water Companies is more than twice as polluted as that delivered by the New River Company, and it will therefore be necessary to renew the animal charcoal used in the filtration of such water at least twice as frequently. Indeed we found that myriads of minute worms were developed in the animal charcoal and passed out with the water, when these filters were used for *Thames* water and when the charcoal was not renewed at sufficiently short intervals. The property, which animal charcoal possesses in a high degree, of favouring the growth of the low forms of organic life is a serious drawback to its use as a filtering medium for potable waters.

We have obtained still more remarkable results by the continuous filtration of water through metallic iron, which had been prepared by the reduction of hæmatite ore, at the lowest practicable temperature, by carbonaceous matter. The iron thus obtained, not having been melted as in the ordinary smelting furnace, is in a finely divided and spongy condition and appears to be a very active agent not only in removing organic matter from water but also in materially reducing its hardness and otherwise altering its character when the water is filtered through the spongy material. The following table contains the results of our analyses of many pairs of samples, one of each pair being the water delivered by the Chelsea Company at our laboratory in Victoria Street, Westminster, and the other the same water after filtration through spongy iron which was supplied to us by Mr. Gustav Bischof, Professor of Technical Chemistry in the Andersonian University, Glasgow,—the discoverer of the remarkable properties possessed by spongy iron in reference to the purification of potable water.

COMPOSITION OF THAMES WATER BEFORE AND AFTER FILTRATION THROUGH SPONGY IRON.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Before filtration, Sept. 1, 1873 -	25·54	**·122**	**·015**	0	·152	·167	**1,200**	1·90	15·4	4·9	20·3	Clear.
After filtration, „ -	12·36	**·028**	—	·070	0	—	**260**	1·90	5·4	3·5	8·9	„
Before filtration, Sept. 15, 1873 -	25·28	**·120**	**·013**	0	·166	·179	**1,340**	1·70	14·5	6·7	21·2	„
After filtration, „ -	13·70	**·025**	**·004**	·002	·031	·037	**10**	1·70	7·4	4·6	12·0	„
Before filtration, Oct. 15, 1873 -	25·84	**·150**	**·072**	0	·229	·301	**1,970**	2·10	13·4	6·0	19·4	„
After filtration, „ -	16·60	**·046**	**·015**	·004	0	·018	**0**	2·10	6·7	4·2	10·9	„
Before filtration, Oct. 30, 1873 -	28·90	**·195**	**·074**	0	·123	·197	**910**	2·00	15·4	6·4	21·8	Slightly turbid.
After filtration, „ -	16·86	**·063**	**·035**	·028	0	·058	**0**	2·00	5·5	6·1	11·6	Clear.
Before filtration, Nov. 13, 1873 -	28·22	**·289**	**·059**	0	·240	·299	**2,080**	2·10	13·4	6·3	19·7	Turbid.
After filtration, „ -	19·84	**·070**	**·047**	·060	·103	·199	**1,200**	2·05	6·5	6·1	12·6	„
Before filtration, Nov. 27, 1873 -	31·22	**·230**	**·047**	0	·235	·282	**2,030**	2·20	19·1	5·4	24·5	Clear.
After filtration, „ -	17·12	**·060**	**·008**	·008	0	·015	**0**	2·20	7·1	4·7	11·8	„
Before filtration, Jan. 24, 1874 -	30·76	**·299**	**·045**	·001	·213	·259	**1,820**	2·10	18·0	5·3	23·3	„
After filtration, „ -	21·94	**·120**	**·031**	·018	·047	·093	**300**	2·10	8·5	5·3	13·8	„
Before filtration, Feb. 10, 1874 -	31·32	**·228**	**·037**	·003	·250	·289	**2,200**	2·00	17·8	6·7	24·5	„
After filtration, „ -	21·62	**·097**	**·023**	·008	·051	·081	**260**	2·00	8·5	6·7	15·2	Slightly turbid.
Before filtration, Feb. 24, 1874 -	30·60	**·200**	**·031**	·002	·173	·206	**1,430**	2·10	17·6	5·7	23·3	Clear.
After filtration, „ -	17·98	**·060**	**·015**	·042	·051	·101	**540**	1·95	8·0	4·9	12·9	„
Before filtration, March 18, 1874 -	30·90	**·228**	**·049**	·001	·211	·261	**1,800**	2·00	15·8	6·6	22·4	Slightly turbid.
After filtration, „ -	18·82	**·113**	**·027**	·050	0	·068	**90**	2·00	7·5	5·4	12·9	Contained suspended particles
Before filtration, March 25, 1874 -	30·02	**·175**	**·026**	·001	·186	·213	**1,550**	2·10	16·7	6·6	23·3	Slightly turbid.
After filtration, „ -	16·62	**·077**	**·021**	0	0	·021	**0**	2·10	7·5	5·1	12·6	„
Before filtration, April 9, 1874 -	26·06	**·210**	**·032**	·002	·150	·184	**1,200**	2·00	13·9	6·7	20·6	„
After filtration, „ -	14·76	**·048**	**·009**	·004	0	·012	**0**	2·00	5·7	4·4	10·1	„
Before filtration, April 23, 1874 -	27·04	**·197**	**·028**	·001	·140	·169	**1,090**	2·00	14·3	6·3	20·6	„
After filtration, „ -	15·40	**·073**	**·013**	0	0	·013	**0**	2·00	6·1	4·0	10·1	„
Before filtration, May 7, 1874 -	24·84	**·152**	**·075**	·002	·076	·153	**460**	1·95	13·5	5·4	18·9	Clear.
After filtration, „ -	13·68	**·077**	**·012**	0	0	·012	**0**	1·95	2·3	5·1	17·4	„
Before filtration, May 21, 1874 -	24·10	**·188**	**·034**	·001	·120	·155	**890**	1·95	11·8	7·3	19·1	„
After filtration, „ -	14·84	**·089**	**·020**	·001	0	·021	**0**	1·95	5·3	4·3	9·6	„

Part III. Specialities. — Deterioration of water in pipes.

The numbers in the foregoing table show in every case a most satisfactory reduction in the proportion of organic matter (organic carbon and organic nitrogen), and of hardening constituents, the hardness being often reduced by about fifty per cent., and this after the filter had been in constant action for upwards of eight months. The spongy iron reduces nitrates and nitrites, converting only a small proportion of their nitrogen into ammonia. It thus often destroys all evidence of previous sewage or animal contamination. Under the influence of this material, *Thames* water assumes the chemical character of a deep-well water.

We desire it to be distinctly understood that, although this purification of water polluted by human excrements may reasonably be considered, on theoretical grounds, to be some safeguard against the propagation of epidemic diseases, there is not in the form of actual experience a tittle of trustworthy evidence to support such a view. On the contrary, the investigation of the epidemic of typhoid fever at Lausen, in Switzerland (*see* Appendix No. 4, p. 463), proves that even very efficient filtration does not prevent the propagation of that fever by water. Nothing short of abandonment of the inexpressibly nasty habit of mixing human excrements with our drinking water can confer upon us immunity from the propagation of epidemics through the medium of potable water.

VII.—ON THE DETERIORATION OF POTABLE WATER BY TRANSMISSION THROUGH MAINS AND SERVICE PIPES.

The storage of water and its distribution to communities necessitate its transmission through mains often to considerable distances, and although this can be accomplished without any injury to the quality of the water, if the mains be properly laid, yet it is not unfrequently the cause of serious and prolonged deterioration if certain necessary precautions are not taken. This evil result may be caused either by the action of the water upon the iron mains themselves or by the improper construction of the joints of the mains.

Injury to potable waters by cast-iron mains.—Water, which was originally clear, not unfrequently becomes turbid during its transmission through cast-iron mains. The turbidity is due to the rusting of the iron, and to the diffusion of the rust through the water in the form of minute brownish yellow suspended particles. The suspended matter is not deleterious to health, but it imparts a repulsive appearance to the water, which renders domestic filtration almost indispensable, and frequently leads to a preference, on the part of the consumer, for the dangerous polluted water of shallow wells. Hard waters appear to have but little action upon cast iron, but soft waters generally attack the metal so vigorously, as not only to become very muddy but also, on the one hand, to seriously weaken the pipes by deep corrosion, and, on the other, to block them up by the formation of concretions. In his evidence before the Royal Commission on Water Supply (Report of the Commissioners, Minutes of Evidence, page 129) the late Mr. T. Duncan, Mem. Inst. C.E., the Engineer to the Liverpool Waterworks, states that:—"At Chorley we have had an application at this moment to take "up and relay a number of pipes in the town because they have become choked up in "consequence of corrosion." In his evidence before the same Commission (*Ibid*, page 270), the late Mr. J. Simpson, Mem. Inst. C.E.,—the Engineer to the Lambeth and Chelsea Waterworks, stated, in reference to the soft water supplied to Aberdeen:—"There is this difficulty with it, that it acts very powerfully on the pipes, and I apprehend "that with all that class of water you would have the same thing occur. In Aberdeen "this action goes to the extent of stopping the pipes up."

Fortunately there is a simple method having the sanction of more than 20 years' experience by which this corrosion and its consequences can be prevented. The process, which was invented by Dr. R. Angus Smith, F.R.S., Chief Inspector of Alkali Works, is conducted as follows:—The newly cast main or pipe is taken before oxidation has commenced, it is heated to about 500° Fahrenheit, and is then dipped perpendicularly into a bath containing a hot mixture of pitch, and heavy coal oil maintained at a temperature of about 430° Fahrenheit. After a few minutes the pipe is raised and the surplus composition runs off. A black shining varnish remains on both inside and outside surfaces of the pipe, and even penetrates deeply into the pores of the iron. For the success of this process it is quite essential that the iron should be newly cast and hot. In his evidence before the Royal Commission on Water Supply (*Ibid*, page 114), Mr. Robert Rawlinson, C.B., Mem Inst. C.E., the Chairman of the Rivers Pollution Commission appointed in 1865, says:—

"I have never laid down cast-iron mains without this varnish. Cast-iron mains that have not been varnished, if they have laid five or six months on the ground, become oxidised both inside and outside,

PART III. SPECIALITIES.

Deterioration of water in pipes.

and pure water coming in contact with the commenced oxidation carries it on more rapidly. If you lay a varnished pipe six months on the surface it shall not show one particle of rust, except where it has been scratched or abraided by rubbing the varnish off. In Whitehaven soft water from Lake Ennerdale acted on cast-iron pipes, and in a very few years those of a small diameter (three inch) were all tuberculed, corroded, crusted up, and filled with oxidized matter, but nothing of that kind has ever occurred in any town that I have had to do with. At all events, where we have cut pipes in Lancaster after eight or ten years' service we have found no such blistering as that spoken of at Whitehaven."

Mr. T. Duncan, in his evidence just quoted, further says:—

"I coat all the pipes I lay down now by Dr. Angus Smith's process. I had occasion to cut out a pipe not more than three months ago which had been down for eight years, and I found the coating upon it not quite perfect, but in a great measure so. I consider it a very great advantage to coat all the pipes with that process. I believe it to be the best at present known."

Injury to water by the improper construction of the joints of the mains.—The mode in which the joints are made in mains through which water is conveyed to great distances exercises, for many years after such mains are laid, a very important influence upon the quality of the water transmitted. It is the too frequent practice to calk the joints with tow or gaskin next the interior of the pipe, and then to run the joint with molten lead. We cannot too strongly condemn this practice. It allows, in a long main, the contact of the flowing water with a large quantity of hemp or other similar matter, which imparts to the water a considerable amount of organic matter, unpleasant to the sight and taste. More than this, however, these hemp-stuffed joints afford a nidus for the breeding, development and decay of animalculæ; so that the deterioration of the water is for a year or two very great, and continues to be perceptible even after the lapse of many years.

A remarkable case, illustrating the fouling of water from this cause, occurred to a portion of the supply of the Southwark and Vauxhall Water Company in the year 1869. A new main had been laid from the company's works at Hampton, chiefly for the supply of Putney and Wandsworth with *Thames* water filtered at Hampton. The main was $9\frac{1}{4}$ miles in length, and had about 4,070 joints, each exposing a quantity of tow to the filtered water in its transit. Immediately after the supply to the above-named districts was made through this new main, loud complaints of the quality of the water arose from the consumers; and a memorial from them and from the Board of Works for the Wandsworth district was forwarded to the Board of Trade, complaining that the water was bad and unfit for domestic purposes, and praying that the Board of Trade would be pleased to appoint a competent person to inquire into the matter. In compliance with this memorial, Captain Tyler, R.E., was appointed to hold an inquiry, the result of which showed that the evil complained of was due chiefly, if not entirely, to the deleterious influence of the tow used in packing the joints of the main. At the time the inquiry was made the pollution of the water had to a great extent subsided; nevertheless, analyses of samples of water made for the purpose of the inquiry by one of ourselves still showed a marked accession of organic matter (organic carbon and organic nitrogen) to the water during its passage through the main, as is seen from the following comparison of the composition of the water before and after transit:—

COMPOSITION OF WATER BEFORE AND AFTER PASSAGE THROUGH A MAIN $9\frac{1}{4}$ MILES LONG.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
Southwark Company's filtered water at Hampton Waterworks, Jan. 4, 1871.	33·24	**·199**	**·024**	·001	·374	·399	**3,430**	2·00	18·2	5·7	23·9	Clear.
Southwark Company's filtered water at King's Head Hotel, Wandsworth, Jan. 4, 1871.	33·26	**·216**	**·034**	·001	·376	·411	**3,450**	1·98	18·6	5·3	23·9	Do.

At the same time, a pair of samples was collected and analysed to ascertain whether this deterioration was perceptible in water which passed through another of the company's mains $2\frac{3}{4}$ miles long, which had been laid with tarred yarn joints instead of tow more than twenty years, and which conveyed filtered *Thames* water from their works at Battersea to the borough of Southwark. The results of these analyses indicate that the polluting effect of tarred yarn joints is not wholly eliminated even after twenty years, the proportion of organic matter in the water which had passed through the main being appreciably increased, as is shown by the following tabulated results:—

COMPOSITION OF WATER BEFORE AND AFTER PASSAGE THROUGH A MAIN $2\frac{3}{4}$ MILES LONG.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness			
									Temporary.	Permanent.	Total.	
Southwark Company's filtered water at Battersea Waterworks, Jan. 4, 1871.	33·46	**·176**	**·022**	·001	·392	·415	**3,610**	1·98	18·3	5·6	23·9	Clear.
Southwark Company's filtered water at cab-rank, St. George's Church Borough, Jan. 4, 1871.	33·72	**·193**	**·027**	·001	·385	·413	**3,540**	1·98	18·6	5·3	23·9	Do.

There are two remedies for this evil. The first consists in employing turned and bored joints; and the second, which is, however, only applicable to mains large enough to allow a man to enter them, in carefully pointing the joint inside the pipe with Portland cement. The East London Water Company has recently laid a main, four feet in diameter, upon the last-named plan, from Sunbury to the east of London for the conveyance of filtered *Thames* water. Mr. Charles Greaves, Mem. Inst. C.E., the engineer to the company, gives us the following information concerning the joints of this main. "Every pipe was lime-whited inside from end to end, the whole was "brushed out to clear away any dirt, and the crevices which usually exist between the "end of one pipe and the socket of another when laid, were filled with Portland cement, "so as to produce as even a surface to the running water, and as uniform a line of tube, "as possible. In this way all hemp dust was shut off from the water, and a mineral or "metallic surface produced throughout for the water, and the joints became in many "parts undistinguishable."

In the laying of this main the prevention of the evils already referred to has been entirely successful. The main is $18\frac{3}{4}$ miles in length, and our analyses of samples of filtered *Thames* water, collected before and after transmission, prove conclusively that the quality of the water did not suffer the slightest deterioration.

COMPOSITION OF FILTERED THAMES WATER BEFORE AND AFTER PASSAGE THROUGH A CAST-IRON MAIN $18\frac{3}{4}$ MILES LONG.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
East London Company's filtered water at Sunbury, August 7, 1873.	22·20	**·159**	**·030**	0	·106	·136	**740**	2·10	—	—	18·3	Clear.
East London Company's filtered water at Finsbury Park, August 7, 1873.	22·68	**·157**	**·029**	0	·101	·130	**690**	2·10	—	—	18·3	Do.

It will be seen from the foregoing results that the proportion of organic elements (organic carbon and organic nitrogen) is very slightly smaller than, but practically the same as, that contained in the water before transmission. This result is the more satisfactory inasmuch as the *Thames* water experimented upon contained, for *Thames* water, a remarkably small proportion of organic elements. It may now, therefore, be considered as established, that potable water can be transmitted through mains of great length, if the latter be properly laid, without any appreciable deterioration of quality.

Injury to potable waters by leaden service pipes.—Potable water having been brought without deterioration into the street mains of a town, the problem of conveying it uninjured into the interior of houses still remains to be solved. Notwithstanding the risk

PART III. SPECIALITIES.

Deterioration of water in pipes

of poisonous contamination which is sometimes felt to be incurred by their use, pipes of lead are almost universally employed for house service. Leaden pipes are undoubtedly perfectly safe for most potable waters, but some such waters act violently on lead, and the use of this metal for the conveyance of these waters has therefore commonly been regarded as dangerous.

The conditions which determine the action or non-action of water upon lead have hitherto been involved in much obscurity. The Commissioners appointed in 1851 by Your Majesty's principal Secretary of State, Home Department (Professor Graham, F.R.S., Professor W. A. Miller, M.D., F.R.S., and Dr. A. W. Hofmann, F.R.S.), conclusively established the fact that the presence of dissolved oxygen, and the absence of more than three volumes of carbonic acid in 100 volumes of water, are amongst the conditions necessary for the attack upon lead. We have devoted considerable attention to this subject, and have carefully ascertained the behaviour of very numerous samples of water from the most varied sources, in contact both with bright and clean lead, and with the metal in that tarnished condition which it assumes after exposure for a short time to the atmosphere. The results of our observations prove conclusively that the commonly received opinion that soft waters necessarily act upon lead is erroneous, and that, whilst many samples attack the metal when its surface has been recently scraped, comparatively few have any action upon the tarnished metal. Amongst the waters examined were many which, though soft, rich in dissolved oxygen, and nearly free from carbonic acid, still exerted no action either upon tarnished or bright lead, and it is therefore obvious, that carbonic acid is not the only protecting agent against the action of water upon lead. We have found that waters which act violently upon lead lose this power by contact for a very short time with animal charcoal. This immunity is obtained by the solution of a minute trace of phosphate of lime from the animal charcoal. Most geological strata contain at least traces of phosphate of lime, and thus most waters take into solution a minute but sufficient amount of this substance to protect them from action upon lead. The soft water of the river *Vyrnwy*, an affluent of the *Severn*, is certainly not protected by carbonic acid, but it contains traces of phosphate of lime, and it has not the slightest action even upon bright lead, whilst on the other hand the water of the *Kent*, in Westmoreland, which contains but a very small proportion of carbonic acid and is perfectly free from any trace of phosphate of lime, exerts a violent action upon lead. Our experiments, however, show that a certain minimum proportion of phosphate of lime is necessary to secure this immunity, because we have ascertained that an admixture of an equal volume of the *Vyrnwy* water with that of the *Kent*, although it greatly diminished, did not entirely prevent the action of the latter upon bright lead.

We have already stated, that very few waters act upon tarnished lead,—a condition of the metal which soon occurs after the lead pipes are manufactured,—and we have now to add that the supply of such water as acts even upon the tarnished metal, may be conducted through leaden service pipes without any appreciable risk. Amongst the waters which we have examined, there is not one which acts more powerfully upon lead than that supplied to Glasgow from Loch Katrine, and yet no symptoms of lead poisoning have been observed since its introduction into that city fourteen years ago; although a close watch for such symptoms has no doubt been kept, owing to the warnings which were given, when the bill authorising the use of this water was under the consideration of Parliament. The water supplied to Manchester and Salford also acts violently upon lead, but although a few slight cases of lead poisoning have been observed there during an experience of 23 years, they have been confined, we believe, to persons who have drunk water which had been conveyed through new service pipes. The lead pipes are doubtless acted upon at first, but a protecting film soon coats their inner surfaces and prevents further attack. With the Manchester water we have proved this to be the case. It is thus evident that even waters of this so called dangerous character can be delivered with reasonable safety through leaden services. This conclusion is also affirmed by the following evidence given before the Royal Commission on Water Supply.

Mr. T. Duncan, engineer to the Liverpool Waterworks says (Royal Commission on Water Supply :—Minutes of evidence, page 130):—

"2299. Have you found that the mixed waters, which you now deliver in Liverpool, have any effect upon the lead pipes ?—No, the pipes become coated inside by the earthy salts which are held in suspension.

"2300–1. Have you had any opportunity of examining the effects of the Rivington water by itself upon lead pipes?—I have not, but I believe that after the lead is once coated over, the water has no effect whatever upon it ; after passing water down through a new pipe or a new cistern, the action of the water on the lead ceases in a very short time.

"2302. At first you imagine that the water does act upon the lead ?—At first chemists tell me that it has an action, but I have not found in practice that we have that continued action."

Part III. Specialities.

Professor W. A. Miller, M.D., F.R.S., late Professor of Chemistry in King's College, London, says (Royal Commission on Water Supply. Minutes of evidence, page 439) :—

Deterioration of water in pipes.

"7117. (*Mr. Prestwich.*) Have you had occasion to notice the effects of soft water upon lead, and if so, what has been the conclusion at which you have arrived upon that point?—I have made a great many experiments upon that subject, and my opinion is that there is no doubt that perfectly pure water acts very rapidly upon lead. In the presence of atmospheric air and carbonic acid the action is extremely rapid, but if the water contains certain salts the action may be reduced to nothing whatever. For instance, the Loch Katrine waters act very rapidly upon both tarnished and untarnished lead in its ordinary condition. If you put a piece of lead into a bottle of Loch Katrine water and leave it exposed to the air it will gradually corrode the lead, and almost the whole of it will be converted into white lead, but that same Loch Katrine water, if it is sent through a pipe continuously, though it acts at first, will ultimately coat the inside of the pipe with a vegetable deposit which will entirely protect the pipe and there will be no action whatever upon the lead. The London waters now have always a trifling action upon lead, but it is so trifling that it is perfectly immaterial. The Loch Katrine waters, I believe, have absolutely no action after they have passed through the services for a certain time. They paint, as it were, the inside of the pipes and cisterns with a deposit of vegetable matter which combines with the oxide of lead, and so forms a closely adherent film which entirely prevents all change. I was certainly of opinion at one time, that the Loch Katrine waters would be exceedingly dangerous to introduce into Glasgow, and I reported accordingly, but further examination has convinced me that that was a mistake.

"7118. Have you had any opportunities of observing the same conditions in other towns supplied with soft water?—Yes, I have examined the soft water supply of several towns, at Manchester, at Whitehaven, and particularly at Inverness, and also at Perth and at Aberdeen. I visited all those towns, especially with regard to the supply of soft water for the purpose of ascertaining the effect upon lead, and I did not find that there were any cases of lead poisoning which could be attributed to the use of soft water. At Whitehaven they had a hard water previously in the town, and a few years ago a very soft supply from Ennerdale lake was introduced and there was no injury there. At first when the water was introduced they observed a few cases of injury traceable to the temporary action of the soft water upon the lead pipes, but they become shortly coated in the same way, and now I believe that no case of lead poisoning is ever heard of excepting where a new lead service is put down.

"7119. In your experience, when visiting those various towns, had you occasion to observe the effect produced upon the health of the inhabitants by the introduction of soft water?—I made general inquiries, but I did not ascertain that there was any difference in that respect.

"7120. (*Chairman.*) What time would be necessary for the formation of such a vegetable deposit upon a lead pipe as would prevent the action of the soft water upon the lead?—It depends very much upon the nature of the water, but with those peaty waters from the lakes it appears to take place pretty quickly, in a few weeks or perhaps less.

"7121. (*Mr. Harrison.*) In the meanwhile, would the effect be injurious to health?—I made careful inquiries at that time, but I did not hear of any except half a dozen cases, perhaps, in Manchester, and one or two cases, perhaps, at Whitehaven, but still there was obviously nothing to be feared from that source of supply in its action upon the pipes generally."

Several substitutes for leaden service pipes have been proposed. Wrought iron and block tin pipes have in turn been suggested: the first are liable to discolour the water by rust; the second, though in every other respect admirable, are too expensive for general use. Messrs. Walker, Parker, and Co. had for some years manufactured leaden pipes with a thin internal lining of block tin. On testing these pipes we were surprised to find that water which had stood in them for some hours contained nearly as much lead in solution, as if it had stood for the same length of time in an unlined leaden pipe. Our surprise ceased however when we learnt the method of manufacture, which was as follows:—A hollow leaden cylinder was cast and allowed to cool, then a steel mandril of sufficient size having been introduced into the interior, molten tin was poured into the space between the mandril and the leaden cylinder. The composite cylinder thus obtained was then drawn out into pipes in the usual manner. The pipes so manufactured were supposed to be lined with pure tin; but it is evident that this could not be the case, because the contact of the molten tin with the lead would immediately cause the solution of the latter in the former metal (the alloy of the two metals being much more fusible than either metal separately); and thus the inner cylinder or lining of the pipe instead of being formed of pure tin consisted of an alloy of the two metals from which water readily extracted lead. At our suggestion, Messrs. Walker, Parker, and Co. manufactured some pipes in such a manner as to admit of the insertion of the tin cylinder in the solid instead of the molten form. We have tested pipes made by this improved mode of manufacture and find that they impart no trace of lead to water even after the latter has stood in them for 24 hours. Such composite services are necessarily considerably more expensive than leaden pipes, but they are quite safe and much cheaper than block tin. We believe that their use is, as a rule, unnecessary; but where lead poisoning is feared, this is, on the whole, the best kind of service pipe at present known.

Although the action of water deficient in carbonic acid and phosphoric acid upon lead is of the transitory character just described, it is far otherwise in the case of some polluted shallow well waters. These not only act upon lead violently, but also continuously, and several instances of poisoning from the use of leaden pump pipes for the conveyance of such water have come to our knowledge. In a recent case of this kind which occurred at Wimbledon, the water yielded the following results on analysis:—

Composition of a Shallow Well Water which dissolved Lead.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Wimbledon, well at Oakfield, February 12, 1874.	23·28	**·109**	**·038**	·026	·062	·121	**510**	4·00	1·0	9·4	10·4	Clear and palatable.

No nitrogen existed in this water as nitrites, and consequently this condition, which has sometimes been asserted to favour action upon lead, was not present; but an analysis of the gases dissolved in this water showed that it contained much less carbonic acid than the proportion which the Commissioners of 1851 found necessary to prevent action upon lead. There was also no protection by phosphates, as no trace of these salts could be discovered in the water, 100 cubic inches of it containing the following gases:—

Nitrogen - - - - -	1·3409	cubic inches.
Oxygen - - - - -	·6091	„
Carbonic acid - - - -	1·4531	„
Total - - - -	3·4031	„

When a galvanised iron pipe was substituted for the leaden one the water became charged with zinc, which gradually separated from solution as a white film, floating on the surface. It has lately been observed that the water of Loch Katrine acts in a similar way upon galvanised iron.

VIII.—ON THE CONSTANT AND INTERMITTENT SYSTEMS OF WATER SUPPLY.

Water is delivered to consumers either under constant pressure through a service pipe from the main, or through such service pipes to a house cistern intermittently, from which it is supplied to the kitchen, scullery, or closet, where it is drawn for use. In the one case it is procured as cold and pure as the company can obtain it or can deliver it. In the other case, cold and pure as it may enter the cistern, it gradually acquires the warmth, and absorbs the impurities of the air, in the midst of which it stands all day. The power of water to take up the soluble matter with which it comes in contact, is strikingly illustrated on page 222, in reference to the solid surface of the interior of a principal main through which it was delivered from the filter beds of the Southwark Water Company. Passing over a surface of 1,400 square feet in all of tow-joint, in the course of its passage at the rate of about 1½ mile an hour, along the four-feet main between Hampton and Wandsworth, 10,000,000 gallons of water had had its organic nitrogen raised from ·024 to ·034 in 100,000 parts. How much more may it not be expected that water in a shallow cistern will suffer from the foulness of the air in the midst of which it continually stands? The Right Hon. Lyon Playfair, M.P., C.B., F.R.S., states in answer to question 2722, in the Report of the Royal Commission on the London Water Supply, "I have "had occasion myself to observe in my laboratory, that when I was working with any "particularly nasty vapour, the water of the cistern got to smell offensively of it, and "that, therefore, water is very absorptive and apt to dissolve those vapours readily." "For example," he is asked, "supposing the case of a house where water is retained in "the vessels referred to, and the house is badly ventilated, and gases are generated in "the sewer and discharged, would the water absorb a large amount of that gas?" And he replies, "It would absorb it very readily, and in no case can it be introduced "more deleteriously into the system than in a state of solution."

PART III. SPECIALITIES.

Constant and intermittent systems of supply.

Even in the better class of houses, there is often a special risk of sewer infection to which water stored in cisterns for dietetic purposes is exposed, arising from the position of the standing waste or overflow pipe. It is not uncommon to find this waste pipe altogether untrapped; and even when a trap exists, inasmuch as the companies will not allow, if they know it, the water to rise in the cistern so that an overflow can take place through the waste pipe, the water which seals the waste pipe gradually evaporates, and in the course of two or three months there is again the same free communication between the drain and the interior of the house. In this way the sewer gases have then access to the surface of the water in the cistern—which is thus liable to absorb them—laden, it may be, with the organic germs present in the more or less infected sewage with which town sewers are certain occasionally to be charged.

It is plain from such considerations as these, that the more immediate and direct the transmission of the water from its source, the less likely is it to suffer in its transit. Having obtained a supply of a certain quality the less it is exposed *en route* to any contaminating influence before it reaches the table of the consumer the better. This is the principal argument in favour of the system of constant supply under which the water never leaves the service pipe until it is drawn for consumption. How great is the risk incurred by exposing it to the open air in the midst of a large town, especially in such circumstances as it meets with on the roof of a house, a cottage, or, as in the majority of examples, in or near a water-closet, may be gathered from the evidence of the medical and scientific witnesses before the Royal Commission on Water Supply.

The Right Hon. Lyon Playfair, M.P., C.B., F.R.S., on this point says (*see* Q. 2720):

"The constant system delivers the water always cool and in good condition; it obviates the necessity for a number of cisterns in badly ventilated houses, and especially in the houses of the working classes, and so prevents a great source of the danger of epidemics which arise from the solution of the polluted atmosphere in the water."

"Under that system the water is kept in one or two reservoirs common to a town, and at a place free from impurities, and it is delivered in a state in which it is immediately fit for drinking."

Mr. John Simon, F.R.S., asked (Q. 2745), "Do you consider the system of inter-"mittent water supply to be a good or bad one?" says, "A very bad one." And he adds:

"My opinions about it are substantially those which I expressed in 1849 and 1850, in the following passages of my reports then made. From report of 1849:—'I consider the system of intermittent 'water supply to be radically bad, not only because it is a system of stint in what ought to be lavishly 'bestowed, but also because of the necessity which it creates that large and extensive receptacles 'should be provided, and because of the liability to contamination incurred by water which has to be 'retained often during a considerable period. In inspecting the courts and alleys of the city, one 'constantly sees butts for the reception of water, either public, or in the open yards of the houses, or 'sometimes in their cellars, and these butts, dirty, mouldering, and coverless, receiving soot and all 'other impurities from the air, absorbing stench from the adjacent cesspool, inviting filth from insects, 'vermin, sparrows, cats, and children, their contents often augmented through a rain-water pipe by the 'washings of the roof, and every hour becoming fustier and more offensive. Nothing can be less like 'what water should be than the fluid obtained under such circumstances, and one hardly knows 'whether this arrangement can be considered preferable to the precarious chance of scuffling or 'dawdling at a standcock. It may be doubted, too, whether even in a far better class of houses the 'tenants' water supply can be pronounced good. The cisternage is better, and all arrangements con-'nected with it are generally such as to protect it from the grosser impurities which defile the water-'butts of the poor, but the long retention of water in leaden cisterns impairs its fitness for drinking, 'and the quantity which any modern cistern will contain is very generally insufficient for the legitimate 'requirements of the house during the intervals of supply. Every one who is personally familiar with 'the working of this system of intermittent supply can testify to its inconvenience, and though its 'evils press with immeasurably greater severity on the poor than on the rich, yet the latter are by no 'means without experience on the subject.'

"From report of 1850:—'On the extreme inconvenience which attends the storage of water in 'the poorer habitations of the City, I have already reported to you, and will now only add that 'increased experience has given much confirmation to my view. Their receptacles are generally 'such as contribute to the contamination of water, and are constantly so arranged as to invite 'an admixture of the most varied impurities. In the large proportion of them, which are open 'casks, one sees habitually a film of soot floating on the surface; one sees (if indeed one can see 'so deeply into water which is often turbid and opaque) that filth and rubbish lie at the bottom; 'one sees the interior of the cask itself dirty and mouldering. I now merely glance at this part 'of the subject, because you have already on other occasions allowed me to state my knowledge at

PART III. SPECIALITIES.

Constant and intermittent systems of supply.

'greater length. But there is one evil in particular to which I would beg leave to advert. Those works 'of drainage which are established under your orders depend for their efficiency on a proper supply of 'water; and in every case where you enforce the construction of house drains, you order that those 'drains shall be served efficiently with water. Your wishes on this subject are nominally complied with 'by those on whom your orders are served, but are often virtually evaded by a filthy and ineffectual 'contrivance. The butt or cistern of the house, that on which the inmates depend for their supply of 'fresh and pure drinking water, is placed in immediate contiguity to the privy, so as to reduce the 'requisite length of connecting pipe to the fewest possible number of inches; the application of water 'is not made discretionary on the users of the privy, nor are any of the cheap and common self-acting 'contrivances introduced; but the waste-pipe of the butt or cistern is conducted into the discharge 'pipe of the privy, so that, periodically, with a frequency varying according to the arrangements of 'the water company, the arrears of excrement are removed, so far as the overflow of the water recep- 'tacle may have power to dislodge and propel them. Frequent evidence has been before me of the 'insufficiency of this arrangement, and, in addition to its actual failure (on the reasons of which your 'surveyor can speak more competently than I) there is strong reason to object to its prevalence on 'other grounds. Water, as you probably know, is a very active absorbent of many gaseous materials, 'and the open butts, which are thus placed in immediate contact and communication with privies, must 'rapidly become infected by their foulness. I need not explain to you how injurious an addition this 'is to the other objectionable incidents of water-storage, or how unattractive as a beverage to the poor 'inhabitants of the City must be this vapid, privy-flavoured stuff.'

"2747. Are you now speaking of London as a whole, or merely what is called the City of London?—When I speak of what I conceive to be the evils of the intermittent supply, I speak generally of it whether in the City or in London entirely, or in any other place. I look upon the intermittent supply as one which ought, if possible, to be got rid of."

Dr. William Farr, F.R.S., Superintendent of the Statistical Department of the General Register Office, quoting the Registrar-General's return of July 28, 1866, says (Q. 2866):

"'Whoever will take the trouble to go among the people now suffering in crowded dwellings, will 'see the danger of the waterbutt; poor women are washing the dirty linen of patients with water 'drawn from those vessels, which are often found close to the waterclosets. It would be a source of 'additional safety to London if the tanks and butts were all abolished, and the pipes were filled on the 'system of constant supply. The time has come for this reform.'

He adds:—"We have all along been convinced of the importance of the constant supply, so as to get rid of those evils which are of course most felt in the houses of the poor, where they have not the conveniences that the rich enjoy."

Dr. E. A. Parkes, F.R.S., Professor of Military Hygiene in the Army Medical School at Netley, says on the same subject:

"There are great sanitary advantages in a constant supply, namely, in doing away entirely with the house storage. The house storage entails a great chance of the water being impure, either from the cisterns being allowed to get filthy or from substances finding their way in from the overflow pipes communicating with sewers and drains, and gases forcing their way back through imperfect traps. All these evils the constant supply entirely does away with."

Dr. Parkes proceeds to speak of the disadvantages of the system of constant supply on the score of the wastefulness which he charges on it, and to this we shall refer in the sequel.

Lastly, Dr. H. Letheby, late Medical Officer of Health to the Corporation of the City of London, says:

"As an abstract question, there can be no doubt that the constant supply is a very advantageous thing to the public, chiefly because they would get their water cooler, more grateful, less liable to the pollution to which it is now subject after it is delivered by the water companies, and if the question really turned upon poor people's houses, I should say that the constant supply to them, whether it be in a court by a standpipe, or whether it be in their own yards by a standpipe, would be a boon, the good of which is hardly to be calculated.

"3914. You have visited every part of the City, and as we all know, there are some parts of the City where a very large number of poor are congregated; do you find that the receptacles in which the water is kept are frequently the cause of great mischief to the health of the inhabitants, by standing near to cesspools or privies?—Yes, by standing in the neighbourhood of privies, in dirty cellars, and so on, no doubt it becomes much polluted.

"3915. I suppose that the water itself would take up any gas that might be generated in that locality?—It would do so. It does not take it up anything like so fast as soft water. Soft water is very prone to the absorption of gases, almost immediately, but hard water is not, from the circumstance that hard water contains such a large quantity already dissolved in it that it shuts out, as it were, the other foul gases. As I say, in the poor people's houses it would be an incalculable benefit: but with regard to the better class of houses it is a matter open to doubt as to whether or not a constant supply should be granted without a cistern of some kind or other to provide against what must happen more or less frequently in the derangement of the mains, and the shutting off of the water, or something of that sort, and it would necessitate a complete alteration in the present mode in which the fittings of the houses are managed."

PART III. SPECIALITIES.

Constant and intermittent systems of supply.

In their report to Your Majesty, the Commissioners before whom this evidence was given, further quote the opinion, in condemnation of the intermittent method of supply, given by the Board of Health in their report so long ago as 1850.

"That the practice of intermittent distribution occasions in the case of the better description of houses the retention of the water in cisterns and butts, and in that of the poorer classes in tubs, pitchers, and such other vessels as can be obtained; and as a consequence of such retention the water imbibes soot and dirt and absorbs the polluted air of the town and of the offensively close crowded and unhealthy localities, and rooms in which the poor reside."

To this body of evidence and of authority on the risks connected with that storage of drinking water on the premises of the consumer, which is a necessary part of the intermittent method of supply, we add, as worthy of consideration, that in the Metropolitan Water Act of 1852, the Legislature, in view of the danger of contamination by storage within reach of a soot and vapour-laden atmosphere, has forbidden the metropolitan water companies to use open storage reservoirs for filtered water within five miles of St. Paul's. Here is a provision by law against a risk incurred by exposing (with an average depth of 11 feet of water in the reservoir) 70 gallons to one square foot of contact with the open air of any London neighbourhood. What are we to think of the consistency of this with the negligence which still gives legislative sanction to a system of supply under which the drinking water of the metropolis is inevitably exposed for hours before its use at the rate (with an average depth of 12 inches in the water) of not more than seven gallons per square foot of surface, to the foul and dangerous vapours which necessarily exist in the midst of every densely populated district. What must the condition of the water in such a cistern be, placed, as in the case of the poorer class of houses it generally is, as an immediate link between the neighbouring sewer and the watercloset, over which, in the back yard, it commonly stands. Even in the better class of houses, some danger of infection must be similarly incurred from exhalations, if not from sewers, at any rate from dwelling rooms and sleeping rooms, which rise towards the attics where in such houses the water cistern generally stands. Surely a carefulness which has forbidden by law the use of open storage reservoirs for London drinking water within five miles of Charing Cross, ought, before this, to have legislated against a system of supply under which the drinking water of the metropolis is necessarily exposed gallon by gallon in small storage reservoirs house by house to far fouler and more infectious exhalations than it is possible to imagine in the open air of any London suburb.

Happily there are no considerable difficulties in the way of the adoption of the better system; and the objections which have been made to it are for the most part confined to those cases in which the intermittent method of supply already exists, and where the house pipes and fittings, adapted to the pressure to which they are subjected from only a house cistern, might, it has been feared, prove insufficient to bear the strain of the greater constant pressure from the probably higher level of the service reservoir of a town supply. The cost of refitting a house with stronger pipes and fittings if they are required when the intermittent is abandoned for the constant system, would no doubt be considerable; but when a town is on the eve of its first general supply and a choice between the two methods has for the first time to be made, the greater extent of cisternage required under the intermittent system will generally make the house fittings for that system on the whole more costly than those which have to be provided under the rival method, notwithstanding the greater strength of pipe and fittings which the latter, it is alleged, requires.

Mr. Hawksley, Past Pres. Inst. C.E., asked by the Royal Commissioners on the London water supply his opinion of the two systems, replied (to Q. 2558), "The con-" "stant supply is much more beneficial than the intermittent supply *per se*, the difficulty" "is in changing from the one to the other."

Mr. James Muir, M. Inst. C.E., the engineer to the New River Company, in answer to a similar question by Sir John Thwaites, said:—

(4055.) In London there are no doubt great difficulties. In a town to be supplied for the first time I think everyone would admit the desirability of a constant supply, care being taken to have everything in reference to the fittings of the houses of a proper description, and means being taken to have such supervision as would keep everything in order. The difficulty in London will arise from the amount of change required to make old premises ready to receive the constant supply."

The cost of this change which Mr. Muir alleges to be required would, he says:—

(4069) "chiefly consist in laying down new lead pipes for those at present in use. Many of the lead pipes in London are very old and very feeble, and the least increase of pressure would cause them to give way. The fittings are also of a very imperfect kind. Under the intermittent system those pipes

PART III. SPECIALITIES. — Constant and intermittent systems of supply.

are all saved from the night pressure. The pressure of water at night, when no one is drawing from the mains, is very much greater than the pressure during the day, and as houses are now served, those lead pipes are only subjected to pressure during the day and are saved therefore from the higher pressure of the night. Under the constant system they would come under that higher pressure, and in the great majority of cases they would give way."

On these allegations, however, of the need of greater strength of service pipes where the constant system is adopted, we have to remark that the maximum of strain upon the strength of a service pipe is necessarily greater in the case of the intermittent system of supply than when a constant supply and constant pressure are the rule. The maximum strain which comes upon a pipe occurs, not when a constant pressure is invariable, but when its variations are excessive and abrupt. Where the constant system obtains, a screw-down tap upon the pipe is usually employed, and this gradually draws or shuts off the water in it. But where the supply is from a house cistern, the common stopcock is generally used, which shuts off the flow with extreme abruptness. It is plain that the sudden stoppage of a full flow of water downwards which is thus produced, must act with percussive violence in straining the pipe in which the flow takes place. The same liability to give way under sudden pressure occurs when the street turncock regulating an intermittent town supply lets the water into the house cistern: the water rushes up the pipe, and as long as it is merely driving the air before it through the ball-cock in the cistern, it passes with facility; but when the water reaches the same opening, the speed receives an abrupt check, which acts with sudden violence upon the pipe; and so much the greater strength is thus required than that which would be sufficient to resist a constant and invariable pressure.

Another allegation in disparagement of the constant method of supply, which is otherwise unanimously preferred, concerns the waste under the two systems respectively. On this point, however, Mr. Hawksley, points out what our own inquiries amply verify, that a perfect remedy for waste exists in active and energetic inspection. He says:

"A constant supply, with proper regulation and proper supervision, takes less water than an uncontrolled intermittent supply; but then you must have that regulation and supervision, and if the public will not submit to the expense and will not submit to the inspection, nothing can be done for them; but if the Legislature choose to empower the companies to make it compulsory upon the landlords, through some other authority, to put everything in a proper state of repair, and keep things in that proper state of repair, there is no reason at all why the constant supply should not be granted to-morrow."

It is the need of increased power of supervision, even to the extent of making it a matter of police,—a degree of power which it might not be expedient to confer on private companies,—which alone apparently hindered Your Majesty's Commissioners from recommending that the constant supply of water be made compulsory in London. They say:—

"We agree with the conclusions arrived at on previous public inquiries, that earnest " and prompt efforts ought to be made to introduce the constant service system to the " farthest extent possible, in the supply of the metropolis. The provisions of the Act of " 1852 in this respect appear to have been ineffectual, and we are not unimpressed with " the difficulties of the case, which we fear would be beyond the power of being success- " fully dealt with by the present companies. The legal powers they now possess would " not be sufficient to enable them to control the house arrangements, or to check the " enormous waste that would arise on the introduction of the new system. And we do " not see our way to recommending that they should be invested with new powers " which, if they are to be effectual, must be of too inquisitorial a character to allow of " their exercise in private hands."

On the whole the several alleged difficulties in the way of the constant supply, which is unreservedly preferred, are stated as follows in the report of the Commissioners:—

1. In the first place it is alleged that there is great leakage from the fittings in the houses, producing a waste of water which, though it can be met when it lasts only an hour or two a day, yet if allowed to go on for the whole 24 hours would amount to such an enormous quantity that the supply could not be kept up with the present means or at the present cost. This leakage always takes place to some extent even in the better class of houses, by inattention to the state of ball-cocks, watercloset apparatus, &c.; but it is in the poorer districts, where, through carelessness and dishonesty, it is impossible to keep the fittings in an effective condition, that the chief difficulties arise.

2. It is also alleged that, assuming all the fittings to be in good order, their strength, particularly that of the lead pipe, though suitable for the small pressure of the inter-

mittent supply, would not be sufficient for the greater strain necessarily induced by constant service at high pressure.

Constant and intermittent systems of supply.

3. The habits of domestic establishments lead the inmates to draw their larger supplies of water at one particular time of the day. During the morning hours the consumption is double the average. Now on the intermittent system this variable draught comes upon the store cisterns, and does not interfere with the power of distributing the quantity pumped uniformly over the day; but under the constant system it would come directly on the mains, and the increased draught at a particular time would lead to much inconvenience. For such of the companies as have no store reservoirs, but are obliged to supply entirely by pumping, the increased draught would require a much greater pumping power to be in readiness, a large portion of it, however, being used only for a short time in the day.

4. This greater draught at a particular time, when it occurred at low levels, would further have the effect of reducing the pressure in the mains and services to such an extent as to render them incapable of supplying at the same time the higher parts of the districts. The leakage also would powerfully contribute to this effect, and thus it would become necessary generally to increase the dimensions of the mains and service pipes throughout the entire metropolis. It is a part of the present system, enforced on the companies by Act of Parliament, to supply the better class of houses up to their highest floors; and as many of these houses are of great height, and stand on elevated ground, a great pressure is required for this purpose. Under the intermittent system this can easily be arranged, but under the constant system these high services would be entirely at the mercy of the draught going on at lower levels. And even in the same building no water could be had on an upper story while lower ones were drawing.

5. In case of any repairs or alterations to the mains, or of any accident whatever interrupting the flow in them (instances of which are said to be of almost daily occurrence in some parts of London), the whole district served by those mains must, under the constant system, be deprived of water; whereas under the intermittent plan the house cisterns keep up the supply. For this reason it is urged that it is advisable to retain the cisterns, even where constant supply is given, whereby one of the advantages alleged in its favour is done away with.

We submit that a sufficient answer to these anticipated difficulties exists in the fact that the constant system is already adopted in a very large number of the principal towns of England and Scotland, and that, including London in the list of towns where the intermittent method of supply exists, the actual consumption of water per family is not upon the whole considerably greater under the constant method. Under good management indeed, even in towns where the difficulties of distribution owing to variations of level are very considerable, a comparatively limited supply, though under constant pressure throughout the house fittings, proves to be sufficient; whereas in towns where supervision is less perfect, there is a larger waste notwithstanding that the supply is intermittent.

In the following table 72 towns supplied upon the constant method, and 24 on the intermittent system are compared; and it appears that although there is a much larger draught in the former series for the supply of factories as well as houses, yet, excluding Liverpool, the volume supplied to which has not been furnished to us, the quantity for the daily use per family under the former system is not more than 135 gallons upon the average, while it is as much as 127 gallons upon the average per house where the intermittent method is adopted in 23 provincial towns, and upwards of 200 gallons per house in the case of the metropolis, which is also supplied on the intermittent system.

Part III.
Specialities.

Constant and intermittent systems of supply.

Towns supplied on the Constant System.

Name.	No. of Houses.	Factories.	Gallons supplied daily.	
			Total.	Per House.
Aberdeen	5,800	100	2,500,000	430
Accrington	3,461	—	270,000	80
Ashton-under-Lyne	10,000	65	600,000	60
Bedford	3,328	35	250,000	75
Birmingham	68,532	—	7,500,000	110
Blackburn	18,000	270	1,350,000	75
Bolton	20,000	396	2,125,000	106
Bradford	28,000	800	6,500,000	230
Bristol	35,000?	—	3,500,000	100?
Burnley	7,100	200	800,000	112
Bury	18,724	547	1,500,000	80
Cambridge	5,680	150	385,000	68
Canterbury	1,372	41	110,000	80
Cheltenham	5,000	—	350,000	70
Chorley	3,000	50	450,000	150
Chester	6,000	—	1,250,000	200
Chesterfield	5,000	50	700,000	140
Darlington	4,000	—	1,000,000	250
Dewsbury	4,000	130	750,000	187
Dukinfield	3,000	10	90,000	30
Dumbarton	700	16	250,000	350
Dundee	6,379	136	3,000,000	470
Durham	3,700	80	480,000	130
Eastbourne	1,600	—	500,000	300
Epsom	930	—	170,000	180
Glasgow	100,000	—	20,000,000	200
Greenock	11,344	77	3,060,000	269
Halifax	13,000	240	3,700,000	280
Hartlepool	4,000	—	850,000	210
Hamilton	1,100	—	225,000	200
Heckmondwike	1,800	60	250,000	139
Heywood	5,200	30	100,000	20
Inverness	2,000	—	414,000	207
Kendal	2,300	100	300,000	130
Kilmarnock	5,000	38	700,000	140
Leeds	56,908	2,500	6,000,000	107
Leominster	700	—	100,000	142
Lincoln	5,079	—	260,000	52
Liverpool	99,284	775	—	—
Macclesfield	8,637	56	1,000,000	120
Margate	2,200	—	500,000	226
Manchester	137,250	9,416	14,500,000	105
Middlesboro	7,000	80	5,000,000	700
Monks Coppenhall	2,809	—	70,000	25
Montrose	1,000	24	300,000	300
Morley	1,200	15	100,000	80
Newark	2,400	—	500,000	208
Newcastle-on-Tyne	43,153	—	4,700,000	110
Oldham	22,000	400	2,750,000	125
Oswaldtwistle	800	5	50,000	60
Ormskirk	1,050	—	200,000	200
Over Darwen	3,861	32	800,000	207
Paisley	10,460	110	2,700,000	258
Peebles	564	—	150,000	266
Perth	47,000	—	414,000	80
Poole	650	—	50,000	75
Preston	18,944	—	2,305,500	124
Rochdale	13,000	—	750,000	60
Salford	15,000	—	1,100,000	72
Stirling	1,543	20	500,000	320
Shipley	1,963	25	300,000	150
Stockport	13,500	370	1,150,000	83
Stockton-on-Tees	5,600	50	1,000,000	170
Southport	3,600	—	600,000	166
South Stockton	1,300	—	168,000	130
Tranmere	2,350	14	353,000	150
Tynemouth	8,000	—	530,000	66
Wakefield	5,650	102	1,000,000	180
Wigan	8,000	—	700,000	66
Wolverhampton	13,729	150	1,110,000	80
York	10,500	162	1,440,000	137
Wallasey	2,498	10	500,000	200
Total (omitting Liverpool, *see* page 231)	889,028	16,087	119,629,500	134·4

PART III. SPECIALITIES.

Constant and intermittent systems of supply.

TOWNS SUPPLIED ON THE INTERMITTENT SYSTEM.

Name.	No. of Houses.	Factories.	Gallons supplied daily.	
			Total.	Per House.
Bacup	1,753	—	96,000	54
Barnet	861	—	144,000	167
Bath	4,650	—	402,000	86
Batley	3,000	100	400,000	130
Beaumaris	380	—	65,000	170
Berwick	1,150	7	380,000	330
Birkenhead	7,600	20	1,860,000	244
Cheltenham	4,000	—	300,000	75
Edinburgh	41,686	360	5,000,000	120
Exeter	7,000	—	862,000	123
Folkestone	1,890	—	550,000	289
Gravesend	3,000	—	225,000	75
Huddersfield	8,500	600	400,000	49
Monmouth	460	—	100,000	217
Oxford	3,500	—	1,200,000	340
St. Helens	6,138	70	660,000	107
Shrewsbury	4,800?	—	500,000	105
Staffordshire Waterworks	28,000	210	3,000,000	107
Skipton	1,160	—	150,000	125
Tunbridge Wells	2,036	—	200,000	100
Torquay	2,000	—	600,000	300
Winchester	2,250	—	250,000	110
Worthing	1,600?	—	120,000	75
Total	137,414	1,367	17,464,000	127
London:				
West Middlesex	44,690	—	9,644,000	215
Grand Junction	34,243	140	12,290,271	358
Southwark	79,000	600	17,500,000	221
Lambeth	48,500	1,500	12,500,000	258
Chelsea	28,270	—	10,000,000	350
Kent	42,000	200	9,000,000	214
New River	120,242	900	21,860,000	182
East London	102,637	2,000	21,000,000	204
Total	636,996	6,707	131,258,271	204

Examples are not wanting, as we have just intimated, showing that the difference is one of administration, and not inherent in the method. Thus 5,079 houses in Lincoln, a city which being set upon the side and summit of a hill presents great variations of level, are sufficiently supplied with 260,000 gallons daily on the constant method, the inspector having power not only to examine all the fittings throughout his district, but to repair them after due notice, at the expense of the tenant; while at Oxford, half the population of the city, corresponding to about 5,500 houses, use 1,200,000 gallons daily, although the whole supply is shut off during the night time. This is a quantity corresponding to nearly five times the supply per house that is found sufficient at Lincoln.

Mr. Hawksley, questioned upon what has been generally assumed to be the inevitably greater waste under the constant system of supply, related to Your Majesty's Commissioners on the Metropolitan Water Supply, another example corresponding to the contrast between Lincoln and Oxford.

2561. (*Sir J. Thwaites.*) Even under proper regulations is it not your opinion that there would be a waste of water with the constant as compared with the intermittent system?—No; that I can give the fullest answer to. On the contrary, where the constant supply is well managed the waste of water is less than upon the intermittent system. I can give you a very remarkable instance, one among a considerable number, but it is so remarkable in itself that it is worth mentioning to you. A few years ago the City of Norwich Waterworks were transferred from a very old-fashioned company to a new one, by whom the system of constant supply had been accepted under an Act of Parliament, that is to say, it was imposed upon them. They tried to work it upon the old principle, and the consequence was that in a very short time the delivery amounted to 40 gallons per head per diem, and that amount of consumption exhausted all their pumping power. They could do no more, and the consequence was that they were obliged to shut off the water at night, and the company fell into a state of ruin; all their efforts were insufficient to check the waste, and the work was very nearly being closed. I was called in amongst other persons, and they obtained a very good manager,

PART III. SPECIALITIES.

Constant and intermittent systems of supply.

and under my advice they applied for an additional Act of Parliament to enable them to correct the fittings. With some difficulty—for the bill was opposed, as is almost always the case, for there is great jealousy about internal inspection, and so on—the bill was carried, and it was put into operation, and now and for many years past, although the constant supply has been unfailingly in use, the water is never shut off, and the consumption has descended to 15 gallons per head per diem as compared with 40 previously.

It is plain that the remedy for waste which is thus indicated is not only adequate in itself but is greatly to be preferred to any such mechanical contrivances as have been recommended for the purpose, which tend to limit the quantity of the supply as well as the liability to waste. Mr. Charles Greaves, C.E., engineer to the East London Water Company, who in answer to the question of the Commissioners (Q. 515-66) declares himself to be upon the whole an advocate for the constant method of supply, qualifies this admission by adding:

"Of course claiming to have the privilege of putting a reduced orifice somewhere on the pipe so as to prevent inordinate waste, I find no difficuly in giving a constant supply in my district. I have now 25,000 houses out of 92,000 which are continuously supplied from year's end to year's end on the constant supply system.

"Will you explain what you mean by a reduced orifice?—Somewhere in the pipe between the pipe which belongs to the company and the cistern which belongs to the consumer, a disc with a small hole in it is inserted so as to prevent the water being drawn beyond a certain speed. That limits the draught of the system, and it saves us from inordinate loss which we know we should suffer, because notwithstanding that we have 25,000 tenants supplied in this way we cannot leave them unguarded, we are obliged to visit and inspect continuously over and over again.

"That limits the size of the supply pipe to the cistern?—Yes.

"What class of houses do you supply in this way?—We supply without distinction now.

"But does that include any of the poorer class of houses?—Yes; in fact seven-eighths, perhaps nine-tenths, of all the houses that we are laying on now we are laying on upon the constant system.

"And all upon that principle?—Yes, all upon that principle.

"With regard to the poor people your experience would be, I presume, that it is of vital consequence to them to have a good supply of water?—Yes, it is. I advocate giving a complete and good supply to the poor on every possible ground, moral, social, and physical, with reference to the ordinary comforts of life. I think the absence of a proper supply of water to the poor is one of the grievances of the day.

"When you do adopt that system and apply a contracted disc for the water to pass through you have of course to assume that you will allow them to have a certain supply in 24 hours?—Yes, certainly.

"What do you assume in that case?—I assume, say 180 gallons in 24 hours per house, that is the maximum, that is to say, if they have no ball-cock, nor any check upon it, and they were to rob me to the utmost they could only take to the extent of 180 gallons a day. A pint a minute is 180 gallons a day."

It seems obvious that a method of supply limited to the rate of one pint per minute would be a most injurious check upon the beneficial use of water, and that whether or not it might prove effectual against the waste to prevent which it is intended, it is on sanitary grounds extremely undesirable that any remedy of such a kind be put into operation. These small orifices, calculated at constant issue to provide the house with an adequate daily quantity of water, would not only rapidly become smaller by incrustation, but even if kept always fully open, they would necessitate the storage of the water against the daily occasions when it is used in quantity, and thus reproduce all the evils of the intermittent method which the constant system is calculated to correct. The true remedy for waste is adequate inspection on the part of the water company's officers.

We conclude with the following quotation from the report of Your Majesty's Commissioners on Water Supply:

"This constant service system is now adopted in many country towns, and it has obviously many advantages over the other plan. It allows the water to be drawn always fresh from the main, free from the pollution often acquired in dirty receptacles (an evil of great magnitude among the poorer classes), and it ensures supplies at all times independent of cistern storage. It is also a great advantage to have the mains always charged in case of fire, without waiting for the intervention of the turncock, as on the intermittent plan."

"Independently, however, of the advantages to the consumers, the constant service plan would seem to be so much more simple and easy to work than the intermittent (which requires much complexity of construction, and trouble of management), that one would think the companies would have adopted it for their own sakes, were there not good reasons to the contrary."

The reasons to the contrary, which the Commissioners proceed to give, have been quoted above. They are we believe sufficiently answered by the experience which we have now described.

PART IV.

Descriptive.

Part IV. Descriptive. The Metropolitan water supply.

This last division of our report is devoted to a description of (1) the present condition of the waters supplied to the metropolis, and (2) to the cities, towns, villages, and (3) to the rural districts of Great Britain which we have visited, or from which we have received official information. To have made this part of the report complete and exhaustive would have required much more time than we could have devoted to it without contravening our instructions, which direct us to include this subject, "provided such extension of "your inquiry will not materially impede or delay the completion of the primary object "of the Commission." There are at least **16,000** cities, towns, villages, and hamlets England, Scotland, and Wales, but the number we have visited or from which we, after repeated applications, have received information is only **610**. Of these inhabited places, however, every variety is copiously represented, and we therefore believe ourselves entitled to conclude that the results of this comparatively limited inquiry fairly express the condition of the water-supply of Great Britain.

We have also (4) inspected the water supplies of Your Majesty's residences at Windsor, Osborne, and Balmoral; and those of Sandringham and Abergeldie—the residences of His Royal Highness the Prince of Wales. Samples of these waters have been submitted to analysis in our laboratory, and the results of the investigations will be found in the fourth section of this part of our report.

Section I.

THE WATER SUPPLY OF THE METROPOLIS.

Out of every thousand inhabitants now existing upon this planet it is believed that four live in London and its suburbs: we need not therefore apologise for giving the first place to the consideration of the quality and quantity, present and prospective, of the water supplied to this vast aggregation of humanity.

Quality.—The quality of the waters supplied to the metropolis has been the subject of repeated and elaborate investigation. As early as the year 1828 a Royal Commission, consisting of Mr. Telford, civil engineer, Dr. Brande, F.R.S., professor of chemistry in the Royal Institution, and Dr. Roget, secretary of the Royal Society, was appointed to inquire into "the description, the quality, and the salubrity of the water" supplied to the metropolis. The Commissioners made careful examinations and analyses and arrived at the following general conclusions: "Taking into consideration the various "circumstances to which we have now adverted, together with the details of evidence "by which they are proved and illustrated, and also the facts derived from our own "observation and experience; we are of opinion, that the present state of the supply of "Water to the Metropolis is susceptible of, and requires, improvement; that many of the "complaints respecting the quality of the Water are well founded, and that it ought to "be derived from other sources than those now resorted to, and guarded by such "restrictions as shall at all times ensure its cleanliness and purity."

"To obtain an effectual supply of clear Water, free from insects and all suspended "matters, we have taken into consideration various plans for filtering the river water "through beds of sand and other materials; and considering this, on many accounts, "as a very important object, we are glad to find that it is perfectly possible to filter "the whole supply, and this within such limits in point of expense as that no serious "objection can be urged against the plan on that score, and with such rapidity as "not to interfere with the regularity of service.

"It must, however, be recollected, that only insects and suspended impurities are "separated by filtration, and that whatever substances may be employed in the construc- "tion of filtering beds, the purity of the Water as dependant upon matters held in a "state of solution, cannot be improved by any practicable modification of the process. If,

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

" therefore, it can be shown that water taken from the parts of the river whence the " companies draw their supplies either is, or is likely to be contaminated by substances " dissolved, or chemically combined, it will follow that the most perfect system of " filtering can effect only a partial purification."

After the issue of this report the companies set themselves earnestly to work to improve the quality of the water by filtration, with the view of obviating the necessity of going to other and purer sources. The first filter on a working scale was constructed and brought into use by the Chelsea Company in the year 1829. The suspended impurities were thus to a great extent removed, and the quality of the water thereby materially improved. But it was soon found, as predicted by the Commissioners, that another class of noxious impurities, viz., organic matters in solution, were not much affected by filtration; and in rainy seasons, when the rivers received the flushings of sewers, streets, and cesspools, the proportion of these soluble matters rose to such an extent as again to cause loud complaints. The evil was also continually increasing with the rapid growth of the metropolis, and with the improved sanitary arrangements by which the excrements of the population were more completely washed into the rivers. It was not, however, until the year 1848 that any attempt was made to remedy a condition of things which had become intolerable. The initiative was taken by the Lambeth Company, who, in that year, obtained an Act authorising them to remove their intake from Lambeth to Thames Ditton, near Kingston, and above Teddington lock, and consequently beyond the reach of the London sewage.

In that and the following year, London was severely visited, for the second time, by epidemic cholera, and the agency of drinking water in spreading the disease forced itself upon the attention of the observant portion of the medical profession. Dr. Snow, in August 1849, formally enunciated the doctrine that the admixture of the excrements of cholera patients with drinking water is the chief mode by which cholera is propagated. Received at first with incredulity, this doctrine was supported, even at that time, by numerous facts, and it soon caused renewed attention to be directed to the quality of the water then being supplied to the metropolis. In May 1850, the General Board of Health (consisting of the following members,—the Earl of Carlisle, Lord Ashley, Edwin Chadwick, Esq., and Dr. T. Southwood Smith), issued a report, in which they stated relatively to the quality of the water of the river *Thames*:—

" 1. That, for domestic use, it is inferior to the average quality of waters supplied to " towns:

" 2. That its inferiority as a supply for domestic use arises chiefly from an excess of " hardness:

" 3. That even when taken above the reach of pollution from the sewers of the " metropolis, it contains an excess, varying with the season, of animal and vegetable " matter:

" 4. That although this latter cause of inferiority may be in part removed or corrected " by filtration, the excess of hardness will still remain, rendering this water especially " unfit for the following uses, namely, for cleansing the skin, and for the ordinary " purposes of washing, by occasioning an excessive consumption of soap; for the preparation of tea, by occasioning waste to the like extent; and for all culinary processes by " diminishing their efficiency and increasing their expense:

" 5. That the quality of the water of the river *Lee* and of the New River is, in " this respect, no better than that of the *Thames* water taken beyond the influence of " the sewage of the metropolis:

" 6. That the water taken by the Lambeth Company from the *Thames* opposite " Hungerford Market is charged with animal and vegetable impurities apparently the " effect of the discharge of sewer-water, which render it wholly unfit for use, and highly " dangerous to the health of the persons who drink it:

" 7. That of the seven principal companies by which pipe waters are conveyed to " the metropolis, four deliver it without previous filtration:

" 8. That the defects in the quality of the water at present supplied, when collected in " its least objectionable condition, and the evils arising from its distribution in the " unfiltered state, are all aggravated by the practice of intermittent distribution:

" 9. That the practice of intermittent distribution occasions, in the case of the better " description of houses, the retention of the water in cisterns and butts, and, in that of " the poorest classes, in tubs, pitchers, and such other vessels as can be obtained; and, as " a consequence of such retention, the water imbibes soot and dirt, and absorbs the " polluted air of the town, and of the offensively close, crowded, and unhealthy " localities and rooms in which the poor reside:

"10. That, from the inferiority of the water at its source as at present collected, and " from the additional pollution and deterioration occasioned by the mode of its distribu- " tion, a large proportion of the population is rendered averse to the daily use of water " as a beverage, and is inclined and almost forced to the use of fermented liquors and " ardent spirits to an extent greatly beyond the consumption of such drinks where purer " water is more accessible:

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"42. That in addition to the properties of clearness and freedom from animal and " vegetable matter, which is apt to pass into decomposition and to prove injurious " to health, one of the most essential properties of water is *softness*, or freedom from " lime and other substances productive of what is termed hardness:

"43. That having made careful and extensive inquiries, with the aid of the Department " of the Ordnance Geological Survey, as to the most suitable sources of supply, having " had those districts which appeared to be the most eligible specially examined by our " engineering inspectors, with other aid, we find upon their unanimous testimony that " from a tract of upwards of 150 square miles of gathering ground, there is derivable a " supply nearly double the present actual domestic consumption, of a quality varying " from one-tenth to one-third the hardness of *Thames* water, and of a purity equalling " the general average of the improved soft water supplies of the districts which have " yet been brought under examination:

"46. That the saving in soap, from the use of soft water, in the operation of washing " (the expense of washing linen and other clothes being estimated, at an average of 1*s*. " per head per week, to be nearly 5,000,000*l*. per annum on the population of the " metropolis) would be probably equivalent to the whole of the money expended at " present in the water supply:

"47. That the saving in tea from the use of soft water may be estimated at about " one-third of the tea consumed in the metropolis:

"48. That other culinary operations would be much facilitated by the use of soft " water:

"49. That soft water is peculiarly suitable for baths as well as for washing:

"50. That soft water would prevent those incrustations and deposits in boilers and " pipes, which render hard water unsuitable for manufacturing purposes:

"We therefore advise the rejection of all the schemes promoted by water Companies " or by parochial vestries and associations, which adopt, as sources of supply, the " *Thames* and its tributaries of the same degree of hardness, wells, and springs from the " chalk or other formations which impart the quality of hardness:

"And further, whilst we believe that *Thames* water, taken up beyond the influence of " the metropolitan drainage, and filtered, may be used without injury to the public " health, and may be employed temporarily until other sources can be laid under " contribution, we advise that *Thames* water, and other water of like quality, as to hard- " ness, be as early as practicable abandoned."

Still Parliament was unwilling to legislate, and early in 1851 the Government appointed a Commission, consisting of the late Professor Graham, F.R.S., master of the Mint, the late Dr. W. Allen Miller, M.D., F.R.S., professor of chemistry at King's College, and Dr. A. W. Hofmann, F.R.S., professor of chemistry at the Royal College of Chemistry, to report upon the following questions, namely:—

"What is the chemical quality of the various waters which are now supplied to the " metropolis?

"What is the chemical quality of the water derived from the sources whence the " Board of Health propose to supply the metropolis?

"What is the chemical quality of the water proposed to be supplied from Watford?

"Whether if the quality of the water now supplied be objectionable, any remedy " can be applied by filtration, or otherwise, without abandoning the present sources " of supply?

"Whether if soft water were to be obtained in sufficient quantity for the supply of " the metropolis, any comparative inconvenience would arise from the use of such " water under the present system of distribution, and if so, whether available means " may be found of obviating it?

"What are the properties to be preferred in the water selected for the supply of the " metropolis?"

The Commissioners did not content themselves with examining the documentary evidence laid before them, but made an elaborate analytical investigation of the various waters at that time supplied to the metropolis, and of others from new sources available for the same purpose. The Commissioners reported, as to quality, that

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

when the *Thames* is in good condition its water after ordinary filtration through sand "possesses the peculiar and agreeable brightness of chalk waters, arising from the "entire absence of colour, combined also usually with good aëration"; it is palatable and "no sufficient grounds exist for believing that the *mineral* contents of the water "supplied to London are injurious to health." "That the water may be circulated "through leaden pipes or preserved in leaden cisterns with an unusual degree of safety." That it fluctuates in temperature like all river and surface drainage water, and that "during the months of June, July, and August, the temperature of the water supplied "to the inhabitants of London is said to be generally above 65° Fahr., and sometimes "above 70° Fahr. This loss of coolness in itself makes the water greatly less palatable, "while it promotes the decomposition of organic matter, which farther impairs the quality "of the water." That in time of flood the water acquires a yellow colour, which is partly due to mineral and partly to organic contamination, and cannot be removed by sand filtration. The river is more particularly liable to this contamination "in the "latter part of autumn and early months of winter, from the extensive decomposition "of vegetable matter in the highly cultivated district through which it flows. This "is one of the disadvantages which the *Thames* shares with all rivers, which do not "originate in a barren non-retentive soil, such as the millstone grit of Lancashire, and "which cannot be collected for town supply near their sources. For the present London "supply this contamination is a serious evil. As the main drain of a large and "populous district, the *Thames* becomes at all seasons polluted by the sewage of "several considerable towns, and by the surface drainage of manured and ploughed land. "Even above Kingston, a population of three-quarters of a million is found upon the "banks of this river and its tributaries. The diverting the sewage of the various "towns entirely from the *Thames* would be attended with so much difficulty that the "project need not be taken into account."

"The contamination by sewage, however, cannot fail to become considerable and "offensive with the increase of population and the more efficient and general drainage "of towns. And it appears to be only a question of time when the sense of this "violation of the river purity will decide the public mind to the entire abandonment "of the *Thames* as a source of supply, unless indeed artificial means of purification be "devised in the meantime and applied."

Of the quality of the water supplied from the river *Lee* by the New River and East London Companies, the Commissioners speak in similar terms; they say however that "it appears less affected (than *Thames* water) by turbidity from floods. The objection-"able impregnations from town-drainage are also inconsiderable in the supply of the "first of these companies."

With regard to the whole of the metropolitan supply the Commissioners remark "Although according to chemical analysis the organic matter never appears to rise, in "the water of the Companies who filter, to a proportion by weight which need excite "alarm or would appear extraordinary to the chemist, and although it may be impossible "to ascertain its origin, still the balance of evidence appears adverse to the conclusion "that what is known to enter is immediately destroyed. No marked increase in the "proportion of nitric acid is observed in the *Thames* within the limits of the metropolis, "which might be expected to mark the destruction by oxidation of much azotized "animal matter if it really took place; while the rapid production of animalcules in "*Thames* water when aided by light and warmth, although not in itself a source of "danger, evinces the abundant presence of organic matter, which if not rapidly assimi-"lated by these lower orders of animal beings, might render the liquid repulsive, and "in all probability actively injurious to the human constitution. The anti-putrescent "property of *Thames* water, which it acquires from its hardness, is opposed to the "immediate destruction of organic impurities, and is perhaps more valuable as adapting "the river to the transport and removal of such matters, than for preserving the water "in a condition suitable for drinking."

The Commissioners further remark that the hardness of the water derived from the *Thames* and *Lee* "is considerable and highly objectionable." "The hardness of water "forms an objection to its use, both in cooking and washing, but the force of the "objection to *Thames* water for culinary purposes is much diminished by the large "amount to which that water is softened by boiling. The injury sustained in washing "from the hardness of the present water supply is greatly more important, but the "estimation of its amount is difficult, and involves the consideration of a variety of "circumstances." They estimate that the maximum loss of soap incurred by the use of *Thames* water is 42 per cent. for linens and 14 per cent. for woollens; but they call attention to the fact that in the coarse washing of the poorer classes much of this loss

PART IV. DESCRIPTIVE. The Metropolitan water supply.

may be avoided by the use of carbonate of soda. They further state—" It is in the " more careful washing of the middle and upper classes that the advantages of soft " water become fully sensible. In the digestion of the linen in hot water, with soap and " carbonate of soda, preliminary to the proper washing, the hardness of the water can " only occasion a trifling loss of soda; but afterwards in the wash-tub, where soda is " avoided, the earthy salts must occasion a loss of their full equivalent of soap. It is " found proper also to avoid boiling any portion of the *Thames* water that is used in the " wash-tub, or even heating that water above a certain point, for the carbonate of lime " precipitates on the linen, carrying down the colouring matter of the water with it, and " producing stains, which there is the greatest difficulty in afterwards removing from " the linen. The colour from the water is thus indeed fixed upon the cloth, by the " precipitated lime, with the tenacity of a mordant. The evil of the hardness of the water " is therefore aggravated by the flood-tinge or clay-colour which the London waters " often exhibit for several months in the year.

" In the washing of the person the saving of soap by the use of soft water is most " obvious. For baths soft water is most agreeable and beneficial, and might contribute " greatly to their more general use. Its superior efficiency to hard water in washing " floors and walls, is calculated also to promote a greater cleanliness in the dwellings of " all classes, both within doors and externally. While in the occasional domestic washing " of linen, the smaller preparation necessary for washing in soft compared with hard " water, the saving of soap which would then be sensible to its full extent, and the more " easy and agreeable nature of the operation, would make a supply of soft water in " a high degree desirable. The use of soda in washing would be gladly avoided by most " housekeepers, owing to its injurious action on the colours of certain prints, and the " permanent yellow tinge and weakness of fibre which it may occasion even in white " linens when exposed to heat before the soda is entirely washed out, as in ironing. " A strong desire exists to avoid its use, and where soda is avoided there is no doubt " that a saving of about one-third of the soap would be made by washing linen in water " entirely soft; supposing the comparison to be made with water of the ordinary " hardness of the London supply, but of which one-third part was previously softened " by boiling. The saving in labour would be even more considerable, if the com- " parison be still made between washing in soft water, and washing in hard water " without the aid of soda."

We shall have occasion subsequently to refer to the other topics treated of in this able and valuable report.

The result of all this evidence as to the unfitness of the water of the *Thames* for the supply of the metropolis, coupled with the deep impression which the frightful mortality from cholera in the year 1849 had made on the public mind, led Your Majesty's Government to introduce a bill in 1851 for the amalgamation of all the companies, with a compulsory clause giving power to the Secretary of State to prescribe the sources from which the water should be obtained. The Government did not succeed in carrying this bill against the strenuous opposition of the water companies, but in the following year a compromise was effected, and " An Act to make better provision respecting the supply " of water to the metropolis " received the royal assent on the 1st of July 1852. The following clauses illustrate the chief objects of this Act:—

Clause 1 provides that it shall not be lawful for any company supplying the metropolis to take water from any part of the *Thames* below Teddington Lock, or from any part of any of the tributary streams within the range of the tide.

Clause 2 stipulates that every storage reservoir within five miles of St. Paul's shall be covered; and clause 3 makes the same provision for aqueducts, unless the water is subsequently filtered.

Clause 4 provides that all water supplied for domestic use shall be effectually filtered, unless it be pumped from wells direct into covered reservoirs.

Clauses 15 and 22 provide for a constant supply at high pressure being given, where demanded by four-fifths of the inhabitants of any district, on certain conditions being complied with by them.

Clause 16 makes any company liable to a penalty of 200*l.* and 100*l.* per month in addition, for violation of the Act, or neglect to comply with its provisions. But, although very numerous violations of the Act have occurred, we believe that in no case has any penalty been inflicted.

The immediate consequence of this Act was the removal of the intake of all the water Companies drawing from the *Thames*, to places above Teddington Lock. The Lambeth and Chelsea Companies erected their new works on the south bank of the river at Long Ditton, nearly opposite Hampton Court Palace, and below the junction of the

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Mole with the *Thames*, whilst the West Middlesex, Grand Junction, and Southwark and Vauxhall Companies, constructed their intakes and pumping establishments on the north bank of the river, at Hampton, above the junction of the *Mole*. The East London Water Company, in 1852, also removed its intake on the *Lee* to Ponders End above the reach of the tide, and about nine miles above the junction of the *Lee* with the *Thames*. In the year 1862, the Kent Water Company abandoned the polluted *Ravensbourne* and thenceforward delivered water raised only from deep wells sunk into the chalk. These alterations effected a very material improvement in the quality of the water supplied to London, and the result was a great saving in human life during the subsequent visitations of epidemic cholera (*see* page 142) in 1854, and especially in 1866.

In 1856 when the works at the new intakes upon the *Thames* had been brought into operation, the Government directed Professor A. W. Hofmann, F.R.S., and Mr. Lindsey Blyth to make a chemical examination of the improved supply. These chemists reported that whilst the hardness and total solid matters in solution had undergone but unimportant alteration, there was a considerable diminution of organic matter. They attributed this improvement partly to the change of intake, but in a great degree also "to the considerable " improvement which has taken place in the collection, filtration, and general manage- " ment of the supply of water to the metropolis." A contemporary engineering report stated that the new works of the different companies had been satisfactorily carried out. It also recommended the introduction of the constant system of supply, and that further inquiry should be made into the removeable causes of contamination of the river above the new intakes of the companies.

In the year 1857 a Report was made to the Right Hon. William Cowper, M.P., President of the General Board of Health, on the Microscopical Examination of the Metropolitan Water Supply, by Arthur Hill Hassall, Esq., M.D. This report was presented to both Houses of Parliament by command of Your Majesty. It stated that whilst a great improvement was manifest in the condition of the water, "the metropolis is still " supplied with water containing considerable numbers of living vegetable and animal " productions, and which are not present in the purer waters, as, for example, that " supplied by the Plumstead, Woolwich, and Charlton Company," from a deep well in the Chalk.

The next inquiry into the condition of the *Thames* and *Lee* as affecting the water supply of London was that entrusted to the first Rivers Pollution Commission, which was appointed in the year 1865, and consisted of Robert Rawlinson, Esq., C.B., M. Inst. C.E., chief inspector in the Local Government Act Office, John Thornhill Harrison, Esq., M. Inst. C.E., and John Thomas Way, Esq., late consulting chemist to the Royal Agricultural Society. Their first report is dated 29th March 1866. In it the Commissioners state that " the river basin above Hampton (the pumping station of the water companies) comprises " an area of about 3,676 square miles, and a population, in 1861, of nearly 900,000 persons. " After making every allowance for retention in cesspools, and for villages and houses " situated within the limits of the Basin, but removed from the banks of the river and " its tributaries, there is no doubt that the number of persons whose sewage daily finds " its way into the water from which London principally draws its supply, amounts to " hundreds of thousands; and this number is destined greatly to increase, not only by " the growth of population, but by the development of the sewerage system, now only " in very partial operation. As the sewage travels down with the flowing water of the " river, a process of oxidation goes on which tends to purification. The volume of " sewage is also small as compared with the volume of the river, and upon analysis the " water pumped into London proves to contain only a very limited quantity of organic " matter. But neither the one nor the other is a satisfactory ground of assurance that " the metropolitan supply is wholesome. Sir B. Brodie's evidence is conclusive, that if " the river be polluted with sewage at Oxford, the process of oxidation which the water " more or less undergoes on its course, is no sufficient guarantee of its arriving at " Hampton purged of injurious sewage taint. The London drinker of *Thames* water may " be drinking with it some remnant of the filth of Oxford. Again, it is the general " opinion of medical men, that what causes the presence of organic matter in water to " be poisonous, is not its quantity, but its quality, and this special quality cannot, as " yet, be detected by either microscopic or chemical analysis, and is indeed at present " known only by its occasionally noxious effects."

"The result seems to be that, as a water supply, the *Thames*, polluted by the sewage " of the inhabitants of the river basin, is open in kind, if not in degree, to the same " objections as well-water infiltrated by liquid from an adjoining cesspool. Well-water " so tainted may appear to sight, taste, and smell to be harmless, and has been known " to have been drunk for a length of time without apparent mischief, but beyond all "doubt that same water is liable, under particular conditions, to become poisonous." The Commissioners also declare "that the river is fouled by refuse from paper mills "and tanneries, as also by floating carcases of animals." Our own recent inspection of the *Thames* and its tributaries above Hampton has incontestibly shown that the disgusting pollution of the river thus described by the Rivers Pollution Commission in 1866 still continues, not only in unabated but in increased intensity.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Of the river *Lee*, the Commissioners state in their Report dated 6th May 1867, that the drainage area is in round numbers about five hundred square miles. "As in the "case of the *Thames*, so in the case of the *Lee*, we have found on enquiry that pollution "of the waters by sewage is general." "The *Lee* begins to be polluted close to its "rise, and while yet a slender stream. The first great source of pollution is the "sewage and manufacturing refuse of Luton, the largest town in the upper valley, "numbering now upwards of 20,000 inhabitants. The town is sewered, and most of "the houses in it are drained; and there are at present from 1,000 to 1,500 waterclosets "in use." The sewage is clarified by lime, and "this process of clarifying sewage "improves it in so far as the solids are removed, but the fluid remains sewage, and if "allowed to stagnate will become putrid and offensive." "The bleaching and dyeing "of straw-plait, the manufacture of which is the staple trade of the town, is undoubtedly "a source of very considerable pollution of the water of the river *Lee*. Large quan- "tities of various metallic salts, dye-stuffs, brimstone, and other objectionable and, in "some cases, poisonous materials are, after use in the processes of cleansing, bleaching, "and dyeing of the goods, discharged into the stream, from which water for the domestic "use of a large portion of London is drawn. It is true that the substances so finding "their way into the river *Lee*, though large in quantity in the aggregate, are diluted "in the much larger volume of water, and that there are natural influences at work "which serve greatly to modify their noxious properties. We learn, indeed, with "something approaching to dismay in the first instance, that one manufacturer alone "employs from one to two tons of oxalic acid in bleaching straw-plaits, but are some- "what reassured upon consideration that the poisonous character of this substance is "entirely destroyed by admixture with the carbonate and sulphate of lime contained "in the water of the river. But the answer to this as to other like pleas for pollution "of rivers founded upon the counteracting influences of natural causes is, that we "ought not to be dependent upon any such fortuitous protection."

"The town next in importance to Luton is Hatfield, which contains a population of "about 4,300. The plan for disposal of the sewage was adopted with a view to its "complete exclusion from the river. But it is essentially a '*dumb-well*' system, and "the effect must be to pollute the subsoil water, which after passing through the chalk "or gravel subsequently finds its way to the river. Except at Luton and Hatfield, "the sewage of the upper district is not dealt with remedially in any manner. Villages "and houses situated immediately on the banks of the stream no doubt pollute the "river; thus we were informed that 'Whitwell is a place where privies hang over the "'water, and in Welwyn the whole of the sewage runs in.' To a certain extent also "the river is polluted by sheep-washing, which is carried on upon a large scale. The "preparation used for dipping sheep contains arsenic. But from the general district "(exclusive of towns on the river and tributaries) the pollution is insignificant, the "population being chiefly agricultural. Almost all the water falling upon this part of "the *Lee* basin is absorbed or evaporated. The *Lee* and its tributaries above Hertford "are consequently rarely flooded, and but slight abrasion of the surface takes place, so "that scarcely any refuse is washed into the streams."

It is doubtless to this circumstance in great measure that the superior quality of the water supplied to London from the *Lee* by the New River Company and, in a less degree, by the East London Company, is due.

The Commissioners divide the *Lee* basin into three districts; the upper district, situated above the intake of the New River Water Company at Hertford, the middle district included between that point and the intake of the East London Waterworks Company at Ponders End, and the lower district which extends from Ponders End to the junction with the *Thames*, and which is not used for the purposes of water supply. The population of the upper district was in 1861 about 73,000, and that of the middle district 79,000. Of the condition of the middle district the Commissioners report that the sewage of 7,000 persons in Hertford is treated with lime and then discharged into the river. The Hertford sewage has also been examined by us before and after this treatment, and we find that its polluting power is thus diminished to only a slight extent, but as the treated sewage flows for about half a mile through a long open conduit full of aquatic plants where it mixes with a considerable volume of spring water, its polluting

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

ingredients are, when vegetation is active, diminished to a marked extent. The report proceeds—"Ware, in its turn, in the disposal of its sewage, shows no consideration "for towns below. It is a town numbering some 6,000 inhabitants, and its sewers receive "the discharge from upwards of 220 waterclosets, as well as household drainage. This "sewage, without any liming or other sort of treatment, is passed direct into the river "by several outlets, an arrangement which tends to diminish the local nuisance, but "does not diminish the total amount of pollution caused to the river. In addition, the "authorities of the town of Ware cause putrid refuse from cesspools to be conveyed "beyond the town, and there thrown into gravel pits. The soakage from these masses "of refuse must in some degree pollute water in adjoining wells, and also the subsoil "water which eventually reaches the river. Below the town of Ware the *Lee* is joined "by the river *Stort*. In time of flood the *Stort* brings down large accumulations of "sewage and mud from the towns on the banks above. The chief of these is Bishop-"Stortford, a town of upwards of 5,000 inhabitants. Drains are general throughout this "town, though main sewers have not been laid down on any proper system; these "drains receive and discharge into the river the sewage refuse of the streets, houses, "and other places, as also the contents of upwards of 300 waterclosets. The effects "of this pollution are very sensible at the lower part of the *Stort*. Mr. Garratt, of "Hunsdon Mill, which is about eight miles below Bishop-Stortford, describes the river "as becoming yearly fouler and fouler; every house on the river drains into it; farm-"yards also; carcases float on the surface, and the bed becomes silted up with refuse."

At Ware, Bishop-Stortford, and other places on the *Lee* and its tributaries, large quantities of barley are steeped in the process of malting, and the steep liquor, which soon becomes very offensive, is discharged into the river.

Below the junction of the *Stort*, the towns of Hoddesdon, Broxbourne, Cheshunt, Waltham-Abbey, Waltham-Cross, and Enfield Highway discharge sewage, the liquid portion of which is carried at all seasons down the stream to the intakes of the water companies; but, in summer, much of the solid fœcal matter accumulates in the still pools of the river until it is flushed out by a freshet. From the evidence of the clerk to the Board of Guardians of Bishop Stortford, however, it appears that these accumulations sometimes, from the stench they emit, become intolerable to the town causing the pollution, and they are then stirred up by barges with heavy rakes behind, so as to mix them up with the flowing water and send them down the stream. He says (Second Report of the Commissioners appointed (in 1865) to inquire into the best means of preventing the Pollution of Rivers, vol. II., Minutes of Evidence, page 68),—

"The nuisance of which the inhabitants have complained from the smell of the river was during the summer of 1864 and 1865, but it was very much abated in consequence of our having wet seasons, and a plan was adopted that succeeded remarkably well, and that was this: during the summer, when the water is very short, the filth will sometimes almost crop up to the mouth of the drains, and when there has been a flood in the winter, this accumulation has been stirred up by a barge and a heavy rake behind, so that we have passed it on to our neighbours to some extent. We thought we had kept it long enough, and by the use of the flood water relieved ourselves from a considerable quantity of stink by that means. There must be a very considerable amount of pollution in the river, because we drain everything into it that we can."

After this, it is not surprising to hear further from this witness:—

"We have been threatened by several parties. Our neighbours at Sawbridgeworth have told us that we have been poisoning them. We have said that we are sorry for it, but we think that they contribute to the nuisance to some extent themselves, and we have therefore not heeded what they had to say."

Such methods of disposing of fœcal matters naturally cause obstructions and deposits in the mill dams below. Mr. Thomas Garratt, of Hunsdon, thus describes (*ibid.*, page 79) his method of removing these:—

"My water after it leaves the wheel is a private water for about three-fourths of a mile to a mile, where there is no navigation, and the mud settles there to a great extent. I find that other people send the mud to me, and I had a large hoe constructed, and I put four horses to it, and I sent the mud down again into the navigation. It is cheaper than throwing it out. We occupy the mill below, and we drive the mud away in the best way we can. We have had iron harrows with two or three horses."

This witness then goes on to speak of the condition of the river in the following terms:—

"The condition of the river has been getting decidedly worse since I have known it. There is not a house near the river but what drains its sewage into the river the whole of the way up. Farm-yards and other houses do so. The surface of the water is covered with green scum like a pond.

There are frequently the carcases of dead animals floating on the surface; and unfortunately, above three weeks or a month ago, I found the body of a dead child floating on the surface. When I find the carcases of dead animals I push them through the gully-hole. I do not bury them, they would stink too much for that. I get my drinking water from a well, and if the well is out of repair I send nearly a mile off for water for the use of the house. I do not in the least think of drinking the river water."

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Such was the condition of the river in 1866 above the intake of the East London Water Company, and evidence was given before the same Commission, that there had been three recent cases of cholera, and cases of fever for several years past, in Bishop Stortford, also numerous cases of cholera and fever at Ware. Our repeated and recent analyses of the *Lee* water as delivered by the East London Water Company, show that no amelioration of the condition of the river has taken place since 1866. Notwithstanding, however, the horrible pollution just described, the *Lee* is much less polluted than the *Thames;* and its water, as delivered in London, is invariably superior to that of the *Thames*.

The inquiries of the Rivers Pollution Commission were not confined to the pollution of the metropolitan water supply; they were not even confined to the basins of the *Thames* and *Lee*, but extended to the condition of all the polluted rivers of England and Wales, to the various causes of their pollution, and to the water supply generally of England and Wales, and specially of the localities visited by the Commissioners. The field of their inquiry was, therefore, very extensive, and the objects requiring their investigation very numerous, so that in consequence of the alleged serious pollution of the metropolitan water supply, and taking into consideration that an ample supply of wholesome water at all times is of essential importance to the health of the population in large towns, Your Majesty was pleased to appoint in the year 1866 a Commission "for the purpose of ascertaining what supply of unpolluted and wholesome water " can be obtained by collecting and storing water in the high grounds of England and " Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient " elevation for the supply of the large towns, and to report, firstly, which of such " sources are best suited for the supply of the Metropolis and its suburbs; and, " secondly, how the supply from the remaining sources may be most beneficially dis- " tributed among the principal towns." In the following year this Commission was revoked and a new one issued in which the subjects of inquiry were thus defined, " for " the purpose of ascertaining what supply of unpolluted and wholesome water can be " obtained by collecting and storing water in the high grounds of England and Wales, " either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation " for the supply of the large towns, and to inquire into the present Water Supply of the " Metropolis, and whether there are other districts in addition to the high districts of " England and Wales from which a good supply of unpolluted and wholesome water " can be obtained; and to report, firstly, which of such sources are best suited for the " supply of the Metropolis and its suburbs; and, secondly, how the supply from the " remaining sources may be most beneficially distributed among the principal towns."

The Commissioners were his Grace the Duke of Richmond, K.G.; Sir John Thwaites, Chairman of the Metropolitan Board of Works; Colonel Harness, R.E., C.B.; Sir Benjamin S. Phillips, Alderman of the city of London; T. E. Harrison, Esq., M. Inst. C.E.; and Joseph Prestwich, Esq., F.R.S., President of the Geological Society.

The Commissioners soon found that an inquiry into the water supply of provincial towns must be one of great magnitude, involving a large amount of statistical and topographical investigation extending over the whole kingdom. They say (Report, page cxxiv) "we felt that it would be impossible for us to undertake this without " further powers, while its prosecution would delay, probably for some years, the more " important and pressing question as to the metropolitan supply." The Commissioners consequently confined themselves to a few general recommendations in connexion with this branch of their inquiry, and their report is substantially limited to the water supply of the metropolis. This branch the Commissioners have treated very elaborately, and in the appendices to their report they have brought together a vast mass of information, and of documentary and vivâ voce evidence, much of which is of great importance and value. With regard to the quality of the present supply to the metropolis, the Commissioners state that they have given due weight to the evidence of "scientific men of " the highest reputation, and who have had the best means of making themselves " acquainted with the subject," but that they have also been obliged on some points to rely on other considerations in arriving at their decision. At page 100 of their Report they remark, "it is absolutely essential to the good quality of the *Thames* water that

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

" it be effectually filtered." And at page 126 they give the following summary of their conclusions as to the quality of the water supplied from the *Thames* Basin:—

" We are of opinion:—

" That there is no evidence to lead us to believe that the water now supplied by " the companies is not generally good and wholesome.

" That for drinking purposes the hardness of the *Thames* water is quite unobjection- " able, and in no way prejudicial to health. The weight of evidence seems in favour of " hard water, as more free from certain dangers inherent in soft waters on account of " their greater solvent power.

" That for cooking no important objection to the *Thames* water has been clearly " proved, except as regards the deposit in kitchen boilers, which deposit is easily " removed.

" That for washing, and for manufacturing purposes generally, soft water is prefer- " able as more efficient and more economical, but there appears no means of expressing " the amount of saving in a money estimate.

" Looking, however, to the fact that the hardness of the *Thames* water is moderate " in degree, and is still further reduced by boiling, and considering also that the pro- " portion of the whole metropolitan supply used for manufacturing purposes is exceed- " ingly small, we cannot see that this advantage is of sufficient importance to render " it necessary to go to a great distance for soft water.

" That the artificial softening process does not appear to be applicable to the *Thames* " waters on a large scale.

" That perfect filtration is highly essential to the good quality of the water supplied; " that this process is at present in many cases very imperfectly performed; and that " more efficient means of enforcing the provisions of the law in this respect are required.

" That *when efficient measures are adopted for excluding the sewage and other* " *pollutions from the Thames and the Lee, and their tributaries, and for ensuring* " *perfect filtration*, water taken from the present sources will be perfectly wholesome, " and of suitable quality for the supply of the metropolis."

Although some of these conclusions appear to differ from those of the scientific Commissions who had previously reported upon the quality of the waters of the *Thames* and *Lee*, the divergence is by no means considerable. It will be observed that whilst the Commissioners believe the water now supplied by the companies to be *generally* good and wholesome, they give no opinion as to its quality in exceptional seasons, such as those in which epidemics of cholera and typhoid fever prevail, when it necessarily becomes fouled by *infected* sewage. We have shown elsewhere (page 69) that the use of water polluted by uninfected sewage, that is the sewage of persons free from those diseases which are propagated by water, does not seem to be incompatible with the enjoyment of ordinary good health. We know that hundreds of thousands, chiefly of the rural population of this country, habitually consume water strongly impregnated with their own excremental discharges; and we have every reason to believe that even millions of persons in Great Britain are under the same conditions of water supply, and yet we have no positive evidence to show that such water is *generally* unwholesome; on the contrary, it is consumed from day to day for years, it may be, without producing any marked effect upon the health of the people drinking it. When, however, such water *exceptionally* becomes contaminated with infected, in the place of ordinary sewage, we have the most cogent and conclusive evidence that it then becomes intensely poisonous, and that most disastrous results ensue from its use for drinking, and probably for other domestic purposes. It was no doubt the imminent risk of such exceptional pollution to which the *Thames* and *Lee* are continually exposed, which led the previous Commissions to recommend the abandonment of these rivers as sources of water supply to the metropolis. Again, if it were practicable to adopt efficient measures for excluding the sewage and other pollutions from the *Thames* and the *Lee* and their tributaries, and for ensuring perfect filtration, there could scarcely be any difference of opinion as to the perfect wholesomeness of the water taken from the present sources; but experience teaches that such measures, at all events as regards the exclusion of sewage and other pollutions, are wholly impracticable. Such sweeping remedies have never yet been seriously proposed. The complete interception of sewage and liquid manufacturing refuse from the *Thames* and *Lee* and their tributaries would involve an expenditure so enormous as to render the execution of the necessary works practically impossible. All that has hitherto been proposed in this direction is the purification of sewage and the refuse liquids from manufactories, to such an extent as to render them admissible into rivers without causing such pollution as would be easily recognised by the senses. We were convinced at an early stage of our inquiries that purification beyond this point could not be carried out without serious injury to industrial processes and manufactures. In our first report we have stated that (*Mersey* and *Ribble* Basins, Vol. 1, p. 112) "Amongst the numerous processes for the cleansing of polluted water with "which we have become acquainted, there is not one which is sufficiently effective to "warrant the use, for drinking, of water which has once been contaminated with "sewage or other similar noxious animal matters." The outbreak of epidemics of typhoid fever at Stuttgart and Winterthur (*see* Appendix No. 4, p. 463) goes far to demonstrate that the admission into drinking water of the effluent water from meadows irrigated with sewage is a potent means of propagating this fever. Even the effective and, at the same time, practicable proposals for the mitigation of the sewage nuisance in the *Thames* and *Lee* and their tributaries, have as yet been carried out in only one town, viz., Banbury, on the *Cherwell*, where the sewage is purified by irrigation before it is admitted into the river. In connexion with this subject, Sir B. C. Brodie, F.R.S., Professor of Chemistry at Oxford, gave the following evidence before the Commissioners, 1866 (Minutes of Evidence, page 435):—

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"(*Mr. Prestwich.*) What course do you consider the most efficacious one to get rid of sewage contamination from the towns on the river?—The best is not to put the sewage into the river at all; that is the best answer I can give, and indeed, that is really the only course by which you can be certain that you have not got it in. I certainly do think it a very good thing to employ the processes used for the filtration and destruction of sewage, and they are *pro tanto* beneficial. They really help the matter a good deal, but I do not think that they are entirely effectual. There is no known process that I am aware of for, on a large scale, destroying the injurious qualities of sewage.

"(*Col. Harness.*) By throwing it upon the land you absolutely get rid of a large portion of the sewage, and what is left is somewhat improved?—Very greatly improved, but I should not like to take a glass of water and drink it from just the spot where it went into the river, still less to make it one's daily and habitual beverage.

"(*Mr. Prestwich.*) If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town and produces no ill results, and chemical analysis fails to detect anything unusual in its character, is it not a fair presumption that such water is wholesome and good water for the use of a town supply?—If it be used without injury to the inhabitants, really chemical analysis is altogether superfluous. But the question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that, under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might long go on using it, for years, and it might not be discovered, and yet you might have some outbreak of disease in the place which, nevertheless, might be connected with the use of that sewage water.

"(*Sir John Thwaites, Chairman.*) Then, under ordinary conditions, although you could not detect in the health of the inhabitants any injurious effect from the water, still if there are in the atmosphere increased causes of zymotic disease, the drinking of that water might ripen those causes to serious effect?—I can understand that, under certain conditions, the water which was uninjurious at one time might become injurious to the inhabitants; but what I was thinking of was, that the water, without being always poisonous, or always containing anything even detrimental might, under certain exceptional conditions, contain matter which would be very detrimental, and this might only occur now and then just as it is supposed to have been the case in the outbreak of cholera in the east of London. Of course the water in London must have been contaminated over and over again with sewage without cholera ensuing."

The evidence of Mr. John Simon, F.R.S., Medical Officer of Your Majesty's most Honourable Privy Council, is still more decisive on this point. He says (Report, Vol. II., page 167 and 441):—

"Judging by chemical analyses, performed on it in what I may call its normal state, I am not aware that there is much fault to be found with the quality of the London water. I am speaking quite generally of all the water supplied by the various companies. Speaking of it in its broad ordinary chemical characters, as it would be reported on from a chemical laboratory, I should say it is a fair water supply, speaking generally of it. But what I thus say of its average chemical constitution in its normal state does not touch the question of the water's liability to accidental very dangerous pollutions. There are dangerous qualities of water supply, with regard to which so far as I know (but I do not speak as a skilled chemist) chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect. It is, I think, a matter of absolute demonstration that in the old epidemics, when the south side of London suffered so dreadfully from cholera, the great cause of the immense mortality there was the badness of the water supply then distributed to those districts of London. In the interval between the 1849 epidemic and the 1854 epidemic, one of the two companies which supply the south side of London had amended its source of supply; it had gone higher up the river; and we at once lost a great part of the mortality on that side of the river. I may refer on this subject to a special report which I made in 1856 to the then general Board of Health, and which was laid before Parliament, on the last two cholera epidemics of London as affected by the consumption of impure water. **(For an extract from the report here alluded to *see* page 146.)**

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"Do you also mean us to understand that a water might be productive of cholera, although it contained nothing which would be detectable by chemists?—Yes, I said something to that effect. A chemist would perhaps report that the water contained 'organic matter;' but 'organic matter' covers an infinite variety of things, and he would have no means that I know for discriminating the organic matter which is really the ferment, the infectious material, of cholera, from a great number of other organic matters.

"The question of good supply or bad supply is not to be judged only by what the chemists from their laboratory can tell you of the water. The greater part of the water supply to London, as you are aware, is pumped from the *Thames*. That portion is taken from the *Thames*, after a million of population has drained into the river. Nothing which chemists in the present state of their science can report (negatively) as to their findings in London water will alter the fact of that filthy admixture. And I know that that fact represents a certain amount of danger to the population that receives the water. I do not know that chemists could have discovered the infectious quality which is believed to have existed in the East London water supply in the beginning of last July. I do not know that chemists could have identified it, or could have come down upon it as they would come down upon arsenic or copper. We trace the sewage into the water, we trace the water into the district, and we trace the inhabitant to his cholera and death. I mean to say that although you detect in this water the presence of organic matter you cannot detect whether this organic matter is or is not of a more or less poisonous quality; that is to say, whether it bears the germs of any particular disease. What one has to do is to guard the supply with the utmost strictness against every foul admixture. *It ought to be made an absolute condition for a public water supply, that it should be incontaminable by drainage.*

"Supposing that sewage is discharged from one of the sewers, say at Windsor, would it be possible to detect the presence of that sewage seven miles lower down the river, having regard to the volume of water in the river?—I believe it would be absolutely impossible for chemists to discover it, but the practical sanitary question is different. Supposing tape worm eggs to be sent into the river with that sewage, would those tape worm eggs be alive seven miles down? Or, supposing cholera discharges to be sent into the river, or the discharges of typhoid fever, and assuming (which is a frequent pathological opinion) that the respective contagia of typhoid fever and cholera are living germs, would those germs be alive seven miles down. It is not a question whether a chemist would find out the organic matter so much as it is a question whether those particular molecules would still have their property seven miles down. I cannot say that they would not.

"Could you detect them at that distance?—Only by their effects.

"Might not the same disease be produced from any other cause?—The particular parasite will only come from its particular egg. You could not get hydatids except from eggs any more than you would get chickens without eggs.

"If it is not possible for a chemist to discover sewage, is it not presumptive evidence either that it does not exist, or that if it does exist it is in such minute quantities that it is in no way deleterious to human health?—I am very decidedly of opinion that that principle is not a safe one to adopt as a basis for sanitary regulations in the matter. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think, even, that allowance should be made for the proper decent taste of people. Water into which sewage has been discharged is, in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. I think the drinking of such water is dangerous. It is not practicable to define the exact line at which the danger in a particular case begins. Everybody knows that water with certain obvious pollutions by sewage is fatal to health, and I do not know where to draw the line in practice between such cases and those which are practically speaking unimportant."

On the question of the connexion between the quality of the water supply of the metropolis, and the spread of epidemic disease in London, there is no higher authority than Mr. William Farr, M.D., D.C.L., F.R.S.,—the Superintendent of the Statistical Department of the General Register Office. In his evidence before the Royal Commission on Water Supply, Dr. Farr after referring to the violent outbreak of cholera in 1866, in the district supplied by the East London Company by water exceptionally polluted, says:—

"In the visitations (of cholera) of 1849 and 1854, houses adjoining each other were supplied by two different companies, and I found throughout the whole of that district, house by house, that the mortality in the houses supplied by the one company was infinitely greater than where they were supplied by the other company. I should say that the Lambeth and Southwark companies were in competition on the south side of the river, and that they often supplied the same street, where the condition of the people was precisely the same in the houses supplied by the two companies. When the epidemic came in 1854, we found that it would be an excellent opportunity for determining the effects of the water, as the two companies supplied the same district, and the houses were nearly of the same class. Dr. Snow, who had started this theory of the distribution of cholera through water came to us, and we gave him every facility for making inquiries, and he went over the houses in the streets supplied by the two companies, and I will just state the result. In 1854 the Southwark Company continued to get its water from Battersea, close to one of the sewers, but the Lambeth Company had gone up to Teddington beyond the range of the London sewage. In 1849 Bermondsey was supplied by the Southwark Company, and the deaths from cholera were 734, and in the 14 weeks ending the 14th October 1854 they were 829; the number of deaths was greater in 1854 than it had been in 1849. In Lambeth it was found that being supplied by the two companies, and only partly by the Lambeth Company, the deaths in 1849 were 1618, and in 1854 only 904. I should state that the Lambeth Company supplied 26,000 houses, and the Southwark Company 40,000 houses. The deaths from cholera during six weeks in the houses supplied by the Southwark Company were 2,284, in 40,000 houses, while 294 deaths occurred in the houses supplied by the Lambeth Company out of 26,000 houses. The proportions are these, to every 1,000 houses supplied by the Southwark Company there were 57 deaths from cholera, and to every 1,000 houses supplied by the Lambeth Company 11 deaths. We afterwards got a return from the companies of the houses they supplied, and we ascertained the number of deaths in those houses from our books, and the general result was summed up in this way, that in the houses supplied by the Lambeth Company the deaths were 12 per 1,000 in 1848–49, and in 1853–54 only four per 1,000. In the case of the houses supplied by the Southwark Company the number of deaths per 1,000 was 12 in 1848–49, and 13 in 1853–54, so that the Lambeth water had fallen from 12 to four, while the Southwark Company had got worse. That seemed a decisive and conclusive experiment, showing the influence of the supply of water in a cholera epidemic. It was that which enabled us so decisively to say that the East London districts which were affected in the same way precisely as those in South London had been, must have been affected through the distribution of the poison by the water. My view is 'generally' that those waters in which human excreta enter to any extent are decidedly dangerous."

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Professor William Odling, M.B., F.R.S., Professor of Chemistry in the University of Oxford, states:—

"I have examined the *Thames* water from time to time fully. I have not found the presence of sewage not decomposed. On general grounds I think it would be very objectionable to drink water that was known to be contaminated with any appreciable proportion of sewage, as sewage. Although London is at present supplied with an agreeable, and in my opinion perfectly wholesome water, still it is evident that for general town supply a soft water such as that of Wales or Cumberland, is upon the whole more suitable than a somewhat hard water, such as that of the *Thames* and *Lee;* and further, that a water which neither contains nor has received sewage impurity is at any rate preferable to a water which certainly has received, even though it does not actually contain any such impurity."

Dr. Edmund A. Parkes, F.R.S., Professor of Military Hygiene in the Army Medical School at Netley, gave the following evidence:—

"I have got a good deal of evidence together as to diseases which may be communicated by water, not only to the troops, but among the civil population. I have made a list of diseases, all of which are occasionally communicated by means of water, not solely communicated by water, but occasionally. For example, typhoid fevers; of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me arising from water impregnated with typhoid sewage, or possibly with simple sewage.

"3115. When you speak of typhoid sewage do you mean sewage from persons suffering from typhoid fever?—Yes.

"3116. Can you detect that after its mixture with the water?—Not by any chemical reagents.

"3117. But under the microscope have you the means of detecting it?—No, there is no possibility of determining the particular substance which causes the fever in other persons. We only know the effect produced upon other persons, and no doubt it is from that cause.

"3118. How did you ascertain that those outbreaks were due to water impregnated with typhoid sewage?—On account of the cases immediately following that impregnation with typhoid sewage. I do not wish to deny that simple sewage might produce the same disease, but that is a question still undecided.

"3119. Have you the means of tracing the discharge of that class of sewage into the water, and the results following in fever?—Yes.

"3120. Have you obtained many confirmatory results from that observation?—There have been altogether a considerable number of cases now placed upon record by different writers of such an effect following the passing of typhoid sewage, or possibly of simple sewage into drinking water. We had a case in the neighbourhood of Southampton only this last year, in a young ladies' school, where a drain pipe passed within three feet of the well; at the point nearest the well the soft ground below the drain pipe had given way, and the pipe had sunk, and the sewage passed into the water of the well. Immediately following that was an outbreak of typhoid fever, which affected something like 80 per cent. of the population, that is to say, 18 or 19 persons were affected out of a population of 24 or 26; there were several deaths, and many of them very severe cases. In that case it was impossible to prove whether or not it had been typhoid sewage passing into the well; but the impregnation of the water with sewage was certain and coincident at that time, and that, coupled with several cases of the same kind, seem to show that the outbreak of the fever is owing to the impregnation of the water with sewage.

"3121. Would not the discharge of sewage into any water which was the source of supply for domestic purposes favour the development of such zymotic diseases. I am not speaking now of typhoid fever sewage only, but of ordinary sewage?—That is the general belief certainly; there may be still a little doubt whether that is really the case. For example, in the instance of cholera, it was formerly believed by most medical men that the impregnation of drinking water with sewage would predispose to cholera at any rate; but during the last year in Germany there have been a good many instances recorded in which very impure water had been drunk during the whole

PART IV. DESCRIPTIVE. — The Metropolitan water supply.

period of the cholera epidemic without apparently producing any predisposition to cholera, I mean water impregnated with common sewage, not choleraic sewage; the inference rather being at present that choleraic sewage must pass into the water to produce cholera. So that I should hardly like to express an opinion too positively as to the effect of sewage predisposing to zymotic diseases."

The witness then goes on to describe a popular division of potable waters into four classes, viz.:—

1. Pure and wholesome waters.
2. Useable waters.
3. Suspicious waters.
4. Impure waters.

"3150. (*Colonel Harness.*) Under which of those heads would you put the London water?—I should put the London water under head No. 3, suspicious.

"3151. Would you do that because there are indications of nitrates?—Yes; I should call any water containing large indications of nitrates and nitrites suspicious water. Such indications may, however, come from water not impregnated with sewage, as some soils give off nitrates and nitrites.

"3152. (*Sir John Thwaites, Chairman.*) Is the result of the Board of Health analyses of the London water sufficient to enable you to judge of its character?—As far as regards nitrates and nitrites and ammonia are concerned, it is quite sufficient to enable one to judge.

"3153. Should you call it suspicious water?—Yes, I should certainly call it suspicious water.

"3154. Which is the first of the London waters in Professor Frankland's analysis?—The first water is the Chelsea water, which contains nearly 28 grains of solid matter.

"3155. Would you call that suspicious or impure?—I should call it certainly suspicious water. It contains nitrates, nitrites, and ammonia in some quantity, and knowing that such substances exist only in small quantities in pure *Thames* water I conclude they are derived from sewage. I think that the mere presence of nitrates and nitrites in water in small quantities would not be hurtful at all; their importance is as indicating their source and showing that there must have been contamination, probably by animal organic matter, in most cases sewage, and of course rendering the chances of such organic matter passing in in sufficient quantities to affect the health very probable, but when such organic matter has been oxidized, then no doubt it becomes, at any rate in most cases, harmless.

"3158. (*Mr. Prestwich.*) Would it not be very difficult to distinguish the origin of the nitrates and nitrites, whether arising from sewage or from the rain, or from the earth, or from vegetation?—From the rain the quantity would be small; indications of nitrites will be found in rain water and in water from the earth, and there is a certain amount of difficulty in determining from what source they come. In our neighbourhood, for example, there is a sort of dark soil under the sand at certain points which contains very large quantities of nitrates and nitrites not derived at all from sewage, and the water drawn from those sources gives indications which might be taken in the first instance for sewage. That mistake could only be avoided by knowing the soils which furnish the water. In the case of the London water, the *Thames* water which is furnished in such large quantities from the chalk, will, I believe, in no case, without sewage contamination, give large indications of nitrites and nitrates; there would not therefore be any difficulty in supposing that the indication of nitrites and nitrates would be owing to organic matter which had found its way into the water from the sewage, still there would be a difficulty in all cases in saying at once that the presence of nitrites and nitrates in water was owing to sewage matter or any other accidental organic matter.

"3177. (*Chairman.*) Is there in your judgment an objection to the *Thames* basin as a gathering area for water by reason of the high state of cultivation in some parts, and from the manuring that it undergoes?—Yes, I think there is a very great objection. No doubt the effect of water passing through a soil with manure is to cause a very rapid oxidation of the organic matter, and a very large quantity is converted into nitrates and nitrites and ammonia, but there is a limit to that, and it is impossible to insure the safety of water where there is the possibility of contamination on a large scale with organic matters derived from sewage.

"3237. (*Mr. Harrison.*) Do you think that in point of health the population of London generally suffer from any impurity in the existing water apart from any special case of cholera in the east of London?—I think that where the population of every town shows a considerable amount of diarrhœa and also of typhoid fever it makes one believe that there must be some impurity in the water at times, and the health of the population as regards those diseases of the intestines seems to be very much influenced by the purity or impurity of its water supply.

"3238. If you had the choice you would prefer to go to such water as you could procure at a large expense, such as the Loch Katrine water?—Yes, if one had the opportunity of course.

"3239. Could you give any measure at all of the difference of value as regards the question of health between the two, that is to say, as between using such waters as are now used in London, and using such waters, if they could be got, as those of Loch Katrine?—I am quite certain that the health of the people would be improved considerably, but I could not give any numerical standard. I believe that most diarrhœa affections would disappear, and typhoid fevers would be diminished, and that the chances of cholera being conveyed by water would be almost entirely taken away. I can hardly conceive that there would be any chance of any conveyance of cholera by water.

"3249. (*Col. Harness.*) Would you object to a site for a hospital where the water to be obtained was of the quality of the London water?—I should certainly say that the London water had been impregnated with sewage from the evidence of the oxidation of nitrogen, and therefore, being impregnated with sewage, I should think that there would be considerable danger in the use of it."

Part IV. Descriptive.

The Metropolitan water supply.

The Right Hon. Lyon Playfair, C.B., M.P., F.R.S., at that time professor of chemistry in the University of Edinburgh, was a member of the Royal Commission for the Health of Towns, and was for a long time chemical adviser to the Board of Health in London. The quality of water had therefore very frequently come under his consideration. He gave the following evidence:—

"The water supplied to London is a hard water. It is not so hard a water as is supplied to many places, but it is decidedly hard water. As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health, but it is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. The effect of a hard water upon its ordinary detergent use is seen in the waste of soap and the difficulty of washing which washerwomen experience, and they are far more important members of the industrial community than is generally supposed. In the case of a dozen of shirts, all the interests of the cotton grower, the cotton spinner, the weaver, the shopkeeper, and the sempstress, may be represented at 72*s.*, but the washerwoman's interest in that dozen shirts is 117*s.* In other words, the washerwoman derives her profit from the dozen shirts by washing three per week for a period of three years, so that her profit during that time is nearly double that of all the other interests combined. Therefore anything that will promote economy in such an occupation is always of much value, for the industry of the washerwoman is in reality large, although not usually considered important on account of its great division.

"2647. I gather from your statement also that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes, it is a curious thing that one never washes one's hands *in* a basin with hard water; where the water is hard you take a small quantity of it in the hand itself and rub the soap until it forms a lather in the small quantity of water that is in the hand, and you merely use the water in the basin to rinse off that which you have employed in cleansing the hands; but with soft water you use the whole mass of water for detergence, and therefore it is much more effective.

"2648. And it is thereby more conducive to health?—Yes, a more thorough cleansing takes place.

"2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

"2649. Supposing that you had a choice between a hard water, such as is now supplied from the basin of the *Thames*, supposing it to be free from impurities of sewage and otherwise, and a pure soft water, which should you give the preference with regard to the question of drinking or its use for culinary purposes?—Undoubtedly to the soft water. In all cases I strongly recommend towns not to accept hard water.

"2713. I believe that it is a misfortune that a large metropolis like this is supplied with a water so hard.

"2681. Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and what would be the effect of the presence of organic matter in such water?—The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water is originally of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

"2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river such as the *Thames* above London, the action of the aeration would be in that case to destroy any moderate amount of organic matter, would it not?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination; by a chemical examination you can do so, but the presence of the most highly oxidised form of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

"2683. Is it not considered that by the time the *Thames* water, with which London is now supplied, reaches the delivery pipes all organic matter is converted into the state of nitrates and nitrites?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not."

PART IV. DESCRIPTIVE.

Dr. Robert Angus Smith, F.R.S., Your Majesty's Chief Inspector of Alkali Works, who has had much experience in the chemistry of potable waters, gave evidence as follows:—

The Metropolitan water supply.

"I may say what I found in the *Thames*. Above Reading very little impurity was found in the *Thames*, but below Reading it was very marked indeed, and it never disappeared in any part below Reading. (*Mr. Harrison.*) For what distance down?—Any part. I went down to London Bridge, and it was visible in any part below Reading. (*Chairman.*) Did you detect the presence of sewage from every sample that you took below Reading to London Bridge?—Yes, what I believe to be caused by sewage; it was organic matter, which in its decomposition showed a great deal of animalcular life, and which I believe to indicate so much organic matter of a very active kind, probably dangerous. (7200.) Supposing there had been no source of contamination below Reading, would you then have been able to detect the presence of sewage in the river, because, as you are aware, down the river there are fresh sources of contamination going on?—Yes, I think there would have been a little."

So long as the zymotic poisons which occasion the different species of epidemic disease remain unidentified, the sciences of chemistry and physiology can only indirectly assist, in elucidating the conditions which favour the development of epidemics, and in pointing out the sources of danger. It is only, however, through carefully collected statistics, that these sciences can be brought to bear upon one of the most important problems that can occupy the attention of mankind. Whatever may be the present relative position of Great Britain with regard to the pursuit of abstract science, it is universally recognised that, in our knowledge of the conditions affecting the public health, we are considerably in advance of every other country. This position is due almost entirely to the laborious collection of health statistics at the General Register Office, and to the admirable weekly and annual reports issued by the Registrar General. The weekly, and, during the prevalence of severe epidemics, daily returns of deaths and their causes are like telegraphic communication in an army; they keep the defenders of the public health *au courant* with the latest movements of pestilential attack, and render possible the timely discovery and prompt remedy of the weak points in our sanitary defences.

Of all epidemics, cholera is the one whose habits have been most thoroughly exposed by these statistics, and it was proved beyond question by the analysed returns of the General Register Office that the fatality of this disease bore a very constant ratio to the quantity of sewage in the water of the several Metropolitan Waterworks Companies. The Thames Companies, as we have already stated, removed their intakes to points above Teddington lock, and some of them provided reservoirs and adequate filtering beds, so as to command the means of supplying filtered water. The close connexion between cholera mortality and polluted water supply once established, it became, in the opinion of the Registrar General, necessary to watch over the purity of the London waters. This duty was first confided to Dr. Robert Dundas Thomson, F.R.S., who continued to discharge it down to the date of his death on the 17th August 1864. The following is one of the last reports made to the Registrar General in July 1864 by this chemist:—

——	Total impurity per gallon.	Organic impurity per gallon.
	grs. *or* °.	grs. *or* °.
Distilled Water	0·0	0·0
Loch Katrine Water, new supply to Glasgow	2·35	·605
Manchester Water Supply	3·33	·680
THAMES COMPANIES.		
Chelsea	17·92	1·12
West Middlesex	16·16	1·24
Southwark	16·48	1·12
Grand Junction	18·80	1·36
Lambeth	16·00	·96
OTHER COMPANIES.		
Kent	25·36	2·32
New River	15·28	1·04
East London	15·36	1·36

"The Table is to be read thus:—Loch Katrine water contains in the gallon 1·35 degrees or grain of foreign matter in solution, of which ·605 degrees or grains are of vegetable or animal origin."

After the death of Dr. Robert Dundas Thomson, the Lords Commissioners of Your Majesty's Treasury appointed Dr. A. W. Hofmann, F.R.S., Professor of Chemistry in the Royal School of Mines, and a few months later, on the translation of Dr. Hofmann to the University of Berlin, they entrusted the duty of making monthly analyses of the London waters to Dr. E. Frankland, F.R.S., the successor of Dr. Hofmann at the Royal School of Mines.

PART IV. DESCRIPTIVE. The Metropolitan water supply.

As will be seen from the following specimen report, Dr. Hofmann made some changes both in the analytical processes themselves, and in the mode of stating their results. He found that the loss suffered by the dry residue of a water on incineration is not due exclusively to organic matter, but that a portion, sometimes a very large one, of the matters driven off consists of inorganic substances, as some of these substances when strongly heated are more or less decomposed and volatilized. He also added to the analytical table a new column showing the amount of oxygen abstracted from permanganate of potash, chiefly by the organic matter present in the water. Lastly, as the weekly returns of the Registrar General are extensively read in France, Germany, Italy, and other States where the volume expressed by an imperial gallon is unknown, Dr. Hofmann stated his results in parts per 100,000. It is important that statistical data for cosmopolitan use should be given in a form not liable to misinterpretation, and the conversion of parts per 100,000 into grains per gallon, or parts per 70,000, is a sufficiently simple process for an Englishman; but the gallon being a measure unknown on the continent, a foreigner can only perform the reverse operation with considerable trouble and even uncertainty.

The following is a specimen of the reports furnished to the Registrar General by Professor Hofmann:—

RESULTS OBTAINED IN THE ANALYSIS OF THE WATERS SUPPLIED TO THE METROPOLIS BY THE SEVERAL WATER COMPANIES IN MAY 1865.

NAMES OF WATER COMPANIES.	SOLID MATTER in 100,000 parts of the Waters.	ORGANIC and other VOLATILE MATTER (included in previous column).	Amount of Oxygen required for oxidation of Organic Matter.
THAMES WATER COMPANIES.			
Chelsea	26·60	2·02	0·0760
West Middlesex	25·70	1·45	0·0551
Southwark and Vauxhall	27·33	1·70	0·0816
Grand Junction	27·85	1·90	0·0508
Lambeth	27·60	1·95	0·0680
OTHER COMPANIES.			
Kent	37·52	1·94	0·0096
New River	24·02	0·65	0·0184
East London	27·40	1·65	0·0488
South Essex	38·50	1·65	0·0104

"The Table may be read thus:—100,000 pounds of the Chelsea Water contained 26·60 lbs. of solid matter, of which 2·02 lbs. of organic and other matters were driven off by incineration. ·0760 lbs. of oxygen were required to destroy organic matter in the Chelsea Water."

"The first column of this table contains the amount of solid matter left on evaporation " and desiccation at 110°—115° C. (230°—240° F.); the second column, the loss which " this solid matter undergoes on incineration; the third column, lastly, the quantity " of oxygen required for the oxidation of the organic matter. The loss by incineration " given in the second column, which is generally stated to be due to the destruction " of organic matter only, represents also several volatile inorganic substances, such " as ammoniacal salts, and nitrates and nitrites, which, when strongly heated, are more " or less decomposed. Loss by incineration is therefore not an exact measure of the " organic impurity of water, since it may partly arise from the volatilisation of the " harmless products of the transformation of vegetal and animal nitrogenous substances. " To obtain an approximate indication of the amount of oxidizable organic matter " which remains, there are given in column 3 the quantities of oxygen which this " residuary organic matter requires for oxidation. These quantities were determined " by the volumes of a standard solution of permanganate of potassium, decolourized " by the same quantity of the several waters. To render these determinations more " accurate, columns of water two feet in depth were submitted to observation. It " deserves however to be mentioned that in exceptional cases mineral matters, such as " sulphuretted hydrogen and protosalts of iron, may be present in waters, which are " likewise oxidized by permanganate of potassium.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"The results are recorded in 100,000 parts. By moving the decimal point one place " to the right the above figures express in milligrams the quantities contained in one " kilogram of the several waters."

Soon after Dr. Frankland undertook the monthly analyses of the waters supplied to the metropolis, he submitted the analytical processes to a critical experimental examination, the details of which are recorded in the Journal of the Chemical Society, vol. XXI. page 77. This examination showed that the methods hitherto used for the estimation of the organic matter in water, and of the amount of oxygen required for its oxidation were altogether untrustworthy. It had been the custom to estimate the organic matter by evaporating the water to dryness and then incinerating the residue, with certain precautions. Chemists had long been discontented with this method, and scarcely less so with that which endeavoured to determine the amount of oxygen required to oxidize the organic matter contained in potable water. It was now proved that the loss on ignition might arise entirely from organic matter, or it might be exclusively due to the dissipation of volatile mineral ingredients. It was shown, on the one hand, that there might be much more organic matter in a water than is represented by the total loss on ignition, and on the other, that this determination might indicate the presence of a considerable amount of organic matter in a water which was wholly free from it. All that could be inferred from the loss on ignition was that, when it was large, the water was probably contaminated with animal or vegetable organic matter, or had been previously in contact with decaying animal matters. It was further shown that permanganate of potash thoroughly oxidizes only one kind of organic matter (oxalic acid) when the latter is dissolved in water. This kind of organic matter is never present in potable water, whilst urea, hippuric acid, starch, sugar, and gum which are sometimes present, are but slightly oxidized by permanganate of potash.

In the monthly analyses of the London waters, these defective methods were then replaced by an analytical treatment which accurately determined, not indeed the weight of the organic matter, for that is still impossible, but the amount of each of the two chief elements of organic matter; viz., carbon and nitrogen. To this were added determinations of ammonia, nitrogen in the form of nitrates and nitrites, chlorine, the hardness or soap-destroying quality of the waters, and an estimation of the previous contamination of each sample of water by animal matters such as sewage and animal manures. For the meaning of these determinations and their bearing upon the wholesomeness of water, see page 3. Observations of the temperature of the water delivered from the mains of each company were also appended to the analytical results.

The following is a specimen of the monthly reports made by Dr. Frankland:—

"ANALYSIS OF THE METROPOLITAN WATER SUPPLY FOR OCTOBER.

" SIR, Royal College of Chemistry, 25th October 1873.

"I HAVE to report to you in the following table the results of the chemical examination of the waters supplied to the Metropolis during the month of October, and " I append also the results yielded by the Birmingham water supply furnished by " Dr. Hill, and by the Glasgow water supply from Loch Katrine forwarded by Professor " Bischof.

"All the samples were clear and transparent when drawn from the Companies' mains. " The river waters had therefore been efficiently filtered.

"Taking the amount of organic impurity contained in a given volume of the Kent " Company's water as unity, the proportional amount in an equal volume of water " supplied by each of the other Metropolitan Companies was:—New River 1·1, Grand " Junction 1·8, West Middlesex 2·0, Chelsea and Southwark 2·1, East London 2·5, " and Lambeth 2·6. Thus, the Lambeth Company, notwithstanding the removal of its " intake to a point higher up the *Thames*, still continues to deliver water inferior in " quality to that of any other Company. The above comparison shows, however, that " the river waters continue to maintain the better quality which they acquired during " the summer months.

"Except in the minor matter of hardness, the Kent Company's water from deep wells " in the chalk continues of excellent quality. Its temperature remains nearly constant " during the entire year. This water is cool and refreshing in summer and less liable " than river water to freeze in winter.

"Dr. Hill, the Medical Officer of Health for Birmingham, reports that the water " supplied to that town was turbid from large suspended particles, and was very much " in need of filtration. This, he considers, probably accounts for the continued high " figure of the organic nitrogen. The ammonia had continued to diminish.

"Professor Bischof, of the Andersonian University, Glasgow, reports that the water " supplied to that city from Loch Katrine was yellow and unusually turbid when seen " through a stratum 150 millimetres thick. He considers that the turbidity fully

The Metropolitan water supply.

" explains the large increase of organic elements. The water did not exhibit the " slightest evidence of previous sewage or animal contamination.

" I am, &c.
" The Registrar General, &c., &c. E. FRANKLAND.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

COMPANIES.	Date and Place of Collection.	Temperature in centigrade degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.
THAMES.		°									
Chelsea	Cab Rank, Horse Guards, 13th October.	13·7	26·56	·130	·023	0	·175	·198	1,430	1·90	20·6
West Middlesex	Cab Rank, Portland Road, 13th October.	14·7	24·72	·122	·026	0	·171	·197	1,390	1·85	19·7
Southwark and Vauxhall.	Cab Rank, St. George's Church, Borough, 13th October.	15·1	25·44	·136	·021	0	·165	·186	1,330	1·80	20·0
Grand Junction	Cab Rank, Woodstock-st., 13th October.	12·5	26·20	·117	·017	0	·175	·192	1,430	1·90	21·5
Lambeth	Cab Rank, Westminster Bridge-road, 13th October.	14·0	27·52	·149	·038	0	·193	·231	1,610	1·95	20 9
OTHER SOURCES.											
New River	Cab Rank, Tottenham-court-road, 13th October.	14·0	26·52	·062	·015	0	·249	·264	2,170	1·75	21 5
East London	Royal Hotel, Mile-end-rd., 13th October.	13·7	27·90	·139	·046	·001	·103	·150	710	2·00	21·8
Kent	Deptford Bridge Police Station, 13th October.	12·1	39·16	·056	·017	0	·471	·488	4,390	2·60	29·1
Birmingham*	No. 91 Holliday-street, 6th October.	13·1	21·40	·288	·044	·004	·266	·313	2375	2·08	14·0
Glasgow†	Loch Katrine Waterworks, 14th October.	10·0	5·60	·256	·028	·001	0	·029	0	·59	·5
Column 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.

* Analysed by Dr. Alfred Hill, of Queen's College, Birmingham.
† Analysed by Dr. Bischof, Professor of Technical Chemistry, Andersonian University, Glasgow.

" The numbers in columns 4, 5, 6, 7, 8, 9, 10, 11, and 12 all relate to 100,000 parts of the waters. " The Table is to be read thus:—The Chelsea Company's water, collected on the 13th October at the " Horse Guards cab-rank, had a temperature of 13°·7 C.; 100,000 lbs. of it contained 26·56 lbs. of " solid impurity; the organic matter, constituting a portion of this impurity, contained ·130 lb. of " carbon and ·023 lb. of nitrogen. The above quantity of water also contained no ammonia and " ·175 lb. of nitrogen in the form of nitrates and nitrites, whilst the total amount of *combined* " nitrogen in every form was ·198 lb. After its descent to the earth as rain, 100,000 lbs. of the water " had been contaminated with animal matter equivalent to that contained in 1,430 lbs. of average " London sewage. By gradual oxidation, this animal contamination had been, so far as analysis can " show, converted into innocuous inorganic compounds before the water was submitted to investi- " gation. The above weight of water also contained 1·9 lbs. of chlorine. Finally, 100,000 lbs. of " the water contained 20·6 lbs. of carbonate of lime, or an equivalent quantity of other hardening " or soap-destroying ingredients.

" As the Kent Company's water is unpolluted, and as it is drawn from deep wells, the evidence " of previous sewage or animal contamination which it exhibits may safely be disregarded.

" The numbers in the analytical Table can be converted into grains per imperial gallon by multi- " plying them by 7, and then moving the decimal point one place to the left. The same operation " transforms the hardness in the Table into degrees of hardness on Clark's scale."

In addition to his monthly reports, the same chemist also makes an annual report to the Registrar-General, commenting upon the variations in the quality of the Metropolitan waters delivered during the preceding year. As these reports form a continuous history of the London water supply, we give them in the Appendix (No. 3) from 1868 to 1872 inclusive, inserting here, as a specimen, the report for the year 1873.

" REPORT on the ANALYSIS of the WATERS supplied by the METROPOLITAN WATER " COMPANIES during the several MONTHS of the YEAR 1873. By Professor " FRANKLAND, D.C.L., F.R.S., &c.

" *Royal College of Chemistry,*
28th January 1874.

" SIR,

" I HAVE to submit to you in the following Tables a summary of the results " obtained in the analytical examinations of the waters supplied to London by the eight

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

" Metropolitan Companies, during the year 1873, supplemented by observations of " temperature and of clearness or turbidity, together with microscopic examinations of " the sediments deposited by the turbid samples.

" Table A. shows the temperature of the water flowing from the Companies' mains " when the samples were taken. The water from the three different sources supplied " to London exhibited the following variations of temperature :—

" The temperature of *Thames* water supplied by the Chelsea, West Middlesex, Grand " Junction, Southwark, and Lambeth Companies varied from 2°·3 C. (36°·1 Fahr.) in " February, to 21°·3 C. (70°·3 Fahr.) in July.

" The temperature of the water derived from the river *Lee*, as delivered by the New " River and East London Companies, ranged from 2°·0 C. (35°·6 Fahr.) in February, to " 20°·0 C. (68°·0 Fahr.) in August.

" The temperature of the Kent Company's deep well water showed a minimum of " 12°·1 C. (53°·8 Fahr.) in October, and a maximum of 14°·5 C. (58°·1 Fahr.) in " December.

" Thus the temperature of the river waters varied through the large range of 19°·0 C. " (66°·2 Fahr.); they were vapid and unrefreshing in summer, and in danger of freezing " in winter; but the Kent Company's water was almost unaffected by change of season, " the extreme range being only 2°·4 C. (4°·3 Fahr.), so that it was cool and pleasant " to drink in summer and far above the freezing point in winter; the highest tempera- " ture noted in the past year being actually in December.

" Table B. gives the weight of solid impurities contained in 100,000 parts by weight " of each sample of water. These consist of a great variety of substances, some of " which are very objectionable and sometimes dangerous, whilst others are by com- " parison innocuous. The very objectionable impurities, which are organic, and form " but a small part of the total impurity, were discovered in the water supplied from " the rivers *Thames* and *Lee* in much larger proportions than in that derived from deep " chalk wells by the Kent Company. During the year 1873 these impurities have " slightly increased in quantity in each of the three classes of water. In the waters " derived from the *Thames* they had a maximum in February and a minimum in " September. In the *Lee* water the maximum occurred in February and the minimum " in August. In the deep well water the maximum was attained in December and the " minimum in October.

" Tables C. and D. exhibit the proportion of organic impurity actually existing in each " water at the time of analysis, as represented by the two most important elements, " carbon and nitrogen. As the organic matters polluting the *Thames* and *Lee* are, to " a large extent, of animal origin, the information thus given is of very great importance " as regards the probable wholesomeness of the waters obtained from these rivers in " different years and seasons. On comparing these results with those obtained in the " year 1872, it will be seen that the character of the water derived from the *Thames* has " undergone a considerable, and that from the *Lee* a slight, amelioration, while the " supply from the chalk has suffered a slight deterioration in quality. The maximum " organic pollution occurred in the months of January, February, March, November, " and December, during which months the water supplied from the *Thames* was seldom " suitable for domestic use. In August, and for some time after, the East London " Company obtained part of its supply from the *Thames* at Hampton, and the analysis " of samples taken on the same day, direct from the main conveying this water, at " Sunbury and at Finsbury Park showed that it had suffered no deterioration by passing " through such an unusual length of pipe; a result which is extremely satisfactory, " as in long mains considerable pollution has been observed to arise from the vicious " system of packing the joints with tow.

" The Kent Company's water from the chalk still maintains its high character for " comparative freedom from organic matter, and is, therefore, again taken as the standard " of comparison in Table E.

" Taking the proportion of organic elements in this water as unity, the maximum, " minimum, and average proportions in each of the other Metropolitan waters during " the year 1873 were as follows;—

	Maximum.	Minimum.	Average.
" Kent - - - -	1·0	1·0	1·0
" New River - - -	5·4	1·1	2·2
" West Middlesex - - -	7·4	2·0	3·5
" East London - - -	7·4	2·1	3·6
" Southwark - - -	8·2	2·1	3·8
" Grand Junction - - -	8·5	1·8	3·8
" Chelsea - - - -	8·1	2·1	4·0
" Lambeth - - - -	8·9	2·6	4·3

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"The *Thames* and *Lee* are, at their chief sources, as free from organic pollution as " the deep well water from the chalk; but on their way to the intakes of the water " companies they are largely contaminated by sewage and the drainage from fields " dressed with animal manure, and this especially in the winter months.

"Tables F. and G. require no comment.

"Table H. exhibits the total weight of combined nitrogen, and thus, after applying " a small correction for the combined nitrogen in rain water, sums up the evidence of " both *past* and *present* contamination of each water by nitrogenous organic matter. " But this evidence is defective in the spring and summer months, since the combined " nitrogen is greatly diminished by serving as food for the myriads of animal and " vegetable organisms then living in the rivers; so that, as evidence of pollution, " attention must be restricted to the combined nitrogen found in the autumn and winter. " It appears, then, that the average amount of total combined nitrogen in 100,000 parts " of *Thames* water in January, February, March, October, November, and December, " 1872, was ·3 part, and in the same six months of 1873 it was ·293 part. In the same " quantity of *Lee* water it was ·317 part in 1872, and ·281 part in 1873. The water " of the Kent Company being derived from deep wells in the chalk is not subject to " this diminution of combined nitrogen from the action of animal and vegetable life, " and the average may, therefore, be taken on the whole year, and it was ·454 part in " 1872, and ·471 part in 1873. On comparing together the three tables C., D., and H., " a considerable improvement is manifest in the condition of the waters derived from " the *Thames* and *Lee*, both as regards the actual organic pollution and the total " combined nitrogen, and a slight deterioration in the case of the Kent Company's " water.

"Table I. shows the *past* as distinguished from the *present* pollution of the water by " sewage and animal matters, giving, in terms of average London sewage, the amount " of previous animal contamination deduced from the results shown in Tables F. and G. " The aquatic life above described as causing a diminution of the total combined " nitrogen in the preceding Table would clearly be equally active in obliterating the " evidence of previous animal contamination. This is well seen in the case of the water " from the river *Lee* distributed by the East London Company, which is known to be " more polluted by animal matter than that taken from the same river by the New " River Company. Notwithstanding this, the water of the former company showed " evidence in November of previous contamination equal to that derivable from 420 " parts of average London sewage in 100,000 parts of water, while that of the latter " company indicated previous pollution corresponding to 2,260 parts of sewage; the " reason being, that the former water had been stored for about eighteen days before " filtration, whilst the latter had been sent direct from the river to the filters. In the " case of the water abstracted from the rivers *Thames* and *Lee*, this evidence of previous " contamination is of serious importance, because there is great probability that the " morbific matter, sometimes present in animal excreta, will be carried down the stream " without decomposition, and will produce disease in those persons who drink the water. " In the case of the deep well water of the Kent Company, however, this evidence may " be disregarded, because the excessive filtration to which such water is subjected in " passing downwards through a great thickness of chalk affords a sufficient guarantee " that all noxious constituents have been removed.

"Table K. shows the proportion of chlorine found in the various waters. The " principal value of this analytical determination is to detect the admixture of water " from the tidal reaches of the *Thames* and *Lee*, as many of the filters and reservoirs of " the companies are situated on the banks of these polluted tidal streams. No such " pollution has been discovered during the year 1873.

"Table L. shows the hardness of each sample analysed; that is to say, the amount " by weight of carbonate of lime or other equivalent soap-destroying substances in " 100,000 parts by weight of water. The average hardness of the *Thames* water " supplied to London during 1872 was 20°·7 or parts in 100,000 of water, and in 1873 " it was 21° or parts. The average hardness of the water from the *Lee* was 21°·9 or " parts in 1872, and 21°·7 or parts in 1873. The average hardness of the Kent Com- " pany's water was 29°·2 or parts in 1872, and 29°·9 or parts in 1873; it is therefore " about 9° harder than the *Thames* water, and 8° harder than the *Lee* water. The use " of any of these waters for washing entails a yearly loss of vast quantities of soap or " soda necessary to soften them before they can be used, but any of them could be " softened to nearly the necessary extent by the use of lime,—an operation which is " employed at Aylesbury, Canterbury, Caterham, and Tring, to soften similar waters " before they are distributed to the public.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"Lastly, Table M. gives the annual average of each determination, and thus brings "into juxtaposition the average results yielded by the water supplied by each company "throughout the year.

"The following table shows the degree of efficiency with which each of the companies "drawing from the *Thames* and *Lee* has filtered the water distributed during the year "1873:—

NAMES OF COMPANIES.	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
THAMES.				
Chelsea - - -	9	2	1	0
West Middlesex -	12	0	0	0
Southwark - -	10	2	0	0
Grand Junction -	9	3	0	0
Lambeth - -	9	2	1	0
OTHER SOURCES.				
New River - -	11	1*	0	0
East London - -	12	0	0	0
Kent - - -	12	0	0	0

* White films, probably due to alterations in the mains.

"The water supplied by the Kent Company, obtained from deep wells in the chalk, "is always clear and transparent without filtration. Only three of the remaining "companies, the West Middlesex, New River, and East London, effected satisfactory "filtration throughout the year; the subsidence reservoirs and filter beds of all the "others are quite inadequate to deal with *Thames* water when the river is in flood. "Since, however, the river has been subject to very few floods during the year 1873, "the condition of the water supplied to consumers has been, as regards filtration, "decidedly better than it was in the previous year.

"On being submitted to microscopical examination, the suspended matters in turbid "water are almost invariably found to contain large numbers of living and moving "organisms, and during the past year the turbid samples of the Grand Junction and "Lambeth Companies exhibited such forms of life on three occasions each, the Chelsea "and Southwark on two, and the New River once only. The following table gives the "results of such microscopic examinations during the past five years:—

	Number of occasions when living organisms were found.				
	1869.	1870.	1871.	1872.	1873.
" Chelsea - - -	3	2	2	3	2
" West Middlesex - -	0	0	0	0	0
" Southwark - - -	8	1	4	1	2
" Grand Junction - -	4	1	1	2	3
" Lambeth - - -	5	0	4	6	3
" New River - - -	0	0	0	0	1
" East London - - -	4	3	3	1	0
" Kent - - -	0	0	0	0	0

"The system of constant supply, but chiefly by means of standpipes, is being gra-"dually introduced into the poorer districts of the Metropolis, and it appears from a "return made by Major Bolton to the Local Government Board, that the inhabitants "of about 10 per cent. of the houses in London are now thus supplied. The extension "of this most desirable system to the actual supply of houses is almost entirely pre-"vented by the excessively stringent and costly regulations which are insisted upon "by the water companies before they will furnish the constant service. These regulations "are now the chief obstacles to the general introduction of a constant supply, since, "according to the return just quoted, there are already within the Metropolis 648½ miles "of mains, out of a total of 2,525½ miles, or upwards of one fourth, which are con-"stantly charged. Such mains are available for the fixing of hydrants, which would "be a very important addition to the means for extinguishing fires now at the disposal "of the Fire Brigade.

"I have, &c.
E. FRANKLAND.

"The Registrar-General,
&c. &c. &c."

Part IV. Descriptive.

The Metropolitan water supply.

Table A.—Temperature (in Centigrade degrees) of the Metropolitan Waters, as delivered from the Companies' Main.

Names of Companies.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	8·3	3·5	6·5	9·0	12·0	16·0	18·8	19·5	17·5	13·7	10·2	9·6	12·0
West Middlesex -	9·0	3·8	7·0	9·3	12·5	18·0	21·0	20·5	18·5	14·7	9·9	10·0	12·8
Southwark -	10·0	3·8	7·5	9·5	13·0	18·3	21·3	19·8	18·3	15·1	10·2	10·2	13·1
Grand Junction -	8·2	2·3	5·0	8·0	11·0	18·3	20·6	18·3	16·8	12·5	9·5	8·9	11·6
Lambeth - -	7·8	3·5	6·5	9·0	12·0	16·3	18·8	19·5	17·5	14·0	10·0	9·6	12·0
Other Sources.													
New River -	8·3	3·0	6·5	10·0	11·8	17·0	19·5	20·0	18·0	14·0	10·0	9·8	12·3
East London -	8·2	2·0	6·0	9·0	11·5	17·2	19·0	19·5	17·3	13·7	9·6	13·6	12·2
Kent - -	12·3	12·2	12·5	13·5	13·5	13·5	14·0	14·0	13·8	12·1	13·3	14·5	13·3

Table B.—Weight of Solid Impurity in 100,000 parts of the Waters.

Names of Companies.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - -	28·52	29·50	27·14	29·72	25·30	27·06	26·38	26·10	25·26	26·56	27·42	28·84	27·32
West Middlesex -	27·56	32·36	28·96	29·40	26·72	23·88	24·32	24·92	23·74	24·72	27·24	30·66	27·04
Southwark -	27·92	31·96	29·32	28·54	26·36	24·90	23·92	24·10	24·64	25·44	28·34	30·86	27·19
Grand Junction -	26·66	31·30	29·30	29·88	25·84	25·54	24·78	25·10	24·10	26·20	27·88	31·10	27·31
Lambeth - -	29·42	31·58	29·00	30·44	27·96	27·06	26·40	25·22	26·10	27·52	30·18	30·72	28·47
Other Sources.													
New River -	31·00	31·90	30·44	29·06	25·94	25·70	26·42	26·00	25·18	26·52	29·98	30·20	28·19
East London -	33·40	36·06	32·90	28·34	25·72	25·38	24·56	22·62	23·56	27·90	26·28	34·64	28·45
Kent - -	40·94	42·94	41·58	41·64	42·20	40·56	40·84	39·82	40·98	39·16	40·00	44·04	41·22

Table C.—Organic Carbon in 100,000 parts of the Waters.

Names of Companies.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Thames.													
Chelsea - -	·447	·201	·259	·143	·121	·132	·138	·154	·121	·130	·323	·198	·197
West Middlesex -	·341	·175	·252	·153	·114	·122	·128	·139	·114	·122	·223	·191	·173
Southwark -	·396	·190	·268	·157	·118	·131	·129	·132	·123	·136	·272	·181	·186
Grand Junction -	·412	·227	·275	·135	·124	·133	·127	·142	·119	·117	·197	·193	·183
Lambeth - -	·449	·215	·287	·143	·125	·130	·145	·171	·145	·149	·308	·201	·206
Other Sources.													
New River -	·257	·168	·178	·097	·063	·063	·074	·064	·059	·062	·109	·085	·107
East London -	·333	·309	·160	·179	·127	·109	·112	·127	·120	·139	·174	·216	·175
Kent - -	·059	·048	·031	·041	·043	·040	·054	·044	·053	·056	·065	·062	·050

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	·056	·026	·050	·018	·013	·025	·023	·043	·019	·023	·067	·040	·034
West Middlesex -	·034	·032	·031	·019	·016	·027	·024	·030	·015	·026	·055	·031	·028
Southwark -	·045	·035	·044	·020	·020	·027	·022	·023	·022	·021	·060	·024	·030
Grand Junction -	·049	·033	·050	·020	·016	·037	·029	·027	·023	·017	·043	·036	·032
Lambeth - -	·065	·042	·052	·023	·021	·043	·026	·045	·027	·038	·065	·031	·040
OTHER SOURCES.													
New River -	·032	·020	·027	·013	·011	·015	·018	·016	·010	·015	·024	·016	·018
East London -	·042	·082	·032	·024	·024	·030	·022	·023	·015	·046	·043	·043	·035
Kent - -	·006	·005	·007	·008	·007	·010	·009	·014	·007	·017	·014	·012	·010

TABLE E.—PROPORTIONAL AMOUNT of ORGANIC ELEMENTS, that in the KENT Company's Water being taken as 1.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES													
Chelsea - -	7·7	4·3	8·1	3·3	2·7	3·1	2·6	3·4	2·3	2·1	4·9	3·2	4·0
West Middlesex -	5·8	3·9	7·4	3·5	2·6	3·0	2·4	2·9	2·1	2·0	3·5	3·0	3·5
Southwark -	6·8	4·2	8·2	3·6	2·8	3·2	2·4	2·7	2·4	2·1	4·2	2·8	3·8
Grand Junction -	7·1	4·9	8·5	3·2	2·8	3·4	2·5	2·9	2·4	1·8	3·0	3·1	3·8
Lambeth - -	7·9	4·8	8·9	3·4	2·9	3·5	2·7	3·7	2·9	2·6	4·7	3·1	4·3
OTHER SOURCES.													
New River -	4·4	3·5	5·4	2·2	1·5	1·6	1·5	1·4	1·1	1·1	1·7	1·4	2·2
East London -	5·8	7·4	5·1	4·1	3·0	2·8	2·1	2·6	2·2	2·5	2·7	3·5	3·6
Kent - -	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0

TABLE F.—AMMONIA in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	·001	·001	·000	·000	·001	·000	·000	·000	·001	·000	·000	·000	·000
West Middlesex -	·001	·000	·000	·001	·001	·000	·000	·001	·000	·000	·000	·000	·000
Southwark -	·001	·002	·001	·000	·002	·000	·000	·000	·000	·000	·000	·000	·000
Grand Junction -	·000	·000	·001	·001	·001	·000	·000	·001	·000	·000	·000	·000	·000
Lambeth - -	·001	·001	·001	·000	·001	·000	·000	·000	·001	·000	·000	·000	·000
OTHER SOURCES.													
New River -	·000	·001	·000	·000	·001	·000	·000	·001	·000	·000	·000	·000	·000
East London -	·001	·001	·000	·001	·000	·000	·000	·000	·000	·001	·000	·000	·000
Kent - -	·000	·001	·000	·001	·000	·000	·000	·000	·000	·000	·000	·000	·000

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

TABLE G.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea -	·235	·389	·255	·284	·248	·155	·178	·153	·148	·175	·265	·218	·225
West Middlesex -	·266	·357	·267	·286	·253	·096	·154	·074	·119	·171	·212	·157	·201
Southwark -	·224	·328	·264	·273	·243	·106	·158	·061	·139	·165	·224	·215	·200
Grand Junction -	·227	·343	·257	·290	·239	·132	·162	·119	·128	·175	·202	·213	·207
Lambeth -	·275	·371	·281	·309	·281	·157	·174	·114	·169	·193	·387	·247	·246
OTHER SOURCES.													
New River -	·329	·362	·319	·295	·254	·158	·178	·202	·183	·249	·258	·188	·248
East London -	·322	·262	·320	·221	·173	·092	·131	·080	·091	·103	·074	·156	·169
Kent - -	·410	·545	·553	·582	·604	·419	·369	·400	·416	·471	·371	·396	·461

TABLE H.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea -	·292	·416	·305	·302	·262	·180	·201	·196	·168	·198	·332	·258	·259
West Middlesex -	·301	·389	·298	·306	·270	·123	·178	·105	·134	·197	·267	·188	·230
Southwark -	·270	·365	·309	·293	·265	·133	·180	·084	·161	·186	·284	·239	·231
Grand Junction -	·276	·376	·308	·311	·256	·169	·191	·147	·151	·192	·245	·249	·239
Lambeth -	·341	·414	·334	·332	·303	·200	·200	·159	·197	·231	·452	·278	·287
OTHER SOURCES.													
New River -	·361	·383	·346	·308	·266	·173	·196	·219	·193	·264	·282	·204	·266
East London -	·365	·345	·352	·246	·197	·122	·153	·103	·106	·150	·117	·199	·205
Kent - -	·416	·551	·560	·591	·611	·429	·378	·414	·423	·488	·385	·408	·471

TABLE I.—PREVIOUS SEWAGE or ANIMAL CONTAMINATION in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea -	2040	3580	2230	2520	2170	1230	1460	1210	1170	1430	2330	1860	1940
West Middlesex -	2350	3250	2350	2550	2220	640	1220	430	870	1390	1800	1250	1690
Southwark -	1930	2980	2330	2410	2130	740	1260	290	1070	1330	1920	1830	1680
Grand Junction -	1950	3110	2260	2590	2080	1000	1300	880	960	1430	1700	1810	1760
Lambeth -	2440	3400	2500	2770	2500	1250	1420	820	1380	1610	3550	2150	2150
OTHER SOURCES.													
New River -	2970	3310	2870	2630	2230	1260	1460	1710	1510	2170	2260	1560	2160
East London -	2910	2310	2880	1900	1410	600	990	480	590	710	420	1240	1370
Kent - -	3780	5140	5210	5510	5720	3870	3370	3680	3840	4390	3390	3640	4290

PART IV.
DESCRIPTIVE.

The Metropolitan water supply.

TABLE K.—CHLORINE in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	1·95	1·85	1·85	1·80	1·90	1·80	1·90	1·90	1·90	1·90	2·20	2·20	1·93
West Middlesex -	1·90	1·80	1·80	1·75	1·80	1·75	1·80	1·90	1·80	1·85	2·30	2·10	1·88
Southwark -	1·85	1·75	1·80	1·80	1·85	1·85	1·90	1·95	1·75	1·80	2·10	1·90	1·86
Grand Junction -	1·85	1·75	1.80	1·80	1·80	1·85	1·85	2·00	1·80	1·90	2·00	1·90	1·86
Lambeth -	1·90	1·70	1·80	1.80	1·90	1·90	1·80	1·85	1·85	1·95	2·30	2·00	1·90
OTHER SOURCES.													
New River -	1·70	1·70	1.65	1.60	1·75	1·80	1·70	1·75	1·70	1·75	1·70	1·90	1·72
East London -	1·95	1·95	1·90	1·95	2·00	2·00	2·10	2·00	1·95	2.00	1·90	2·00	1·97
Kent - -	2·45	2·50	2.40	2.45	2·50	2·60	2·60	2.60	2·60	2·60	2·60	2·60	2·54

TABLE L.—DEGREES of HARDNESS (1 deg.=1 part of Carbonate of Lime, or its equivalent) in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1873. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - -	19·7	21·8	20·9	22.7	20·3	20·6	21·2	20·6	20·3	20·6	18·9	22·1	20·8
West Middlesex -	20·9	22·7	21·5	22·4	20·9	19·1	19·9	20·6	19·4	19·7	20·9	23·3	20·9
Southwark -	18·9	23·0	21·5	22·4	19·7	19·7	19·7	20·0	20.0	20·0	21·5	23·6	20·8
Grand Junction -	20·0	23·0	21·8	23·0	19·4	20·0	19·4	20·3	20·9	21·5	20·9	24·2	21·2
Lambeth -	20·3	23·3	20·6	23·3	21·5	20·9	20·9	21·2	20·9	20·9	20·0	23·3	21·4
OTHER SOURCES.													
New River -	22·7	24·8	23·3	22·1	20·9	21·2	21·5	21·2	18·9	21·5	22·7	24·8	22·1
East London -	24·8	24·8	23·9	20·9	19·4	20·6	19·4	17·1	19·4	21·8	19·7	23·6	21·3
Kent - -	30·6	29·7	29·7	29·7	28·8	29·4	29·1	31·3	29·4	29·1	31·3	30·6	29·9

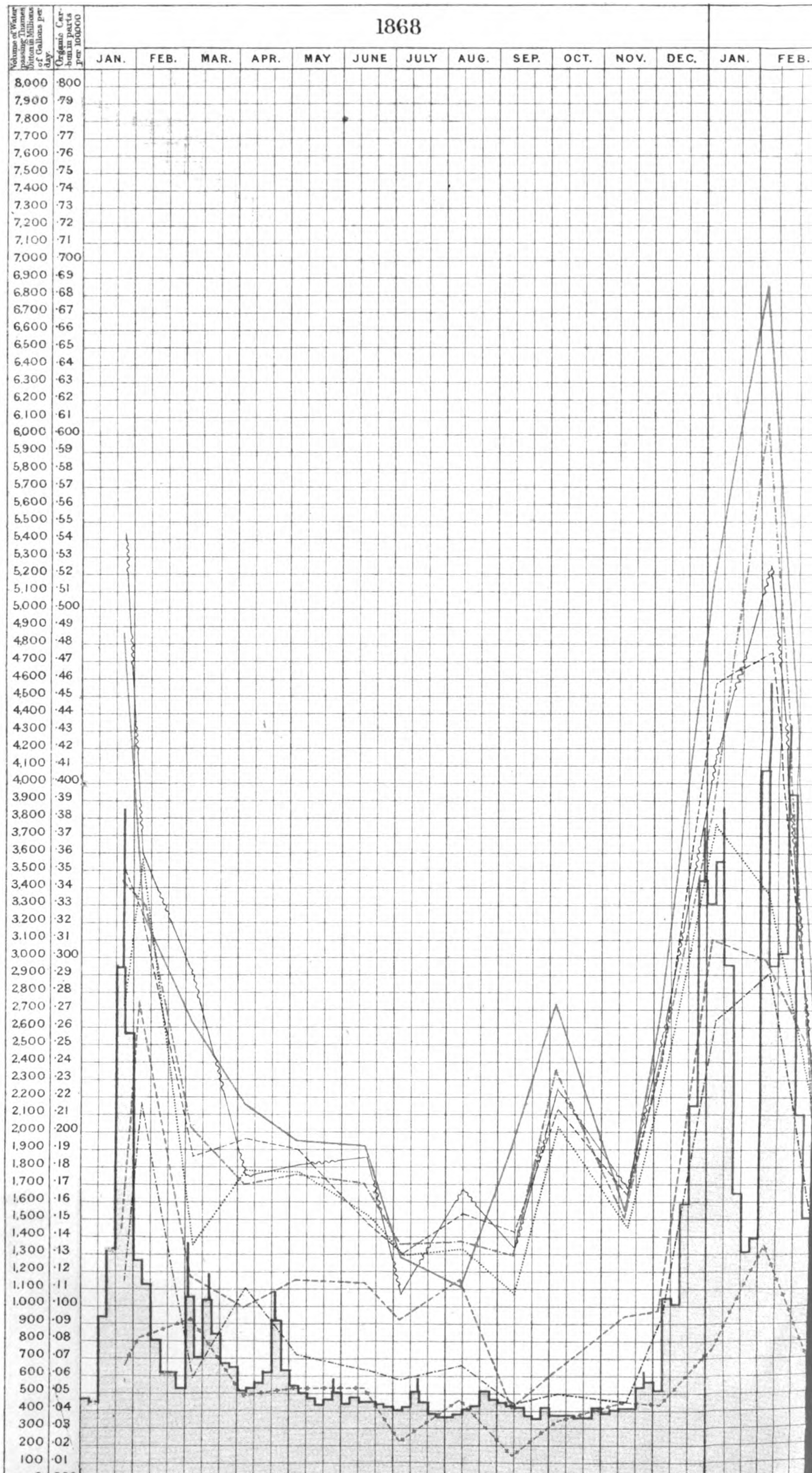
TABLE M.—AVERAGES for 1873.

The Numbers in this Table relate to 100,000 parts of each Water.

NAMES OF COMPANIES.	Temperature in Centigrade Degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.	Proportional Amount of organic Elements, that in the Kent Company's Water being taken as 1.
THAMES.											
Chelsea - - -	12·0°	27·32	·197	·034	·000	·225	·259	1940	1.93	20·8	4·0
West Middlesex - -	12·8	27·04	·173	·028	·000	·201	·230	1690	1·88	20·9	3·5
Southwark - - -	13·1	27·19	·186	·030	·000	·200	·231	1680	1·86	20·8	3·8
Grand Junction - -	11·6	27·31	·183	·032	·000	·207	·239	1760	1·86	21·2	3·8
Lambeth - - -	12·0	28·47	·206	·040	·000	·246	·287	2150	1·90	21·4	4·3
OTHER SOURCES.											
New River - - -	12·3	28·19	·107	·018	·000	·248	·266	2160	1·72	22·1	2·2
East London - -	12·2	28·45	·175	·035	·000	·169	·205	1370	1·97	21·3	3·6
Kent - - -	13·3	41·22	·050	·010	·000	·461	·471	4290	2·54	29·9	1·0

As affecting the wholesomeness of the metropolitan waters, tables C. and D. are of most importance. They record the proportions of the two chief elements of the organic matter found in each sample of water submitted to analysis. This organic matter is

DIAGRAM No. 1.



Volume of Water passing Thames Ditton in Millions of Gallons per day.
Organic Carbon in parts per 100000
1868
JAN.
FEB.
MAR.
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MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.
JAN.
FEB.
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7,800 ·78
7,700 ·77
7,600 ·76
7,500 ·75
7,400 ·74
7,300 ·73
7,200 ·72
7,100 ·71
7,000 ·700
6,900 ·69
6,800 ·68
6,700 ·67
6,600 ·66
6,500 ·65
6,400 ·64
6,300 ·63
6,200 ·62
6,100 ·61
6,000 ·600
5,900 ·59
5,800 ·58
5,700 ·57
5,600 ·56
5,500 ·55
5,400 ·54
5,300 ·53
5,200 ·52
5,100 ·51
5,000 ·500
4,900 ·49
4,800 ·48
4,700 ·47
4,600 ·46
4,500 ·45
4,400 ·44
4,300 ·43
4,200 ·42
4,100 ·41
4,000 ·400
3,900 ·39
3,800 ·38
3,700 ·37
3,600 ·36
3,500 ·35
3,400 ·34
3,300 ·33
3,200 ·32
3,100 ·31
3,000 ·300
2,900 ·29
2,800 ·28
2,700 ·27
2,600 ·26
2,500 ·25
2,400 ·24
2,300 ·23
2,200 ·22
2,100 ·21
2,000 ·200
1,900 ·19
1,800 ·18
1,700 ·17
1,600 ·16
1,500 ·15
1,400 ·14
1,300 ·13
1,200 ·12
1,100 ·11
1,000 ·100
900 ·09
800 ·08
700 ·07
600 ·06
500 ·05
400 ·04
300 ·03
200 ·02
100 ·01
0 ·000

The Metropolitan water supply.

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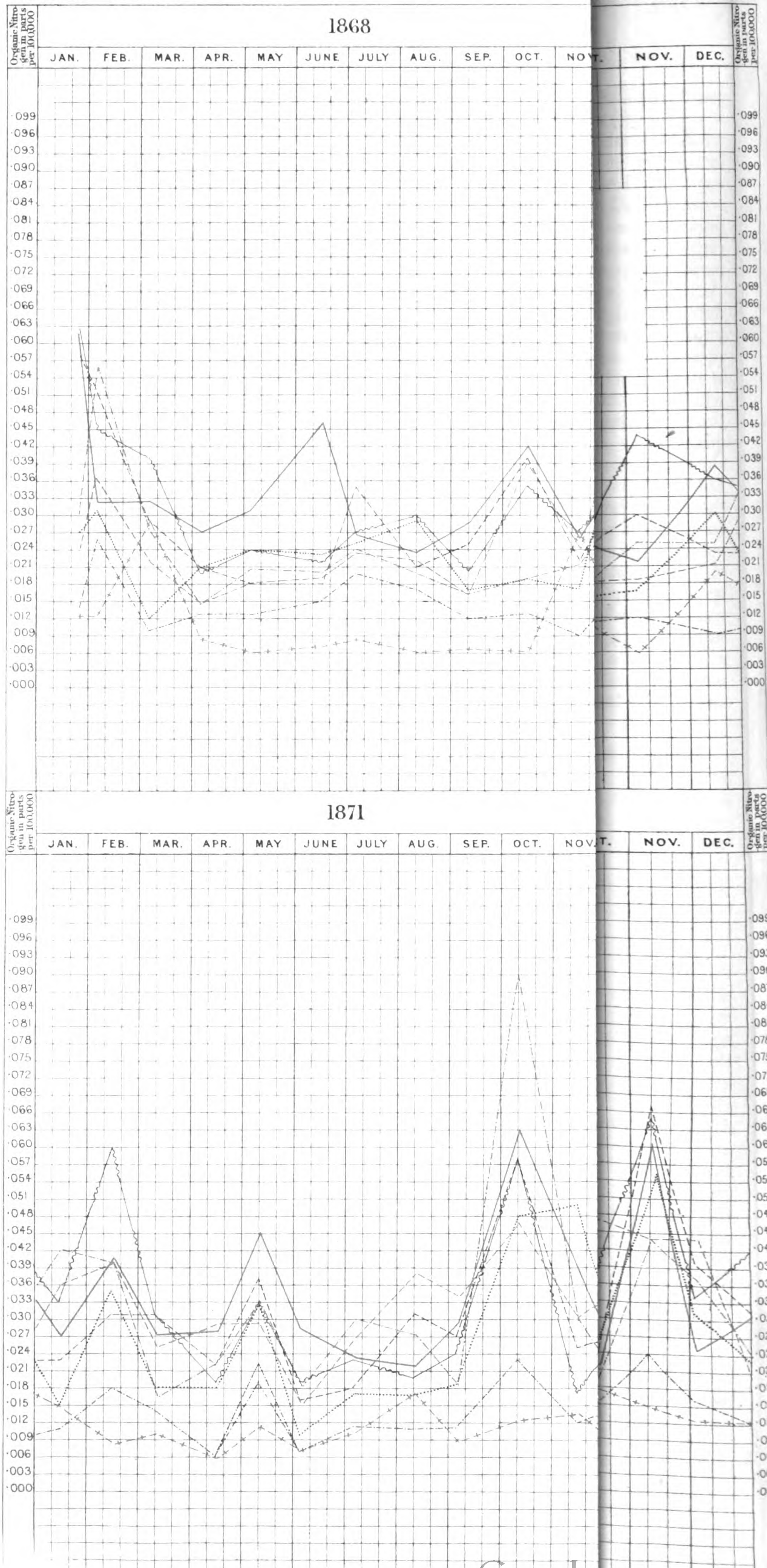
DIAGRAM No. 2. ... EAT BRITAIN_1874.



Stanford's Geog. Estab. London

partly of animal and partly of vegetable origin. In so far as it is of animal origin it represents the extent to which the waters are actually polluted by sewage and by the washings of manured fields. Careful observations made by us have demonstrated that in the river waters supplied to London, the soluble organic matters, and some of the suspended matters of sewage and manure, reach the water drinker in a few hours, and in substantially the same condition in which they leave the sewers and fields; but the organic matter present in deep well water, although it may originally have had the same origin, has been subjected to the powerful oxidizing influence of porous chalk for a period of many months, if not years, before it is raised to the surface and distributed. Although the limit to the vitality and persistency of zymotic germs has never been determined, yet it is obviously very improbable, firstly, that they should retain their vitality for long periods, and secondly, that they should not be removed by such prolonged and perfect filtration as that to which the deep well water supplied to London is subjected during its passage through a vast thickness of chalk. As a matter of fact, which can be demonstrated at any time, the river waters supplied to London, even after the most efficient artificial filtration, and when they appear to the ordinary observer quite clear and sparkling, are found to be full of very minute suspended particles when they are placed in a dark room whilst a ray of bright light is made to pass through them. Under these circumstances the thousands of solid particles suspended in a tumbler of the most brilliant *Thames* and *Lee* water are easily seen with the naked eye. These suspended particles are not entirely absent from deep well water, but they are comparatively sparsely distributed:—in the artificially filtered river water they are probably at least one thousand times as numerous as they are in the naturally filtered deep well water supplied to the metropolis. The exhaustive filtration to which the deep well water supplied to London has been subjected must therefore be regarded as a great safeguard against the presence of any noxious qualities in the organic matter contained in such water. Moreover, the proportion of organic matter in the deep well water is very small, and it varies from month to month, and year to year, between very narrow limits, whilst the corresponding variations in the river waters are very great.

PART IV.
DESCRIPTIVE.

The Metropolitan water supply.

It is difficult to obtain, from the foregoing analytical tables, a clear view of the variation from month to month of the proportions of organic carbon and organic nitrogen contained in the waters delivered by the respective companies; we have therefore represented them by curves in the accompanying diagrams. We have also drawn, upon the same plates, curves showing the variations in the flow of the *Thames*, at the intake of the Chelsea Water Company at Long Ditton, nearly opposite Hampton Court Palace. The copy of the daily gaugings from which this latter curve is plotted was furnished to us by Mr. John Taylor, M. Inst. C.E.,—the engineer of the Lambeth Water Company. This copy will be found in Appendix No. 9 of this Report. It is interesting to compare the curve of organic pollution with the curve representing the volume of water passing down the river at or near the intakes of those water companies who draw their supplies from the *Thames*. Unfortunately no similar set of gaugings have been executed on the river *Lee*, but probably the rainfall and its effect upon the river flow are not very different in the two basins; at all events, the curves in the diagrams facing pages 261 and 262, representing the organic impurity in the waters of the New River and East London Companies which are drawn from the *Lee*, follow closely the curves of the *Thames* waters, although the maximum pollution produced by floods in the *Lee* valley is seen to be always less than that observed in the *Thames* just above Teddington lock. The plotting of these curves has also brought out the interesting fact, that the quality of the deep-well water delivered by the Kent Company is not entirely, though it is nearly, unaffected by very heavy rain. In the years 1868 and 1869, the apex of the deep-well water curve of the Kent Company coincides with that of the waters of the *Thames* and *Lee* too frequently to be the result of accident. Whether this arose from the actual admission of a small proportion of surface water into the wells, or from an acceleration of the process of natural filtration by surface pressure, can at present only be matter for conjecture. Since the improvements in the works at Deptford, mentioned at page 275, this effect has been barely, if at all, perceptible.

Diagram I. shows the proportion of organic carbon in 100,000 parts of the water delivered by each London company. This diagram also shows the variations in the flow of the *Thames* at Long Ditton above and below the summer datum line.

Diagram II. compares in like manner the proportion of organic nitrogen in the different waters.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Diagram III. exhibits the same comparisons, but in this table the amounts of the two organic elements (organic carbon and organic nitrogen) are taken together.

Diagram IV. shows the mean monthly organic contamination of the *Thames*, *Lee*, and deep-well waters delivered in London, and compares it with the flow of the *Thames* at Ditton.

To prevent inconvenient complication of the curve representing the flow of the *Thames*, averages of five daily gaugings are plotted; but, in many cases the maximum height of the flood during the five days is shown by a blue line rising from the curve. Thus the average daily flow of the river during the last five days of March 1872 was 1,280 millions of gallons; but on the 29th of March it was, as shown by the blue line, 2,370 millions of gallons. These maximum lines obviously become of great importance when they occur just before the collection of the samples of water, as for instance on the 5th of March 1870 (Diagram III.)

Diagram III. shows conclusively that the quality of the river waters delivered in London, and especially that of the *Thames* water depends, as regards intensity of organic pollution, upon (1) large floods in the *Thames*; (2) small floods when the river is low; and (3) decay of vegetation in autumn.

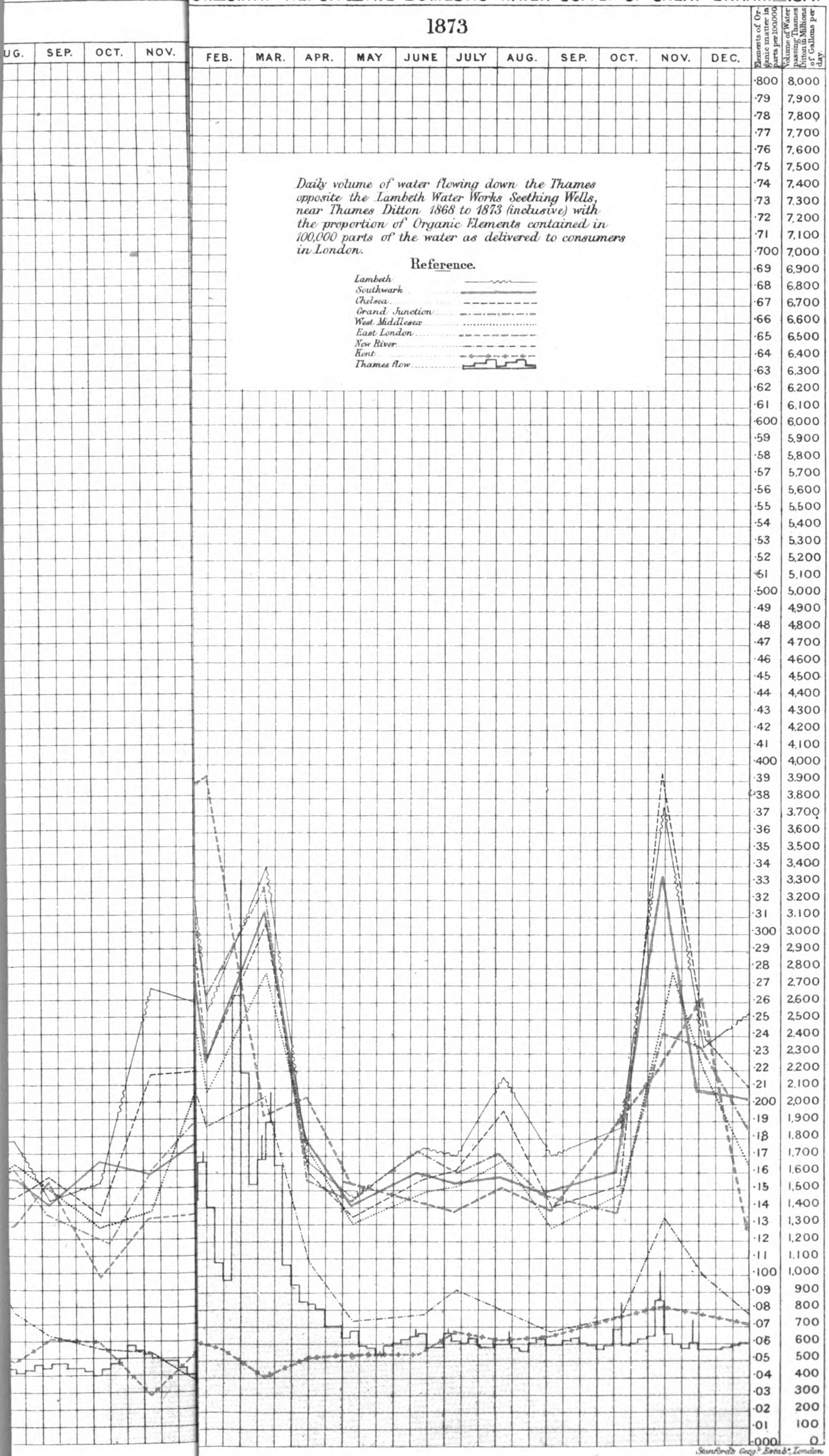
That the organic pollution of the *Thames* is enormously increased by heavy floods is strikingly seen throughout the diagram, but it is especially exemplified by the abrupt rise of the curves representing the proportions of organic impurity, in the *Thames* water delivered by the five companies drawing from that river, in the months of January, February, and December 1869; in January 1870; in January, February, April, and December 1872; and in January and March 1873. Reference to the curves representing the organic impurity of the water drawn from the *Lee* by the New River and East London companies shows that the organic impurities in the *Lee* are simultaneously affected, but, as a rule, to a less violent extent.

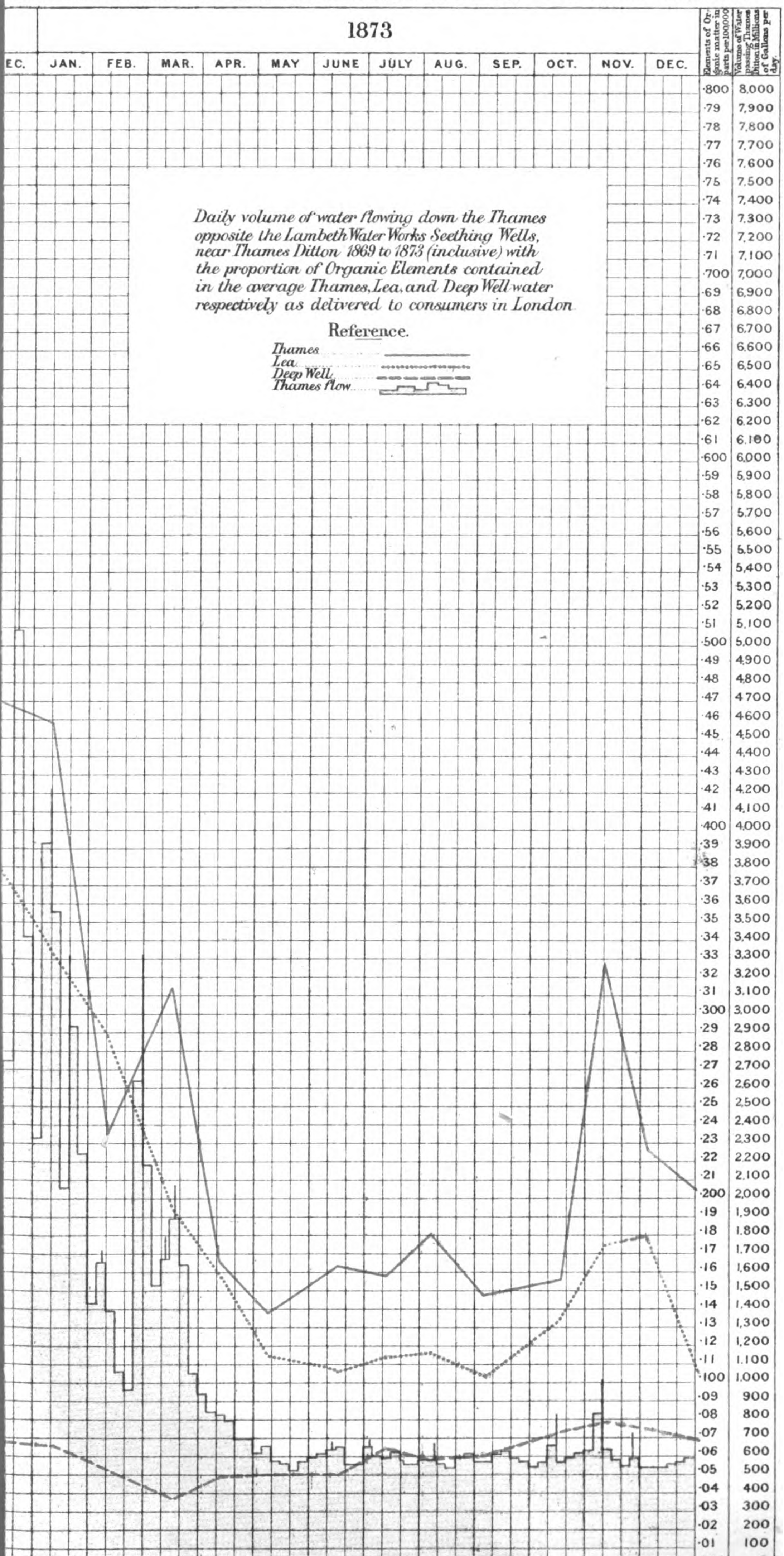
Not only do heavy floods bring down the *Thames* a vast quantity of filthy organic matter, but in dry weather a thunder shower, for instance, will sometimes suddenly wash into the river or its tributaries the polluting matters which have been accumulating for weeks in cess-pools and stagnant ditches, and this without increasing the flow of the river to any great extent. In this way a very small flood upon a low river will sometimes impart to the water a greatly increased proportion of organic impurity. Thus in October 1869, June 1870 and November 1873 the foulness of the water was markedly increased by such small floods.

Independently of floods, however, the decay of vegetation late in autumn always produces a well-marked deterioration in the quality of the river waters delivered in London; as in October 1868 and November 1870. Even a small flood at this time of the year, or soon after "the fall of the leaf," produces an enormous effect upon the quality of the water; thus early in December 1869, a rise of the river from 430 millions of gallons, to 920 millions of gallons daily flow, increased the organic impurity to double its previous amount: between September, and the 10th of October 1871, a rise from 410 millions of gallons to 840 millions of gallons, which last number represents about the average flow of the *Thames*, to more than three times its previous amount: whilst in November 1873, an increase of daily flow by only 180 millions of gallons augmented the organic impurities to double their previous amount.

Lastly, the study of Diagram III. is of great importance in connection with the question of storage reservoirs, reference to which will be again found at page 281. The West Middlesex Company has storage for about seven days supply, and though water is taken into their works from the river every day, the volume so impounded is reduced as low as possible during floods; the other companies drawing from the *Thames* have little or no storage space, and are consequently compelled to take in water daily, to the extent wholly, or nearly so, of their daily supply. This greater storage capacity enables the West Middlesex Company to escape some of the worst effects of floods; thus on February 4th, 1869, a heavy flood caused frightful pollution of the water delivered by the Chelsea, Lambeth, Southwark and Grand Junction Companies, but the West Middlesex Company allowed this flood to pass, and actually sent out water of better quality than that which they had delivered in the previous months. Similar cases occurred in the following months of May and December, in October 1871, and in April 1872. But the system of storage practised by the West Middlesex Company is very imperfect, it not only permits the abstraction of some polluted water from the *Thames*, during even the height of the worst floods, but it does not allow of the replacement of the stored water by fresh river water, when the latter becomes less polluted than the former. On the subsidence of floods therefore, it occasionally happens that the quality of the water distributed by the

ON_SIXTH REPORT_THE DOMESTIC WATER SUPPLY OF GREAT BRITAIN_1874.





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The Metropolitan water supply.

West Middlesex Company is, notwithstanding its superior filtration plant, inferior to that sent out by several of the other companies drawing from the *Thames*. This was so in February 1868, June 1869, February 1870 and November 1871. Also in February 1872, the quality of the water is very conspicuously deteriorated by the retention in the storage reservoirs of some of the water of the great flood which occurred about ten days earlier.

Finally; with reference to the question of the storage of *Thames* water generally, Diagram III. shows that whilst fifteen or twenty days storage, properly worked, will always enable the water companies to reject floodwater in spring and summer, nothing less than 80 or 90 days storage will render them independent of flood water in autumn and winter.

We shall comment below upon the widely different quality of the metropolitan waters derived from (1) the *Thames*, (2) the *Lee* and (3) deep wells in the chalk as exemplified in Diagrams I., II., and III., but especially in Diagram IV.

After the passing of the Metropolis Water Act of 1872, it was deemed necessary to place the works of the various metropolitan water companies under Government inspection, and Major Frank Bolton, R.E., was appointed by the Board of Trade to make monthly reports on the appearance of the *Thames* and *Lee* at the intakes of the companies drawing from those rivers, and on the state of the filter beds, storage reservoirs, and engineering plant generally of the respective companies engaged in the supply of water to London. Subsequently the superintendence of the metropolitan water supply was transferred to the Local Government Board, to whom Major Bolton's monthly reports are now addressed. The following specimen of these reports illustrates the nature of the monthly inspections made by this officer:—

The Metropolitan water supply.

REPORT of the EXAMINATION made during the Month of September 1873, of the WATER

No.	NAME OF THE COMPANY.	Source of Supply.	Situation of Works.	Total Volume which may be supplied daily. — Gallons.	Average Daily Supply during the Month. — Gallons.	Number of Houses supplied.	Reservoirs. Subsiding and Storage Unfiltered Water. No.	Area in Acres.	Available Capacity. — Gallons.	Storage Filtered Water, Covered, Reservoirs within the Radius prescribed. No.	Capacity. — Gallons.	Engine Power. No.	Horse Power.
1	KENT WATERWORKS COMPANY.	From the chalk wells.	- - - -	Not restricted	6,749,928	42,141	—	None		—	—	—	[illegible]
			Deptford	—	—	—				2	2,000,000	7	[illegible]
			Woolwich	—	—	—				2	1,925,000	—	—
			Charlton	—	—	—				—	—	2	[illegible]
			Plumstead	—	—	—				1	750,000	1	[illegible]
			Greenwich Park	—	—	—				1	1,125,000	—	[illegible]
			Chislehurst	—	—	—				1	450,000	—	[illegible]
			Bromley	—	—	—				—	—	2	[illegible]
			Crayford	—	—	—				—	—	1	[illegible]
			Dover Road	—	—	—				—	—	2	67
			Total of Kent Waterworks	—	6,749,928	42,141	—	—	—	7	6,250,000	15	[illegible]
2	NEW RIVER COMPANY.	From the *Lee* and other sources.	- - - -	Not restricted	26,602,000	121,601	—	—	—	—	—	—	[illegible]
			New River Head	—	—	—	1	¾	700,000	—	—	2	[illegible]
			Claremont Square	—	—	—	—	—	—	1	3,500,000	[illegible]	[illegible]
			Stoke Newington	—	—	—	2	42¼	90,000,000	—	—	8	[illegible]
			Hornsey	—	—	—	2	8	8,500,000	—	—	1	[illegible]
			Maiden Lane	—	—	—	—	—	For street watering only.	2	15,000,000	—	—
			Highgate	—	—	—	13 (Highgate and Hampstead)	30	30,000,000	1	1,000,000	2	[illegible]
			Hampstead	—	—	—				1	500,000	—	—
			Camden Park Road	—	—	—	1	1	900,000	—	—	—	—
			Amwell	—	—	—	—	—	—	—	—	3	75
			Hoddesdon	—	—	—	—	—	—	—	—	1	50
			Turnford	—	—	—	—	—	—	—	—	1	80
			Cheshunt	—	—	—	2	18¾	39,000,000	—	—	1	30
			Tottenham	—	—	—	—	—	—	—	—	2	125
			Total of New River Company	—	26,602,000	121,601	21	100¾	169,100,000	5	20,000,000	20	[illegible]
3	EAST LONDON WATERWORKS COMPANY.	From the *Lee* and *Thames* at Sunbury.	- - - -	From *Thames*. 10,000,000	20,222,270	104,481	—	—	—	1	3,000,000	—	[illegible]
			Old Ford	—	—	—	—	—	—	—	—	6	[illegible]
			Walthamstowe	From *Lee*, not restricted.	From *Lee*	—	8	220	600,000,000	—	—	1	[illegible]
			Lea Bridge	—	—	—	—	—	—	—	—	6	[illegible]
			Sunbury	—	2,433,280	—	—	—	—	—	—	2	[illegible]
			Hanworth	—	From *Thames*	—	1	2	5,000,000	2	2,500,000	3	[illegible]
			Hornsey Wood	—		—	—	—	—	1	5,000,000	—	—
			Total of East London Waterworks	10,000,000	22,655,550	104,481	9	222	605,000,000	4	10,500,000	18	[illegible]
4	SOUTHWARK AND VAUXHALL WATERWORKS COMPANY.	From the *Thames* at Hampton.	- - - -	20,000,000	19,496,752	79,506	—	—	—	None		—	—
			Hampton	—	—	—	3	5½	20,000,000			5	[illegible]
			Battersea	—	—	—	3	12	46,000,000			6	1,200
			Nunhead	—	—	—	—	—	—			—	—
			Total of Southwark and Vauxhall Waterworks	20,000,000	19,496,752	79,506	6	17½	66,000,000	—	—	11	[illegible]
5	WEST MIDDLESEX WATERWORKS COMPANY.	From the *Thames* at Hampton.	- - - -	20,000,000	9,590,863	45,041	—	—	—	—	—	—	—
			Hampton	—	—	—	—	—	—	—	—	2	210
			Hammersmith	—	—	—	—	—	—	—	—	5	900
			Barnes	—	—	—	3	20½	56,950,000	—	—	1	6
			Campden Hill	—	—	—	—	—	—	1	3,672,000	—	—
			Barrow Hill	—	—	—	—	—	—	1	4,750,000	2	[illegible]
			Finchley Road	—	—	—	—	—	—	1	2,500,000	—	—
			Total of West Middlesex Waterworks	20,000,000	9,590,863	45,041	3	20½	56,950,000	3	10,922,000	10	1,206
6	GRAND JUNCTION WATERWORKS COMPANY.	From the *Thames* at Hampton.	- - - -	20,000,000	11,821,919	34,243	—	—	—	—	—	—	—
			Hampton	—	—	—	2	2	6,000,000	—	—	2	220
			Kew	—	—	—	2	5	13,500,000	—	—	6	1,200
			Campden Hill	—	—	—	—	—	—	3	18,000,000	3	400
			Kilburn	—	—	—	—	—	—	—	—	—	—
			Total of Grand Junction Waterworks	20,000,000	11,821,919	34,243	4	7	19,500,000	3	18,000,000	11	1,820
7	LAMBETH WATERWORKS COMPANY.	From the *Thames* at Molesey.	- - - -	20,000,000	13,586,200	50,012	—	—	—	—	—	—	—
			Molesey	—	—	—	—	—	—	—	—	—	—
			Long Ditton	—	—	—	1	½	1,800,000	—	—	7	970
			Brixton	—	—	—	—	—	—	2	12,000,000	8	390
			Streatham	—	—	—	—	—	—	1	3,750,000	—	—
			Selhurst	—	—	—	—	—	—	1	2,500,000	—	—
			Rockhill	—	—	—	—	—	—	2	615,000	—	—
			Coombe	—	—	—	—	—	—	1	1,150,000	—	—
			Total of Lambeth Waterworks	20,000,000	13,586,200	50,012	1	½	1,800,000	7	20,015,000	15	1,360
8	CHELSEA WATERWORKS COMPANY.	From the *Thames* at Ditton.	- - - -	20,000,000	8,371,000	28,270	None			—	—	—	—
			Seething Wells	—	—	—				—	—	8	1,025
			Putney Heath	—	—	—				1	10,000,000	—	—
										1	1,000,000*		
			Total of Chelsea Waterworks	20,000,000	8,371,000	28,270	—	—	—	2	11,000,000	8	1,025
	From *Thames*			110,000,000	65,300,014	—							
	Other Sources			Not restricted	53,574,198	—							
	GRAND TOTAL FOR THE METROPOLIS			—	118,874,212	505,295	44	368¼	918,350,000	31	96,687,000	108	12,961

* Not in use.

The Secretary to the Local Government Board, Whitehall, S.W.

supplied by the METROPOLITAN WATER COMPANIES before and after Filtration at the Works.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Greatest lift by Steam Power.	Head of Pressure in the District supplied. Greatest.	Least.	Filters. Filter Beds. No.	Area in Acres.	Depth of Sand and other Materials.	Average Rate of Filtration per Square Foot of Area in Gallons per Hour.	No. of Acres of Filter Beds cleaned during the Month.	Date of Examination.	Appearance of Water. Before Filtration.	After Filtration.	Remarks.
Feet. 314	Feet. 314	Feet. 50	None		—	—	—	29th Sept.	This water is pumped from the Chalk, it is clear and bright, and does not require filtering.	- - -	The water supplied by this Company is taken from Chalk Wells, and is therefore not filtered.
—	—	—	—	—	—	—	—	—			
260	260	40	3 7 3	2¼ 7 2	ft. in. Sand - - 2 3 Gravel - 3 0 Increasing in coarseness towards bottom.	2½	6	26th Sept.	(FROM *Lee* AND OTHER SOURCES.) The water at the intake has been very good during the month.	Clear, bright, and well filtered.	The construction of a new high service covered reservoir has been commenced at Southgate, to contain 1,000,000 gallons. This Company has separate mains for the unfiltered water for street watering and trade purposes, through which they have delivered during the month a daily average of 3,600,000 gallons, which is therefore deducted from the average daily supply in calculating the rate of filtration. This Company having good impounding reservoirs avoids taking in water when floods prevail.
—	—	—	13	11¼	5′3″	2½	6	—			
— 335 — 140 — 140* For *Thames* supply.*	80 upon serving mains.	40	19 6	18 5	ft. in. Sand - - 2 0 Hoggin - 0 6 Coarse gravel 1 0	1	10½ 1	26th and 27th Sept.	(FROM THE *Lee* AND *Thames* AT SUNBURY.) The water at the intakes has been very good during the month.	Clear, bright, and well filtered.	The supply of this Company is drawn from the impounded reservoirs at all times, and the intake is closed during floods. The auxiliary works at Sunbury were at work all the month.
—	—	—	25	23	3′6″	1	11½	—			
240	174	20	3 6	3½ 10¾	ft. in. Harwich sand 3 0 Hoggin - 1 0 Fine gravel - 0 9 Coarse gravel 0 9 Boulders - 1 0	1½	15	25th and 27th Sept.	(FROM *Thames* AT HAMPTON.) The water at the intake has been very good during the month.	Clear - -	This Company has not at present any provision for the storage of filtered water, but two reservoirs are in course of construction at Nunhead, for the storage of 18,000,000 gallons of filtered water. To maintain a good and proper supply, impounding reservoirs should be constructed near the intake, so as to avoid taking in water during floods. Additional boilers and works are being constructed at Hampton.
—	—	—	9	14¼	6′6″	1½	15	—			
195 150	190	130	5	8	ft. in. Harwich sand 1 9 Barnes sand - 1 0 Gravel - 2 3 Screened to different sizes and arranged in layers.	1½	5½	25th and 27th Sept.		Clear, bright, and well filtered.	A 68-inch cylinder engine of 135 H.P. is being constructed for Hammersmith, and another 68-inch cylinder engine of 120 H.P. for Hampton. The engine power is at present in excess, but this work is undertaken with a view to secure ample power for the requirements of constant supply. This Company having large reservoir capacity avoids taking in water during floods.
—	—	—	5	8	5′0″	1½	5½	—			
180 100	150	20	4	7¾	ft. in. Harwich sand 2 6 Hoggin - 0 6 Fine gravel - 0 9 Coarse gravel 0 9 Boulders - 1 0	1½	2	25th, 27th, and 29th Sept.		Clear and bright.	This Company's storage of filtered water will be increased by 6,000,000 gallons when the covered reservoir near Kilburn is taken into use. It is now completed, and the mains are being laid to Campden Hill. An increase of subsiding reservoir capacity is required. Additional boilers and works are being constructed at Hampton.
—	—	—	4	7¾	5′6″	1½	2	—			
380	380 upon pumping mains. 150 upon serving mains.	20	5	2¼	ft. in. Thames sand 3 0 Shells, &c. - 1 0 Coarse gravel 3 0	6½	1½	23rd and 30th Sept.	(FROM *Thames* AT MOLESEY.) The condition of the river at Molesey has been the same as at Hampton during the month.	Clear but insufficiently filtered, consequent upon the small filtering area. The filtration will not be efficient until the new beds are completed.	The works connected with conversion of the reservoirs at Ditton into filter-beds and the construction of impounding reservoirs near the intake at Molesey are in rapid progress. The open reservoir at Streatham is being covered in, and is at present out of use.
—	—	—	5	2¼	7′0″	6½	1½	—			
175	148	40	4	3¼	ft. in. Thames sand 3 3 Shells, &c. - 0 3 Gravel - - 4 6	3¾	3¼	30th Sept.	(FROM *Thames* AT HAMPTON.) The water at the intake has been good during the whole of the month.	Clear, but too rapidly filtered. The filtration will not be efficient until the new beds are taken into use. One of 1 acre area has just been completed and another nearly so.	The following important works have been authorised by the Company:— 1. An addition to the present filtering area to the extent of four acres by the conversion of the present subsiding reservoirs into filter beds. 2. The removal of the intake from the present site at Seething Wells to a point higher up the river, whereby the outflow of the rivers Mole and Rye will be avoided. 3. A reservoir of large capacity to enable the Company, when the river is in good condition, to impound and store water sufficient for several days' consumption, and thereby avoid taking water from the river when floods prevail. The works for the extension of the filtering area by the conversion of the reservoirs at Seething Wells into filter beds (as recommended) are making good progress.
—	—	—	4	3¼	8′0″	3¾	3¼	—			
—	—	—	65	69¾	—	—	44¼	—			

FRANK BOLTON, *Water Examiner.*

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

" *General Remarks.*—During the month of September the state of the river at Hampton, Molesey, and Sunbury, where the intake of the West Middlesex, Grand Junction, Southwark and Vauxhall, Lambeth, and East London Companies are situated, was good during the whole of the month. The highest flood state of the river at Hampton during the month was 7 inches above the (6 feet) summer level, and the lowest 1 inch below.

" At Ditton (where the Chelsea Company now alone draws its supply) the state of the water in the river was good during the whole of the month. The highest state of the flood water at this place was 6 inches, and the lowest 2 inches above summer level. The highest temperature of the water during the month was 63°, and the lowest 56°, while the highest temperature of the air at the same place was 70°, and the lowest 49°. These observations were made daily at 9 a.m. The rain-fall during the month was 2·35 inches.

" The construction of additional subsiding and impounding reservoirs by the Chelsea, Grand Junction, and Southwark and Vauxhall Companies is most desirable.

" The Kent Company, in accordance with the notice given in January last, have completed the arrangements for, and are now giving constant supply to about 1,500 houses in their district, situated in the parishes of St. Mary's Rotherhithe, and St. Paul's and St. Nicholas, Deptford, and have applied to the Metropolitan Board of Works in conformity with sec. 34 of the Metropolitan Water Act, 1871, for instructions for affixing hydrants to the mains in the district now under constant supply.

" The New River Company have now the power of affording effective constant service in their district. They have also commenced a new high service covered reservoir to contain 1,000,000 gallons at Southgate, in anticipation of the requirements of the water supply to Edmonton parish. The Company have in a number of cases afforded constant supply by means of standpipes, and have recently agreed with a committee of the Corporation of the City of London to furnish constant supply at once, to a large number of the houses of the poor within the city bounds, whenever the arrangements of the officers of the Corporation in connection therewith are completed.

" The East London Company are extending the constant system of supply in their district, and have completed the arrangements for supplying the 6,328 houses in the special district referred to in previous returns.

" The Southwark and Vauxhall Company are constructing covered service reservoirs at Nunhead, to contain 18,000,000 gallons, and are erecting additional engine power for high pressure constant supply. Additional boilers and works are also being constructed at Hampton.

" The West Middlesex Company are giving constant supply to a number of houses on the application of the owners, who have provided fittings according to the Board of Trade regulations of the 10th August 1872, and are fully prepared to extend the constant supply when called upon. This company is also constructing extensive works and additional engine power at Hammersmith and at Hampton to ensure effective constant supply.

" The Grand Junction Company have completed a high service reservoir near Kilburn, to contain 6,000,000 gallons for constant supply, and are now laying a line of main pipes to connect up this reservoir with the works at Campden Hill, and are likewise erecting additional boilers and works at Hampton.

" The Lambeth Company are carrying out extensions and improvements in their works. At Molesey, the construction of reservoirs is being proceeded with to contain 110,000,000 to 120,000,000 gallons of water, with pumping engines to fill them to a level of 12 feet above the river. When full these reservoirs will contain 10 to 12 days' winter supply to the District, and during the months when floods prevail (by selecting the times of pumping when the river water is in the best condition) a good deal of flood water will be allowed to pass. Several days subsidence will thus be provided, and consequently an improvement in the water should take place. The water from the reservoirs will run by gravitation through the new conduit to the filters at Ditton, which are in course of extension by the conversion of the two reservoirs there into filter beds, which, when finished, will increase the present filtering surface by 70 per cent.

" During the time these works are in progress the filtration is inefficient, but every effort is being made to complete the works as soon as possible.

" The Company are also giving constant supply by means of standpipes in a number of courts and alleys, and arrangements have been made to supply upwards of 5,000 houses of this class. The alterations in fittings under the new Board of Trade rules

The Metropolitan water supply.

" and regulations are being gradually effected as occasion offers, and are carried out in " all new buildings.

" The Chelsea Company are proceeding rapidly with the construction of the new filter " beds at Ditton. One of about one acre area is already completed, and another nearly " so. A considerable improvement in the filtration of this company should shortly be " effected.

" The Act of 1871 provides power to compel the Companies to give constant supply " as, and when the public authorities may see fit to move.

" It is anticipated that greater safety from fires would result from the constant supply, " since it would enable the use of hydrants instead of fire-plugs, and thus more rapidly " and effectively extinguish fires. Hydrants might now and for some time past have " been substituted for fire-plugs upon about one-third of the entire mains of the metro- " polis, which are constantly charged, but they have not yet in any case been supplied. " The Kent Company, however, are about to affix hydrants in that portion of their " district now under constant supply.

" If the following clause of the Board of Trade Regulations, 1872, relative to waste- " pipes, is carried out in its integrity, it will prevent contamination of the water from " the gases generated by sewage, which are extremely liable to flow back into the cisterns " and become absorbed by the water:—

> " Regulation 14. ' No overflow or waste-pipe other than a " warning-pipe " shall be " ' attached to any cisterns supplied with water by the Company, and every such " ' overflow or waste-pipe existing at the time when these regulations come into " ' operation shall be removed, or at the option of the consumer shall be converted " ' into an efficient " warning pipe," within two calendar months next after the Com- " ' pany shall have given to the occupier of, or left at the premises in which such " ' cistern is situate, a notice in writing requiring such alteration to be made.'

" The particular object of the above is to prevent the waste of water, but it will also " effect an object of far greater importance by getting rid of the poisonous effluvia and " gases from the drains which would otherwise ascend through the pipe, and not only " be partly absorbed by the water in the cistern but be partly mixed with the air in " the houses, thereby becoming a cause of fever and disease. The attention of all " householders may with advantage be given to the fittings and cleanliness of their " cisterns, upon which depends in a great measure the purity and abundance of the " domestic water supply, and the Metropolitan Water Companies should cause frequent " surveys to be made of such portions of their respective districts as are badly provided " with cisternage, and furnish proper means of supply. Recent investigation has shown " that some houses in Rotherhithe have through inadequate cisternage and appliances " been limited to a bare 16 gallons daily, a quantity altogether insufficient for domestic " purposes. Prompt action however, will be taken to remedy the evil in this case.

" FRANK BOLTON,
Water Examiner."

" London, 30th September 1873.

London is at present supplied with water by eight private companies, six of whom abstract the water entirely from the *Thames* and *Lee*, these are :—

COMPANIES ABSTRACTING WATER EXCLUSIVELY FROM THE THAMES AND LEE.

The Chelsea Company.
The West Middlesex Company.
The Southwark and Vauxhall Company.
The Grand Junction Company.
The Lambeth Company.
The East London Company.

The New River Company takes the water it distributes chiefly from the *Lee*, but partly from springs and deep wells, whilst the Kent Company supplies deep well water only.

The quality of the water of the *Thames* as it emerges from the water-bearing stratum which has held it, is of course very different from that which it possesses when it reaches

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Kingston. The rivulets and river channels in which it has been carried have received the drainage of cultivated fields, farmyards, houses, villages, and towns. Tan yards and paper manufactories have contributed their waste liquids. Large quantities of excremental matter have necessarily found their way, more or less directly, into the general drainage channels of the several districts, and have been carried onwards to the river. The fact that river pollution inevitably bears a direct proportion to the density of the population within the river basin, illustrated in our Fourth Report by a comparison of various river basins in the north, has the force of a general law, and applies to agricultural as well as to manufacturing districts; and thus the population statistics of any district furnish a sufficient explanation of the quality of its river water. The agricultural statistics of Berkshire, Oxfordshire, Buckinghamshire, Hertfordshire, and Surrey may probably be adopted as representing those of the Thames basin above the intake of the London water companies. The area of these counties, 2,261,555 acres, is not very different from that (2,352,640 acres), which drains into the river above Kingston; and the portions of Buckinghamshire and Hertfordshire outside this part of the river basin which this area includes, may be taken as representing with sufficient fairness, in an agricultural sense, the portions of Gloucestershire and Wiltshire within the river basin which it excludes. Of these 2,261,555 acres, about 1,800,000 are enclosed and in the hands of farmers, and of this more than one-third is in permanent pasture, the remainder being arable. There are thus more than 400,000 acres unaccounted for, including down lands, waste lands, wood lands, water, and roads; besides the space occupied by towns and villages, and separate houses, cottages, and gardens. The whole territory is occupied by a population of about 900,000 people, including more than 200,000 living in towns of 2,000 inhabitants and upwards. There are besides this, 60,000 horses, 160,000 cattle, 900,000 sheep, and 120,000 pigs. Taking the effect of this immense animal population in detail, we find everywhere waterclosets almost at the very outset of a rivulet, privies washed into it, farmyards draining into it, live stock fouling it at their drinking places, woollen factories, paper mills, and tanyards discharging their liquid refuse matters into it, drainage from plough lands to which manures have been applied running into it, garden and house waste thrown into it, all within a very few miles of its origin. Thereafter, some miles lower down, it may be pumped to reservoirs to supply the drinking water of a town; and thence, through chamber utensils, sculleries, and waterclosets, it finds its way through sewers to the river channel once more. Uniting with other streams which have been abused in a similar way, but in a different, possibly in a less degree, it forms the river *Thames*, which grows in volume, not only by the accession of successive affluents, but, during certain portions of its course, and notably between Wallingford and Reading, by the mixture of pure spring water rising in enormous volumes in its bed, until at length it reaches the intake of the Metropolitan water companies, and is distributed by the Chelsea, West Middlesex, Grand Junction, Southwark and Vauxhall, and Lambeth Companies, and occasionally by the East London Company for the domestic use of the inhabitants of the Metropolis.

Taking these in the order in which their several works are stationed on the river, the East London Water Company stands first upon the list. From its pumping station above Sunbury it can deliver 10,000,000 gallons daily to its filter beds near Hanworth. There are here five acres laid out in six filter beds, and two acres of reservoir, in which the unfiltered river water is first received, and from which a depth of six feet can be drawn. A section of the filter beds at Hanworth shows two feet of sand upon two feet of fine and coarse gravel above the closely-set drain pipes which feed the well from which the pumping engines draw. Three pumping engines, together 750 horse-power, are here provided, capable of delivering 10,000,000 gallons daily over a stand pipe 240 feet in height and three feet in diameter, whence, with an average fall of five feet per mile, it commands the Company's reservoir near Tottenham. These works are only used when the supply from the *Lee* to this company's station at Lee Bridge falls short.

The West Middlesex Water Company takes nearly 10 millions of gallons daily from the *Thames* above Hampton, at a point about two miles below the intake of the East London Water Company, pumping it unfiltered thence to its reservoirs below Barnes on the south side of the river. Water is drawn from the river every day, whatever its state may be, but in times of exceptionally foul water the intake is reduced as much as possible. The following specimen page from the book of the Company, in which a record of the state of the river is kept, illustrates the great difficulties which even this Company, with its comparatively great storage capacity, has to contend with, in dealing with the water in its filthiest condition.

Part IV. Descriptive.

The Metropolitan water supply.

Date, 1872–3.	Weather.		Hampton.		Water.	
	Remarks.	Wind and Barometer.	River Gauge.	State of Water in the River.	Filtered Water, examined through a Glass Tube 2 feet in Length.	Tons of Water pumped weekly.
1872.			ft. in.			
Dec. 28 -	Very fine and warm -	S.W. 29.71	5 6	Fining down -	Very bright.	
„ 29 -	Fine and mild - -	S.W. —	—	„ -	„	
„ 30 -	Wet and strong wind -	W. 29.96	—	„ -	„	
„ 31 -	Very fine and warm, and rain at night.	W. & S.W. 29.82	4 4	„ -	„	
1873.						
Jan. 1 -	Much rain, and fine at intervals.	S.W. 29.63	—	Very thick -	„	
„ 2 -	Very high wind, and much rain and cold.	S.W. 29.68	—	„ -	„	
„ 3 -	Heavy gale and rain -	S.W. & W. 29.68	—	„ -	„	287,992
„ 4 -	Wet and high wind - -	S.W. 29.86	5 2	Puddle - -	„	
„ 5 -	Fine and showery - -	S.W. —	—	„ - -	„	
„ 6 -	Windy and fine - -	S.W. 30.05	—	„ - -	„	
„ 7 -	Very fine and mild - -	S.W. 30.10	—	„ - -	„	
„ 8 -	„ „ - -	S.W. 29.80	6 5 and rising.	Very turbid - -	„	
„ 9 -	Wet and windy and cold, and much rain at night.	S.W. 29·64	—	„ - -	„	
„ 10 -	Wet morning and fine afternoon.	S.W. 29.74	—	„ - -	„	286,672
„ 11 -	Fine and mild - -	W. 29.81	6 0	Very turbid, but a little clearer.	„	
„ 12 -	Fine, cold at night - -	S.W. —	—	„ -	„	
„ 13 -	Windy and dull; heavy rain early in morning.	S.W. 30.00	—	„ -	„	
„ 14 -	Gloomy and windy and mild	S.W. 30.17	—	„ -	„	
„ 15 -	Gloomy and mild - -	W. 30.04	—	Little better -	„	
„ 16 -	Fine and warm - -	W. 30.07	—	Little better -	„	
„ 17 -	Fine, and rain at night -	W. & N.W. 29.98	—	„ -	„	285,227
„ 18 -	Fine and cold, and rain at night.	W. 29.70	4 2	Fining down fast -	„	
„ 19 -	Wet and cold - -	W. —	—	„ -	„	
„ 20 -	Gloomy and cold; much lightning at night.	W. 28.60	—	Much coloured -	„	
„ 21 -	Very fine and cold; rain at night and slight frost.	W. & N.W. 28.96	—	„ -	„	
„ 22 -	Cold and dull, and rain at night.	W. 28.84	—	„ -	„	
„ 23 -	Very fine and cold, and slight frost.	W. 29.55	—	„ -	„	
„ 24 -	Gloomy and cold - -	E. & S.E. 29.80	—	„ -	„	283,383

The page records the condition of the raw and filtered water from December 28, 1872, to January 24, 1873,—a period of 28 days. During this period, the river water arriving from Hampton is described as "puddle" on four days, as "very thick" on three days, as "very turbid" on seven days, and as "much coloured" on five other days. Nevertheless during the whole of this period the Company sent out to their customers bright and transparent water. They improved the water to the utmost extent in their power, but they could not remove from it the soluble filth with which it was polluted.

There is at Barnes an extent of eight acres laid out in five filter beds, which are supplied from three reservoirs, together upwards of 20 acres in extent, into which the *Thames* water from the Hampton pumping engines pours, and where it is allowed to subside. These reservoirs are used in succession for the supply of the filter beds, and 10 to 12 feet of water can be drawn from them. Thus giving a storage capacity of about 60,000,000 gallons or six days' supply. A section of the filter beds here shows a thickness of one foot nine inches of Harwich sand, over one foot of Barnes sand, and two feet three inches of gravel which is screened to five different sizes and arranged

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

in layers. When freshly laid, this filter will deliver two and a half gallons, or five inches in depth, an hour per superficial foot,—a quantity which dwindles to about one-third as much as the surface becomes clogged with the deposited mud. The average rate of filtration is stated to be 15 gallons per square yard per hour, a quantity equal, when six acres of filter are engaged, to the delivery of 10½ millions of gallons daily. When the delivery falls to nine gallons per square yard, the filter bed is disused, the water is drawn off, and the surface of the bed is scraped, the dirty sand is washed, and a fresh layer is deposited before the water is let in again. The filter beds at Barnes deliver their cleansed water by two 36-inch pipes passing underneath the river to the pumping engines at Hammersmith, together 900 horse-power, which deliver daily from 9 to 11 millions of gallons to the Company's district of about 12 square miles in extent, containing, in April 1874, 45,604 houses, and an estimated population of about a quarter of a million, resident between the river and a line from Kew to Kensington, and again between the Great Western Railway line and the district of the New River Company, eastward of Primrose Hill, where there is a reservoir, and southward below Regent's Park as far as Oxford Street.

The following table contains the results of our analyses of three samples of water illustrative of the operations of this company :—

COMPOSITION OF THAMES WATER AT THE WEST MIDDLESEX COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
Thames water from Hampton before subsidence, February 7, 1873.	29·84	**·276**	**·053**	·009	·346	·406	**3,210**	1·80	15·2	6·6	21·8	Turbid.
Ditto after subsidence in two reservoirs, February 7, 1873.	31·22	**·209**	**·071**	·005	·329	·404	**3,010**	1·80	15·4	7·9	23·3	Slightly turbid.
Ditto after filtration, February 7, 1873.	30·56	**·198**	**·043**	·001	·335	·379	**3,040**	1·80	14·7	7·4	22·1	Clear.

The above results indicate a marked improvement in the quality of the water by the subsidence which it receives on the premises of this company; the comparatively large capacity and advantageous form of their subsidence reservoirs enable the company to effect a better clarification than is achieved in most of the other metropolitan waterworks; and the comparison instituted in the above table hardly shows the full effect, because, during the 10 days immediately preceding, the flow of the *Thames* had gradually decreased from 2,442,720,000 gallons to 1,697,360,000 gallons daily (*see* Appendix No. 9), and the quality of its water had presumably undergone a corresponding improvement; consequently the subsided water was the result of the clarification of a more impure water than that which was being abstracted from the river on the day when the samples were taken. The above analyses show that, as regards organic impurity, subsidence removed 15 per cent. whilst subsequent filtration got rid of a further 14 per cent. The advantages attending the large storage possessed by this company are not without some counteracting drawbacks, which have been already commented upon at page 262. (*See* also page 281.) The general and marked superiority of this company's water over that of all the other metropolitan companies drawing from the *Thames* is strikingly seen by reference to Diagram III. facing page 262.

Close to the Hampton pumping station of the West Middlesex Water Company is that of the Grand Junction Company, which supplies almost the whole of the district north of the river down to Kew, whence its southern boundary is the edge of the West Middlesex district to the south of it, north of which it extends as far as the Great Western Railway, and as far west as the Edgware Road. There are here nearly 34,243 houses, and 140 manufactories to which upwards of 12½ millions of gallons are supplied daily. This Company, which before 1852 used to take its supply from the river as far down as Chelsea, and latterly at Kew Bridge, has since then been supplied wholly from its Hampton pumping station, whence the river water is delivered to the subsidence reservoirs at Brentford, which, together with those at Hampton and Kew, have an area of seven acres and an aggregate capacity of 17½ millions of gallons or less than two days average supply. There is at Brentford an area of seven and a half acres in four filter beds, of which three are always in use, while the fourth is being cleansed. The filtering medium consists of two feet of sand over successive layers of one foot of coarser sand, nine inches of fine gravel, nine inches of coarser gravel, and one foot of boulders. The filtration is declared to be at the rate of three inches of water per hour, at which rate six acres are equal to the delivery of not quite nine and a half millions of gallons in 24 hours. The quantity at present taken is, however, more than 12½ millions of gallons daily, equal to about four inches of filtration per hour. But as the engines pump only 2,000,000 gallons during the night, and as one-fourth of the filtering area is generally out of use, it follows that the maximum rate of filtration must occasionally amount to 6·3 inches per hour. The quantity beyond immediate need passes to the Company's covered reservoirs at Campden Hill, Kensington, three acres in area, containing 18 millions of gallons, which is the amount of surplus available for an occasional demand beyond the current pumping power of the engines.

The Metropolitan water supply.

The following analyses show the condition of the water (1) as it arrived at the Kew works from Hampton on the day of our inspection; (2) after subsidence, and (3) after subsidence and filtration:—

COMPOSITION OF THAMES WATER AT THE GRAND JUNCTION COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Thames water from Hampton before subsidence at the Kew Works, February 3, 1873.	31·78	**·246**	**·033**	·005	·355	·392	**3,270**	1·75	17·9	6·6	24·5	Slightly turbid.
Ditto after subsidence and before filtration, February 3, 1873.	31·42	**·262**	**·042**	·004	·356	·401	**3,270**	1·75	18·9	4·7	23·6	Slightly turbid.
Ditto after filtration, February 3, 1873.	30·68	**·231**	**·032**	·001	·345	·378	**3,140**	1·70	17·6	5·7	23·3	Clear.

In the interpretation of this table, it must be borne in mind that the Grand Junction Company does not, virtually, allow the water to subside before filtration. Its total storage capacity for unfiltered water is only 17½ millions of gallons, whilst its daily delivery averages more than 12,000,000 of gallons. It is not surprising to find, therefore, that the water receives no benefit from the so-called subsidence at these works, indeed the analytical numbers show a slightly higher proportion of organic elements (organic carbon and organic nitrogen) in the water passing to the filter beds, than in that just arriving from Hampton. This was no doubt owing to the circumstance that the *Thames* was falling at the time, and the quality of its water consequently improving. (*See* Appendix No. 9.) The filtration at the time of our visit was efficient, the effluent water from the filter beds being clear and bright. The results of analysis before and after filtration show the removal of 14 per cent. of the organic matter from the water. Nevertheless the filtered water still contained an excessive proportion of organic impurity. For a comparison of the amount of organic impurity in this Company's water with that present in the supplies of the other Metropolitan Companies during the years 1868 to 1873 inclusive, see Diagram III. facing page 262, where can also be seen the dependance of the amount of this impurity upon the rate of flow of the *Thames*.

The Southwark and Vauxhall Water Company has its intake from the river immediately below that of the Grand Junction Company above Hampton. It has here three and a half acres in three filter beds, and delivers 5,000,000 gallons daily of filtered water from this point to its Richmond, Mortlake, Barnes, and Wimbledon districts. The maximum rate of filtration is fully six inches per hour. Five engines, having an aggregate of 800 horse-power, are employed in pumping, besides this quantity of filtered water, upwards of 12 millions of gallons of unfiltered water to the reservoir at Battersea. The Company's district lies along the whole southern margin of the river from Teddington to Southwark, the boundary at that point, between this district and that of the Kent Waterworks Company, lying to the east of Camberwell, the Grand Surrey Canal, and Peckham, and the southern boundary line lying north of Kingston, Balham, Tulse Hill, and Dulwich. There are in this district upwards of 79,000 houses and 600 manu-

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

factories, and railway stations, and a daily supply is furnished of nearly 18 millions of gallons. Besides the filter beds at Hampton, from which the western suburban district is supplied, the company has six filter beds with an aggregate area of 10¾ acres at Battersea, whence six engines of 1,200 horse-power pump daily between 12 and 13 millions of gallons of filtered water to their town district and to their reservoir at Peckham. Besides these filter beds, there are three reservoirs, together 12 acres in extent, and holding 46,000,000 gallons. The filtering medium is more than six feet thick, consisting of three feet of sand, over one foot of "hoggin" (coarse sand), nine inches of fine gravel, nine inches of coarse gravel, and one foot of boulders. There are generally between seven and eight acres of filter beds in use, and their present delivery of 12,000,000 gallons daily corresponds to a rate of five inches of water per hour during the day, and one and a half inch per hour during the night over that area. Until the year 1871 there was an arrangement at these works by which the foul water of the *Thames* at Battersea could be admitted into one of the storage reservoirs, but the conduit used for this purpose has now been permanently closed, and the reservoirs adjoining the *Thames* have been lined with concrete, and it is believed that by these means the leakage of the tidal water of the *Thames* into them, which previously occurred at high-water, has been rendered impossible. This company is constructing six or seven covered reservoirs at Peckham for the storage of 18,000,000 gallons, and it has secured 60 acres of land for additional service reservoirs at Nunhead.

The following analyses of six samples of water illustrate the operations of this company on the days of our inspection of the works at Hampton and at Battersea:—

COMPOSITION OF THAMES WATER AT THE SOUTHWARK AND VAUXHALL COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Thames water at Hampton, Jan. 31, 1873.	31·84	**·285**	**·050**	·002	·331	·383	**3,010**	1·80	18·5	5·1	23·6	Slightly turbid.
Ditto after subsidence and before filtration at the Hampton Works, January 31, 1873.	32·00	**·321**	**·063**	·001	·317	·381	**2,860**	1·80	15·0	8·3	23.3	Turbid.
Ditto after filtration at the Hampton Works, January 31, 1873.	31·56	**·273**	**·042**	0	·286	·328	**2,540**	1·80	17·7	5·6	23·3	Clear.
Thames water from Hampton before subsidence at the Battersea Works, February 5, 1873.	32·10	**·224**	**·042**	·003	·375	·419	**3,450**	1·80	18·9	5·0	23·9	Slightly turbid.
Ditto after subsidence and before filtration at the Battersea Works, February 5, 1873.	31·80	**·239**	**·047**	·005	·348	·399	**3,200**	1·80	18·3	5·3	23·6	Slightly turbid.
Ditto after filtration at the Battersea Works, February 5, 1873.	30·90	**·226**	**·035**	·001	·315	·351	**2,840**	1·80	18·6	5·6	24·2	Clear.

These results again illustrate the evils of the present system of storage with a falling river. From January 26th to February 5th, 1873, the flow of the *Thames* was steadily diminishing (see Appendix No. 9) and the quality of the water improving. As a consequence of this state of things, the water in the subsidence reservoirs at Hampton was more muddy, and altogether of a worse quality, than that which was flowing in the adjacent river on the 31st of January; and the same was the case, as regards organic impurity, at the Battersea works on the 5th of February, when the raw river water there being received from Hampton was markedly superior to that which had been allowed to subside for several days.

We found the filtration at both these stations efficient, the effluent water being, on the days of our visit, clear and transparent. At the Hampton works the filters were removing 18 per cent. and those at the Battersea works 9 per cent. of the organic impurity present in the water. Notwithstanding this improvement, the water still contained an excessive amount of organic impurity. For a comparison of the degree of organic impurity in this water with that present in each of the other Metropolitan waters, and the dependence of this amount upon the rate of flow of the *Thames* during the years 1868 to 1873 inclusive, see Diagram III. facing page 262.

At Thames Ditton, two miles lower down, are the pumping stations of the Lambeth and the Chelsea Waterworks. The district of the Lambeth Water Company lies to the south of that supplied by the Southwark and Vauxhall Company, including Kingston

Mitcham, Balham, Dulwich, Norwood, and Beckenham, in all 60 square miles of area, stretching as far east as the *Ravensbourne*, which separates it from the district of the Kent Water Company. There are in this district altogether 50,000 houses of which about 1,500 come under the class of factories and other works. The Lambeth Water Company has obtained sufficient acreage for extensive reservoirs above Hampton, where the present intake is situated. At the time of our visit to the works in January 1873 there were only two and a quarter acres of filter bed, and these delivered about 12,500,000 gallons daily, during the summer months;—a quantity which would cover all that area rather more than 20 feet deep. The quantity filtered must therefore have exceeded 10 inches per hour night and day, and when any portion of the filter bed was taken out of use to be cleaned, it sometimes reached the very high rate of 12 inches per hour,—a rate far beyond the maximum at which efficient filtration can be conducted. We are informed that new filter beds have since been constructed and that the maximum rate has been reduced. The filter beds are made seven feet deep, and the filtering medium is three feet of Thames sand, one foot of shells, and three feet of gravel. The pumping engines at Thames Ditton deliver to reservoirs at Brixton, Streatham, and Norwood, for the service of the large district within which the company delivers its supply.

The following table contains the results of analysis of three samples of water collected on the day when we inspected this Company's works at Thames Ditton :—

COMPOSITION OF THAMES WATER AT THE LAMBETH COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
The *Mole* at Ditton Bridge, Jan. 31, 1873.	25·00	**·236**	**·042**	·007	·328	·376	**3,020**	1·90	11·3	5·6	16·9	Turbid.
Thames water before subsidence, January 31, 1873.	31·36	**·325**	**·076**	·003	·312	·390	**2,820**	1·75	18·3	5·6	23·9	Turbid.
Ditto after subsidence and before filtration, January 31, 1873.	32·96	**·273**	**·067**	·004	·348	·418	**3,190**	1·80	18·5	5·1	23·6	Slightly turbid.
Ditto after filtration, January 31, 1873.	32·74	**·258**	**·038**	·001	·361	·400	**3,300**	1·80	17·9	5·7	23·6	Clear.

The *Mole* which joins the *Thames* a short distance above the works of the Lambeth and Chelsea companies is commonly regarded as more polluted than the *Thames*, and it does, in all probability, as indicated by the higher proportion of chlorine in the above analytical results, receive, for a given volume, a larger proportion of sewage than that which is poured into the *Thames ;* nevertheless, as regards actual or present pollution, it is, as shown by the above analysis, decidedly superior to the latter river, and it is, moreover, considerably softer. But the *Mole* is a turbid river, and it contains argillaceous matter in suspension which is peculiarly difficult of removal by filtration, unless the operation be slowly conducted. In the year 1872 the Company, in consequence of this difficulty, removed its intake from Thames Ditton, below the junction of the *Mole* to Molesey, nearly opposite Sunbury, four miles above the junction of that affluent. This removal has cost a sum which would have gone far to enable the Company to abandon the *Thames*, and to supply its consumers with pure and wholesome deep well water, softened by Clark's process.

On the day of our visit, the filtration at these works was tolerably satisfactory, the effluent water was free from visible suspended matters, and nearly transparent. By subsidence and filtration, 28 per cent. of the organic impurity was being removed from the raw *Thames* water ; but the filtered water was still charged with an excessive amount of organic impurity. For a comparison of the proportion of organic impurity contained in this company's water from 1868 to 1873 inclusive, see Diagrams I., II., and III., facing page 261 and 262.

The Chelsea Water Company has three and a quarter acres of filter beds at Thames Ditton in four plots, and it is doubling their extent. The Company delivers 10,000,000 gallons in summer, and about 8,000,000 gallons daily in winter, filtering nearly 6 inches of water an hour, when three of the beds are at work. It too is seeking to obtain subsidence and storage reservoirs. At present there are none, the water passing directly from the river on to the filter beds. These last are nearly 8 feet deep, including 2 feet

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

9 inches of fine sand, over 6 inches of a coarse sand, 3 inches of shells, and 4 feet 6 inches of fine and coarse gravel. They feed eight engines of an aggregate of 1,025 horse power, which deliver to covered reservoirs on Putney Heath, thence supplying upwards of 28,270 houses, including factories and stables, and probably 250,000 people, between Fulham and Westminster, including Chelsea, Brompton, Kensington, and Belgravia;—in fact the whole of the district, about 5 square miles, lying between the West Middlesex and Grand Junction Companies' service and the river.

The annexed table gives the results of our analysis of a pair of samples collected at this Company's works during our inspection:—

COMPOSITION OF THAMES WATER AT THE CHELSEA COMPANY'S WORKS.
RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Thames water before filtration, January 31, 1873.	31·36	**·325**	**·076**	·003	·312	·390	**2,820**	1·75	18·3	5·6	23·9	Turbid.
Ditto after filtration, January 31, 1873.	31·10	**·258**	**·032**	0	·307	·339	**2,750**	1·70	17·0	5·7	22·7	Clear.

The filtration at these works was efficient, the water issuing from the filter beds being clear and transparent. No less than 28 per cent. of the organic impurity of the raw *Thames* water was, on the day of our visit, removed by the filters. Considering that the Company has no subsidence reservoirs, this result is very satisfactory, and could not be attained without the use of the exceptionally deep filters provided at these works. To this circumstance must also be attributed the almost invariable superiority of the water delivered by this Company over that distributed by the Lambeth Company, as shown by the curves representing organic impurity in Plate III., facing page 262. But, even after this improvement, the water still contained an excessive proportion of organic impurity, as is seen from the above analytical numbers,—the proportion of organic carbon being ·258 part in 100,000 parts of water, whilst we have recommended that a maximum of ·2 part per 100,000 should never be exceeded in water destined for dietetic purposes (*see* page 5). For a comparison of the organic impurity in this water with that present in the other metropolitan waters during the years 1868 to 1873 inclusive see Diagram III. facing page 262.

These are the whole of the companies whose water supply is taken from the *Thames*. Their powers extend to the abstraction of 110,000,000 gallons daily. They at present take not much more than half this quantity, supplying it to the whole of London west of a line running from Hampstead along the eastern side of Regent's Park, and southwards to the river at Charing Cross, and again from a point opposite St. Paul's Cathedral running south-east towards the *Ravensbourne* above Lewisham. Water is thus supplied to more than 230,000 houses, accommodating a population probably exceeding 1,200,000, besides an indefinite number in poorer districts who are supplied by stand pipes.

The Kent Waterworks Company supplies more than 42,000 houses in the south-eastern district of the metropolis and its suburbs with upwards of 9,000,000 gallons of water daily, derived wholly from deep wells in the chalk. The area thus supplied extends from Camberwell to Dartford in one direction, and from the *Thames* to Chiselhurst and Bromley in the other. The wells which supply this enormous area are situated at Deptford, Charlton, Plumstead, Crayford, Shortlands and Belvidere. There are three wells 250 feet deep at Deptford. The "Bath" well will yield one and a half million, the "Garden" and "New" wells each four and a half millions of gallons daily. There are two wells of nearly the same depth at Shortlands, yielding about one and a half million gallons. At Crayford there are two wells 150 feet deep, of which only one is in use, yielding about 900,000 gallons daily. At Plumstead one well 500 feet deep yields 700,000 gallons, and at Charlton there are two wells, the one in use yielding 600,000 gallons daily. In addition to these there is a well 70 feet deep at Belvedere near Erith, from which 200,000 gallons are daily pumped for the supply of that immediate locality. The shafts of these wells are, with the exception of those at Charlton and Belvidere, lined with cast-iron cylinders from 70 to 100 feet in depth, and are thus properly protected against surface infiltration; from the bottom of the shafts bores are taken to the full depth

Part IV. Descriptive.

The Metropolitan water supply.

of the wells, or adits are driven laterally where a productive depth had been already reached. The water stands in the shafts at a height generally 10 to 20 feet above that of ordnance datum; and, as for example at Deptford, the level of the water is not reduced by the most rapid pumping more than 50 or 60 feet below that at which it naturally stands. So large is their productiveness, that the late Mr. W. R. Morris, M. Inst. C.E., the engineer to this Company, when stating six years ago to the Royal Commission on Water Supply (1869) that their then yield was 7,000,000 gallons daily, did not hesitate to declare that while the existing machinery could supply 10,000,000 gallons daily, the wells were certainly capable of yielding double the quantity then drawn from them.

The following table contains the results of our analyses of eight samples of water, illustrative of the water service of this Company:—

Composition of Deep Well Water at the Kent Company's Works.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.												Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
New well at Deptford, February 8, 1873.	42·94	**·048**	**·005**	·001	·545	·551	5,140	2·50	20·1	9·6	29·7	Clear.
Bath well at Deptford, February 8, 1873.	35·44	**·044**	**·007**	0	·363	·370	3,310	2·30	18·6	8·0	26·6	,,
Garden well at Deptford, February 8, 1873.	40·96	**·056**	**·011**	0	·354	·365	3,220	2·40	20·2	8·6	28·8	,,
Well at Shortlands, February 8, 1873.	30·64	**·021**	**·007**	0	·354	·361	3,220	1·60	19·3	4·6	23·9	Turbid.
Well at Crayford, February 8, 1873.	35·20	**·031**	**·005**	0	·505	·510	4,730	2·25	20·3	5·4	25·7	Clear.
Well at Belvidere, February 11, 1873.	40·52	**·100**	**·037**	0	2·079	2·116	**20,470**	3·35	10·8	11·6	22·4	,,
Well at Plumstead, February 11, 1873.	50·80	**·081**	**·011**	0	·338	·349	3,060	4·60	16·8	13·8	30·6	,,
Well at Charlton, February 11, 1873.	92·80	**·139**	**·028**	0	·901	·929	**8,690**	19·70	21·3	21·3	42·6	,,

These results, if compared with those yielded by the foregoing samples of *Thames* water, show most conclusively the general and great superiority of the deep well water delivered (without any subsidence or filtration) by this company. Omitting the sample from the well at Charlton (which is polluted, but far less so than any of the samples of filtered *Thames* water) the average proportion of organic impurity in these waters is less than one-fourth of the average found in filtered *Thames* water. All the samples were clear and brilliant, except the one from the well at Shortlands, which was, at the time of our visit, rendered turbid by the operations of workmen in an adjoining well. The natural filtration of this water through chalk is always far more efficient than any artificial filtration. By observations made under a strong light, river water most carefully filtered by artificial processes is seen to be full of minute suspended solid particles, whilst the deep well water of the Kent Company exhibits, under the same test, only sparsely distributed solid particles. The sole defect of these waters is their hardness, which exceeds that of *Thames* water; but this can, in nearly all cases, be removed by the application, at the Company's works, of Clark's process (*see* page 205), and it does not, for reasons given at length at page 184, render the water unwholesome. The well waters in the foregoing list, which are more or less unsuitable for this softening process, are those from the wells at Belvidere, Plumstead, and Charlton, but of these the well at Belvidere, though unpolluted at present, is unsuitable for domestic supply, owing to the access of drainage from heavily manured market gardens; whilst the well at Charlton must be condemned on account of actual sewage pollution. The great superiority of the water supplied by this Company from their wells at Deptford over that distributed from rivers by the other metropolitan companies is strikingly seen by reference to the curves representing organic impurity given in Diagrams III. and IV. facing page 262. The supply of such water, either softened or unsoftened, to the metropolis generally would be a priceless boon, and would at once confer upon it absolute immunity from epidemics of cholera. We are very decidedly of opinion that the metropolitan companies should receive, from Your Majesty's Government, sanction for increase of capital, only

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

on condition that such capital shall be expended on works necessary for the supply of this palatable and perfectly wholesome beverage.

As the water of the Kent Company is all derived from deep wells, the evidence of previous sewage or animal contamination which it exhibits may safely be disregarded, if it does not exceed 10,000 in 100,000 parts, and the organic carbon does not exceed 0·1 part in 100,000 parts of water (*see* page 5). In the list of waters in the foregoing table, these standards are infringed only by the waters from the Belvidere and Charlton wells, and hence the previous sewage or animal contamination, in these waters only, is expressed in the above table in emphasised type.

Previous to the year 1872 part of the water of the wells at Deptford was pumped into an uncovered reservoir, and was there liable not only to atmospheric pollution, but also to the admixture of water from the adjacent foul *Ravensbourne*. Diagrams III. and IV. facing page 262, show that during the continuance of this infraction of the Water Act of 1851, the purity of the Kent Company's supply from these wells was perceptibly affected by heavy rainfalls. Since the covering of the reservoir this effect is scarcely if at all appreciable.

The water companies already named supply about one half of the town and suburban population of London. The remainder, including upwards of 220,000 houses, and a population probably exceeding 1,250,000 resident north of the *Thames* and east of Regent's Park and Charing Cross, receive their water supply chiefly from the *Lee*, but partly from the Chadwell spring and from deep wells, all situated in the *Lee* basin. This they do through two companies—the New River Company and the East London Water Company. The former dates from the reign of James I., when Sir Hugh Myddelton brought the water of the Chadwell spring near Hertford by a contoured open conduit 40 miles in length, delivering it to a reservoir at Clerkenwell, and thence distributing it through wooden pipes to the surrounding population. The East London Water Company takes its supply directly from the *Lee* below Waltham, and has lately, as already stated, constructed works at its intake on the *Thames*, above Hampton, to obtain 10,000,000 gallons daily from that source when required.

The basin of the *Lee*, which thus supplies one half of the drinking water of the metropolis, includes upwards of 500 square miles, one half of which is on the Chalk, and the rest on the Plastic and London Clay formations. The greater part of the permanent water flow, which, measured at Fielde's weir below the junction of the *Stort*, amounts on the average to 45,000,000 of gallons daily, is derived from the springs by which the upper tributaries of the river are fed, and in which they originate. The *Stort*, the *Rib*, the *Beane*, the *Mimram*, and the *Lee*, all rise in the Chalk, uniting, almost all of them, before the entrance of the river within the Clay district, through which it flows, but little increased in volume except in wet weather, to the *Thames* at Blackwall. The upper district of the river above Hertford is occupied by 80,073 people, and the lower district, whose drainage enters the river between Hertford and Ponder's End below Waltham, at the intake of the East London Company, by 87,812 people. In the upper district the town of Luton, and in the lower district the towns of Hertford, Ware, and Waltham, with Bishop Stortford on the *Stort*, discharge their drainage waters into the *Lee*, or its tributaries, after various attempts at defecation.

The New River Company has long taken not only the water of the Chadwell Spring, but as much as 15 to 20 millions of gallons daily from the *Lee*, below its junction with the *Beane* but above the outfall of the Hertford sewage; and this is further supplemented in dry seasons by pumping from wells at Ware, Amwell, Cheshunt, Hoddesden, and Wormley at successive points along the course of Sir Hugh Myddelton's old conduit—the New River. The produce of the Chadwell Spring varies between 1,800 and 4,400 gallons per minute. It rises at the foot of the mass of high-land Chalk below which the river valley lies, and is no doubt the produce not only of the general soakage of the immense sponge, as it were, of porous rock above it within the basin of the *Lee*, but also of drainage from districts outside the watershed, which, disappearing through swallow holes, thus swells the *Lee* after long subterranean travel.* Taking a figure midway of those just quoted we may assume the average yield of this spring

* In his evidence before the Royal Commission on Water Supply, Mr. R. W. Mylne, F.R.S., stated :—
" There is another feature lying beyond the watershed drainage area of the *Lee* which there can be little
" doubt has an important bearing on the source of these springs, viz., the existence of an isolated clay catch-
" ment basin of 23 square miles, which has no direct surface outfall, the central and lowest part of which
" is between North and South Mimms where the surface is chalk, and several swallow holes exist in the
" locality, which absorb the drainage water of the district. The natural tendency in this case would be for
" the waters to flow in the direction of the general dip of the chalk basin, but from the inclination of the
" strata towards the east, there can be no doubt a considerable portion of the water is carried off in that
" direction, issuing in the form of springs largely between Hertford and Hoddesdon."

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

to be 4,500,000 gallons of water daily, and this added to the average intake from the river at Hertford, and to the occasional produce of the pumping stations, amounts to about 25 millions of gallons, which the New River Company supply daily to 122,063 houses, and about 700,000 people. This is done by Sir Hugh Myddelton's old conduit, which, with an average width of 18 feet and a depth of 5 feet, and an average fall of five inches per mile, has now for 270 years supplied a large proportion of the London water. Its course, originally 40 miles in length, has been shortened by various cuts, occasionally aqueducts, in one case a syphon, and in another a tunnel, by which the old contour line has been cut across; and the fall of many miles thus taken out, is given abruptly at one or two of the more important of these works as a step or weir, the removal of which hereafter may be used to quicken the flow of the stream, and thus render the old channel available for the delivery of a larger quantity than it at present carries. The flow is at present about one-third of a mile an hour, which corresponds to a daily delivery of more than 20 millions of gallons. We carefully inspected the whole course of the New River, being drawn down it in a boat from the Chadwell Spring to Hornsey, and walking round those portions of the old contour, which, though no longer used, might possibly receive pollutions, owing to ultimate communication more or less directly with the flow. During the two days of our inspection, the water was muddy opaque, and of a pale yellow colour. The Chadwell Spring, rising a mile below Hertford in a circular pond about 30 yards across, within a carefully fenced and well-kept grassy enclosure, was then yielding 500 cubic feet per minute of a water even muddier than that of the river, which was being taken in at the floating sluice above the weir at the rate of 1,700 cubic feet a minute. In summer the river water is sometimes abstracted to the extent of 2,500 cubic feet per minute. The water of the spring, we were informed, becomes muddy after heavy rains about three days later than that of the river, being evidently fed at such times from the surface water to which we have already referred as escaping through the swallow holes in the upper chalk district. The two streams, from the river and the spring respectively, unite in the New River channel almost immediately; and the latter was carrying on the day we floated down it about 2,200 cubic feet a minute, or rather more than 20,000,000 gallons daily.

The sewage of Hertford is brought down to the margin of the open conduit which supplies the New River from the *Lee*, in an open sewer and is passed beneath it in two iron pipes, which on the day of our visit were running full. A water mark, of floated refuse, showed that the sewage in this open drain sometimes rises to about the same height as the water in the New River Cut, when the escape of the sewage into the drinking water must be imminent. Proceeding down the New River conduit we found it on the whole carefully fenced and well protected from the ingress of polluting streams; we found no pipe opening into it throughout its whole length. On the contrary the leakage which has to be guarded against is a leakage from the channel, not into it; for it traverses, during great part of its course, an open porous subsoil, which has to be kept tight by puddling. We noticed, however, even along its fenced banks, places specially provided in pasture fields where cattle could drink and stand in the water; in other places the banks are not fenced and do not even belong to the New River Company, and here cattle have free access to the stream. There are also several places where the conduit freely communicates with the ornamental waters in the grounds of private mansions, and here it is possible that some sewers or cesspools may discharge into it. The open conduit passes through villages, parks, and gardens; in some places running through secluded woods, in others skirting high roads. At Broxbourne high road bridge, there was, close to its bank, a large manure heap, with much filthy water around it, standing at a higher level than the New River, into which it was probably soaking.

At Nag's Head Lane the water flows from the conduit through a main four feet in diameter to Bush Hill. At this point there was at the time of our visit a large deposit of stable manure on the right bank, in such a position as to allow soakage from it to pollute the water. There is also here a large market garden sloping down to the conduit.

At Enfield, the right bank of the river is freely exposed to pollution from cattle in the adjoining fields. For a distance of about one third of a mile, the left bank is here occupied by gardens, some of which are slightly fenced off, whilst others allow free access to the stream; in some of the latter, cabbage stalks and other vegetable refuse and house ashes were scattered about near the brink of the conduit in a slovenly manner. Opposite Enfield Court, there is free access for cattle to the river on the left bank. The right bank also here was obviously trodden down by cattle.

Along Chase Side for a distance of about half a mile the New River is freely exposed to cattle on both sides, and the banks have been evidently trodden down. Chase

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Side is a village, and gardens and footpaths on the banks of the stream are here abundant. There is also a specially constructed drinking place where cattle can wade into the river.

From Hornsey to Stoke Newington, both banks are exposed to pollution from cattle, and as the open conduit approaches and enters London, the chances of contamination become multiplied.

About one fifth of the total supply of the Company passes onwards to the so-called New River Head at Clerkenwell. From the Company's works at Stoke Newington to Quadrant Road, N., the water is conducted in a 48 inch iron main to an open conduit a quarter of a mile long passing round the ornamental grounds of Newington Park. Here a meadow with fine overhanging trees forms the right bank, whilst lawns and shrubberies extend to the left. Emerging from these private grounds the conduit still keeps the meadow with overhanging trees for its right bank, but the left is now bounded by a much frequented public road (Paradise Road), from which it is only slightly fenced off by two horizontal iron bars. It continues open to the junction of Green Lanes with Petherston Road, altogether about half a mile, and is skirted by the gardens of villa residences on the right, and by a much frequented public footpath and by houses on the left, being separated from the footpath by open iron railings. From Green Lanes to St. Paul's Road, a distance of about three quarters of a mile, the water is conveyed through a 48 inch iron main. Thence to Essex Road, Islington, the conduit is again open and to some extent exposed to accidental pollution. In this part of its course it passes under the Canonbury Road, from which it is only protected by an open iron railing at the bridge. An iron main 48 inches in diameter covers the remainder of the distance (about 1,000 yards) to the New River Head, where the Company's filter beds and pumping engines deal with this fraction of their supply. (*See* map of New River channel south of the Green Lanes station facing this page.)

It is our duty thus to enumerate in detail the defects which we observed in our inspection of this ancient conduit, but we are equally bound to declare that, on the whole, it is kept in excellent order, and is, as a rule, most carefully guarded from pollution,—statements which are confirmed by the great superiority in quality which the New River Company's water always exhibits when compared with the river water delivered by any other metropolitan company. Nevertheless from considerations described at page 140, we are of opinion that the conveyance of drinking water in an open conduit, through the wide spreading suburbs of London and almost to the very heart of the metropolis itself, is fraught with peril to the health of the consumers, which, however well guarded against, ought no longer to be allowed to continue. A conduit of this kind, in the days of Sir Hugh Myddleton, ran but little risk of contamination, but it can obviously now only be preserved from pollution by the most rigid and incessant inspection; and we are of opinion that the health of a vast community ought not to be permitted thus to depend upon the watchfulness of fallible inspectors.

Following the course of the New River from its source, the following hydraulic works are encountered:—At Amwell end, near Ware, is the first well and pumping station, where a 50 h.p. engine can lift 2,000,000 gallons daily into the New River when the Chadwell Spring or the flow of the river *Lee* itself falls below the requirements of the Company. The bore here is 419 feet in depth, and the water rises in the well to within a few feet of the surface, the level being lowered as much as 30 feet by pumping that quantity. At Amwell Hill, two miles further, there is another pumping station, where an engine of 25 h.p. is capable of lifting nearly 2,000,000 gallons daily; the well is 80 feet deep, with level adits at that depth, and a further bore of 40 feet. At Hoddesden is a third pumping station, with a bore of 402 feet, yielding, when the engine of 50 h.p. is at work, 2,300,000 gallons daily. At Turnford near Broxbourne, from a well 254 feet deep, of which the shaft is 180 feet, two 18-inch borings going 74 feet lower, 2,600,000 gallons may be pumped daily by the 80 horse power engine there provided. In all these cases the infiltration of surface water is said to be carefully provided against by water-tight iron cylinders carried to a sufficient depth. At Cheshunt two reservoirs of 7 and 11 acres in extent respectively are provided, capable of holding 39,000,000 gallons, collected from a gathering ground above them; and a pumping engine (20 horse power) is provided for refilling these reservoirs with water from the river *Lee*, whenever they may have been drawn upon. This storage is not used for domestic service, but is kept available in case of large fires in London. Our analysis given below shows this water to be highly polluted and altogether unfit for domestic purposes.

Hornsey is reached after about 25 miles of channel from the Chadwell Spring. There are here eight acres of subsidence-reservoir, producing, however on the day of our inspection, but little apparent effect on the opacity and muddy colour of the water which they

received and delivered. There are also three filter beds two acres in extent, the filtering medium being two feet of sand above three feet of gravel. About 600,000 gallons of filtered water are pumped daily from this station to the Highgate and Hampstead reservoirs. At the Green Lanes, Stoke Newington, whence the main supply of the New River Company's water is delivered, there are 42 acres of subsidence-ponds, which, however, on the day of our visit, also appeared to exert but little influence on the muddiness of the water; and there are besides seven filter beds, in all seven acres in extent, delivering four to five inches per hour. Six engines, together 1,080 horse power, pump from 10,000,000 to 15,000,000 gallons daily to the Pentonville and Maiden Lane service reservoirs,—of an aggregate capacity of 18,000,000 gallons. The perfectly filtered bright and clear water thus delivered was in admirable contrast to the muddy unfiltered water which the beds were receiving from the subsidence-ponds. The remainder of the water flows to the New River Head, a reservoir of about three quarters of an acre in extent, the original termination provided by Sir Hugh Myddelton, at Clerkenwell. There are here three filter beds, about two and a quarter acres in extent, which are capable of delivering 5,000,000 gallons daily. The filters are carefully and frequently cleansed. In addition to the storage reservoirs at Cheshunt, Hornsey, Stoke Newington, and New River Head, and seven service reservoirs at Highgate, Hampstead, Islington, and Maiden Lane, the Company has a series of 13 open ponds at Hampstead, and one at Camden Park Road. In these, water is collected from springs and gathering ground, and is distributed unfiltered for street watering. The supply for this last purpose can also be increased, to a great extent, by direct pumping from the *Thames* at Blackfriars.

Part IV. Descriptive.

The Metropolitan water supply.

The following table contains the results of our analyses of samples of water connected with the various works of the New River Company. All the samples were collected by ourselves, except the one marked thus *, the data belonging to which are taken from the Report of the Royal Commission on Water Supply (1869).

COMPOSITION OF LEE, DEEP WELL, AND SPRING WATER AT THE NEW RIVER COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Chadwell Spring, January 24, 1873.	29·80	·420	·084	·001	·299	·384	2,680	1·80	13·4	6·6	20·0	Very turbid.
The *Lee* at New River intake, January 24, 1873.	34·40	·287	·067	·005	·381	·452	3,530	1·80	19·7	6·0	25·7	Turbid.
New River below junction of Chadwell spring and conduit from River *Lee*, January 24, 1873.	34·20	·324	·076	·003	·365	·443	3,350	1·70	19·2	5·6	24·8	"
Amwell well, May 5, 1868* -	31·88	·076	·009	0	·406	·415	3,740	1·39	16·5	5·9	22·4	Clear and colourless.
Amwell well, July 17, 1873 -	33·56	·161	·055	0	·432	·487	4,000	1·85	19·2	4·7	23·9	Turbid.
Cheshunt storage reservoirs, January 24, 1873.	23·08	·863	·156	·011	0	·165	0	1·90	·6	10·0	10·6	Very turbid.
New River at Hornsey Wheel House, January 25, 1873.	32·90	·375	·059	·005	·371	·434	3,430	1·70	18·9	5·3	24·2	Turbid.
Ditto, after subsidence and filtration, January 25, 1873.	22·00	·227	·043	·002	·186	·231	1,560	1·65	9·2	7·4	16·6	Clear.
New River at Stoke Newington after subsidence but before filtration, January 25, 1873.	31·98	·350	·084	·004	·310	·397	2,810	1·70	16·4	6·6	23·0	Very turbid.
Ditto after filtration, January 25, 1873.	30·16	·246	·042	0	·310	·352	2,780	1·65	16·4	6·6	23·0	Clear.
New River at New River Head (Clerkenwell), after subsidence and before filtration, January 27, 1873.	31·96	·330	·061	·004	·339	·403	3,100	1·70	16·9	7·3	24·2	Turbid.
Ditto after filtration, January 27, 1873.	31·56	·242	·043	0	·334	·377	3,020	1·70	15·9	7·7	23·6	Clear.

These analytical results reveal several important facts connected with the sources whence the New River Company abstracts water. They show, in the first place, that the Chadwell spring is liable to very serious pollution, and that on the 24th of January 1873, its water was greatly inferior to that of the neighbouring polluted *Lee*, and quite unfit for domestic supply. The composition of the filtered water then being supplied by the New

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

River Company, as shown in the foregoing table, and also in the weekly returns of the Registrar-General, proves that notwithstanding the cleansing which it had received from subsidence and filtration it was, though clear, badly polluted by organic matter in solution; and reference to Diagram III., facing page 262, shows that similar pollution, though not quite so intense, occurred in the winters 1868–69, 1869–70, and 1871-72. Nevertheless, on all these occasions the water supplied by this company was the best river water delivered in London. The second analysis of the Amwell Well water shows, that this well is also occasionally liable to some degree of pollution, but this arises probably from the imperfect exclusion of surface water. The table further proves that the water collected in the large storage reservoir at Cheshunt is grossly polluted by organic matter; it is much less hard than any of the other samples, and might therefore be used for washing, but its dietetic use would be very dangerous, and it is satisfactory to be informed by the Company that it is never supplied for domestic purposes. Finally, the analyses show how great is the reduction in the proportion of organic matter resulting from the very efficient system of subsidence and filtration practised by this Company. The pairs of samples collected at the filtering stations at Hornsey, at Stoke Newington, and at the New River Head, show a reduction in the proportion of organic elements (organic carbon and organic nitrogen) varying from 27 to 38 per cent.

We have been unable to collect any satisfactory samples of the various supplemental waters which are added to the volume of the New River on its way from its sources—the Chadwell spring and the *Lee*. The wells at Amwell End, Amwell Hill, Hoddesdon, and Turnford, providing these supplemental supplies which have been described above, are used only when the *Lee* and Chadwell spring are insufficient for the demand of the metropolis, and this rarely happens oftener, or for a longer time, than once a year, during a few weeks in the autumn. It was, however, of importance to the value and completeness of this Report that every circumstance at any time affecting the water supply of the enormous population within the New River district should have been investigated, and we regret that this does not appear to have been sufficiently considered by the directors of the New River Company. A sample collected from one of their auxiliary wells soon after the pumping from it began last year proved to be turbid, and of bad quality, and it was fairly objected to by the officers of the Company as inaccurately representing the ordinary condition of the water. A subsequent proposal to collect fair samples made, as it happened, after the pumping had been discontinued for the season, was acceded to by the directors only on the condition that they should be reimbursed the cost of putting their engines to work for this purpose. We desire to acknowledge the courtesy with which the directors facilitated our inspection of their works; and it is also especially incumbent upon us to express our acknowledgments not only to the directors of every other Metropolitan Water Company, but to the officers of a large number of Corporations, Local Boards of Health, and Water Companies in the country, to whom we have had occasion to apply, for the frankness of their answers to our inquiries, and for the often laborious and sometimes expensive assistance which, without charge, they have rendered to an investigation of great public importance carried on under this Your Majesty's Commission.

The East London Water Company supplies the district north of the *Thames* and east of a line almost due south from Tottenham High Cross, which is the eastern boundary of the New River Company's area. It thus supplies 20,000,000 to 22,000,000 gallons daily to 104,637 houses and about 675,000 people, including in that number 2,000 meter supplies; about 5,000,000 gallons daily is for trade and manufactures, the remaining 16,000,000 being for domestic purposes. The whole of this enormous quantity is taken from the *Lee* at Ponder's End, where a former mill conduit has become the property of the Company, and is used for the supply of the subsidence reservoirs at Walthamstow, between Lee Bridge and Ponder's End. There are here eight reservoirs, 220 acres in extent, and capable of holding 400,000,000 gallons of water. At Chingford mill other reservoirs, on a somewhat higher level, holding about one half this quantity, will be available in addition; but the arrangements for the working of these last had not been completed at the time of our visit.

The water after prolonged subsidence in these immense reservoirs flows into a conduit rather more than one mile further to Lee Bridge, where no less than 19 acres of filter beds are in use, and others are being constructed. The water passes through 18 inches of fine sand and 24 inches of coarser sand and fine and coarser gravel, and from this station more than 20,000,000 of gallons daily are pumped by both steam and water power, three-fourths of it direct to consumers, and the rest to the covered

The Metropolitan water supply.

reservoirs at Old Ford, where other engines deliver it throughout the immense district supplied by the Company. The arrangements of the Company for the filtration of the water of the *Lee* are not surpassed in completeness by those of any other of the London Water Companies. Not more than 1½ gallon is drawn per square foot of surface per hour, equal to a depth of about 3 inches of water passed through the filters in that time. Although a vigorous inspection is said to be maintained of all the drainages into the river channel above the intake, the water received from the *Lee* is necessarily fouler than that of the New River Company which is taken so much higher up; and the careful filtration performed is all the more necessary on this account. The reservoirs at Old Ford, which are now covered and used for storage, had formerly a connexion by sluice with two uncovered reservoirs which received soakage from the foul river as it passed them; and Mr. Charles Greaves, M. Inst. C.E., engineer to the Company, gave evidence, December 10, 1866, before the Rivers Pollution Commission of 1865, that that connexion was available, and had been actually used three times during that year. We are informed that it is now entirely cut off, and that no water can find its way into this service of the East London Company which has not entered the subsidence ponds at Ponder's End, and passed through the filter beds at Lee Bridge.

The following table contains the results of our analyses of several samples of water illustrating the operations of this Company:—

COMPOSITION OF LEE AND THAMES WATER AT THE EAST LONDON COMPANY'S WORKS.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
Lee water at intake at Walthamstow, February 1, 1873.	36·90	**·240**	**·057**	·015	·384	·453	**3,640**	1·95	18·9	8·0	26·9	Turbid.
Ditto from last subsidence reservoir at Walthamstow, February 1, 1873.	34·66	**·481**	**·092**	·015	·290	·394	**2,700**	2·00	19·0	7·0	26 0	„
Ditto at intake to filters at Lee Bridge, February 1, 1873.	34·68	**·363**	**·082**	·004	·311	·396	**2,820**	1·95	16·6	7·0	23·6	„
Ditto, after filtration, February 1, 1873.	34·70	**·305**	**·041**	·001	·314	·356	**2,830**	1·90	17·1	7·1	24·2	Clear.
Filtered water from pumping well at Old Ford, February 1, 1873.	34·40	**·299**	**·047**	·002	·301	·350	**2,710**	1·90	17·1	7·1	24·2	„
Filtered *Thames* water from main at Sunbury, August 7, 1873.	22·20	**·159**	**·030**	0	·106	·136	**740**	2·10	—	—	18·3	„
Ditto at Finsbury Park, August 7, 1873.	22·68	**·157**	**·029**	0	·101	·130	**690**	2·10	—	—	18·3	„

These analytical results are very instructive, they not only show the great improvement effected by the filtration of the highly polluted water then stored in the subsidence reservoirs at Walthamstow, but they illustrate forcibly a very grave defect in the system of storage commonly employed by water companies. The obvious use of storage reservoirs, which are employed by water companies who draw their supply from rivers, is to preserve the water, when in good condition, for use when the river is in flood; but it is equally obvious that if, owing to a prolonged flood, water of bad quality has been admitted into the reservoirs, means ought to be provided for the immediate return of that water to the river, as soon as the latter becomes of superior quality to the impounded water. Storage reservoirs are worse than useless when they deliver water of a quality inferior to that which is flowing in the river by the side of them. Not only were these the relative conditions of the flowing and impounded water at Walthamstow on the occasion of our visit, but the above analyses show that the *unfiltered* river water was actually less polluted by organic matter than the impounded water *after filtration*. We have already referred, at page 262, to the occasional evil effects of this system of storage upon the quality of the water delivered by the West Middlesex Company after a prolonged flood.

The pair of samples in the above table, illustrating the composition of filtered *Thames* water before and after passage through this Company's main from Sunbury to Finsbury Park, have already been commented upon at page 223.

The capital invested in the supply of water to the Metropolis by these eight companies represents a total sum of 10,384,029*l*.

PART IV.
DESCRIPTIVE

The Metropolitan water supply.

The following table collates several of the more important of the particulars contained in the replies to our inquiries:—

Name of Company.	Area of District.	Number of Houses and Factories supplied.		Volume of Daily supply.	Area of Subsidence Reservoirs.	Area of Filter Beds.	Rate of Filtration per hour.	Expenditure to March 31, 1874.		
	sq. miles	houses	factories	galls.	acres	acres	inches	£	s.	d
Lambeth	60	48,500	1,500	12,500,000	(*)	2¼†	10	1,024,000	0	0
Southwark and Vauxhall	—	79,000	600	17,500,000	12	14¼	4	1,544,482	19	11
Grand Junction	—	34,243	140	12,290,271	7	7½	3	1,037,666	4	4
West Middlesex	12	44,690		9,644,000	20	4⅓	4	881,454	18	8
Chelsea	5	28,270		10,000,000	0	3¼‡	6	851,876	0	0
Kent	60	42,000	200	9,000,000	—	—	—	496,596	0	0
New River	22	120,242	900	21,868,000§	100	11¼	4–5	2,684,134	2	3
East London	?	102,637	2,000	21,000,000	220	25	3	1,868,813	14	4‖
								10,384,029	0	1

* A subsidence reservoir is in course of construction to hold 120 millions of gallons.
† Two others in course of construction with collective area of 1½ acres.
‡ Three additional filters of 3¼ acres total area are in course of construction.
§ This is the quantity of filtered water delivered throughout 1872.
‖ Capital stated to be 568,910*l.*

The Metropolitan shallow well waters.—Substantially the Metropolis is supplied with water by the eight private companies whose works have just been described, but there are still in use, for dietetic purposes, a considerable number of public pumps drawing their supplies from shallow wells. A large area of London is built upon gravel, averaging from 10 to 20 feet in thickness. This gravel rests upon a stratum of Clay, which is rarely less than 100 feet thick, and as the superficial stratum is very permeable, and the lower one not appreciably so, the former becomes charged with a mixture of rain water, percolations from sewers and cesspools, and the soakage from badly-paved streets, courts, and alleys. Until Sir Hugh Myddleton constructed the New River conduit in 1613, London was almost entirely supplied with water by shallow wells sunk into this gravel, supplemented only by water pumped from the *Thames* at London Bridge. Indeed the direction in which the metropolis extended was controlled by this water-bearing stratum. In his address to the Geological Society, 1872, the President,—Mr. Joseph Prestwich, F.R.S., one of Your Majesty's Commissioners on Water Supply appointed in 1867, thus describes the dependence of metropolitan extension upon the existence of surface gravel:—

"The early growth of London followed unerringly the direction of this bed of gravel:—eastward towards Whitechapel, Bow, and Stepney; north-eastward towards Hackney, Clapton, and Newington, and westward towards Kensington and Chelsea; while northward it came for many years to a sudden termination at Clerkenwell, Bloomsbury, Marylebone, Paddington, and Bayswater; for north of a line drawn from Bayswater, by the Great Western station, Clarence Gate, Park Square, and along the north side of the New Road to Euston Square, Burton Crescent, and Mecklenburg Square, this bed of gravel terminates abruptly, and the London Clay comes to the surface, and occupies all the ground to the north. A map of London so recent as 1817, shows how well-defined was the extension of houses arising from this cause. Here and there only beyond the main body of the gravel there were a few outliers, such as those at Islington and Highbury; and there habitations followed. In the same way, south of the *Thames*, villages and buildings were gradually extended over the valley-gravels to Peckham, Camberwell, Brixton, and Clapham; while, beyond, houses and villages rose on the gravel-capped hills of Streatham, Denmark Hill, and Norwood. It was not until facilities were afforded for an independent water-supply by the rapid extension of the works of the Water Companies, that it became practicable to establish a town population on the clay districts of Holloway, Camden Town, Regent's Park, St. John's Wood, Westbourne, and Notting Hill.

"On the outskirts of London a succession of villages grew up for miles on the great beds of gravel ranging on the east to Barking, Ilford, and Romford,—on the north, following the valley of the *Lee*, to Edmonton and Hoddesdon,—and on the west up the *Thames* valley, to Hammersmith, Ealing, Hounslow, Slough, and beyond; whereas, with the exception of Kilburn, hardly a house was to be met with a few years since between Paddington and Edgware, or between Marylebone and Hendon, and not many even between the New Road and Highgate and Hampstead. As a marked case of the excluding effects of a large tract of impermeable strata close to a great city, I may mention the denuded London Clay district, extending from a mile north of Acton, Ealing, and Hanwell, to Stanmore, Pinner, and Ickenham near Uxbridge. With the exception of Harrow (which stands on an outlier of the Bagshot Sands), Perivale, and Greenford (on outliers of gravel), there are only the small villages of Northall and Greenford Green. In the earlier edition of the Ordnance Maps there was a tract of ten square miles north and westward of Harrow within which there were only four houses. Yet the ground is all cultivated and productive. But immediately eastward of this area, and ranging thence to the valley of the *Lee*, the ground rises higher, and most of the London Clay hills are capped by gravel of an older date than that of the London valley, and belonging to the Boulder Clay series. On these we have the old settlements of Hendon, Stanmore, Finchley, Barnet, Totteridge, Whetstone, Southgate, and others.

"There is yet another very common source of well-water supply from beds of gravel, directing population to low sites in valleys, which is this. Everywhere on the banks of the *Thames* and its tributaries there is a lower-lying bed of valley-gravel or of rubble on, and often passing beneath, the river-level. This bed is fed by the rain falling on it, by springs thrown out from the adjacent hills, or by the drainage from those hills, and in places by infiltration from the river, when, from any cause, the line of water in the gravel falls below that of the adjacent river; while, on the other hand, the surplus land-supplies find their way, direct and unseen, from the bed of gravel to the river. A great part of London south of the *Thames*, also Westminster, Battersea, and a number of towns up the *Thames*, as Hammersmith, Brentford, Eton, Maidenhead, and others, together with Newbury and several villages on the *Kennet*, and the towns of Ware and Hertford on the *Lee*, have this shallow well supply. A great many towns and numberless villages along most of our river-valleys all through England, and on whatever formation situated, are dependent on this superficial source of supply—a supply much more permanent than the other shallow-well supplies, in consequence of the outside aid from springs and rivers. It is, however, only in case of exceedingly dry seasons or of excessive pumping, that the supply requires to be supplemented by the river-waters. As, in ground of this description, the land water is generally claimed back by the stream, the level of the water in the wells, which are always shallow, varies with the level of the water in the streams, rising and falling more or less with them."

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Such being the position and surroundings of the gravelly stratum supplying water to the shallow wells of London and its suburbs, it is clear that this water must, even under the most favourable of those conditions, be seriously polluted, and where the conditions were less favourable, the foul matter became in many instances so evident to the senses that its presence could no longer be ignored, and the wells were reluctantly abandoned.

On the 26th of February 1872, a return was moved for in the House of Commons by Mr. U. J. Kay Shuttleworth, M.P., giving the name, position, and depth where known, of every public shallow well within the metropolis, specifying which of them have been permanently closed. We have collected samples from all the wells named in this return which have not been permanently closed, and also from several other shallow wells in the metropolis not mentioned in that document. These samples, on being submitted to analysis in our laboratory, yielded results which are given at page 85, and which prove them to be, with very few exceptions, of most disgusting origin; although, owing to the marvellous purifying power of the gravel through which the filthy liquids filter, many of them contain less actual polluting organic matter than is found in the *Thames* water delivered in London during the winter months.—It is thus evident that slow soakage through a few feet of gravel destroys more organic matter than does a flow of many miles in the *Thames*.—Nevertheless it cannot be doubted that the partially purified sewage which supplies these shallow wells is, at all times, consumed as a beverage with imminent risk to health, and is occasionally the cause of deplorable results, witness (*see* page 150) the frightful mortality from cholera around a pump (since closed) in Broad Street, near Golden Square, when 609 persons lost their lives, in a few days, by drinking water obtained from that pump.

The series of samples examined affords examples of every degree of pollution, from that of the water taken from the pump in Wellclose Square, St. George's-in-the-East, which is derived from the percolation of a liquid at least 2½ times as rich in animal matter as London sewage, down to the water furnished by the pump near the S.E. entrance to Kensington Gardens, which, being at a considerable distance from human dwellings, exhibits evidence of only 2½ per cent. of previous sewage contamination. The water of the well in Wellclose Square has a slight saline taste, which may make it more piquant to some water drinkers, but nearly all the other samples were quite palatable, although some were not quite bright and clear. The following are the wells in which the pollution appeared to be most recent, and consequently most dangerous to human health:—

Well on Duck Island, St. James's Park, used for supplying the ornamental water and not used by the public.
Pump at S.E. corner of Red Lion Square.
Pump at railing of garden, Queen Square, Bloomsbury.
Pump at crossing between Devonshire Street and Gloucester Street, Queen Square, Bloomsbury.
Pump in King Square, St. Luke's, City Road.
Well at Fountain Inn, Mile End Road.
Pump at St. Michael's, Cornhill.
Aldgate Pump.
Pump at St. John's, North End, Hampstead Heath.
Well at Trinity Almhouses, Mile End Road.
Pump at corner of Clifton Street, Larkhall Lane, Clapham.
Pump in Wandsworth Road, near Union Road, Clapham.
Pump in Rectory Grove, opposite Fitzwilliam Road, Clapham.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

In the entire list there are only three wells or pumps, the water of which can be used for drinking without very considerable risk to health. These are,—

Well at Southwark Water Company's works at Battersea, not accessible to the public.

Pump near the S.E. entrance to Kensington Gardens, much used by the public.

Well at Maritime Almshouses, Mile End Old Town.

The quality of the water from the last-named well is very remarkable, and entirely unlike that of any other shallow well water in London which we have examined. The water exhibits no evidence of previous sewage or animal contamination, and contains but a very small quantity of organic matter. It is much softer than any of the other samples, and even than *Thames* water as delivered in London. The total solid impurity is also very much less than that present in nearly all the other samples, and is about equal to that usually found in *Thames* water. Altogether this water was of such an anomalous degree of purity, as to induce us to analyse a second sample which we collected nearly a month after the first, but, as will be seen by a reference to the analytical table at page 85, the two samples do not differ from each other in any important respect.

With the exception of the three wells just mentioned, we are not aware that there is any shallow or surface well in London which yields water fit for human consumption, and we are therefore of opinion that all other wells of this description should, in the interests of the public health, be immediately closed. Power to do this has already been given to the Sanitary Authority by the Public Health Act of 1872.

To this detailed description of the water supply of the Metropolis we append the following general remarks:—

The quality of that portion of the London Water Supply which is derived from the Thames.—The analyses and investigations of all former Commissions, our own chemical examination of no less than forty samples of *Thames* water taken from the river and its affluents above Teddington lock, and our minute inspection of the *Thames* and its tributaries above the intake of the respective water companies drawing their supply from that source, have conclusively proved:—

1. That the river receives the sewage from a large number of towns and other inhabited places, the washings of a large area of highly cultivated land, and the filthy discharges from many industrial processes and manufactures.

2. That the river is used for bathing, and for the washing of sheep and cattle; dirty linen is also washed in it, and the putrid carcases of animals float upon its surface.

3. That it is the common water-way for a large amount of polluting matter much of which is dangerous to the health of communities using the water for domestic purposes.

4. That in time of flood a large proportion, both of the suspended and dissolved filth, is conveyed down to the intakes of the metropolitan water companies, and that in ordinary weather a considerable proportion of the soluble organic matter of sewage, discharged into the river and its tributaries, likewise makes its way down to the works of the water companies, and is still present in the water distributed by them in London.

5. That the water is, nevertheless, when efficiently filtered, free from any offensive taste or odour.

6. That notwithstanding the application of partial remedies for sewage pollution at Banbury, Eton, and Windsor, and the greater care exercised by most of the companies in the storage and filtration of the water, the organic pollution contained in the *Thames* water delivered in London, though subject to fluctuations from the greater or less prevalence of floods, does not diminish.

Taking the mean proportion of organic impurity in the *Thames* water delivered in London in 1868 as 1,000, we find that, in subsequent years down to 1873 inclusive, the following proportions were present:—

Year.	Proportion of organic impurity present in *Thames* water as delivered in London.
1868	1,000
1869	1,016
1870	795
1871	928
1872	1,243
1873	917

The Metropolitan water supply.

7. That there is no hope of this disgusting state of the river being so far remedied as to preclude the presence of animal and other offensive matters, even in the filtered *Thames* water as delivered in the metropolis. (*See* p. 221.)

8. That the *Thames* should therefore, as early as possible, be abandoned as a source of water for domestic use.

9. That the temperature of the water drawn from the companies' mains is liable to excessive fluctuations, being near the freezing point in winter and so warm in summer, as to be vapid and unpalatable.

The quality of the water supplied to London from the Lee.—The pollution of the river *Lee* above the intake of the water companies, is similar in character to that of the *Thames*, but considerably less intense. Our investigation of the water of the *Lee* has led us to the following conclusions:—

1. That sewage and other disgusting matters reach the intakes of the metropolitan water companies drawing from this river, and that the soluble portions of such matters are not wholly eliminated by the efficient filtration to which the water is subjected before delivery.

2. That the water of the *Lee*, though less impure than that of the *Thames*, is slowly though irregularly deteriorating from year to year, and that there is no hope of purifying it to such an extent as to render it, at all times, safe for domestic use.

Taking, as before, the mean proportion of organic impurity in the *Thames* water delivered in London in 1868 as 1,000, we find in that, and subsequent years down to 1873 inclusive, the following proportions present in the *Lee* water delivered by the New River* and East London Companies.

Year.	Proportion of organic impurity present in *Lee* water as delivered in London.
1868	484
1869	618
1870	550
1871	604
1872	819
1873	693

3. That the *Lee* should therefore also be abandoned as a source of potable water, but that this measure is not so urgent as the relinquishment of *Thames* water.

The quality of the water supplied to London from deep wells in the Chalk.—We have devoted much attention to the water supplied by the Kent Waterworks Company from deep wells in the Chalk at Deptford and other places. So long as the water derived from the wells at Deptford was stored in an open reservoir, it was liable to occasional pollution, but since the covering of the reservoir in 1872, the water has been, so far as organic pollution is concerned, uniformly good. Our analyses and inspection of the sources of these deep well waters lead us to the following conclusions:—

1. That the water supplied to some of the suburbs of London from the wells at Charlton and Belvidere is of objectionable quality; but that the water from all the other wells of this Company is, though hard, good and wholesome.

2. That the water supplied to London by the Kent Company from the wells at Deptford is free from sewage or other objectionable organic matter.

3. That without any artificial filtration this water is always clear, sparkling, transparent, and palatable.

4. That it is uniformly a wholesome water.

5. That the water supplied from deep wells in the Chalk at Deptford contains much less organic matter, and a more uniform proportion of it, than the supplies from the *Thames* and *Lee*. Taking the mean proportion of organic impurity in the *Thames* water delivered in London as 1,000 we find (*see* Diagram III., facing page 262) in that and

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* A small proportion of the New River supply is always taken from the Chadwell spring, and occasionally, though rarely, from deep wells in the chalk; but the volume of water, other than *Lee* water, distributed by this company is too small to affect the comparison materially.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

subsequent years down to 1873 inclusive, the following maximum and average proportions present in the *Thames*, *Lee*, and Deptford deep-well water respectively:—

YEAR.	Proportion of organic impurity present in the water as delivered in London.					
	Thames.		Lee.		Deptford Wells.	
	Maximum.	Average.	Maximum.	Average.	Maximum.	Average.
1868	2,498	1,000	1,278	484	505	252
1869	3,164	1,016	1,431	618	600	310
1870	1,845	795	1,530	550	360	244
1871	2,465	928	1,249	604	244	149
1872	2,399	1,243	1,902	819	285	219
1873	2,126	917	1,617	693	327	248

6. That the temperature of the water is nearly uniform throughout the year, being far removed from the freezing point in winter, and of refreshing coolness in summer.

7. That it is very hard, and therefore not quite so useful a water for washing and cleansing purposes as the supplies furnished by the *Thames* and *Lee*.

8. That the continued and extended supply of this and similar water to the metropolis is very desirable.

The quality of the water derived from public shallow wells in the metropolis.—With the exception of the pump near the S.E. entrance to Kensington Gardens, and a well at Maritime Almshouses, Mile End Old Town, all these wells yield water most disgustingly polluted and quite unfit for human consumption. With the two exceptions just mentioned, all these wells ought, in the interests of the public health, to be immediately closed.

In our opinion therefore the *Thames* and *Lee* ought to be abandoned as sources of metropolitan water supply. We have arrived at this conclusion after a very prolonged and searching personal investigation, not only of the main streams themselves, but of all the chief affluents at their source, and at their junction with the two rivers. As one result of this investigation, we find that nearly all the affluents are polluted immediately after leaving their sources, in some cases even much more seriously than the main streams themselves at the intakes of the metropolitan water companies. Nothing would be gained therefore by the abstraction of the water at any higher points, short of the springs forming the sources of the tributaries.

PROPOSED NEW OR IMPROVED SOURCES OF WATER SUPPLY FOR THE METROPOLIS.

The hopeless condition of the *Thames* and *Lee* has already called forth several recommendations for sources of water supply outside these river basins. Of these it will be necessary here to notice two only, viz.:—

1. A scheme for bringing to London some of the head waters of the *Severn;* proposed by John Frederick Bateman, Esq., C.E., F.R.S.

2. A scheme for bringing to London water from certain lakes in Cumberland; by George Willoughby Hemans, Esq., C.E., and Richard Hassard, Esq., C.E.

Mr. Bateman's Scheme.—Mr. Bateman proposed to obtain all the water required for the metropolis from the mountain ranges of Cader Idris, and Plynlimmon, in North Wales, which constitute the chief sources of the *Severn.* These mountains, which receive a rainfall of from 70 to 150 inches per annum, consist of the upper and lower Silurian formations,—strata which we have everywhere found to constitute excellent gathering ground for the collection of surface water. These rocks are but very slightly absorbent, and consequently a very large proportion of the rainfall runs off their surface; they also contain but very little calcareous matter, and the water finding its way into the mountain streams is therefore, generally, very soft; moreover, except in flood time, it contains but a moderate amount of peaty matter. Mr. Bateman stated that the valleys in the south-eastern flanks of these mountains;—

"Afford sites for magnificent reservoirs, which may be constructed with perfect safety and facility and of sufficient capacity to economise the full annual rainfall I have assumed, and to last out droughts of from 140 to 150 days' duration both for town supply and river compensation. One of these districts of 66,000 acres in area is situated a little to the east of the range of mountains of which Cader Idris and Aran Mowddy are the highest summits, forming the drainage ground of the rivers *Banw* and *Vyrnwy.* The other district of about equal area is situated immediately to the east of Plynlimmon, 2,500 feet in height. The discharge pipes of the lowest reservoir in each

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

of these districts will be placed at an elevation of about 450 feet above the level of Trinity high-water mark. The water will be conducted by separate aqueducts of 19 miles and 21½ miles in length respectively, to a point of junction near Marten Mere, from whence the joint volume of the water will be conveyed by a common aqueduct to the high land near Stanmore, where extensive service reservoirs must be constructed, which will be at an elevation of at least 250 feet above Trinity high-water mark. From these reservoirs the water will be delivered to the city at high pressure and under the constant supply system. The total distance from the reservoirs on the *Severn* to London will be 183 miles. One of the revervoirs on the river *Vyrnwy* will, by an embankment of 76 feet in height, form a lake of five miles in length, and will contain 1,089,000,000 cubic feet. Another on the river *Banw,* by an embankment of 80 feet in height, will form a lake of four miles in length and contain 940,000,000 cubic feet, and a third in the same district by an embankment of similar height will contain 732,000,000 cubic feet. Amongst the reservoirs on the *Severn* will be one which, by an embankment of 75 feet in height, will contain 2,230,000,000 cubic feet, this single reservoir being 150 per cent. greater than the available waters of Loch Katrine."

Mr. Bateman estimates the cost, for the delivery of 220,000,000 gallons per day in London, at 10,850,000*l.*, the interest upon which, together with cost of maintenance, would, in his opinion, be met by a domestic rate of 10*d.* in the pound and a public rate of 2*d.* in the pound. The total gathering ground in this scheme was estimated at 204 square miles.

As to the feasibility of this scheme, the Royal Commission on Water Supply arrived at the following conclusions:—

" That Mr. Bateman's scheme is, in an engineering point of view, feasible and prac-" ticable, and that by it a large supply of water might be obtained for the metropolis; " but that experience warrants great caution in judging of the sufficiency of a gravita-" tion scheme of such magnitude.

" That the outlay for the scheme would be very large, amounting, according to the " evidence laid before us, to about 11,000,000*l.*; but in the absence of detailed surveys, " and in a project involving works of such great magnitude and novelty, and subject to " such large contingencies and elements of uncertainty, we do not consider that it is " possible to arrive at any trustworthy estimate of the cost.

" That, even assuming the work could be carried out for the estimated amount, the " cost to the metropolis of obtaining water by this scheme would be much greater than " is incurred by the present plan, and would continue to be so up to any quantity " likely to be required within a reasonable lapse of time.

" That the scheme, if ever brought before Parliament, would probably be strongly " opposed by interests connected with the river *Severn.*

" That grave doubts may be entertained whether it is desirable that the metropolis " should be dependent on one source of supply so far removed, and which might be " liable to accidental interruption.

" That great anxiety would be felt as to the formation of immense artificial reservoirs " at the head of the *Severn* valley."

The quality of the waters from the sources of the *Severn* may be judged of from the analytical table at page 35. Though somewhat peaty, they are excellent mountain waters, soft, and, if the more peaty streams be excluded, well adapted for all domestic purposes. As it is not, in our opinion, necessary to go outside the *Thames* basin for an abundant supply of excellent water to the metropolis, we shall not discuss this scheme in detail; but we may state that we entirely concur in the opinions above quoted of the Royal Commissioners as to the feasibility of the scheme. A more elaborate criticism of these waters will be found at page 37.

The scheme of Messrs. Hemans and Hassard.—This scheme was proposed to supply not only all the water required by the metropolis, but, where necessary, the populous and thriving towns of Lancashire, of the Potteries and of the Midland Counties. The sources of supply were the lakes of Ullswater, Haweswater and Thirlmere, in Cumberland. The descriptive particulars of the project are as follows:—

"The districts from which water is proposed to be taken, with two small exceptions, lie on the northern slopes of the range of hills towering over Grasmere, Windermere, and Kendal, and draining into the rivers *Lowther* and *Greta*, and into the lakes of Haweswater, Ullswater, and Thirlmere.

"On the eastern side of the collecting ground the works would commence on the river *Lowther* at Cooper's Green, in Sleddale, by an intercepting conduit, passing from thence round the hills to Swindale, where the first auxiliary reservoir would be constructed, and on to Haweswater, the surface of which would be raised 42 feet, or to 736 feet above the Ordnance datum.

"From the north end of Haweswater another intercepting conduit would be constructed, passing round the eastern slopes of Bampton Common, and conveying to that lake the waters of the *Hows Beck, Gill Beck*, and *Heltondale Beck* streams.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

"A third conduit or watercourse would be constructed from the river *Lowther*, commencing at a point about 1½ miles below the village of Askham, passing round the hill to the west of Clifton, along the eastern slope of the valley of the river *Eamont*, and terminating at the north end of Ullswater, into which lake and into the river *Eamont* it would deliver at Pooley Bridge.

"These three conduits would intercept all the waters of the river *Lowther* and its tributaries above Clifton, and conduct them into the Swindale auxiliary reservoir, and into the Haweswater and Ullswater lakes. From the north-western end of Ullswater a conduit would be constructed to Dacre Bridge, which would intercept and conduct into it the waters of the *Dacre Beck* and its tributaries.

"Thirlmere would be raised 64 feet, or to 597 feet above the Ordnance datum, and from its northern extremity conduits or catchwater drains would be constructed in easterly and westerly directions; the first named would pass round the northern slopes of Matterdale Common, and intercept the waters of the *Mosedale Beck*, *Trout Beck*, and *Barrow Beck* streams, and complete a zone of intercepting conduit and watercourse between the northern extremities of Ullswater and Thirlmere lakes.

'The other conduit or catchwater drain would pass round Bleaberry Fell and along the edge of the table-land east of Watendlath, and extending up to the Blea Tarn would intercept all the upper waters of the Watendlath and Coldbarrow Fells."

"By constructing a tunnel from the south end of Thirlmere under Dunmail Raise Pass, and some short intercepting conduits from its southern extremity, the waters of about six square miles of a very wet district on the southern face of the hills may be conducted to and impounded in that lake.

"When Thirlmere is full, or the streams in flood, the waters may be passed into a reservoir to be constructed on St. John's Beck immediately below that lake, where they would be impounded, and given out as compensation to the millowners on the river *Greta* at and above Keswick; when both are full the surplus waters may be passed into Ullswater, which with the auxiliary reservoirs to be constructed in Martindale would, in conjunction with Thirlmere, be used for towns' supply only.

"The waters of the river *Lowther*, although of admirable quality, are the least desirable in the scale of excellence, and it is proposed to use them mostly for compensation, passing them in the first instance down the river *Lowther* itself to a point 1½ miles below Askham, from whence they would be conveyed by a new channel to Pooley Bridge, and there delivered into the river *Eamont*.

"The water supplied to London and the intervening towns would be taken almost entirely from Ullswater and Thirlmere lakes, and would be of extraordinary purity and excellence, being under two degrees of hardness, and containing per imperial gallon not more than about four grains of total impurity, of which scarcely more than half a grain would be organic matter.

"Haweswater and Thirlmere are lonely and unfrequented lakes, occupying deep valleys, embosomed in mountains, and afford admirable sites for the construction, at comparatively trifling expense, of immense reservoirs, to which additional supplies of water can with great facility be conducted.

"The particulars of the reservoirs would be as follows:—

Name.	Area of collecting ground in square miles.	Area of reservoir in acres.	Contents in cubic feet.		Total Storage.
			For supply to Towns.	For Compensation.	
Swindale - - -	38	166	—	187,000,000	187,000,000
Haweswater - - -		683	235,200,000	961,100,000	1,196,300,000
Martindale - - -	95	255	336,000,000	—	336,000,000
Ullswater - - -		2,300	1,742,400,000	—	1,742,400,000
Thirlmere - - -	44*	875	1,721,977,600	—	1,721,977,600
St. John's Beck Reservoir -		360	—	380,000,000	380,000,000
	177	4,639	4,035,577,600	1,528,100,000	5,563,677,600

* If thought desirable, the waters from a further area of about eight square miles draining into the *Airy Beck* and *Dacre Beck*, and now flowing into Ullswater, can be easily diverted and conveyed to Thirlmere.

"equal to 120 days' supply at 250,000,000 gallons per day, and to 157 days supply at 200,000,000 gallons per day—after giving credit for the average minimum summer yield, which will not be less than 40,000,000 gallons per day—and to 120 days compensation at 450,000 gallons per square mile of drainage area; this will more than suffice in a district of such constant rain.

"There would not be any necessity, in the first instance, for constructing the auxiliary reservoirs in Swindale and Martindale, as until the towns' supply exceeded 200,000,000 gallons per day, Thirlmere and Ullswater would contain sufficient storage, and would be able, after giving credit for the summer yield, to work up to 135 days' supply, whilst compensation water would be given out from Haweswater and from *St. John's Beck* Reservoirs; when the demand exceeds 200,000,00, gallons per day these auxiliary reservoirs may be constructed, and, if necessary, others in addition, as many sites are available; should the demand eventually exceed 250,000,000 gallons per day, a further area of 53 square miles of collecting ground may be obtained on the southern slopes of the range of hills above Ambleside and Kendal, by constructing reservoirs in the valleys traversed by the

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Trout Beck, the *Kent*, the *Sprint*, and the *Bannisdale Beck* streams, and an additional quantity of about 75,000,000 or 80,000,000 gallons daily may easily be obtained from these sources of supply.

" It must be borne in mind also that Mr. Marshall's observations relate to the rainfall at Kendal, which in many cases is not more than one half of that in the mountainous districts above, where there is often a considerable amount of rain, whilst it is fine weather in the low country adjoining.

" The water from Thirlmere would be drawn off at its northern extremity, and conveyed to Ullswater by conduit and tunnel; the tunnel would be eight miles in length, but shafts can be put down over the entire distance, and in such a case it is obvious that there would be no greater difficulty in constructing a long tunnel than a short one; it is simply a question of greater length and of additional shafts.

" From Ullswater the supply would be drawn off from the south end of the lake at Patterdale, and from thence carried by tunnel under Kirkstone Pass.

" This tunnel would be the only work of unusual magnitude connected with the project; it would be 7¼ miles in length, but of this 5½ miles would be ordinary and rather shallow tunnel, and would therefore present no difficulty; the central portion immediately under Kirkstone Pass would be 1¾ miles in length between the shafts, and would, at the rate of progress which has been effected at the Mont Cenis tunnel, occupy in its construction about three years after the shafts were sunk.

" No doubt, with the rock-boring machines of the present day, it might easily be completed in that or a less period of time.

" From the south end of the tunnel the water would be conveyed to London by conduit, tunnel, and iron pipes; the aqueduct would pass by Ambleside and Kendal, and down the eastern side of Lancashire, avoiding the Wigan coal field, to the east of Manchester and of the Potteries district, and to the east of the Staffordshire coal-field and of Birmingham, and onwards towards London, following a route nearly parallel with that of the London and North-western Railway, and would terminate in a large regulating reservoir to be constructed to the north of Harrow, at a distance of about 12 miles from Cumberland Gate, Hyde Park.

" The project may in fact be briefly described as an aqueduct, or arterial conduit, deriving its supply from the great rainfall and natural reservoirs of the lake country, passing through the heart of England, and capable of affording *in transitû* a practically unlimited quantity of the purest possible water to the vast manufacturing districts and population on the line of its route, as well as to the metropolis itself."

The estimated mean annual rainfall in the district was stated to be 80 inches, and the cost of the project to bring to London a daily supply of 250,000,000 gallons was estimated at 12,200,000*l*.

On this scheme the Royal Commission on Water Supply make the following remarks:—

" This plan has so many points of resemblance to that of Mr. Bateman, that many of " the remarks on the Welsh project will be applicable to this also.

" The plan is practicable, and has the advantage of the existence of the natural lakes " at a high level, but the estimates of cost are more uncertain than in the former case, " on account of the less detail in which the promoters have prepared their plans, the " greater length of the conduit (about 90 miles longer than Mr. Bateman's), and the " greater uncertainty as to its exact route and nature.

" The quantity of water obtainable is abundant, as the rainfall, whatever may be its " exact amount, is admitted on all hands to be very large.

" There would probably be less formidable opposition to this scheme than to Mr. " Bateman's, on account of the less magnitude and importance of the rivers flowing " from the district. But the objections from the possible stoppage of the flow in the " conduit would be increased in proportion to its greater length."

With these remarks we entirely concur. The scheme would, without doubt, yield a very large supply of soft and otherwise excellent water for domestic and manufacturing purposes, and the transference of water to London from such distant regions as the lakes of Cumberland according to this project, or the sources of the *Severn* in Mr. Bateman's plan, could not reasonably be objected to, if really necessary for the health and comfort of the 4,000,000 people who are aggregated in the metropolis and its suburbs. It is because, after an elaborate investigation of the resources of the *Thames* basin itself, we feel convinced of the ample sufficiency of these resources, that we cannot recommend recourse being had to either of those schemes. It is, however, far otherwise when we consider them in relation to their possible future application to the supply of the still vaster aggregate population in the great manufacturing counties of Lancashire, Yorkshire, and Staffordshire (6,114,176), where the lack of water, especially for manufacturing purposes, is already beginning to be experienced. If the present

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

gross pollution of the rivers in those counties be allowed to continue unchecked by legislative enactment, it will be absolutely necessary to the further development of the staple manufactures of the districts, that the heavy cost of these or similar schemes, should be encountered.

Abundance of wholesome water in the Thames basin.—The gaugings of the *Thames* at Long Ditton (*see* Appendix No. 9) and of the *Lee* at Feilde's weir show conclusively, in our opinion, that, even leaving out of consideration altogether the large areas of the *Thames* catchment which do not drain to those points, there is an ample supply of water for the metropolis and its suburbs for many years to come; but, as we have already recorded (page 283), the whole of this water is irremediably fouled by most disgusting impurities, and rendered quite unfit for human consumption, not only by the time it reaches the present intakes of the metropolitan water companies, but even immediately below the very sources of the rivers. Of the very numerous affluents of the *Thames* there are only three, the *Coln*, the *Ampney Brook*, and the stream from Ewen and Thames Head springs which are fit for domestic purposes when they join the main stream. It is obvious that, even with the most efficient river conservancy imaginable, aided by the best efforts of the legislature, the *Thames* must always receive so much pollution, as to render its use for the supply of the metropolis highly objectionable. No preventive measures can hinder the washings of highly manured land, the droppings of cattle, the imperfectly purified sewage of towns and villages, and the partially cleansed discharges from paper mills, skinneries, and tan yards, from mingling with the streams in enormous volumes. Such matters, though not obviously offensive to the senses (when the highest practical stage of purification has been reached), are still, from a sanitary point of view, of a very dangerous character (*see* Appendix No. 4, p. 463). But even if this were not so, and if fatal results had never been known to follow the domestic use of such water, the refined feeling which separates the civilized man from the savage, and which excites loathing at the bare idea of organic matter which has formed part of a human body, being supplied for human consumption, ought here to make itself felt and to secure the rejection of such a beverage.

It is hopeless to try to prevent the admixture of disgusting matters with the *Thames* or any other river running through a cultivated and populous district. Such a river may, by the adoption of the remedies for pollution which we have described in our five preceding reports, be rescued from unsightly and unsavoury foulness, but it can never be rendered a safe source of water for domestic use. Nevertheless, although the discharge of undrinkable water into the *Thames* and its affluents cannot be practicably intercepted, the pure spring water by which the river is almost wholly fed in dry weather, can be, to a certain extent, diverted for domestic use before it is allowed to mingle with the body of polluted water in the river or affluents. By thus preserving the required volume of potable water from admixture with the unpotable water of the streams,—instead of abstracting it after pollution and then vainly attempting to purify it by artificial filtration,—a thoroughly wholesome, brilliant, and palatable water would be obtained and an ideal and impracticable river conservancy dispensed with.

In the whole course of our experience, we have found no catchment basin so rich in springs of the finest drinking water as that of the *Thames*. We have been convinced, by the most conclusive evidence, that the Chalk, Oolite, Lower Greensand, and New Red Sandstone are the best water bearing strata in the kingdom; their water-holding capacity is very great, and the unsurpassed quality of the water which three of them yield will be seen by consulting the following five analytical tables. Of these strata, the three first-named make up a very large proportion of the collecting ground of the *Thames* basin, and even where they dip below the London Clay or other impervious formations, they are still charged with water and easily accessible to the boring rod.

We are of opinion that the whole of the metropolis and its suburbs should be supplied exclusively with the spring and deep well water of the *Thames* basin.

We base this opinion firstly upon the excellency of the quality of the water, and secondly upon its abundance within a moderate distance of the metropolis.

The quality of the spring and deep well water of the Thames basin.—We have spent much labour in the inspection of numerous springs and deep wells in the *Thames* basin, submitting to chemical analysis samples of all that we visited. There are, however, numbers of deep wells, and doubtless, many springs which did not come under our cognizance; but the very uniform quality of the water of those which we have examined, at so many and widely distant points, warrants us in concluding that they fairly represent the general yield of the respective strata from which they were obtained.

The Metropolitan water supply.

The following table contains the results of our analyses of spring and deep well water from the Oolitic formations in the *Thames* basin:—

COMPOSITION OF UNPOLLUTED OOLITIC WATERS FROM THE THAMES BASIN.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Remarks.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	
Thames-Head well, near Cirencester, May 2, 1873.	10·5	27·44	**·037**	**·018**	0	·316	·334	2,840	1·35	18·0	5·0	23·0	Clear and palatable.
Bourton-on-the-Water, springs above, May 31, 1873.	10·0	26·70	**·023**	**·011**	0	·249	·260	2,170	1·15	17·8	4·9	22·7	Do.
Bourton-on-the-Water, Eyeford spring, near, Aug. 2, 1873.	10·0	26·86	**·028**	**·004**	·001	·290	·295	2,590	1·25	18·3	5·6	23·9	Do.
Cirencester, Cerney springs, near, Nov. 4, 1870.	10·8	33·86	**·052**	**·016**	·001	·282	·299	2,510	1·30	22·8	3·9	26·7	Do.
Cirencester, Cowley springs, near, May 2, 1873,	10·0	24·32	**·027**	**·005**	·001	·232	·238	2,010	1·10	14·5	4·9	19·4	Do.
Cirencester, the Seven springs, near, May 2, 1873.	10·2	22·60	**·012**	**·009**	·001	·510	·520	4,790	1·10	11·3	5·6	16·9	Do.
Cirencester, Syreford spring near May 2, 1873.	10·0	22·34	**·029**	**·008**	0	·222	·230	1,900	1·20	13·8	5·1	18·9	Do.
Cirencester, Winson spring, near, May 2, 1873.	10·0	27·54	**·029**	**·011**	0	·427	·438	3,950	1·15	17·1	4·4	21·5	Do.
Cirencester, Winson, another spring in pond, May 2, 1873.	12·5	26·24	**·059**	**·022**	0	·164	·186	1,320	1·20	17·4	4·4	21·8	Do.
Cirencester, Ablington spring, near, May 2, 1873.	12·0	29·04	**·036**	**·008**	·001	·089	·098	580	1·20	16·7	5·4	22·1	Do.
Cirencester, Bibury spring, near, May 2, 1873.	10·5	29·16	**·038**	**·007**	0	·161	·168	1,290	1·15	17·9	5·7	23·6	Do.
Cirencester, Ampney Park springs, near, May 2, 1873.	10·5	26·70	**·048**	**·015**	·001	·361	·377	3,300	1·20	15·8	5·7	21·5	Do.
Cirencester, the Bitnell springs at Ewen, May 2, 1873.	10·1	28·14	**·025**	**·007**	0	·312	·319	2,800	1·40	19·3	4·0	23·3	Do.
Daventry, source of the *Cherwell*, June 7, 1873.	9·0	27·30	**·023**	**·009**	0	·434	·443	4,020	1·70	16·7	5·7	22·4	Do.
Donnington Mill, one source of the *Windrush*, May 30, 1873.	10·0	27·48	**·039**	**·017**	0	·347	·364	3,150	1·40	17·3	6·6	23·9	Slightly turbid; palatable.
North Leach, Seven springs above, May 31, 1873.	9·5	29·82	**·040**	**·015**	0	·489	·504	4,570	1·30	20·6	5·1	25·7	Clear and palatable.
Seizincote, Pope's Hole, source of the *Evenlode*, May 30, 1873.	9·9	25·82	**·047**	**·010**	·001	·690	·701	6,590	2·20	12·0	7·1	19·1	Do.
Starveall, spring above Coppice, May 31, 1873.	9·5	28·76	**·034**	**·012**	0	·590	·602	5,580	1·30	16·9	7·6	24·5	Do.
Stow-on-the-Wold, spring at roadside, May 30, 1873.	9·9	24·44	**·037**	**·010**	0	·753	·763	7,210	1·40	14·3	6·3	20·6	Do.
Stow-on-the-Wold, spring flowing into tank, May 30, 1873.	9·3	28·32	**·033**	**·021**	0	1·034	1·055	**10,020**	1·40	13·8	8·0	21·8	Do.
Taddington, one source of the *Windrush*, May 30, 1873.	11·8	31·20	**·047**	**·014**	0	0	·014	0	1·10	25·7	4·3	30·0	Contains traces of iron.
Average - - -	10·3	27·34	**·035**	**·012**	0	·379	·391	3,485	1·31	17·0	5·5	22·5	

These analytical results prove that all these specimens of Oolitic water from deep wells and springs in the *Thames* basin contain the merest traces of organic matter, and that only in one instance is the evidence of previous animal contamination sufficient to cast any suspicion upon the water. This sample was collected at Stow-on-the-Wold, from a spring outside the town and at a lower level: it doubtless receives some of its water from the Oolitic rock beneath the town. As the water of this spring contains but slight traces of organic matter, and as the evidence of previous contamination is only just in excess of that which may be reasonably considered harmless, this water,—the worst sample from Oolitic springs which we have found in the basin—may, at present, be used for domestic purposes without appreciable risk.

Most of the Oolitic waters are somewhat harder than the present metropolitan river supply, but this does not interfere with their wholesomeness, although, as is the case with that supply, it unfits them for washing and cleansing purposes. They are all, however, admirably adapted for the softening process by lime, which we have fully described at page 205. After being submitted to this simple method of treatment, the Oolitic waters mentioned in the foregoing analytical table would, whilst

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

losing nothing of their palatability and wholesomeness, undergo the following reduction in hardness:—

HARDNESS OF OOLITIC WATER BEFORE AND AFTER SOFTENING.

—	Hardness before Softening.	Hardness after Softening.
Thames Head well	23·0	5·0
Springs above Bourton-on-the-Water	22·7	4·9
Eyeford spring, near Bourton-on-the-Water	23·9	5·6
Cerney springs, near Cirencester	26·7	3·9
Cowley " "	19·4	4·9
The Seven springs "	16·9	5·6
Syreford spring "	18·9	5·1
Winson springs "	21·7	4·4
Ablington spring "	22·1	5·4
Bibury spring "	23·6	5·7
Ampney Park springs "	21·5	5·7
Bitnell springs, at Ewen, near Cirencester	23·3	4·0
Source of the *Cherwell* at Daventry	22·4	5·7
One of the sources of the *Windrush* at Donnington Mill	23·9	6·6
The seven springs above Northleach	25·7	5·1
Pope's Hole spring at Seizincote	19·1	7·1
Spring above coppice at Starveall	24·5	7·6
Spring at roadside East of Stow-on-the-Wold	20·6	6·3
Spring flowing into tank North of Stow-on-the-Wold	21·8	8·0
One of the sources of the *Windrush* at Taddington	30·0	4·3
Average	22·5	5·5

It will be seen from the above comparison that the addition of lime to the hardest of the Oolitic waters renders it tolerably soft and well adapted for washing. This treatment with lime reduces the hardness of these waters, on the average, to about one-fourth of its original amount.

The following table contains the analytical results yielded by deep well and spring waters from the Lower Greensand in the *Thames* basin.

COMPOSITION OF UNPOLLUTED LOWER GREENSAND WATERS FROM THE THAMES BASIN.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
Farnham, spring in Mother Ludlam's Cave at Moor Park, 1868.	—	4·55	·030	·010	·001	·034	·045	30	—	0	·7	·7	Clear and palatable.
Hindhead, Surrey, spring on north side of Gibbet Hill, March 7, 1873.	9·2	10·02	·032	·004	0	·196	·200	1,640	3·10	0	3·2	3·2	Clear and palatable.
Sevenoaks, spring in railway tunnel, Feb. 21, 1873.	9·0	34·36	·015	·002	0	·416	·418	3,840	2·10	13·7	5·7	19·4	Slightly turbid; palatable.
Witley, Surrey, spring at Vicarage, Witley Park, March 7, 1873.	11·1	8·80	·031	·008	·001	·635	·644	6,040	2·20	0	3·5	3·5	Clear and palatable.
Redhill, overflowing well at railway station, Feb. 14, 1873.	11·0	33·52	·054	·006	·001	0	·007	0	2·40	20·6	5·1	25·7	Slightly turbid; palatable.
Average	10·1	18·25	·032	·006	·001	·256	·263	2,310	2·45	6·9	3·6	10·5	

These waters like those from the Oolites are of most excellent quality. They contain but the merest traces of organic matter, are uniformly colourless, clear, sparkling, brilliant and perfectly wholesome. The great variation in hardness which they exhibit is doubtless owing to the origin of the water entering the Lower Greensand; if the stratum obtains its supply from rain, the water remains soft; but if, owing to want of continuity in the superior stratum of Gault separating the Greensand from the Chalk, the water from the latter stratum percolates into the former, it of course retains the hardness which it had acquired in the cretaceous rock. Thus, whilst the Greensand supplying the springs at Moorpark, Hindhead, and Witley in Surrey receives the soft water, which it furnishes, direct from the clouds, the water issuing from the spring in the railway tunnel at Sevenoaks has been, to a considerable extent, supplied by the Chalk. The water which overflows from the well at the Redhill railway station, although issuing from the Greensand, has a hardness seven times as great as true Greensand water. It doubtless permeates the Chalk before reaching the stratum from which it issues. The excessive

Part IV. Descriptive.

The Metropolitan water supply.

hardness of some of the Greensand waters, being thus due to Chalk, can of course be removed by means of lime which so effectually softens Chalk waters. On being submitted to this process the two hard waters just mentioned become softened as follows :—

Hardness of Greensand Waters before and after Softening.

——	Hardness before Softening.	Hardness after Softening.
Spring in railway tunnel at Sevenoaks - - -	19·4	5·7
Well at Redhill railway station - - -	25·7	5·1

The following tables contain the analytical results of our investigation of the spring and deep well waters from the Chalk in the *Thames* basin, together with certain analytical numbers extracted from the Appendix to the Report of the Royal Commission on Water Supply (1869). The latter are marked with an asterisk in the column headed "Description."

Composition of Deep Well Waters from the Chalk of the London Basin.

Results of Analysis expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.								Hardness.			Remarks.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
Amwell, New River Co.'s well at, May 5, 1868.*	11°·0	31·88	·076	·009	0	·406	·415	3,740	1·39	16·5	5·9	22·4	Clear and palatable.
Well at Belvidere, Feb. 11, 1873 -	11·5	40·52	·100	·037	0	2·079	2·116	20,470	3·35	10·8	11·6	22·4	Do.
Well at High Elms, Bromley, Oct. 30, 1870.	—	30·48	·041	·026	0	·440	·466	4,080	1·18	21·3	3·5	24·8	Do.
Bushey Station, well at, Nov. 11, 1870	10·0	36·08	·034	·018	0	·174	·192	1,420	1·90	19·7	6·0	25·7	Do.
Bushey, Herts, borehole in Bushey Meadows, Nov. 11, 1870.	10·6	33·88	·027	·006	·006	·314	·325	2,870	1·35	23·8	3·8	27·6	Do.
Ditto, ditto, March 5, 1873 - -	—	33·16	·071	·026	·029	·343	·393	3,350	1·40	23·2	4·3	27·5	Do.
Mr. Marjoribank's well near Bushey, March 5, 1873.	—	38·20	·038	·017	·003	·695	·624	5,750	1·80	21·9	6·9	28·8	Turbid; palatable.
Caterham Waterworks well, May 12, 1868.*	11·0	31·08	·020	·006	0	·027	·033	0	1·35	14·4	9·0	23·4	Clear and palatable.
Caterham Waterworks well, Feb. 14, 1873.	11·2	27·68	·028	·009	0	·021	·030	0	1·55	15·2	6·0	21·2	Do.
Chatham, well at waterworks, March 8, 1871.	—	33·84	·049	·006	·001	·365	·372	3,340	2·40	22·9	4·3	27·2	Do.
Crayford, Kent Water Co.'s well, Feb. 8, 1873.	11·4	35·20	·031	·005	0	·505	·510	4,730	2·25	20·3	5·4	25·7	Do.
Croydon, well at waterworks, May 11, 1868.*	13·5	32·00	·040	·007	·001	·551	·559	5,200	—	12·9	9·1	22·0	Do.
Deptford, new well at Kent Water Co.'s works, Feb. 8, 1873.	12·2	42·94	·048	·005	·001	·545	·551	5,140	2·50	20·1	9·6	29·7	Do.
Deptford, Bath well at Kent Water Co.'s works, Feb. 8, 1873.	12·2	35·44	·044	·007	0	·363	·370	3,310	2·30	18·6	8·0	26·6	Do
Deptford, Garden well at Kent Water Co.'s works, Feb. 8, 1873.	12·2	40·96	·056	·011	0	·354	·365	3,220	2·40	20·2	8·6	28·8	Do.
Grays, well of South Essex Water Co., Feb. 15, 1873.	8·8	41·74	·058	·018	0	·908	·926	8,760	4·70	18·6	7·4	26·0	Do.
Grays, open shaft at South Essex Water Co.'s works, Feb. 15, 1873.	10·8	44·80	·064	·017	·001	·929	·947	8,980	5·05	20·7	8·7	29·4	Do.
Great Bookham, H. D. Barclay's well, Jan. 23, 1872.	—	38·40	·019	012	·002	·900	·914	8,700	2·45	24·7	5·3	30·0	Clear and palatable.
Great Bookham, Mr. Wood's well, Jan. 23, 1872.	—	35·90	·094	·037	·003	·698	·737	6,680	1·75	19·7	6·6	26·3	Very turbid; palatable.
Hertford, well at Waterworks, Jan. 24, 1873.	9·4	37·06	·026	·008	0	·497	·505	4,650	1·90	21·4	4·6	26·0	Clean and palatable.
Highmore well, Oxfordshire, Nov. 19, 1870.	10·0	46·80	·061	·031	·001	1·372	1·404	13,410	3·25	31·4	5·7	37·1	Turbid; palatable.
Nettlebed well, Oxfordshire, Nov. 19, 1870.	10·1	48·10	·053	·038	·001	1·167	1·206	11,360	2·92	31·1	6·7	37·8	Clear and palatable.
Plumstead, Kent Water Co.'s well, Feb. 11, 1873.	12·0	50·80	·081	·011	0	·338	·349	3,060	4·60	16·8	13·8	30·6	Do.
Gallows Tree well, near Reading, Nov. 19, 1870.	9·5	23·30	·051	·017	·001	·105	·123	740	1·00	16·4	2·7	19·1	Slightly turbid; palatable.
Kidmore End well, near Reading, Nov. 19, 1870.	8·3	66·34	·071	·040	·002	2·277	2·319	22,470	4·56	38·6	11·4	50·0	Very turbid; palatable.
Rickmansworth, well in Lord Ebury's Park, Feb. 18, 1871.	—	36·12	·033	·014	0	Trace.	·014	0	1·68	27·3	4·6	31·9	Clear and palatable.
Shortlands, Kent Water Co.'s well, Feb. 8, 1873.	11·5	30·64	·021	·007	0	·354	·361	3,220	1·60	19·3	4·6	23·9	Turbid from workmen in an adjoining well; palatable.
Sittingborne, well at Waterworks, April 22, 1873.	11·7	34·00	·131	·010	·002	·343	·355	3,130	2·10	23·1	4·4	27·5	Clear and palatable
Stoke Row well, near Nettlebed, Nov. 19, 1870.	9·4	29·20	·052	·024	0	·059	·083	270	1·18	21·9	3·5	25·4	Do.
Streatley, Bower's Farm well, Nov. 19, 1870.	9·4	62·64	·108	·064	0	1·129	1·193	10,970	11·10	33·3	11·0	44·3	Do.
Streatley, Hill Cottage well, Nov. 19, 1870.	9·4	30·38	·044	·030	0	·490	·520	4,580	1·20	20·8	3·4	24·2	Very turbid; palatable.
Tring, well at Chiltern Water Co.'s Works, Nov. 6, 1868.	9·2	28·60	·036	·010	·001	·094	·105	630	1·39	23·0	3·3	26·3	Clear and palatable.
Watford, well at Waterworks, Nov. 11, 1870.	11·2	38·20	·030	·015	·001	·752	·768	7,210	1·60	24·2	4·6	28·8	Do.
Watford, well at Waterworks, March 5, 1873.	—	37·26	·042	·011	·001	·774	·786	7,430	1·80	22·2	6·0	28·2	Do.
Watford, Sedgwick's Brewery well, Nov. 11, 1870.	11·1	35·16	0	0	0	·635	·635	6,030	1·50	21·9	6·0	27·9	Do.
Woodgreen well, Nov. 19, 1870 - -	10·0	48·28	·056	·046	·006	·822	·873	7,950	4·80	28·8	6·6	35·4	Turbid; palatable.
Wouldham, well at Cement Co.'s Works, Dec. 26, 1868.	—	30·00	·079	·051	·002	·834	·887	8,040	2·23	14·9	7·4	22·3	—
Wouldham, new well in chalk pit, April 1869.	—	25·98	·067	·024	·001	·605	·630	5,740	2·10	13·9	6·4	20·3	—
Average - - -	10·7	37·45	·052	·019	·002	·610	·631	5,806	2·53	21·5	6·5	28·0	

PART IV.
DESCRIPTIVE.

The Metropolitan water supply.

COMPOSITION OF SPRING WATERS FROM THE CHALK OF THE LONDON BASIN.

RESULTS of ANALYSIS expressed in PARTS per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	
Hughenden, spring at, October 9, 1873.	29·90	·024	·013	0	·274	·287	2,420	1·40	20·9	3·6	24·5	Clear and palatable.
Lambourne Park, spring in, May 5, 1873.	27·12	·051	·009	0	·431	·440	3,990	1·10	15·8	5·1	20·9	"
Letcombe Basset, spring at, May 5, 1873.	27·36	·047	·013	·001	·298	·312	2,670	1·05	15·2	5·1	20·3	"
Nine Waters Lane, spring at, source of the *Loddon*, October 11, 1873.	32·06	·052	·011	·001	·426	·438	3,950	1·50	22·0	4·9	26·9	"
Sevenoaks, Mr. Spottiswoode's spring, August 8, 1873.	34·40	·053	·009	0	·277	·286	2,450	1·30	25·3	6·9	32·2	Slightly turbid. Palatable.
Watford, Otter's pool spring, April 8, 1868.*	32·36	·026	·012	·002	·422	·436	3,920	1·26	21·0	3·7	24·7	Clear and palatable.
Wendover, the source of the *Thame* at Well Head, August 6, 1873.	28·10	·034	·010	0	·369	·379	3,370	1·30	19·4	5·7	25·1	Slightly turbid. Palatable.
West Wycombe, Long Meadow spring, October 9, 1873.	29·86	·038	·005	0	·336	·341	3,040	1·40	23·3	4·6	27·9	Clear and palatable
Average - -	30·14	·041	·010	·001	·354	·365	3,226	1·29	20·4	4·9	25·3	

Like the Oolites and Greensand, the Chalk yields to springs or deep wells, water which contains but the merest traces of organic matter (organic carbon and organic nitrogen), and it is only when the source is in close proximity to human habitations, cesspools, and sewers, that the evidence of previous sewage or animal contamination becomes sufficiently strong to establish a suspicion against the water. Thus in the above tables, out of 46 samples, there are only 5 which fall under this suspicion. These are a deep well at Belvidere which is situated in the midst of highly manured garden ground, and three deep wells situated in the villages of Highmore, Nettlebed, and Kidmore End, Oxfordshire. These wells are surrounded by privies, cesspools, and gardens; they are not properly protected from the admission of surface water, and they must be regarded as warnings against the sinking of wells in such positions without proper protection, rather than as examples of good and wholesome wells. We have the same remark to make respecting the remaining suspicious well which is sunk at Bower's Farm near Streatley, and doubtless receives soakage from a neighbouring middenstead and horsepond. Nevertheless, even these suspicious wells were not polluted when we visited them. The thickness of the stratum through which the polluting matter had to soak was sufficient to oxidize and destroy nearly every trace of the organic matter which it originally contained; there is however no guarantee that this will always be the case, or that when the organic polluting matter becomes infected, zymotic germs shall not gain access to the water. Hence the grounds of suspicion.

The foregoing samples from the Chalk are all derived from sources where the water-bearing stratum is free from a covering of London Clay. As soon as the Chalk in the *Thames* basin dips beneath the Lower Tertiary Sands and London Clay, the quality of the water it yields undergoes a remarkable alteration. The total solid impurity augments largely; the nitrogen as nitrates, either becomes very small in quantity, or disappears altogether; whilst a considerable proportion of ammonia makes its appearance. The hardness is much mitigated, indeed it is sometimes almost obliterated, owing to the replacement of bicarbonate of lime by bicarbonate of soda. These waters are also distinguished by containing a large proportion of common salt. When unpolluted, they are, with few exceptions, good wholesome waters, clear, transparent and palatable, and they hold in solution only a very small proportion of organic matter.

PART IV. DESCRIPTIVE. — The Metropolitan water supply.

The following table contains the results of our analyses of several deep well waters of this class.

COMPOSITION OF WATER FROM CHALK AND LOWER TERTIARY SANDS UNDER THE LONDON CLAY.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
Richmond, Artesian well at, Oct. 16, 1874.	—	40.92	·078	·033	.115	0	·128	630	4·92	6·0	2·3	8·3	Clear and palatable.
New Wimbledon, bore hole on common, July 7, 1868.	12·5	33·38	·063	·038	·004	·047	·088	182	2·38	6·3	7·0	13·3	Clear and palatable.
Epping, Artesian well, July 10, 1872.	—	64·88	·088	·005	·050	·084	·130	930	6·20	0	·9	·9	Slightly turbid. Palatable.
Harrow, Middlesex, well at waterworks, Oct. 22, 1868.	—	104·42	·063	·067	·001	·012	·080	0	16·58	29·5	9·0	48·5	Clear and palatable.
Ditto, ditto, Nov. 11, 1870	10·6	100·88	·059	·030	·118	0	·127	650	16·30	19·0	25·4	44·4	Do.
Ditto, ditto, March 5, 1873	—	98·08	·078	·053	0	0	·053	0	16·00	15·4	25·4	40·8	Do.
London, well at Trafalgar Square, May 6, 1869.	—	83·40	·150	·012	·070	0	·070	260	16·55	3·0	2·9	5·9	
Ditto, well at Royal Mint, May 31, 1869.	—	83·96	·195	·025	·060	0	·074	170	13·92	7·7	9·7	17·4	—
Ditto, well at Barclay's Brewery, July 9, 1869.	12·1	73·30	·085	·008	·060	0	·057	170	14·08	4·5	2·8	7·3	—
Ditto, new well at Barclay's Brewery, July 14, 1869.	—	71·56	·055	·010	·075	·035	·107	650	12·90	4·0	3·9	7·9	—
Ditto, well at Albert Hall, May 1872.	—	61·68	·168	·042	·009	·066	·115	410	15·10	3·4	2·2	5·6	Slightly turbid. Palatable.
Ditto, St. Pancras well, Midland Railway, July 31, 1873.	—	65·40	·063	·021	·060	0	·070	170	11·20	3·0	2·3	5·3	Clear and palatable.
Average	11·7	73·49	·095	·028	·052	·020	·091	352	12·18	8·5	8·6	17·1	

The sample from an artesian well at Epping, is the most remarkable of the series. It is a most excellent potable water, and the softening action, which goes on under the London Clay, has here proceeded nearly to the utmost limit; the water from this well being as soft as that from Loch Katrine, and containing no less than $35\frac{1}{2}$ parts of carbonate of soda in 100,000 parts of water. On the other hand, the water from the deep well from which Harrow is supplied is exceedingly hard. It contains a larger proportion of saline constituents than is desirable in a water used for domestic purposes, but it holds in solution only a small quantity of organic matter. Both the saline matter and the hardness of this water appear to be gradually decreasing, as is seen from the following comparison:—

—	Total solid Impurity.	Total Hardness.
Sample collected Oct. 22, 1868	104·42	48·5
" " Nov. 11, 1870	100·88	44·4
" " March 5, 1873	98·08	40·8

The artesian wells at Trafalgar Square, the Royal Mint, and the Albert Hall are slightly polluted by surface soakage. They contain proportions of organic elements about twice as large as those found in unpolluted Chalk water. The Royal Mint water is also hard, but the others are soft, and therefore well adapted for washing and cleansing. The water from the artesian well at Richmond, from the two wells at Barclay's brewery, and from a well in St. Pancras belonging to the Midland Railway Company are palatable, tolerably soft, and of excellent quality for all purposes. Except at Harrow, where, however, the water is objectionable solely on account of its excessive hardness, these wells appear to yield water of good and tolerably uniform quality, if surface drainage be excluded; but the quantity obtainable from them is not sufficient to warrant the conclusion that the sinking of similar wells would be of much use for the supply of the metropolis. The water bearing strata beneath the London Clay appear to be much more compact than those which have not the superincumbent pressure of this stratum to bear; they are therefore less efficient sources of potable water. Even if we assume that all risk of surface soakage can be avoided in properly constructed artesian wells, we are of opinion that the strata beneath London will not be found to be an available source for any important portion of the metropolitan water supply, although the water, if preserved from surface soakage, would be, in respect of softness, much superior in quality to the ordinary Chalk and Oolitic waters.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

The quantity of the spring and deep well water in the Thames basin.—The basin of the *Thames*, including that of its tributary the *Lee*, is upwards of 5,000 square miles in extent. Of its whole surface rather more than one half, including the Oolitic, Cretaceous, and portions of the Tertiary formations, is covered by a porous soil upon a permeable water-bearing stratum: and the greater portion of this area is cultivated. The remainder, occupied by the Oxford, Kimmeridge, Gault, and London Clays, is covered by a clayey soil upon a stiff impervious subsoil; and the area here is for the most part permanent meadow land and pasture.

The annual rainfall of the district is estimated to average about 28 inches. Upon the clay land, after it has saturated the soil, it collects in surface runnels, streamlets, rivulets, and brooks; and ultimately finds its way, considerably diminished by evaporation, to the central drainage channel of the basin. That which falls upon the more pervious districts, and does not evaporate, sinks for the most part where it alights. It thus accumulates in the rock or sand below, until the water-bearing stratum becomes full, or charged with more than it can hold above the lower level of the nearest river channel. In the latter case, as where the valley of the *Thames* traverses the hilly chalk district between Wallingford and Reading, a large accession to the volume of the river is made by springs in the river bed. In the former case, the porous stratum over-charged with water overflows at the lowest edge of either of the two clay formations, the one below it and the other geologically above it, by which it is enclosed. Springs of water at the junction of the two formations are thus created, which, flowing along the lines of lowest level, unite in the central river-tributary or in the *Thames*.

Of these springs there are innumerable examples all round the edge of the *Thames* basin and at various points within it; as where the water falling on the immense Chalk area within it, and sinking through that porous rock, is thrown out by the Gault Clay on which it rests—and where the rainfall of the Oolitic district is thrown out by the Clay of the Fuller's Earth below it, or escapes over the edge of the Oxford Clay geologically above it.

Confining ourselves to that portion of the *Thames* basin which drains into the river above the intake of the London water companies, we gather the following particulars regarding it from the evidence of Mr. J. Thornhill Harrison, M. Inst. C.E., given before the Royal Commission on Water Supply (1869). Of 3,676 square miles which are included within it as much as two thirds lie upon permeable strata; a comparatively small portion of the London Clay formation draining into the *Thames* above Kingston. One inch of rain over the whole of this area amounts to rather more than 50,000 millions of gallons of water. The average annual rainfall over this portion of the *Thames* basin thus amounts to nearly 1,500,000 millions of gallons. The actual quantity of water, as daily gauged by Mr. John Taylor, M. Inst. C.E., (*see* Appendix No. 9) during 11 years, which passed Long Ditton yearly, does not exceed 500,000 millions of gallons; about 1,000,000 millions of gallons being thus annually lost by evaporation or used in vegetable growth. Two-thirds of the whole rainfall draining seaward by the *Thames* may be thus considered, in the climate and on the soils of the *Thames* basin, to be lost by evaporation; while of the remaining third one-half passes away in floods, and the other half is delivered by means of springs. It is to the latter that we owe the ordinary dry-weather river flow, and this amounts, according to the gaugings at Long Ditton, to about 600 millions of gallons daily.

This in fact is the amount of the ordinary outflow of the great subterranean reservoirs existing, mainly in the Chalk and the Oolitic beds, within the district; the former being a sort of inverted reservoir, as Mr. J. Thornhill Harrison describes it, holding by capillary attraction a greater or less amount of water piled up within its hill masses above the level of the neighbouring rivers; the latter rather to be considered as a reservoir of the ordinary kind, holding in its rock chambers a great storage, which can only gradually escape over the edge of the beds of Clay between which it is confined.

It has been proposed to increase the quantity of the ordinary dry-weather river flow, or (maintaining that) to provide a separate constant supply of pure spring water in addition to it, by forming great artificial reservoirs in the upper clayland districts of the *Thames* basin, in which the winter floods might be collected, and from which they might be discharged at a uniform rate during the dryer months. It is plain that any arrangement would be equally efficient for this purpose by which the quantity of water present in the natural subterranean reservoirs could be artificially brought to a lower level before the occurrence of the autumn and winter floods. These reservoirs would thus be rendered capable of receiving those heavy rainfalls which at present, unable to find storage room below, either run off the saturated surface and constitute the early winter floods or make their way under-ground to the *Thames* and its affluents. By wells sunk in the Oolite, for example, down to the impervious floor on which its waters rest, it would be possible to make the immense natural reservoir within that mass of rock available to an enormous extent for the reception of much of the earlier flood waters upon that district which now run to waste. By pumping from these wells, an artificial discharge could be effected during the autumn months, when the springs begin to fail, in excess of the amount which they ordinarily deliver, so as to reduce the level within the water-bearing stratum, before winter, sufficiently to provide immense storage spaces for the reception of the earlier winter floods which it is desired to save. And a similar increased storage could be equally well provided by pumping from wells sunk in the Chalk, down to the level or below the level of the neighbouring river channels. The present springs would thus be artificially supplemented during the summer and autumn months, and the water supply from that source would be more uniformly distributed throughout the year; a larger space within the porous rock being artificially provided for the storage of the heavy autumn rainfalls now going to increase those lowland or create those upland springs of the wetter months, which at present shrink or disappear in summer.

The volume of water delivered by the existing springs along the edge of the several water-bearing strata within the *Thames* basin is in many instances exceedingly large. There are wonderfully copious springs at the head of the *Windrush*, *Leach*, *Colne*, and *Churn*, in the Oolitic district. There are also abundant springs at the head of the *Thame* and *Wye*, the *Ray* and *Cole* and *Ock*, in the Chalk districts of the *Thames* basin. At the head of the *Windrush* we saw, above Donnington Mill near Stow-on-the-Wold, at Acton Farm above Bourton-on-the-Water, and at Roaring Wells by Eyeford in the same neighbourhood, immense volumes of water rising over a few acres of bottom land, in each instance in quantity sufficient to be at once available for mill power, amounting altogether to at least 25 or 30 millions of gallons daily. These waters unite below Bourton, where the *Windrush* is already a considerable stream, only two or three miles from its sources. At the "Seven Springs" near Northleach at least half a million of gallons of water is discharged daily, forming the source of another tributary of the *Thames*—the *Leach*. At Syreford near Andoversford and at Ablington, Winson, and Bibury below it, there are a series of magnificent springs rising from the same geological formation, which are thus an outlet of the same vast subterranean reservoir. They constitute the head waters of the *Colne* which joins the *Thames* above Lechlade. The Syreford spring varies a good deal in productiveness during the year; it was yielding probably 5,000,000 gallons daily on May 2, 1873, when we saw it. The Winson springs were yielding about 3,000,000 gallons. The Ablington spring was then much smaller. The Bibury spring is a magnificent outburst at one spot of more than 10,000,000 gallons daily. At Ampney Park on the same day there were rising over several acres of pond and marshy ground with no very definite single origin, at least 20,000,000 gallons daily, which, serving immediately for mill power, ultimately joins the *Thames* by the *Marston Brook* below Cricklade. Going further east we enter the water-shed of another tributary, the *Churn*. There are at the so-called Seven Wells, its source, and at various parts in its channel below that point, several millions of gallons of water discharged daily. And at Boxwell, near South Cerney on the other side of Cirencester, another considerable spring exists, yielding one or two millions of gallons daily, which ultimately flows into the same tributary, the *Churn*. The pump at *Thames* head delivers 3,000,000 gallons daily into the *Thames* and *Severn* Canal at a point about three miles south-west of Cirencester; and there is a spring close by, which disappears, however, in the dryer months, which yields a million gallons or more daily during winter into the true *Thames* river channel. At Ewen, near this point, another spring of at least 1,000,000 gallons daily delivers its water into the same river channel.

From the Oolite beds alone on the north side of the *Thames* we have thus a total of at least 70,000,000 gallons delivered daily by only a dozen springs; a quantity moreover which is largely exceeded at the time of their greatest productiveness during the winter and early spring months, and which might no doubt be maintained at this greater rate by pumping during the dryer summer and autumn months; thus lowering the water level of the subterranean reservoir from which it flows, and making storage room for the winter rainfall, so as to make available as pure spring water, that which at present runs to waste from off the surface of the land as a turbid and polluted flood.

Turning now to the southern side of the *Thames* basin we find at various points below the Chalk escarpment which bounds the valley of the White Horse, a number of productive springs of Chalk water thrown out by the Gault Clay; as at Wroughton at the head of the *Ray*, at Chisledon and Liddington at the head of the *Cole*, and above

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

Wantage at the head of the *Ock*. Similar springs exist further along the edge of the same escarpment, where it traverses Oxfordshire and Buckinghamshire, on the northern side of the *Thames* basin. The largest of these is at Wendover, where the *Thame*, a few hundred yards below its source, is already large enough to drive a mill. At Bledlow and Adwell and Ewelme also, there are springs of similar geological origin, the two former flowing into the *Thame*, the last an extremely copious spring yielding probably 3,000,000 gallons daily, flowing directly into the *Thames* above Wallingford.

This enumeration of some of the *Thames* springs has not included those of its larger tributaries, the *Cherwell* and the *Kennet*, nor those of the *Loddon*, *Wey*, and *Mole*, upon its southern bank, and of the *Colne* upon the northern side of the valley, all of which join the river above Kingston. Samples of most of these waters, and of others which we have not named, will be found in the foregoing tables of analyses, wherein the composition of the Chalk, the Greensand, and the Oolitic spring waters of the *Thames* basin is represented.

We have to thank Mr. John Bravender of Cirencester, who has had great experience in the flow of springs and streams in the upper basin of the *Thames*, for the following statement of the flow of several of the springs above enumerated chiefly from gaugings executed by himself in the year 1859. (Appendix No. 5.)

	Daily flow in gallons.
Ewen spring	1,000,000
Boxwell spring	1,000,000
Ampney Crucis spring	12,000,000*
Bibury spring	12,000,000
Ablington spring	2,000,000
Winson spring	1,500,000
Thames Head Well	3,000,000
Total	32,500,000

The same gentleman also calls our attention to the disappearance of the water flowing from some of these springs on its way to the *Thames* (Appendix No. 5.) He says, " The Seven Springs is a place about four miles from Cheltenham upon the road to " Cirencester, and is the head of the river *Churn*. There the water is thrown out by " the Lias, and it is the furthest tributary of the *Thames*. At the Seven Springs the " flow was 11 cubic feet per minute. At a quarter of a mile below the Springs the " flow was 31 cubic feet per minute, at three-quarters of a mile below it was 61 feet, at " one mile below it was 73 feet, at two miles below it was 105 feet, at $2\frac{1}{2}$ miles below " it was 165 feet, at $4\frac{3}{4}$ miles below it was 312 feet, and at $5\frac{1}{2}$ miles below, estimated at " the maximum, it was 320 feet. Then we got off the Lias on to the rubble beds of " the under Oolite which were absorbing a large quantity of water, which I had pointed " out before the observations commenced, but at this point the volume of the river " instead of increasing began to diminish, for at $6\frac{1}{2}$ miles below the spring the flow had " decreased to 290 cubic feet per minute, at 7 miles below it has decreased to 235 feet, " at $7\frac{3}{8}$ miles to 179 feet, at $8\frac{1}{8}$ miles to 113 feet, at $8\frac{7}{8}$ miles to 45 feet, at $9\frac{3}{4}$ miles to " 33 feet, and at $12\frac{1}{2}$ miles below it had decreased to 30 cubic feet per minute, the bed " of the river absorbing almost the whole of the springs above. The loss of water " in descending the *Colne* is much greater than the loss to the *Churn*." (For further remarks on this subject by Mr. John Bravender, *see* Appendices Nos. 5 and 6.)

Although there is not much water to be obtained from the Chalk below London itself, we are of opinion that it would not be necessary, for many years to come, to resort to the distant springs of the upper *Thames*. We believe that within 40 miles of St. Paul's a sufficient volume of deep well and spring water can be obtained for the present daily wants of the metropolis, and that the radius of the circle of supply would only require to be very slowly lengthened to meet the requirements of an increasing population. We base this opinion upon the following considerations:—

The capacity of the vast storage reservoir existing in the Chalk and Upper Greensand above the Gault, over which they lie, may be estimated in part by considering the quantity of the rainfall on its area. There is within 30 miles of London an area of nearly

* In April 1866, Mr. Bravender measured the flow of the aggregate of the Ampney Crucis springs, "and found it to be considerably more than 20,000,000 gallons in the day." Again in the year 1868 he found on one occasion "that upwards of 30,000,000 gallons were passing the bridge near the mill."

849 square miles covered by these formations; within 40 miles of the metropolis, the area is 1,597 square miles, and within 50 miles, excluding the Chalk beds in the neighbourhood of Brighton as not being within the Thames basin, it is no less than 2,150 square miles. Of these several areas (within the 30, 40, and 50 miles radius respectively) $635\frac{1}{2}$, 1,298, and $1,668\frac{1}{4}$ square miles are on the north side of the London Clay formation, and $213\frac{1}{4}$, 301, and 482, respectively, are on the south. These figures are calculated from the outlines of the formations on the geological map of England.

Part IV. Descriptive.

The Metropolitan water supply.

Though that portion of the annual rainfall upon this large extent of porous rock, which sinks to reappear in springs and streams, be taken at only six inches annually—which is somewhat less than the quantity observed in experiments for determining this point by Mr. John Evans, F.R.S., at Kings Langley, and Mr. Charles Greaves, M. Inst. C.E., at Lee Bridge* during the years 1861–65—the water absorbed by this area within the 50 mile radius would amount annually to the enormous volume of 187,000 millions of gallons; corresponding to 512 millions of gallons a day. And according to this calculation, that, therefore, is the quantity which at present escapes by springs at the heads of the rivulets which take their rise within this area, or in the beds of the rivers which traverse it, or lastly in that of the sea beyond the limits of this estuary. Of this, the northern portion, 145,000 millions of gallons annually corresponding to 398,000,000 gallons a day are derived from 1,067,000 acres which drain into the *Thames* and its tributaries, the *Wye* and the *Colne*, and into the *Lee:* and the southern portion, 42,000 millions of gallons annually, or rather more than 115,000,000 of gallons daily are derived from nearly 308,000 acres draining also into the *Thames* by the *Lodden*, the *Wey*, the *Mole*, the *Darent*, and the *Medway*. A similar calculation limited to the area of the chalk within 30 miles of the metropolis indicates the quantity of 202 millions of gallons daily as the theoretical maximum supply available from that area.

These figures represent the volume of water which remains after the rainfall upon these areas has been used in the feeding of plants, and after a vast quantity has been lost by evaporation. And it is plain, therefore, that they indicate the volume available for all the other purposes which water serves, whether for power, for sanitary or domestic use as a cleansing agency, or for dietetic purposes for both man and animals. The greater portion of this water which now escapes in springs and in the river beds at the lower levels of the absorbent district on which it falls might, it is plain, be abstracted by a sufficient number of wells, sunk below the present spring heads of the district, and so constantly drawn upon that there should always be a void for the reception of unusual rainfalls below the level at which the drainage of the district naturally escapes. The above quantities represent accordingly the maximum water supply from chalk wells available within 30 and 50 miles respectively of the metropolis.

This conclusion is arrived at on, to some extent, theoretical grounds; but the power of the Chalk to furnish an ample metropolitan water supply has been practically tested, in the experience of the Kent and New River Water Companies. Thus the five principal wells of the Kent Water Company, yield more than eight millions of gallons daily throughout the year; and the six wells of the New River Company yield, when pumped, also more than eight millions of gallons daily.† These are all within the 30 mile circle, and we believe that within a forty mile radius an ample volume of water from springs and deep wells in the Chalk can be obtained for the present wants of the metropolis. Certainly no necessity can for a long time arise for going beyond the 50 mile circle for this purpose, but if this should eventually be the case, there are still vast quantities of pure water available within the *Thames* basin outside that circle, in the springs thrown out from the Chalk and Oolite beds by the Gault and Oxford clays, to which we have already called attention.

The very few instances in which deep wells and borings into the Chalk have failed to find water do not invalidate the undoubted fact that immense volumes of water are stored in these formations, and have been, and may be, abstracted from it by wells sunk into it in suitable places. Your Majesty's Commissioners on Water Supply, of course, do not agree with those who expect to get an almost unlimited increase of water "by simply tapping the natural reservoirs in the chalk, for the supply to them "must evidently be limited by the amount of the rain water." But though in this they are obviously right, yet the quantity which may be calculated on from this source within 50 miles of the metropolis amounts, according to the above calculation, to no

* Mr. J. Thornhill Harrison, M. Inst. C.E., Royal Commission on Water Supply, Q. 2958, &c. See also Appendix No. 2 to this Report.
† See Report of Royal Commission on Water Supply, Appendix B., F.

PART IV. DESCRIPTIVE.

The Metropolitan water supply.

less than five times the volume of the river water which is at present supplied by the metropolitan companies. The Commissioners add:—"Moreover, as the water which "penetrates into the reservoirs" [that is, the subjacent porous Chalk] "raising "the water-line more or less above the level of the adjoining valleys, ultimately in "greater part finds its way by springs into streams at the lower level of the district, "any water drawn from the store by artificial means will most probably be at the "expense of these streams. If this be true it follows that any water obtained by tapping "the chalk reservoirs that feed the river *Lee* or the *Thames* would only *pro tanto* "diminish these streams and would therefore be little or nothing gained to the general "supply." This is no doubt true with reference to the *quantity* of the water supply available for the metropolis; but the still more important question of *quality* is here left out of consideration, and it is certain that the displacement of the polluted river water at present distributed would be an incalculable advantage to the inhabitants of London. If the water of the *Colne*, for example, could be taken from springs or wells before it reaches the channel of that stream, it would correspond in excellence of quality to the deep-well water which the Kent Water Company supplies,—it would not, as at present, first receive the drainage of the large populations of St. Albans, Watford, and Uxbridge, and the gross pollution from numerous paper mills and other manufactories before it reaches the *Thames* and flows down to the pumping stations of the other London Water Companies drawing from that river above Hampton.

Section II.

THE WATER SUPPLY OF PROVINCIAL CITIES, TOWNS, AND VILLAGES.

Aberavon. Aberdeen.

We now proceed to describe the water supply of the provincial cities, towns, and villages which we have visited, or from which we have received official information.

Aberavon (*Glamorganshire*), an urban sanitary district of 3,396 inhabitants, is supplied with water for domestic purposes from private wells and streams; there are several springs which the urban sanitary authority utilise as far as possible. It is stated that waterworks would be a great boon to the public, as the present supply is inadequate.

Aberdare (*Glamorganshire*), an urban sanitary district of 39,000 inhabitants, is supplied with water from streams. The works were established by a private company, but have since been purchased by the urban sanitary authority for the sum of 42,000*l.* The water is abstracted from the stream at a point about a mile from its source, and flows through pipes to the storage reservoir, and thence on to filter beds and into service reservoirs; the reservoirs are built above the surrounding ground but are not covered. Unfiltered water is supplied during drought, a supply of 230,000 gallons for domestic purposes and 40,000 gallons for trade purposes is delivered daily to 22,000 persons on the constant system living in 4,110 houses and carrying on business in 51 works and manufactories; the supply is direct from the mains, but is inadequate, and additional works are in course of construction; the rate of charge for water is 6*l.* per cent. on all houses under 20*l.*, 5*l.* per cent. above 20*l.*, rateable value. Waterclosets, if more than one in a house, are charged extra; the water has not been analysed.

Aberdeen, a city of 88,108 inhabitants, is chiefly supplied with water from the river *Dee*, at Cairnton; but partly also from springs which flow into the aqueduct. The first waterworks were established in 1831, when the water was abstracted from the *Dee*, at about two miles from its mouth. In the year 1866, however, the intake was removed to Cairnton, about fifteen miles higher up the river. The works belong to the Commissioners of Police. The reservoirs are situated at Invercannie (15,000,000 gallons), at the hill of Pitfodles (6,250,000 gallons), and at the Brae of Pitfodles (500,000 gallons). The Commissioners abstract from the *Dee*, 2,500,000 gallons of water daily, but they have power to abstract 6,000,000 gallons daily. The area of the district supplied is $2\frac{1}{2}$ square miles; it contains 5,800 houses supplied for domestic purposes, also 100 factories and works taking water for manufacturing purposes; the supply is constant, and 2,500,000 gallons are delivered to the district daily, of which $\frac{1}{18}$th is for trade and manufacturing purposes. About 15,000 gallons of water are supplied daily for the flushing of courts and sewers for 250 days in the year, and 4,500 gallons daily for watering the streets for 100 days in the year, principally in the months of June, July, and August. Ninety per cent. of the houses which have waterclosets are supplied with cisterns, and the overflow-pipes from the cisterns are in every case connected with the soil pipes, which again are connected with the sewers. The present supply is stated to be adequate for the town. Inspection of the cocks and valves of cisterns is made by the police officials, in order to prevent waste. It is stated that the improved water supply has had a beneficial effect upon the health of the inhabitants. The rate of charge is as follows:—The public assessment for water is 8*d.*, in addition to which when the water is introduced into a house there is a charge of 6*d.* in the pound; total 1*s.* 2*d.* in the pound of the yearly value of the premises. Beyond the police boundary, the low service supply, exclusive of the charge for interest on pipes, is 1*s.* $3\frac{1}{2}$*d.* in the pound, and high service 1*s.* 5*d.* in the pound of the yearly value. The new waterworks have cost 160,781*l.* 10*s.* 4*d.* about 13,500*l.* for land and 14,000*l.* for Parliamentary expenses.

Mr. John Legge, engineer to the waterworks, stated in his evidence before us that the quality of the water (from the lower intake) was not as good as was desired. The paper mills at Culter, employing 200 or 300 people, were situated above the old intake; the excrements of these people, as far as he knew, passed into the water. The present intake is only affected by the sewage of Ballater (population about 3,000), which has lately been thoroughly drained and the sewage of which passes unpurified into the water. The water supplied to Aberdeen is filtered through sand and shingle, and the filtered water is stored in an uncovered reservoir about two miles from the centre of the town. Dr. Francis Ogston, the medical officer for Aberdeen, said in his evidence before us, "In "1866, there was a change in the water supply to the town, and the new supply has "improved the health of the inhabitants. The water supply has always been a soft one." In reply to the question, "Do you, or do you not, approve of soft water as a domestic "supply to a population?"—he said, "I have always had a good opportunity of judging, "and I am positive that soft water is preferable to hard water. Hard water generally

PART IV. DESCRIPTIVE.

Abergavenny. Aberystwith.

"produces bowel complaints, principally diarrhœa." Our analysis of the water supplied to Aberdeen on 12th September 1870 (*see* page 33) shows it to be very soft and free from all evidence of previous sewage or animal contamination. It was, however, slightly turbid, showing imperfect filtration, and it exhibited a perceptible yellow tint from the presence of peaty matter, the proportion of which was about the same as that present in the *Ness*, as supplied to Inverness (*see* page 36), but the peaty matter in the *Dee* water was much less nitrogenous than that in the supply of Inverness. A comparison of the analytical numbers in the table (at page 33) shows how greatly the water of the *Dee* is deteriorated during its flow from Balmoral to Cairnton, both the total solid impurity and organic elements having increased nearly threefold. On the other hand the remarkably low proportion of chlorine present at Balmoral is but very slightly augmented, indicating that in 1870 the *Dee* was not being perceptibly polluted by sewage above the intake of the water supply.

Abergavenny (*Monmouthshire*), an urban sanitary district of 4,803 inhabitants, is supplied with water for domestic purposes from springs situated about a mile from the town, and about 400 feet above the town level. Waterworks were commenced in 1861, and belong to the Abergavenny Improvement Commissioners and cost 5,000*l.* About 1,000 houses are supplied with water for domestic purposes. The supply is constant, and direct from the mains, and is said to be adequate for the requirements of the town and district. The rate of charge for water is 5 per cent. upon the rateable value. Previously to the establishment of the waterworks, the inhabitants obtained their supply of water from brooks, and from shallow private wells. The improved water supply is said to have had a beneficial effect upon the inhabitants, typhoid fever has not appeared since the introduction of the improved water supply.

Abersychan (*Monmouthshire*), an urban sanitary district of 14,569 inhabitants, is supplied with water for domestic purposes by the Pontypool Gas and Water Company. The supply is obtained from springs. Waterworks were established in 1851. The water is not filtered. The supply is constant, direct from the mains, and is adequate for the requirements of the district. The rate of charge varies from 1*s.* 9*d.* to 2*s.* per quarter for cottages. The only step taken to prevent waste is, that persons detected are summoned before the magistrates. Previously to the establishment of waterworks, the inhabitants were supplied with water from shallow wells and springs. The improved water supply is said to have had a beneficial effect upon the health of the inhabitants.

Aberystwyth (*Cardiganshire*), a borough of 6,898 inhabitants, with waterworks the property of the Town Council, which have cost 6,000*l.* The water is obtained partly from a shallow well in the river-side gravel, outside of the town and situated 100 yards from the nearest dwelling house, and partly from an upland gathering ground 600 acres in extent, of which one half is pasture and the other half arable land "manured principally "with stable manure." The water is not filtered; the supply is intermittent, and 164,000 gallons are daily delivered to 1,300 houses, two railway stations, and two manufactories. The present supply is declared to be inadequate.

The following table contains the results of our analyses of numerous samples of water collected in and around the town.

COMPOSITION OF POTABLE WATER IN AND AROUND ABERYSTWITH.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
ABERYSTWITH.												
PRESENT SUPPLY.												
Water supply from waterworks, June 1, 1871.	39·34	**·528**	**·041**	·050	·324	·406	**3,330**	11·50	2·5	6·7	9·2	Clear.
Trefechan well, near railway bridge, Oct. 5, 1872.	18·24	**·076**	**·011**	·001	·346	·358	3,150	3·70	0	6·7	6·7	"
AVAILABLE SOURCES FOR NEW SUPPLY.												
From Nanteos, Dec. 23, 1869 -	8·42	**·168**	**·029**	·009	·200	·236	**1,750**	1·90	·2	2·2	2·4	Slightly turbid.
Old well south spring on Llandabarn Flat, Dec. 23, 1869.	6·70	**·094**	**·042**	·005	0	·046	**0**	1·30	0	2·1	2·1	" "
From *Domen* Valley, Dec. 23, 1869	7·30	**·157**	**·030**	·001	·073	·104	**420**	1·70	0	2·1	2·1	Clear.
From Cwm Valley, *Clarach*, Dec. 23, 1869.	11·60	**·094**	**·022**	0	·334	·356	3,020	2·30	0	3·1	3·1	"
From Craiglâs reservoir, Dec. 23, 1869.	17·60	**·153**	**·023**	·005	·447	·474	**4,190**	4·60	0	5·0	5·0	Slightly turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The water distributed from the waterworks was, when our sample was collected, much contaminated by organic matter, and it exhibited considerable evidence of previous sewage or animal contamination. The hardness was moderate. It was not suitable water for the supply of a sanitarium like Aberystwith. The Trefechan well is a spring which yields most excellent water, soft, clear, wholesome, and palatable, and containing only a very small proportion of organic matter. The previous animal contamination which it exhibits may be safely disregarded. All the available sources for new supply mentioned in the above table yield water of much better quality than that now distributed from the waterworks. The best of these sources are the South spring on Llandabarn flat, and the water from Cwm Valley, Clarach. These are clear soft and palatable waters containing only small proportions of organic matter.

Abingdon (*Berks*), a borough containing 5,809 inhabitants (1871), has no waterworks. It is dependent on the neighbouring river and on shallow wells for its supply. The composition of the water of the *Ock*, a tributary of the *Thames*, at its junction with that river in the town is given in the analytical table at page 51. From this it is evident that the *Ock* is here much polluted by organic matters, some of them of animal origin. It is consequently a dangerous water if used for dietetic purposes.

Accrington (*Lancashire*), an urban sanitary district of 21,788 inhabitants, is supplied with water by the Accrington Gas and Waterworks Company, from springs, streams, and reservoirs. The works were established in 1841. The reservoirs are at Burnley road, Mitchell's house, and Higher Booth. The area of gathering ground is 600 acres. The reservoirs contain 110,000,000 gallons; the water is not pumped or filtered. A part of the district receives water pumped from a coal mine. 3,461 houses are supplied for domestic purposes; the supply is constant, and 270,000 gallons is furnished by the waterworks company to the district daily. No water is used for watering streets or flushing sewers. The supply is direct from the mains, and is ample for the wants of the district. The water is not filtered. From evidence given before us (First Report, Vol. II., *Minutes of Evidence*, part 3, Q. 2741,) the water from the coal mine appears to be regarded as of suspicious quality. The analysis given at page 91 however shows it to have been, at the time our sample was taken, an excellent water for domestic purposes, except that it was somewhat hard.

Airdrie (*Lanarkshire*), a burgh of 15,671 inhabitants, obtains its supply of potable water by gravitation from an artificial loch situated at Roughrigg, about 5 miles distant. The works were established in 1846, and belong to the Airdrie and Coatbridge Water Company, which is incorporated by Act of Parliament. The water is filtered through 2 feet of broken whinstone, 15 inches of gravel, 1½ inch of perforated tiles, and 2 feet of sand. The supply is constant; but the volume in gallons supplied to the district daily for trade and domestic purposes, or for watering the streets and flushing sewers is not known. The houses are partly supplied with cisterns. The present supply is adequate for the requirements of the town and district. The rate of charge for the water is 5*s*. per annum and 1*s*. in the pound. Waste, where it is detected, is prevented, by enforcing the penalties imposed by the Statute. The waterworks, which supply a large district in addition to the town of Airdrie, cost 52,000*l*. Previously to the establishment of the waterworks, the burgh was supplied with water from wells and the collected rainfall; the improved supply is believed to have had a very beneficial effect upon the health of the inhabitants. The sample of this water which we collected for analysis was of a yellowish colour and slightly turbid. It contained rather a large proportion of peaty organic matter; in other respects it was a fairly good water of moderate hardness. Dr. Thomas Torrence, the Medical Officer of Health, states in his evidence that Airdrie was visited by cholera only in 1849, and then only slightly. He says, "in the district round, there was a considerable mortality from cholera. I considered "that our comparative freedom from it was owing to the water supply that we had. In "the district around they had none of the company's water. There was one place "where there ought not to have been any cholera, because it is a very elevated place, "and there they took water out of a pond. At another place, which is a low-lying one, "and where now they get a water supply, they got their water from the ditches, and "there was great mortality from the cholera there. *Q.* Do you suppose that in that "case excrementitious matters found their way into the ditches?—Yes, they all got into "them. *Q.* Was Airdrie then supplied by the Airdrie and Coatbridge Water Com-"pany?—Yes, there were not above half-a-dozen cases of cholera in the town, and "where those cases occurred the people obtained their water from draw wells; they did "not use the company's water,—I do not know of any single case of cholera among "people who drank the company's water." There was an epidemic of typhus and typhoid fever in 1866, which the medical officer attributes to the habits of the people, bad arrangements in the houses, and over-crowding.

PART IV.
DESCRIPTIVE.

Aldershot.
Alloa.

The following are the results of our analysis of this water:

COMPOSITION OF WATER SUPPLIED TO AIRDRIE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature, Centigrade.	Dissolved Matters.								Hardness.			REMARKS.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary.	Permanent.	Total.	
AIRDRIE water supply, July 29, 1870.	17·2	23·98	·381	·047	·002	·014	·063	0	1·38	0	9·8	9·8	Slightly turbid, yellowish.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Aldershot Camp (*Hants*) is supplied with upland surface water from a storage reservoir. The water is very peaty, and is consequently yellowish and somewhat unpalatable, but it is otherwise wholesome. It is of moderate hardness, and exhibits no evidence of previous sewage or animal contamination. (For analysis, *see* page 42.)

Aldershot (*Hants*), an urban sanitary district of 11,615 inhabitants, is supplied with water for domestic purposes from springs; the works belong to a private company and cost about 9,000*l*; 10,000 gallons of water per hour is pumped through a brick conduit from springs into service reservoirs, from whence it flows by gravitation and is supplied direct from the mains to about 500 houses.

Alford, a small town of 482 inhabitants in Aberdeenshire, is supplied with water from shallow wells. Our sample was taken from the principal one situated at the side of the road in the midst of the village. The water is nearly three times as hard as that of the river *Don* flowing past the town, but it is otherwise of excellent quality for drinking and culinary purposes. (*See* analytical table at page 69.) It contains only a very minute proportion of organic matter, and the mere trace of evidence of previous contamination which it exhibits may be safely disregarded.

Alfreton (*Derbyshire*), an urban sanitary district of 3,680 inhabitants, has no waterworks, but depends on shallow wells dug in a densely populated district. The supply is stated to be not one-tenth of what is required. The Local Board of Health report that an admirable supply is to be had at a proper level, and within a distance of 6 miles, but that they are not allowed to go out of their district. The coal-pits are stated to have taken all the water. The water of the wells has not been analysed.

Allerton (*Lancashire*), an urban sanitary district of 720 inhabitants, is supplied with water by the waterworks belonging to the Corporation of Liverpool. (*See* p. 368.)

Allerton (*Yorkshire*), an urban sanitary district of 2,903 inhabitants, is supplied with water by waterworks belonging to the Corporation of Bradford. (See p. 321.)

Alloa (*Clackmannanshire*), a burgh of 9,362 inhabitants, is supplied with water from the *Black Devon*. The present works, filtering ponds, and conducting pipes belong to the Police Commissioners; the service reservoir at Gartmoor, 320 acres in area, is the property of the Earl of Kellie who has granted a lease of the same to the Police Commissioners. About 100,000 gallons of water are abstracted from the river daily. The water is declared to be unpolluted before entering the reservoir; it is filtered through sand. The area of the district supplied is 320 acres; about 500 houses have the service pipes brought inside, and the remainder, about 350, are supplied by stand pipes, called "public wells," in the streets. There are also 30 factories, breweries, and works supplied. The supply is constant. No water is used for flushing sewers or watering streets. A number of the better class of houses are furnished with cisterns, but the greater portion of the houses are supplied direct from the mains. The overflow pipes from the cisterns are connected with the soil pipes, and these latter with the sewers. The present supply is said to be adequate for the requirements of the town and district. There is no special water rate, but it is included in the general assessment of 2*s*. in the pound. The only steps taken to prevent waste are those provided in the General Police (Scotland) Act, 1862. The waterworks have cost upwards of 3,000*l*. exclusive of the construction and maintenance of the Gartmoor reservoir. The burgh previously to the establishment of the waterworks, was supplied from wells and from *Alloa Burn*. The improved water-supply has greatly diminished the number of cases of typhoid fever and scarlatina in the borough. The water is of moderate hardness somewhat peaty, but otherwise wholesome. It is quite free from any evidence of previous sewage or animal contamination. (*See* analytical results at page 44.)

Alvaston and Boulton (*Derbyshire*) urban sanitary district of 851 inhabitants, report that the water supply of their district for domestic purposes is derived entirely from wells sunk in soil of a gravelly nature.

PART IV. DESCRIPTIVE.

Alvaston. Ashton-under-Lyne.

Andover (*Hampshire*). From this borough of 5,500 inhabitants we have received the following report. "There is no waterworks company in Andover."

Annan (*Dumfriesshire*), a royal burgh of 3,177 inhabitants, has a most efficient natural supply of excellent water for domestic purposes from three powerful springs capable of supplying the whole town, if necessary. Besides these, almost every house has its pump well, which is said to yield excellent spring water, the river also which flows through the town, is clear and unpolluted. The water has not been analysed.

Arbroath (*Forfarshire*), a burgh of 20,169 inhabitants, is stated, by the local authorities to be supplied with water from public and private wells. The term "public well" is frequently applied in Scotland to fountains deriving their water from distant springs or gathering grounds. Some of the public wells in Arbroath are thus supplied with water from a well at Nolt Loan, on the outskirts of the borough, and sunk 45 feet deep. Our analysis (*see* page 89) shows this water to be of excellent quality for drinking, and for all domestic purposes except washing, for which it is somewhat too hard. It is sparkling, colourless, and palatable, and contains but a very small proportion of organic matter. As it is deep-well water, the moderate evidence of previous animal contamination which it exhibits may be safely disregarded. A very different description of water appears to be furnished by the private wells of this burgh, if we may judge from a sample which we took from that of Mr. Wilson, 121, High Street. (For analysis, *see* page 71.) This water consisted chiefly of the soakage from sewers or cesspools. Its previous sewage or animal contamination was very great, and it also contained a very appreciable quantity of unoxidized sewage matter. Though clear, bright, colourless, and palatable, the use of such water for domestic purposes is highly dangerous.

Ashbourne (*Derbyshire*), an urban sanitary district of 2,083 inhabitants reports :— "No waterworks."

Ashford (*Kent*), an urban sanitary district of 6,950 inhabitants, is supplied with water from three wells, varying from 24 to 36 feet deep, sunk through the gravel into the lower greensand at Henwood, about half a mile from the town. Our analyses given at page 97 show this water to be palatable, wholesome, and of most excellent quality for all dietetic purposes. It is too hard for washing, but might be reduced to about one-fifth of its present hardness by Clark's process, *see* page 205.

Ashton-in-Mackerfield (*Lancashire*), an urban sanitary district with a population of 7,463, has no public waterworks, but is supplied with water from shallow private wells, streams and rain water.

Ashton-under-Lyne (*Lancashire*), a borough of 31,985 inhabitants, is supplied from waterworks belonging to the Corporation. The principal source is from works constructed at Knott Hill and Swineshaw. The reservoirs at Knott Hill were constructed in 1836, and belong to the Corporation, and the Swineshaw reservoirs jointly to the Corporations of Ashton and Stalybridge. The latter supply Ashton, Stalybridge, and Mossley. The impounding reservoirs are at Knott Hill, about two miles, and Swineshaw about five miles from the town.

The gathering ground at Knott Hill is of about 600 acres in extent, but some of the water from that source is unfit for use and is not used. The area of the gathering ground at Swineshaw is 1,290 acres. The area of the five reservoirs is 84 acres with a capacity of 450,000,000 gallons.

The water from the Knott Hill reservoir is partially filtered through beds of gravel. That from Swineshaw is

The service reservoir is much higher than the town and the water flows into the high-service reservoir; pumping is not required.

The area is about 7,000 acres, but little more than one-third of it is at present supplied, the out-districts being principally agricultural. 10,000 dwelling-houses are supplied for domestic purposes; also 188 inns and beer-houses; and 65 manufactories by meter. The supply, about 600,000 gallons, is constant. The mills are supplied from the river, canal, and an old coal pit. About 1,800,000 gallons annually are used for watering the streets, partly from the waterworks and partly from collieries, and the remainder from the river.

All the houses are supplied direct from the mains. Houses in the borough up to 6*l.* rental are charged 4*s.* yearly, from 6*l.* to 10*l.*, 6*s.*; 10*l.* to 12*l.*, 8*s.*; above 12*l.* 5 per cent. on rental; places outside the borough under 5*l.* rental are charged 6*s.*; from 5*l.* to 10*l.*, 8*s.*; 10*l.* to 12*l.*, 10*s.*; beerhouses and inns, extra. The provisions of the *Waterworks Act* are enforced, and periodical inspection of fittings is made.

The quality of the water, which at the time of our visit during the long drought of 1868 was stated to be not so good as usual, was by no means bad; it did not contain, as shown by the analysis given at page 44, an inordinate amount of organic matter, and it exhibited but faint traces of previous animal contamination. It was, however, hard, owing doubtless to the admixture of coal pit-water, which was to be discontinued as soon as new and extensive works then in progress were completed.

Askern (*Yorkshire*), an urban sanitary district with a population of 456, is supplied at present with water from private wells, or in some cases with filtered rain water. We have analysed several samples of the well-water, as also others taken from certain springs, which are available for the supply of the village.

The waters from Mr. Middleton's well and Mr. Haigh's well are dangerous, as they contain actual or unoxidized excremental matters. The water from Mr. Pettit's well, though somewhat better, also contains a large proportion of nitrogenous organic matter whilst it exhibits evidence of serious previous pollution with sewage or animal matters. (For analysis *see* page 88.) In respect of organic matter, Mr. Townend's spring is extremely pure; it seems to come from a very deep seated spring, and although there is some evidence of previous pollution, this has been so completely oxidized and transformed by excessive filtration, that the water might be drunk with perfect safety if it were not so excessively hard. On the whole, Mr. Eridge's spring must be pronounced the best adapted for domestic purposes, since, like the last-mentioned, it contains but a minute proportion of organic matter, whilst its hardness is much more moderate. The sample of Mr. Eridge's spring as received was slightly turbid, but this was probably owing to unskilful collection, as spring waters are very rarely turbid. If, however, it be really turbid as it issues from the spring, it should be filtered before use. (For analysis, *see* page 125.)

Astley Abbots (*Shropshire*), an urban sanitary district with a population of 668, has no waterworks, but is supplied with water from private wells.

Astley Bridge and Halliwell (*Lancashire*), an urban sanitary district of 5,000 inhabitants, is supplied with water from the corporation waterworks of Bolton. (*See* p. 320.)

Atherstone (*Warwickshire*) a rural sanitary district of 3,667 inhabitants, has hitherto been supplied with water from shallow wells. The proposed supply from the higher spring is of excellent quality for all domestic purposes, but especially for drinking. As it is spring water the slight evidence of previous animal contamination which it exhibits need not be regarded. (For analysis, *see* page 116.)

Atherton (*Lancashire*), an urban sanitary district of 7,532 inhabitants, is supplied with water by the Manchester Corporation (*see* Manchester, page 362) through the Tyldesley Local Board of Health, from a reservoir situate at Prestwich, near Manchester, and also from private wells sunk into the stratum overlying the Coal Measures. The supply is constant and direct from the mains. The rate of charge for domestic purposes is 1*s.* 6*d.* in the pound, and for trade purposes 1*s.* 6*d.* per 1,000 gallons. The mains and fittings cost 7,414*l.* In order to prevent waste close inspection is made of the water taps and fittings. The well water has not been analysed.

Austonley (*Yorkshire*), an urban sanitary district with a population of 1,535, has no public waterworks, but is supplied with water from shallow private wells. The water has not been analysed.

Awre (*Gloucestershire*), an urban sanitary district with a population of 1,345, has no public waterworks, but the inhabitants are supplied from shallow private wells.

Ayr, a burgh of 17,954 inhabitants, is supplied with water by gravitation from springs seven miles distant from the burgh. The waterworks were established in 1840, and belong to a private company. The reservoirs are situated at Laighgrange, parish of Maybole and Caroline, and contain 16,000,000 gallons. The water is said to be unpolluted before entering the reservoirs. It is filtered through gravel and sand 2 feet 9 inches deep. The supply is constant, and 500,000 gallons of water are delivered to the district daily. About 6,240 gallons per day, from March to November, are used for watering the streets and flushing sewers. The houses having waterclosets are generally furnished with cisterns, and the overflow pipes are connected with the soil pipes. The present supply is said to be adequate for the town and district.

The waterworks have cost 41,000*l.* Previously to their establishment the town was supplied from wells. The improved supply is said to have had a good effect upon the health of the inhabitants.

Our analysis of this water given at page 114 shows that it contains only a very minute proportion of organic matter. It is clear, colourless, palatable, and of moderate hardness. Being derived from springs, the evidence of previous animal contamination which it exhibits may be disregarded; it is a reasonably safe water.

Bacup. Banff.

Bacup (*Lancashire*), an urban sanitary district of 18,200 inhabitants, obtains half its supply of water from springs and wells, and the remainder from the Rosendale Waterworks Company which was established in 1853. This company has a gathering ground of 350 acres principally moorland, so that the water has a slightly peaty colour. It is not filtered. There are two reservoirs to receive the water; one which can contain 14,000,000 gallons, is reserved for domestic purposes; and the other containing 8,000,000 gallons, furnishes the compensation water to the mills. From the returns sent in, it would seem that the company, though supplying only 1,753 houses out of 3,200 or little more than half of the town, failed during three months in 1868 to supply any water from the large reservoir appropriated for domestic purposes; luckily, however, the compensation reservoir gave a supply of about 10 gallons daily per head of population dependent upon the company, and was able also to furnish water to the factories to the extent of 62,000 gallons daily. The Local Board say very emphatically that the supply is inadequate; they estimate their want at 400,000 gallons per day, and as the reservoir for household purposes would only hold a supply for 35 days, a drought such as that of 1868 would leave the inhabitants without water for more than six weeks.

The area of the district supplied is about 600 acres, containing 1,753 houses, and 36 works and manufactories. The supply is intermittent only in dry seasons; the daily supply for domestic purposes is 96,000 gallons, for works 64,000 gallons.

Most of the houses are furnished with cisterns, and the overflow pipes are connected with the soil pipes, an arrangement which we regard as very objectionable. Rate of charge, an average of about 6*l.* 10*s.* per cent. upon the rental, no single owner paying more per annum than 10*l.*, nor less than 6*s.* No special means are taken to prevent waste, beyond looking well after the taps, valves, and plugs. The waterworks cost 16,000*l.* We have not analysed the water.

Baildon (*Yorkshire*), an urban sanitary district of 4,784 inhabitants, is supplied with water from springs conveyed through sanitary pipes into two reservoirs situated above the town, which contain 5,000,000 gallons. The water is said not to be polluted before entering the reservoirs and it is not filtered. The supply is constant and direct from the mains, and is adequate for the requirements of the town and district. About 50,000 gallons, for domestic purposes only are delivered to 860 houses within an area of 450 acres daily. The rate of charge is 1*s.*, 2*s.*, 2*s.* 6*d.*, and 3*s.* in the pound on the rental, In order to prevent waste, proper supervision is made of the taps and apparatus. The works have cost 6,700*l.* Previously to the establishment of the waterworks the town was supplied with water from private wells. The improved water supply is said to have had a beneficial effect upon the health of the inhabitants. The waterworks belong to the Local Board of Health.

Bakewell (*Derbyshire*), an urban sanitary district of 2,283 inhabitants, is supplied with water for domestic purposes from springs. The waterworks were established in 1831, and belong to his Grace the Duke of Rutland. The reservoirs are situated at Manner's Wood on the east side of the district. The area of the reservoir is 1,200 yards, and the maximum depth 6 feet. The water is not polluted before it enters the reservoirs; and is not filtered. The supply is constant except in very dry weather. The houses are supplied direct from the mains, and the waterclosets from cisterns, the overflow pipes from which are connected with soil pipes. The present supply is adequate for the requirements of the district. The waterworks cost 1,000*l.* Previously to the establishment of the waterworks, a supply was obtained from the rivers and from wells.

We have analytically examined a sample of this spring water, it was clear, colourless, palatable, and of excellent quality for drinking and culinary purposes. It contained a remarkably small proportion of organic matter which was of vegetable origin.

The water being derived from a deep-seated spring, the moderate amount of previous animal contamination which it exhibited may therefore be disregarded.

The only objection that can be urged against this water is that it was rather too hard for washing. If Clark's softening process were applied to it before delivery, it would then be one of the best waters in the kingdom for town supply. (For analysis, *see* page 112.)

Balsall Heath (*Worcestershire*), an urban sanitary authority district of 14,000 inhabitants, is supplied with water by the Birmingham Waterworks Company. (*See* p. 314.)

Banbury (*Oxfordshire and Northamptonshire*).—This urban sanitary district of 11,726 inhabitants is supplied with water from the *Cherwell*. The river is here much polluted by sewage and animal matters, and its water is quite unfit for dietetic purposes. It is too hard for washing. (For analysis, *see* p. 50.)

Banff (*Banffshire*).—This burgh of 7,461 inhabitants is supplied with water from 14 public wells or reservoirs in the streets, and about 30 private wells. Water is also

Barkisland. Barrow-in-Furness.

supplied by a waterworks company to those who wish it introduced into their houses. The waterworks were established about 60 years ago. The reservoirs are situated in Cluny Street and Back Path, and contain about 43,000 gallons. The supply from the waterworks is intermittent. The mains are charged only from 6 a.m. to 8 p.m. Many of the houses are furnished with cisterns, and the overflow pipe is usually connected with the soil pipe. The present supply is inadequate, and a proposal is now under consideration to increase the water supply. The rate charged by the water company is 1*s.* in the pound on the rental.

Barkisland (*Yorkshire*), an urban sanitary district of 3,056 inhabitants, is supplied with water from shallow private wells.

Barmouth (*Merionethshire*), an urban sanitary authority district of 1,175 inhabitants, is supplied with water from streams and private wells. Public waterworks are in contemplation, but not carried out.

Barnard Castle, an urban sanitary district of 4,500 inhabitants, is at present supplied with water from streams and private wells.

A better source of supply is being sought for, and we have analysed two samples of water available for this purpose.

The spring water from the Railway Rock Cutting is of excellent quality for drinking and cooking. It is too hard for washing—about the hardness of *Thames* water—but this evil could be remedied by the application to it of Clark's process (*see* page 205), whereby its hardness would be reduced to about one-third. (For analysis, *see* page 116.)

The *Blue Beck* water, although it contains more than four times as much organic matter as the first-named sample, is still a very good water for all domestic purposes. Its hardness is less than one-half of that of the spring water. It ought to be filtered before use for drinking. (For analysis, *see* page 46.)

The spring water as received by us was turbid, but this was probably due to carelessness in the collection of the sample, for spring water is rarely or never turbid. If it be really turbid as it issues from the spring, it would require filtration before being supplied for domestic use. We should decidedly prefer the spring water for the supply of a town.

Neither sample exhibits any evidence of previous excremental contamination.

Barnet (*Herts*), an urban sanitary district of 3,720 inhabitants, is supplied partly by private shallow wells and partly by a private company with water from a well at New Barnet, 6 feet in diameter, and 140 feet deep, with a borehole in addition 10 inches in diameter, and 290 feet deep, sunk through the London clay into the chalk. About 144,000 gallons are thus pumped daily; the company's customers at present include the railway station and 861 houses. The supply, which is intermittent, is at present insufficient for the summer demand; but a new well is being sunk at Finchley, 8 feet in diameter, and 250 feet deep, with a borehole in addition 16 inches in diameter, and at present 243 feet deep, when, it is believed, sufficient will be obtained for a large extension of the present consumers.

Barnstaple (*Devon*), a borough of 12,000 inhabitants, is supplied with water from the river *Yeo*. The water is abstracted at a point about five miles above the town, and it is conveyed partly in an open conduit and partly in an earthenware pipe. The water is filtered before use. An unlimited supply is available, and at present, 1,700 houses and nine works receive their water from this source.

Our sample, the analysis of which is given at page 48, was clear colourless, palatable and of very moderate hardness. Organic matter was present in but moderate proportion and was exclusively, or nearly so, of vegetable origin. The river drains some cultivated or manured land which imparts to the water some evidence of previous animal contamination. Though not altogether free from suspicion, this water cannot be pronounced unwholesome.

Barton, Eccles, Winton and Monton (*Lancashire*), an urban sanitary district of 16,000 inhabitants, is supplied with water from the waterworks of the Manchester Corporation. The water is supplied direct from the mains. The rate of charge for domestic purposes is 5 per cent. on the rental. There are also numerous private wells sunk into the Red Sandstone whence, it is said, an ample supply of water can be had.

Barrow-in-Furness (*Lancashire*), a borough of 25,000 inhabitants, is supplied with water from a gathering ground of 670 acres, 170 acres of which is arable and the remainder moorland pastured by sheep; the water flows into three subsidence reservoirs, which contain in the aggregate 34,000,000 gallons, and thence into an impounding reservoir containing 162,000,000 gallons, built above the surrounding ground; the water remains in the subsidence reservoirs for a period of three and not exceeding 14 days, and is stored in the impounding reservoir for a space of from one to six months; the water

Part IV. Descriptive. Basingstoke. Bath.

is not filtered, and a volume of 800,000 gallons is delivered for domestic, 1,500,000 for trade, and 250,000 gallons for sanitary purposes on the constant system, daily to 6,427 houses and 119 works and manufactories daily. The rate of charge for water is five per cent. on the rental. Additional charge is made for waterclosets if there are more than one in a house. The water has been analysed by Professor H. E. Roscoe, F.R.S.

Basingstoke. This borough of 5,574 inhabitants is supplied with water by a private company from a well sunk into the Chalk. The shaft of the well is 11 feet in diameter and 34 feet deep, and is situated at a distance of several hundred yards from any houses or buildings. 130,000 gallons of water is pumped daily to a covered reservoir 120 feet above the town, and about three-quarters of a mile from the well and also from the town. This reservoir is 49 feet square and 10 feet deep and contains two days' supply. The supply is constant, direct from the mains, and 40,000 gallons of water is delivered to 300 houses, 80,000 gallons to 10 works and manufactories and the railway station daily. No steps are taken to prevent waste; the rate of charge for water for domestic purposes is five per cent. on rateable value of the houses. Our analysis given at page 100 shows that this water is bright, clear, sparkling, palatable, and wholesome. It contains only mere traces of organic matter and is of excellent quality for all dietetic purposes. It is too hard for washing but might be cheaply softened by Clark's process (*see* page 205). The evidence of previous sewage or animal contamination which it exhibits may be safely disregarded.

Baslow (*Derbyshire*), an urban sanitary district of 820 inhabitants, and about 100 houses, with an area of 300 acres, is supplied by gravitation and on the constant system direct from the mains, with water from neighbouring springs in the Millstone Grit.

Bath (*Somersetshire*), a city of 52,548 inhabitants, is supplied with water from springs principally from the Upper Lias, and the chief waterworks were established in 1846. The works belong to the Corporation and eighteen private companies. There are also a few private wells which are sunk into the Inferior Oolite. The Corporation works supply 30,000 of the inhabitants, and the other companies about 13,000. There are three reservoirs belonging to the Corporation and situated about four miles from Bath; two of them have an area of three acres and contain about 9,000,000 gallons. The third has an area of one-sixth of an acre, and contains 115,000 gallons. The water is not polluted before entering the reservoir; it is not filtered, but is passed through fine wire strainers. The area of district supplied is 560 acres; houses, 4,650 for domestic purposes; and 71 breweries and soda-water works, for manufacturing purposes. The supply is intermittent, and the mains are only charged two hours daily. A volume of about 402,000 gallons is delivered to the district daily for domestic purposes, and 30,000 for trade purposes. The houses are furnished with cisterns, the over-flow pipes from which are not connected with the soil pipe, but lead on to the sinks, and thence into the sewers. The present supply is inadequate for the requirements of the city and district. The rate of charge for water is from 2 to 5 per cent. on the rental of the houses supplied. Breweries and manufactories are charged by meter. Waste is prevented by constant inspection of the taps and fittings. The Corporation has only expended 35,000*l.* on waterworks, but further works are in progress. Previously to the establishment of the waterworks the city was supplied with water from wells and small springs. The improved supply is said to have had a beneficial effect on the health of the inhabitants.

The samples of the waters at present supplied to Bath which we have examined vary considerably in quality, that supplied to the Bathwick district from Beacon springs being the best, but even this sample, besides exhibiting some evidence of previous animal contamination, contains more unoxidized organic matter than is usually met with in spring water. The next water, in point of quality, is that supplied to the Abbey district from Sham-Castle springs; it contains rather more organic matter than the sample from Beacon springs, and exhibits twice as much previous animal contamination; but, as shown by the small proportion of chlorine in both cases, the pollution was caused nearly if not entirely, by solid animal matters and not by sewage or the soakage of cesspools. The water supplied to the Walcot district from Batheaston exhibits about the same evidence of previous contamination by the same kind of animal matters as the last-named two samples, but it contains twice as much organic matter, and is therefore not a desirable water for domestic use. The remaining two samples, which resemble each other closely (the water supplied to the Belvidere district from Beacon Hill spring and the water supplied to Lincombe and Widcombe district from springs under Beechen Cliff), have been heavily contaminated with animal matters and are altogether of very inferior quality, containing, for spring waters, a very large proportion of organic matter.

PART IV. DESCRIPTIVE

Bath.

Batley.

With the exception of the water supplied to the Bathwick district, all the samples are excessively hard, and therefore not well adapted for cleansing operations. (For analyses *see* page 127.) Such being the character of the present water supply of Bath, it is satisfactory to find that the new supply which it is intended to bring into the city shortly, is of much better quality. We have examined samples from the two springs which will form the projected supply, the Eyford spring and the Monkswood spring. The analyses of these waters are given at pages 118 and 117. The first is excellent water for drinking, containing, as it does, the merest traces of organic elements, whilst, although the Monkswood spring water contains ten times as much organic matter, yet it is fully equal in quality to the best sample of the present supply which we have examined. But even these new waters are very hard and would be greatly improved, in this respect, by the application to them of Clark's simple and inexpensive process of softening by lime. (*See* page 205.) By being submitted to this operation the Eyford spring water would have its hardness reduced from 27¼ to 5½ parts in 100,000, and the Monkswood spring water from 29 to 6 parts in 100,000. The palatability of the softened water would be fully equal to that of the original spring, whilst it would be rendered suitable for washing and cleansing operations, for which purposes it is not adapted in its original condition. Moreover, the softened water would have no tendency to form encrustations in the mains, of which there are some remarkable examples at Bath.

The moderate amount of previous animal contamination which the Eyford and Monkswood waters exhibit need not be regarded with suspicion, as the very perfect filtration through rock which they have undergone reduces the risk from the presence of noxious matters to a vanishing quantity.

We examined a sample of spring water issuing from the Oolite on Hampton Down. (*See* page 118.) The land immediately above the spring is pastured by sheep whose excrements are scattered profusely over the surface, there are also some cultivated and manured fields at some distance, but they probably do not affect the spring much, if at all. We found comparatively small evidence of anterior animal pollution in this sample.

Although the thermal springs of Bath have frequently been submitted to careful chemical analysis, the organic elements contained in them have never been determined; we have therefore analysed the waters of the Hetling and King's bath springs, and find that they contain, for deep spring waters, a large proportion of organic elements, and they thus resemble, in this respect, most of the cold spring waters of the neighbourhood. The following table contains the results of analysis of these waters:—

COMPOSITION OF THE BATH THERMAL WATERS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Temperature. Centigrade.	Dissolved Matters.											REMARKS.
		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
										Temporary.	Permanent.	Total.	
BATH. Hetling Thermal spring, March 12, 1870.	44·4°	240·52	·161	·036	·029	·439	·499	4,310	26·50	22·0	82·8	104·8	Clear.
BATH. King's Bath Thermal spring, March 12, 1870.	42·2	245·40	·190	·019	·030	·447	·491	4,400	26·67	22·0	82·8	104·8	Clear.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Batley (*Yorkshire*), a borough of 22,000 inhabitants, is supplied with water for domestic purposes from gathering grounds, delivering into reservoirs capable of holding altogether over 300,000,000 gallons. The water is said to be unpolluted before entering the reservoirs, and is not filtered. The district supplied, 2,038 statute acres, contains upwards of 3,000 houses, and 100 works and manufactories. The supply is constant except in time of drought, when it is only turned on for a certain time in the day; and 400,000 gallons are delivered daily to the district for trade and domestic purposes. The supply is direct from the mains, and is said to be inadequate to the requirements of the town and district. The rate of charge for the water is on a graduated scale according to the rental, varying from 8*s*. 8*d*. per annum for houses rented at 5*l*. 10*s*. and upwards. No steps have been taken to prevent waste. The waterworks have cost Batley 61,000*l*. Our sample of water was taken from the main at Batley; it was yellow and very turbid. The water is soft and well adapted for manufacturing and washing purposes, but in September 1869, it contained too much peaty matter to be an acceptable beverage. It could also scarcely be regarded as a potable water without previous filtration. Analysis reveals no previous animal contamination. The Local Authorities state that the health of the people has improved since the introduction of this mountain water in the place of the previous supplies from polluted rivers and wells. (For analysis *see* page 39.)

Battle.

Battle (*Sussex*), an urban sanitary district of 3,459 inhabitants, is supplied with water from a well 90 feet deep through the Wealden Beds, with headings driven for the collection of springs. The water is pumped to an open reservoir, holding 72,000 gallons, situated midway between the well and the town. The tank "is filled every " week in summer time, but not so often as this in the winter, as for several months " there is a supply from a spring near the town connected with the service pipes." 102 houses are at present supplied. The supply is not sufficient for the requirements of the district and many houses have private wells.

Beaconfield (*Bucks*), an urban sanitary district of 1,521 inhabitants, is supplied with water for domestic and other purposes from springs.

Beaumaris (*Anglesey*), a borough of 2,013 inhabitants, is supplied with water for domestic use chiefly from springs which flow into a small filter bed, and thence to a reservoir capable of holding 200,000 gallons, built partly above the surrounding ground, of stone, grouted with cement, and lined with bricks in cement, whence about 65,000 gallons daily are delivered to 380 houses on the intermittent system. The filter is cleansed about every 21 days, and 1½ inch of sand is then removed and washed.

Beccles (*Suffolk*).—This urban sanitary district of 4,841 inhabitants is supplied with water from a well and borehole sunk into the Middle Drift to a total depth of 137 feet from the surface. The borepipe rises to a height of about 13 feet above the bottom of the well, which is 91 feet deep, and the water can be pumped from this bore or not as required, as there is a distinct set of pumps for it. Samples taken both from the well and borepipe were analysed.

Both samples were slightly turbid, and if this be the usual condition of the water it should be allowed to subside before distribution to consumers. The suspended matter was, however, quite innocuous. Both waters were wholesome, palatable, and fit for drinking and all domestic purposes except washing, and contained only very small proportions of organic matter. The water from the well exhibited a moderate amount of evidence of previous animal contamination, but this, in a deep well water, may be safely disregarded.

The waters were too hard for washing, but this was their only defect. (For analyses, *see* page 104.)

Bedford (*Bedfordshire*), a borough of 16,850 inhabitants, is supplied with water from a large well in the Oolite. The works are the property of the Corporation, and are situated about two miles from the town near the river *Ouse*. The water-bearing stratum here is the Oolitic Limestone. The well is 30 feet deep with headings driven at that depth in two directions 150 and 75 feet long respectively. About a quarter of a million of gallons is pumped from the well daily, for the service of 3,328 houses and 35 works. The covered service reservoir holds about 1½ day's supply, and the supply is constant. There is a mineral spring (for analysis *see* p. 125) close to the well which furnishes water of almost identical composition with that which is pumped from the well. The water is clear, colourless, palatable, and otherwise of fairly good quality, except that it is very hard. There are some shallow wells still used in the town, one of these supplies the Pillory pump, the water of which consists, as shown by our analysis at page 80, largely of percolations from sewers or cesspools. The water is dangerous and the pump ought to be closed.

Bedford (*Lancashire*), an urban sanitary district of 6,610 inhabitants, reports that there are no waterworks in existence there. A public supply of water is greatly needed. At present the inhabitants are supplied from "private wells which are situated " in the midst of privies, cesspools, &c., which have been ascertained to contaminate the " water. The localities in which these wells are sunk are densely populated."

Bedlington (*Northumberland*), an urban sanitary district of 13,494 inhabitants, supplements its water supply, obtained from shallow wells and springs, by pumping from collieries in the neighbourhood. This water is delivered into tanks, and thence finds its way to houses direct from the mains. The supply is stated to be inadequate. The works have cost 1,500*l*.

The water from Bedlington pit is clear and transparent, and contains very small proportions of organic elements (organic carbon and organic nitrogen.) It is too hard for washing; but it may be safely used for drinking and other domestic purposes. It exhibits no evidence of previous animal contamination. (For analysis, *see* page 91.)

PART IV. DESCRIPTIVE.

Beeston. Berwick-on-Tweed.

Beeston (*Nottinghamshire*), an urban sanitary district of 3,000 inhabitants, obtains water from wells, varying from 9 to 11 yards deep in Gravel, Clay, and New Red Sandstone. There is on an average one well to every four tenements,—" very few if any of them " very near to privies."

Benfieldside (*Durham*), an urban sanitary district of 4,434 inhabitants, is supplied by Consett's Waterworks Company, with a capital of 33,500*l.* The water is derived from springs rising in Muggleswick Common on the Millstone Grit formation. It flows through earthenware pipes direct into the iron service pipes. The supply is constant and about one million gallons daily are delivered to between three and four thousand houses and about 24 manufactories, within an area of 16 square miles.

Berwick-on-Tweed, a borough of 13,198 inhabitants, is supplied with water from springs and gathering grounds. The works were established in 1855, and extended in 1871 by the appropriation of a spring at Tweedmouth, and belong to the Local Board of Health. The store reservoir is situated in New East Farm, distant three miles from Berwick. The high service reservoir is situated close to the town. The area of the gathering ground is 338 statute acres. The area of the storage reservoir is 5 acres, and it contains 8,500,000 gallons. The water from the spring at Tweedmouth is pumped to the high service reservoir, containing 255,062 gallons. The water is not filtered. The high service reservoir is built partly above and partly below the ground ; it is covered, and the water is delivered thence by gravitation to the town. The district supplied is 120 acres in extent, including 1,150 houses and seven manufactories. The supply is constant for about nine months in the year, and intermittent during the remaining three months, when the mains are kept charged for about 14 hours a day. The volume of water delivered daily for domestic and trade purposes is 380,000 gallons, or 28 gallons per head, and for watering streets about 4,000 gallons per day for the months of May, June, July, August, and September. Some of the houses are furnished with cisterns, but by far the greater number are supplied direct from the mains, the overflow pipe from the cistern being connected with the soil pipe. The present supply is adequate for the requirements of the town. The Local Board do not levy a water rate separately as a rate ; each property in Berwick being charged with a special general district rate, according to its rateable value, which entitles the proprietor to have it supplied with such quantity of water as can be given. In order to prevent waste, frequent inspection is made of the taps and fittings. Attempts have been made sometimes to convict persons at the petty sessions of wasting water, but in several cases ineffectually, owing, it is alleged, to the clumsy working of the various statutes relating to public health. A revision and condensation of such statutes is exceedingly desirable. The waterworks have cost about 16,000*l.*

The service pipes of the waterclosets are connected directly with the mains, and evidence was given before us by Dr. Thomas Davidson to the effect that regurgitations of excrementitious matters and of blood from slaughter-houses had, in some instances, passed into the street mains.

We inspected the existing works and the Tweedmouth spring, which last had already, at the time of our visit, been suggested as an available source of good water. The analytical results yielded by the sample collected on that occasion are contained in the table on page 112. They placed beyond doubt the great superiority of the water from the Tweedmouth spring, both as regards softness and comparative freedom from organic matter. It contained but one fifth of the amount of organic matter present in the water which was delivered to Berwick on the 4th of April 1870, and that entering the storage reservoir from the gathering ground on the 20th September 1870 (*see* table on page 53, columns headed " organic carbon " and " organic nitrogen "). The water of the Tweedmouth spring is clear and colourless, pleasant to the taste, and well adapted for domestic use. Its hardness is only 11·4 degrees, whilst that of the water then used in the town was 19·5 degrees. The evidence of previous animal contamination is moderate, and is of no importance as the water is derived from a deep seated spring. In accordance with our suggestion, the Local Board have adopted this spring as an auxiliary source of supply. The water from the gathering ground is unfit for domestic use.

The service reservoir occupies a good position and appears to be well suited to its purpose, and the Nine Wells Eye spring, one of its feeders, might be retained, if necessary, as an accessory supply. Though the water of this spring is by no means equal to that of the Tweedmouth spring, it contains but mere traces of organic matter, and is, in other respects, tolerably free from risk (*see* p. 112) ; it might therefore be allowed to mix with the water of the Tweedmouth spring, if it be considered desirable to reduce the cost of pumping the entire volume required for the town supply from Tweedmouth.

The water from the *Whitedam Head* brook, which was also proposed as an additional source of supply for Berwick, is very little better than that entering the storage reservoir and would therefore not be available for domestic use. (For analysis, *see* p. 53.)

Bethesda (*Carnarvonshire*), an urban sanitary district of 9,500 inhabitants, is supplied with water from springs which are conducted to various points by private individuals. There are no public waterworks.

Bicester (*Oxfordshire*), an urban sanitary district of 3,300 inhabitants, is supplied with water for domestic purposes wholly by private and public shallow wells, sunk in the Oolitic rock.

Bideford (*Devonshire*), a borough and urban sanitary district of 6,919 inhabitants, is supplied with water from a gathering ground of 500 acres, 350 acres of which is pasture and the remainder arable. No refuse from privies, middens, or ashpits is used as manure. The water flows into an impounding reservoir, containing 15,000,000 gallons, and from thence into an uncovered service reservoir holding about 70,000 gallons. The supply is constant, direct from the mains, and 54,000 gallons of unfiltered water is delivered to the district daily; the present supply is adequate. "Waste preventers" are used on service fittings; the rate of charge for water is 1*s.* 2*d.* in the pound on the gross rateable value; the supply to waterclosets is not charged for in addition to this rate. The water has not been analysed in the laboratory of this Commission.

Bilborough (*Yorkshire*), an urban sanitary district of 207 inhabitants, has no public water supply.

Bilston (*Staffordshire*), an urban sanitary district of 24,000 inhabitants, is supplied with water from the Wolverhampton Corporation Waterworks. (*See* Wolverhampton, p. 411.)

Bingley (*Yorkshire*), an urban sanitary district of 9,000 inhabitants, is supplied with water chiefly from springs leased to the authority by W. B. Ferrand, Esq. for an unexpired term of 18 years at 600*l.* per annum, and partly from the works of the Corporation of Bradford. The waterworks cost 6,000*l.*, and if the loan of the springs is not renewed Mr. W. B. Ferrand has to take the works at a valuation. The water flows from springs through pipes into an uncovered service reservoir, holding about 280,000 gallons. 2,000 houses are supplied for domestic purposes, and six works for trade purposes; the supply is direct from the mains; the supply is inadequate. The village of Cullingworth is supplied with water from springs. The waterworks were established about five years ago, and belong to the Local Board of Health of Bingley. The reservoir is situated within a very short distance of the village, and contains 750,000 gallons. The water is said to be unpolluted before entering the reservoir; it is not filtered, and is not pumped. The area of district supplied is about 200 acres; houses, 250, and one manufactory. The supply is intermittent during three months of the year, and about 10,000 gallons of water are delivered to the district daily. The supply is direct from the mains, and is not adequate for the requirements of the district. The rate of charge for the water is 1*s.* in the pound on the rental. The waterworks cost 750*l.* The water has not been analysed.

Birkdale (*Lancashire*), a Local Board of Health district of 3,307 inhabitants, is supplied with water from the Southport Waterworks Company. (*See* p. 396.) There are 500 houses thus supplied on the constant system. The present supply is more than adequate to the requirements of the district.

Birkenhead (*Cheshire*), an urban sanitary district of 45,418 inhabitants, is supplied with water from two reservoirs and pumping stations, one situated at Spring Hill, Birkenhead, and the second near Flaybrick Hill in Claughton. The whole supply of water is obtained from wells sunk in the New Red Sandstone. The wells at Spring Hill are 8 feet diameter and 99 deep, with bore-holes in addition 300 feet deep below bottom of well. The well at Flaybrick Hill is 16 feet by 8 feet and 205 feet deep, with bore-hole in addition 322 feet below the bottom of the well. The united capacity of the storage reservoirs, which are built partly above ground and not covered, is 5,300,000 gallons and 77,800 gallons of water are pumped into them every hour for 24 hours daily. The high-service reservoir near Flaybrick Hill is constructed of iron at the top of the engine-house, and is covered.

The area embraces the whole of Birkenhead, including Claughton, 1,684 acres and also the shipping in the docks; the district contains about 7,600 houses and 20 manufactories. It is supplied on Sunday, Monday, Tuesday, Thursday, and Saturday, from half-past 5 a.m. until half-past 10 p.m., and on Wednesday and Friday from noon until half-past 10 p.m., but several fire mains throughout the town are constantly charged. A volume of 1,867,200 gallons is daily delivered.

The houses are chiefly supplied with cisterns, and the overflow is generally connected with the nearest house drains or pipes. The present volume is fully adequate; the rates

Birkenshaw.
Birmingham.

allowed under the *Act of* 1858 vary according to the rental of the house, from $7\frac{1}{2}$*d.* in the pound to 5 per cent. on the rental, but from these rates the Commissioners have made an abatement of 20 per cent. To prevent waste constant inspection is made of taps and fittings. The waterworks cost 130,000*l.* The water from both wells is of unimpeachable quality for all dietetic purposes. It is clear, palatable, and wholesome, and contains only minute traces of organic matter. The water from the Flaybrick Hill well is soft, and that from the Spring Hill well of moderate hardness. Few towns in Great Britain have such an excellent water supply. (For analysis *see* page 93.)

Birkenshaw (*Yorkshire*), an urban sanitary district of 3,000 inhabitants, is supplied with water from wells. The Local Board of Health have not executed either water, gas, or sewerage works.

Birmingham (*Warwickshire*), a borough of 343,787 inhabitants living in 68,532 houses, within an area of 15 square miles, receives a constant daily supply of $7\frac{1}{2}$ millions of gallons, of which a considerable portion goes for manufacturing and sanitary purposes. The works are the property of a private company, and have cost 750,000*l.* Three-fourths of the supply is said to be from wells and boreholes, varying from 130 to 400 feet deep, into and through beds of the New Red Sandstone formation. The remainder of the supply is impounded from various streams constituting the head waters of the *Tame*,—an affluent of the *Trent*. The *Perry Brook*, the *Witton Brook*, *Plant's Brook* and the rivers *Blythe* and *Bourne* are thus made to contribute, and the *Tame* itself has hitherto been drawn upon largely for the water supply of Birmingham. The last-named source is not, however, now made use of except for manufacturing purposes, or in times of emergency, for domestic purposes, on account of the pollution to which that river has of late years been exposed. The other streams are drawn upon at points varying from 7 to 20 miles from their respective sources, and the Company report that they are believed to be unpolluted. The water of these streams flows into a number of open subsidence reservoirs of an aggregate area of 89 acres, and capacity of 200,000,000 gallons, and another storage reservoir is about to be constructed at Whitacre to hold other 300 millions of gallons. They have also constructed seven filter-beds, four acres in extent in the aggregate, on which the water of the *Blythe* and *Bourne* will be received. At present none of the Company's water is filtered.

We inspected these works on the 16th of May 1873, and collected numerous samples of water, the analysis of which gave the chief results contained in the following table:—

Composition of Water supplied to Birmingham.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.			
									Temporary.	Permanent.	Total.	
River Waters.												
The *Bourne*, Nov. 17, 1869	36·00	**·211**	**·039**	·006	·275	·319	**2,480**	1·82	18·1	8·6	26·7	Turbid.
The *Blythe*, at Whitacre, Nov. 17, 1869	38·46	**·453**	**·074**	·006	·153	·232	**1,260**	1·93	7·2	10·9	18·1	"
Plant's Brook, at Pumping Station, Dec. 7, 1869.	24·38	**·350**	**·054**	·012	·320	·384	**2,980**	1·40	4·7	10·9	15·6	Slightly turbid.
The *Bourne*, in flood, March 4, 1870.	29·20	**·640**	**·059**	·007	·415	·480	**3,890**	1·56	10·0	11·5	21·5	Very turbid.
Ditto, filtered through 5 feet of sand	26·84	**·460**	**·045**	·006	·299	·349	**2,720**	1·55	10·0	12·3	22·3	Clear.
The *Blythe*, in flood, March 4, 1870	28·60	**1·164**	**·111**	·008	·276	·394	**2,510**	1·44	3·3	12·6	15·9	Very turbid.
Ditto, filtered through 5 feet of sand	25·62	**·923**	**·075**	·009	·171	·253	**1,460**	1·35	3·8	9·3	13·1	Turbid.
Plant's Brook, at Pumping Station, April 14, 1870.	22·26	**·323**	**·038**	·007	·245	·289	**2,190**	1·52	7·1	6·1	13·2	Slightly turbid.
Perry Brook, near Birmingham, April 14, 1870.	30·00	**·260**	**·032**	·005	·583	·619	**5,550**	1·90	10·1	9·5	19·6	Turbid.
The *Tame*, at Salford Bridge, Nov. 30, 1872.	85·32	**·520**	**·168**	·088	·359	·599	**3,990**	7·60	4·9	25·7	30·6	Very turbid.
The *Blythe*, at Whitacre, from storage reservoir, May 16, 1873.	28·64	**·463**	**·132**	·004	0	·135	**0**	1·70	8·4	11·9	20·8	Slightly turbid.
The *Bourne*, at Whitacre, May 16, 1873.	32·10	**·116**	**·040**	·003	·277	·319	**2,470**	1·70	18·3	5·6	23·9	Turbid.
Plant's Brook, at pumping station, May 16, 1873.	19·64	**·440**	**·092**	·008	·063	·162	**380**	1·60	6·1	7·0	13·1	Slightly turbid.
The *Witton Brook*, near King's Vale Well, May 16, 1873.	22·28	**·323**	**·053**	·008	·756	·816	**7,310**	2·20	0	10·0	10·0	Turbid.
Spring and Deep Well Waters.												
Aston Well Waterworks, May 16, 1873.	19·42	**·034**	**·006**	0	·176	·182	1,440	2·00	9·7	5·4	15·1	Clear and palatable.
Perry Well Waterworks, May 16, 1873.	23·24	**·031**	**·007**	0	·469	·476	4,370	1·75	7·8	6·6	14·4	Clear and palatable.

COMPOSITION OF WATER SUPPLIED TO BIRMINGHAM—*continued.*

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters. Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
Shortheath Well, Witton, May 16, 1873.	15·08	**·009**	**·004**	0	·447	·451	4,150	1·30	4·6	5·1	9·7	Clear and palatable.
King's Vale Well Waterworks, May 16, 1873.	18·06	**·037**	**·012**	0	·677	·689	6,450	1·80	3·8	7·4	11·2	Clear and palatable.
Spring below Witton reservoir, May 16, 1873.	15·54	**·052**	**·019**	·001	·504	·524	4,730	1·75	0	8·3	8·3	Clear and palatable.
MIXED RIVER AND DEEP WELL WATER.												
Service reservoir from which Birmingham is supplied, May 16, 1873.	20·10	**·040**	**·010**	·001	·169	·180	**1,380**	2·05	7·8	6·6	14·4	Clear.
Water as supplied to Birmingham at 105, Summer Lane, May 16, 1873.	19·32	**·123**	**·025**	0	·139	·164	**1,070**	2·10	9·6	4·7	14·3	Slightly turbid.
Water as supplied to Birmingham at Taylor's Buildings, Sept. 18, 1873.	22·60	**·218**	**·041**	·002	·162	·205	**1,320**	2·00	3·6	9·3	12·9	"

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

At the Whitacre new works, about 11 miles from Birmingham, arrangements have been made for impounding, filtering, and pumping the waters of the *Bourne* and the *Blythe*, but these works have not yet been brought into operation, the Company possessing parliamentary authority for distributing the waters of these and other rivers in an unfiltered condition. The basin of the *Blythe* contains a considerable population above the company's intake, that of the *Bourne* is more sparsely populated, but it is highly cultivated. The water flowing down the *Blythe* appeared to be considerably polluted, but our sample was taken from the impounding reservoir where it had been stored for about three weeks, and it had thus lost all evidence of *previous* sewage or animal contamination. It still contained, however, a very large proportion of *actual* organic matter of unmistakably animal origin, and it was altogether one of the worst waters for domestic supply, we have ever encountered. Our analysis shows the water of the *Bourne* to be of much better quality, for although it exhibited strong evidence of previous animal contamination, the proportion of actual animal organic matter which it contained was but little more than one-fourth of that present in the *Blythe* water. Much of this water is said to be derived from springs and consequently the evidence of previous animal contamination, has not so serious an import. The drainage area of the basin of the *Bourne* above the Company's intake is only about 15 square miles, whilst that of the *Blythe* above the intake is about 79 square miles, but the average delivery of water from the two basins appears to differ to a much less extent.

Plant's Brook, as it entered the well of the pumping station, on the day of our visit, was slightly turbid and yellow; but we were informed that the water sometimes became very turbid, and was the chief cause of the complaints which are occasionally made by consumers at Birmingham. This stream receives the *Sutton Brook* into which the borough of Sutton drains. The water was much softer than that from either the *Blythe* or the *Bourne.* It contained nearly as much organic matter as the *Blythe,* and although a smaller proportion of this was, in the case of *Plant's Brook,* of animal origin, yet we feel bound to condemn this water as quite unfit for dietetic purposes even after filtration.

The *Witton Brook* is a stream yielding about half a million gallons daily, rising in agricultural land, crossing without protection the high road at Witton, and then joining the company's conduit from the King's Vale well. The water of this brook is highly charged with organic matter, which is for the most part of vegetable origin, it is the softest of the streams utilized by the company but has still the moderate hardness of 10°. In the condition in which we saw it, the water was not fit for domestic supply.

Perry Brook yields water of somewhat better quality than that flowing in *Witton Brook ;* nevertheless it contains a large proportion of organic matter and exhibits very strong evidence of previous animal contamination.

The *Tame,* at the point where the Company is still authorized by their Act to draw water for distribution to the inhabitants of Birmingham without previous filtration, is a filthy stream highly polluted by sewage and manufacturing refuse, and it is needless

PART IV. DESCRIPTIVE.

Birmingham.

to say that the supply of such water for domestic purposes is fraught with extreme danger to the public health.

The remaining sources of supply are deep wells in the New Red Sandstone yielding water of unexceptionable quality. One of these wells is situated at Aston; it is 120 feet deep with a borehole carried down to 400 feet. When the pumps are not at work the water rises 8 feet above the surface of the ground. This well yields a magnificent stream of bright and sparkling water delivering 3¼ millions of gallons daily. Our sample collected directly from the delivery channel of the pump was clear, colourless, and palatable. It contained but mere traces of organic matter and was, for a well water, of moderate hardness. Coming as the water does from the sandstone rock, the evidence of previous animal contamination which it exhibited may be safely disregarded.

Perry well is 170 feet deep and 12 feet in diameter. It yields a daily supply of two millions of gallons of magnificent water, the qualities of which are almost identical with those of the Aston well water. It was however somewhat softer. The water here spontaneously rises above the level of the surface.

Short Heath well, near Witton, is 130 feet deep and 10 feet in diameter, with a borehole 20 inches in diameter carried down to 400 feet. It yields 2¼ millions of gallons per day, of water of still greater purity than that furnished by the previously mentioned wells. It is also much softer, having only 9·7 degrees of hardness, and is one of the best waters for dietetic and domestic purposes we have ever encountered.

King's Vale well is 170 feet deep and 13 feet in diameter, with a borehole 20 inches in diameter descending 300 feet lower. It also yields water of excellent quality, and of a hardness only 1½° greater than that of the Short Heath well water. The supply is, however, at present not so abundant, amounting only to half a million of gallons per diem, and this is the only well of the series in which the water does not rise above the surface. Our sample was taken from the conduit pipe where it joined the *Witton Brook*.

A small contribution to the water of the company is made by a spring (James's spring) issuing into their conduit just below Witton reservoir. This water is also of very good quality, and is softer than that from any of the other sources. It has only 8 degrees of hardness.

Our inspection of these sources and the chemical analyses of the water yielded by each show that the Birmingham Water Company are in possession of two classes of waters of widely different quality, viz., river water of, generally, very bad quality, and deep well water of most excellent quality. With the exception of the *Bourne*, all the rivers drawn upon are incapable of furnishing, even in dry weather, water which is fit for domestic purposes. The *Bourne* in flood is also equally unsuitable. Our experiments upon the filtration of the flood waters of the *Bourne* and *Blythe* through sand demonstrate that, even after filtration, these rivers in flood still contain far too large a proportion of organic matter of questionable origin to permit of their safe use for dietetic purposes. We are of opinion, therefore, that all the river sources, except the *Bourne*, should be abandoned as soon as possible. The company's great success in obtaining, for a moderate outlay, abundance of excellent and wholesome water from deep wells in the New Red Sandstone leaves no doubt that the whole of their supply might without difficulty be drawn from this source. Even at the present moment the aggregate yield of their wells exceeds the total volume which they supply, and which they state to be 7½ millions of gallons.

	Daily yield.	
Aston well - - - - - -	3,250,000	gallons.
Perry well - - - - - -	2,000,000	„
Short Heath well - - - - -	2,250,000	„
King's Vale well - - - - -	500,000	„
	8,000,000	„

The quality of the water which we collected at the Mint of Messrs. Ralph, Heaton, and Sons, the analysis of which is given at page 93, shows that the water bearing New Red Sandstone extends under the town itself, and everywhere yields a beverage of uniformly excellent quality.

The analysis of the samples of water which we drew almost simultaneously on the 16th of May 1873, from the service reservoir at Aston, and from the company's main in Summer Lane, Birmingham, shows that the water contracts a marked amount of organic impurity during its passage through the mains, the proportion of this impurity having been nearly tripled during the transit from Aston to Summer Lane.

At the time of our visit the service reservoir was filled, as shown by the analytical results in the above table, by water derived almost exclusively from the Aston well, but on the 18th September 1873, when we collected our second sample of the town's supply, a large proportion of the water then distributed to consumers was drawn from rivers; and this appears to be generally the case, as is shown by an examination of the following analytical results obtained by Dr. Alfred Hill, the Medical Officer of Health for Birmingham, who reports monthly to the Corporation of Birmingham on the quality of the water, the reports being printed in the Registrar-General's weekly returns:—

PART IV. DESCRIPTIVE. — Birmingham.

COMPOSITION OF WATER SUPPLIED TO BIRMINGHAM.

RESULTS of ANALYSIS expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BIRMINGHAM water supply:												
January 11, 1870 - -	28·80	**·324**	**·039**	·010	·448	·495	**4244**	1·83	6·4	12·0	18·4	Slightly turbid.
May 10, 1870 - - -	22·02	**·214**	**·033**	·004	·289	·325	**2603**	1·41	4·9	9·1	14·0	" "
June 4, 1870 - - -	18·96	**·262**	**·039**	·002	·214	·255	**1843**	1·77	3·0	10·3	13·3	" "
July 5, 1870 - - -	49·60	**·308**	**·069**	·002	·172	·242	**1420**	5·32	6·0	19·1	25·1	" "
August 3, 1870 - -	64·80	**·573**	**·094**	·003	·188	·229	**1036**	7·44	–	–	26·6	Turbid and of a bright green colour from minute vegetation.
September 5, 1870 - -	38·90	**·353**	**·038**	·008	·009	·053	**0**	3·54	–	–	20·3	Slightly turbid.
October 4, 1870 - -	24·96	**·314**	**·050**	·002	·162	·213	**1320**	2·12	4·0	11·8	15·8	" "
November 4, 1870 - -	23·96	**·374**	**·062**	·004	·209	·274	**1810**	1·41	4·3	11·1	15·4	" "
December 5, 1870 - -	22·64	**·290**	**·031**	·002	·267	·299	**2375**	1·41	–	–	16·8	Clear.
January 5, 1871 - -	51·80	**·267**	**·038**	·019	·262	·316	**2462**	3·70	10·6	19·4	30·0	Slightly turbid.
February 6, 1871 - -	41·50	**·306**	**·028**	·008	·439	·473	**4140**	3·01	–	–	24·3	—
March 6, 1871 - -	24·30	**·191**	**·020**	·001	·277	·298	**2463**	1·59	6·1	12·7	18·8	Slightly turbid.
April 6, 1871 - - -	23·70	**·104**	**·055**	·002	·237	·294	**2067**	1·59	5·1	11·7	16·8	" "
May 4, 1871 - - -	22·70	**·180**	**·051**	·003	·221	·274	**1917**	1·67	5·1	9·9	15·0	" "
June 6, 1871 - - -	23·21	**·459**	**·046**	·003	·208	·256	**1789**	1·42	3·1	11·0	14·1	Turbid, large floating particles.
July 3, 1871 - - -	22·20	**·378**	**·039**	·002	·205	·245	**1753**	1·70	4·3	9·4	13·7	Slightly turbid.
August 4, 1871 - -	24·66	**·316**	**·053**	·003	·159	·214	**1305**	2·12	–	–	15·4	Turbid.
September 5, 1871 - -	38·66	**·415**	**·064**	·004	·215	·282	**1869**	3·36	5·3	12·7	18·0	"
October 4, 1871 - -	24·74	**·500**	**·058**	·004	·190	·251	**1611**	1·77	2·8	12·0	14·8	Very turbid.
November 6, 1871 - -	23·70	**·305**	**·045**	·002	·008	·054	**0**	1·70	3·4	14·0	17·4	Very turbid, allowed to subside before analysis.
December 5, 1871 - -	22·10	**·163**	**·023**	0	·172	·195	**1405**	1·72	5·4	10·0	15·4	Slightly turbid.
January 6, 1872 - -	26·36	**·320**	**·034**	·004	·288	·325	**2595**	1·42	6·1	8·4	14·5	Turbid.
February 6, 1872 - -	26·64	**·209**	**·028**	·002	·336	·366	**3064**	1·54	3·0	11·0	14·0	Slightly turbid
March 6, 1872 - -	27·40	**·235**	**·039**	·002	·356	·396	**3260**	1·70	5·3	10·3	15·6	" "
April 6, 1872 - -	25·18	**·218**	**·034**	·003	·236	·273	**2362**	1·54	7·3	6·7	14·0	Turbid.
May 7, 1872 - - -	22·86	**·158**	**·020**	·002	·120	·141	**898**	1·87	5·8	9·0	14·8	Clear.
June 5, 1872 - - -	28·22	**·320**	**·046**	·004	·331	·379	**3022**	1·71	4·7	9·7	14·4	Turbid.
July 6, 1872 - - -	17·98	**·240**	**·054**	·005	·105	·163	**774**	1·72	1·2	11·4	12·6	Very turbid.
August 2, 1872 - -	25·64	**·240**	**·035**	·002	trace	·036	**0**	2·05	–	–	18·7	Turbid.
September 5, 1872 - -	24·38	**·298**	**·041**	·003	·146	·189	**1167**	1·77	5·4	8·6	14·0	Slightly turbid from large particles.
October 5, 1872 - -	23·64	**·171**	**·041**	·004	·099	·103	**709**	1·72	1·7	13·9	15·6	Slightly turbid.
November 4, 1872 - -	26·00	**·263**	**·035**	·002	·286	·322	**2562**	2·05	7·0	11·0	18·0	" "
December 6, 1872 - -	28·44	**·335**	**·043**	·006	·394	·442	**3679**	2·06	4·7	11·7	16·4	" "
January 6, 1873 - -	24·04	**·182**	**·059**	·002	·068	·129	**382**	1·71	5·0	10·1	15·1	" "
February 5, 1873 - -	25·60	**·230**	**·044**	·003	·388	·434	**3583**	1·71	3·7	10·3	14·0	Clear.
March 7, 1873 - -	27·22	**·214**	**·048**	·004	·183	·234	**1542**	1·73	6·3	9·6	15·9	Slightly turbid.
April 4, 1873 - -	24·74	**·263**	**·037**	·004	·366	·406	**3377**	1·73	6·0	9·1	15·1	Clear.
May 6, 1873 - - -	24·80	**·242**	**·052**	·003	·335	·389	**3053**	2·08	4·9	8·9	13·8	Turbid from large suspended particles.
June 6, 1873 - - -	22·32	**·227**	**·032**	·002	·263	·296	**2328**	1·73	4·9	8·5	13·4	Slightly turbid.
July 7, 1873 - - -	23·38	**·263**	**·046**	·002	·232	·279	**2018**	1·26	4·0	9·1	13·1	Turbid.
August 5, 1873 - -	23·60	**·295**	**·026**	·024	·271	·317	**2597**	2·08	5·7	8·8	14·5	"
No. 3 Court, Bradford Street, September 6, 1873.	23·80	**·247**	**·038**	·006	·248	·286	**2215**	2·08	3·8	10·2	14·0	Slightly turbid.
Back, 91, Holliday Street, October 6, 1873.	21·40	**·288**	**·044**	·004	·266	·313	**2375**	2·08	3·6	10·4	14·0	Turbid from large suspended particles.
Nos. 30 & 31, Bloomsbury Street, Nov. 6, 1873.	21·80	**·411**	**·042**	·001	·432	·475	**4000**	1·70	5·3	8·4	13·7	Slightly turbid.
No. 28, Green Lane, December 6, 1873.	25·38	**·271**	**·030**	0	·375	·405	**3436**	2·00	4·6	10·6	15·2	Pretty clear.
No. 4 Court, Norfolk Street, January 7, 1874.	27·40	**·203**	**·042**	·002	·379	·422	**3480**	1·73	6·6	9·6	16·2	" "
No. 2 Court, Nelson Street, South, Feb. 6, 1874.	23·80	**·086**	**·024**	·002	·271	·296	**2411**	1·74	5·6	10·0	15·6	" "
Glebe Street, St. Luke's, March 6, 1874.	24·00	**·248**	**·029**	·002	·316	·347	**2860**	2·08	4·3	11·8	16·1	Slightly turbid.
Montpellier Place, Kyrwick's Lane, April 7, 1874.	19·60	**·179**	**·043**	0	·304	·347	**2720**	2·08	5·0	10·7	15·7	" "
No. 93, Lawley Street, May 6, 1874	22·24	**·316**	**·064**	·004	·194	·261	**1659**	1·74	4·3	9·1	13·4	Very turbid.

***Note.*—For the translation of these numbers into grains per gallon, *see* note to table on page 29.**

PART IV. DESCRIPTIVE.

Birstal. Blackburn.

In addition to the company's water, shallow wells are still used to a considerable extent in Birmingham. We have inspected and collected samples from eight of them. The analytical results yielded by these samples will be found at page 75. They are, without exception, liquids of most filthy origin, entirely unfit for human consumption,—the soakage from sewers, cesspools, and badly-paved yards. We were therefore not surprised to learn from the Medical Officer of Health, who accompanied us on our inspection, that fever is an almost constant guest in many of the courts from which the samples were taken. Access to such dangerous water ought to be at once rendered impossible.

Birstal (*Yorkshire*), an urban sanitary district of 7,000 inhabitants with an area of 1,400 statute acres, is supplied with water for domestic purposes from the Bradford Corporation Waterworks. (*See Bradford, Yorkshire*, page 321.) The supply is constant, and 85,000 gallons are delivered daily to the district "when the supply is equal to the demand." The supply is direct from the mains, but is quite inadequate for the requirements of the town. The rate of charge varies for the domestic supply from 8*s*. 8*d*. yearly for houses of the yearly value of 3*l*., to 2*l*. for houses of the yearly value of from 50*l*. to 60*l*. For trade purposes, the supply is by meter; varying from 1*s*. 3*d*. per 1,000 gallons for the quarterly consumption of 5,000 gallons, to 9*d*. per 1,000 gallons for the quarterly consumption of 500,000 gallons. "No steps are taken to prevent waste." The cost of the water mains and apparatus was 6,360*l*. A 6-inch main is being laid to the Board's reservoir from the Corporation reservoir at Dudley Hill in lieu of the present 4-inch main. The improved supply is said to have had a decidedly beneficial effect upon the health of the inhabitants.

Bishop Auckland (*Durham*), an urban sanitary district with a population of 8,736, is supplied with water from a shallow well sunk close to the *Wear* and a tunnel running beneath the river. Upwards of 400,000 gallons are delivered daily on the constant system. Our analysis given at page 44 shows the water to be turbid and highly charged with peaty matter. The river was somewhat in flood at the time of our visit, but as it does not exhibit any evidence of previous sewage contamination, it follows that the evidence of such contamination, which analysis reveals in the water supplied to the town must be derived from soakage from the sewers discharged into the river near the waterworks. The water is of moderate hardness, but its quality is, in other respects, not satisfactory.

Bisley (*Gloucestershire*), an urban sanitary district of 4,985 inhabitants, obtains its supply of water from private wells.

Bitteswell (*near Lutterworth, Leicestershire*). This village is supplied with water from shallow wells. With the exception of the water from the Rev. G. Mornington's pump, all the samples contain an extraordinarily large proportion of total solid impurity, and independently of all considerations as to organic contamination, they are all too hard to be safely used for drinking. All the samples, except the one just mentioned, and the water from the public pump below the Almshouses, exhibit evidence of great previous contamination with sewage matter, whilst the water from Mr. See's well, the public pump below the Almshouses, Miss Powell's well, and Mr. Smart's pump, contain a considerable proportion of actual or unoxidized sewage matter. The analytical results leave no doubt that the water from the public pump below the Almshouses was also originally much contaminated with sewage matter, although the usual evidence of this contamination has been effaced. The only sample, therefore, which is not actually dangerous to use for domestic purposes, is that from the Rev. G. Mornington's pump, but even this has been too much in contact with decomposing animal matters, to allow it to be considered as a desirable water for domestic use. (For analyses, *see* page 79.)

Blackburn (*Lancashire*), a borough of 78,000 inhabitants, is supplied from waterworks, the property of a private body, which have cost 177,000*l*. The water for domestic purposes is obtained principally from a gathering ground of about 800 acres in the hilly district between Haslingden, Darwen, and Blackburn; but Parliamentary authority has been obtained for an additional gathering ground of 1,620 acres, of which a small part only has yet been utilised. The gathering ground is, for the most part, uncultivated moor, and of that which is enclosed only a small part is arable. The water from these gathering grounds is received into five reservoirs, of an aggregate capacity of 447,000,000 gallons. The supply is constant, and amounts to from 1,200,000 to 1,500,000 daily to 18,000 houses, and 270 works, within an area of 2,047 acres. The quantity is declared to be adequate. The water was slightly turbid when our sample was collected. It was soft and rather peaty, but wholesome and free from all evidence of previous sewage or animal contamination. (For analysis, *see* page 39.)

Blackrod. Bodmin.

Blackrod (*Lancashire*), an urban sanitary district of 3,796 inhabitants has no public waterworks; the inhabitants obtain a supply of water from private shallow wells and from streams.

Blaenavon (*Monmouthshire*), is an urban sanitary district of 10,000 inhabitants. There are here about 500 families at present supplied with water for domestic purposes by a private company on the constant system direct from the mains, at the rate of 30 gallons per head daily, from a spring in the Millstone Grit formation which flows through a covered conduit into a reservoir holding 2,000,000 gallons. The rate of charge for water is 6*s*. 6*d*. per annum for each cottage. The works cost 4,000*l*., and the supply is adequate; the water has not been analysed.

Blairgowrie (*Perthshire*), a burgh or barony of 5,252 inhabitants, is supplied partly with water from pit-wells, but chiefly from works which obtain water from *Loch Benachally*, about eight miles distant, belonging to the Duke of Athol. The waterworks belong to the Corporation. The area of the gathering ground is 1,810 acres. The area of the *loch*, which is a natural reservoir, is 131 acres, and its capacity 357,000,000 gallons. The water is said to be unpolluted before entering the *loch*, and not to require filtering. The contents of the high service tank are 46,500 gallons, it is built partly above and partly under the surrounding ground, is embanked outside up to the water level, and is covered. The area supplied—130 imperial acres—contains 700 to 800 houses. The supply is constant, and 300,000 gallons of water is delivered daily. The rate of the charge for water is 1*s*. in the pound on the rental. To prevent waste, periodical inspection is made of the taps and fittings. It is computed that the whole cost of the works will be about 5,500*l*. The water has been analysed by Dr. Stevenson Macadam, who states,—"That it is of first-class quality for domestic use; it is free from "the presence of any impurity, and the saline and organic constituents dissolved therein "are characteristic of all wholesome waters. The quantity of the ingredients in "solution is comparatively small, being decidedly below the amount found in domestic "waters generally, and in this respect the water ranks in the very highest scale, and is "practically soft. I have satisfied myself by actual experiments that the water can be "safely conveyed through *lead* service pipes, and be stored in *cisterns lined with lead*. "The iron mains should be coated with Smith's composition of enamel, so as to prevent "the water from acting upon the iron, and forming an ochry deposit therein, which "might now and again render the water of a reddish tinge. I consider that the inhabi- "tants of Blairgowrie are extremely fortunate in securing a water for domestic supply "which, alike for a beverage, for culinary purposes, and in washing operations, is "eminently suitable, and ranks in the highest class."

Blandford Forum (*Dorset*), an urban sanitary district of 4,000 inhabitants, obtains a supply of water for domestic purposes from shallow private wells; the water has not been analysed.

Blaydon-on-Tyne (*Durham*), an urban sanitary district of 3,000 inhabitants, has been at the cost of 817*l*. 11*s*. 6*d*. in conducting the water of a neighbouring spring rising in a carboniferous stratum into a reservoir capable of holding 30,000 gallons whence it is delivered to houses direct from the mains.

Bodmin (*Cornwall*), a borough of 4,672 inhabitants, is supplied partly with well water and partly from a small tributary of the *Camel* called *Butterwell*, but at a considerable distance from any habitation. The water is pumped by water-power, at the rate of 7,000 gallons per hour, into a reservoir capable of holding 250,000 gallons; and thence the supply is constant. Bodmin is also supplied with water from a number of town wells, the analyses of which are given in the table at page 70.

The water supply in Upper Bore Street is a fairly good water for all domestic purposes. It exhibits however some evidence of previous sewage or animal contamination which ought to be traced to its source; if no sewage or surface washings of manured land be found gaining access to the water this evidence may be safely disregarded. (For analysis, *see* page 48.)

If the well from which the St. Leonard's pump draws its water be 20 or more feet deep it may be safely used. It is fairly good well-water of moderate hardness, but the sample as it reached us was turbid and therefore unfit to drink without previous filtration.

The water from the Apud-le-Bore pump contains a minute quantity of organic elements, but as it exhibits evidence of very considerable *previous* sewage contamination we cannot recommend its use for drinking or culinary purposes unless the well be at least 50 feet deep. The same remarks apply but more strongly, to the St. Nicholas pump water.

PART IV. DESCRIPTIVE.

Bognor. Bolton.

The water of the Prison Lane pump (No. 119.) consists of very thoroughly purified sewage. That of the Prison Lane pump (No. 57.) is a dangerous water as it contains a large proportion of actual or unoxidized sewage. A sewer passes within 3 feet of this pump. All the waters except that from St. Nicholas pump and Prison Lane pump (No. 119.) are sufficiently soft to be used for washing.

The samples from Church Style Mouths well and Bree Shute well were clear, colourless, and palatable. The former is, in all respects, of excellent quality for all domestic purposes. It is obviously derived from deep-seated springs, and therefore the evidence of previous sewage or animal contamination which it exhibits may be safely disregarded. The sample from Bree Shute is not so good either for drinking, cooking, or washing. It falls within our category of suspicious waters, and if its use for domestic purposes be continued, great care should be taken to prevent the admission of surface soakage to the well.

Bognor (*Sussex*), an urban sanitary district of 2,811 inhabitants, has no public waterworks. The inhabitants obtain a supply of water from shallow private wells.

Bollington (*Cheshire*), an urban sanitary district of 3,666 inhabitants, has no public waterworks, its supply is derived from springs and pumps.

Bolton (*Yorkshire*), a rural sanitary district of 1,271 inhabitants, is supplied with water from shallow private wells and surface springs. The present supply is considered adequate for the requirements of the district. The water has not been analysed.

Bolton (*Lancashire*), a borough of 90,000 inhabitants, is supplied with water for domestic and manufacturing purposes by means of gravitation from a gathering ground 3,200 acres in extent on the moorlands lying four to five miles north-west of the borough. The works are now the property of the Bolton Corporation and cost 491,936*l*. The five reservoirs furnishing the supply have a united capacity of nearly 935,000,000 of gallons. The water is declared to be free from pollution before entering the reservoirs; and is not filtered. The area of the district supplied with water by the Corporation comprises, in addition to the borough, the townships of Tonge-with-Haulgh, Darcy Lever, Great Lever, Farnworth, Kearsley, Halliwell, Heaton, Rumworth, Worsley, Little Hulton, Clifton, Longworth, Entwistle, Edgeworth, Turton, Quarltor, Bradshaw, Harwood, and Breightmet. About 27,000 houses receive a supply for domestic purposes, and the water is also supplied to 628 works or manufactories for trade purposes. The volume of water delivered (unfiltered) to the district daily for trade and domestic purposes is 3,000,000 gallons. Very little water has been used for the streets, and none has been taken for flushing the sewers. Besides the reservoirs belonging to the Corporation as part of their waterworks undertakings, they have a small one in the town known as the Bolton Moor reservoir, which was constructed about the year 1842 by the Great Bolton trustees, and derived its supply from the watershed of lands forming part of what was known as Bolton Moor. This reservoir has long ceased to be used for domestic purposes, but it furnishes a supply to some of the works in the town, and also for watering the streets. The present supply is constant, direct from the mains, and abundant. The Corporation by their officers exercise vigilant supervision of the mains and service pipes to prevent waste, and enforce penalties against persons detected wasting or misusing the water.

The water collected in the Entwistle reservoir was of excellent quality, soft and free from all evidence of previous animal contamination. That collected in Sweetlove's and Heaton reservoirs, though fairly good, is inferior to the Entwistle water; it exhibits traces of anterior pollution and contains a large proportion of vegetable organic matter. All these waters contain a remarkably large proportion of ammonia. The following table shows the results of our analyses of these waters.

COMPOSITION OF WATER SUPPLIED TO BOLTON (LANCASHIRE).

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BOLTON WATER SUPPLY.												
Gathering grounds, Entwistle Reservoir, June 22, 1868.	9·37	**·297**	**·018**	·024	·010	·048	**0**	1·19	·1	5·0	5·1	Slightly turbid.
Sweetlove's Reservoir, June 24, 1868.	7·74	**·333**	**·047**	·015	·029	·088	**94**	1·14	·7	2·8	3·5	
Heaton Reservoir, June 24, 1868 -	11·84	**·355**	**·024**	·018	·044	·083	**269**	1·39	·3	5·7	6·0	

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Bonsall.

Bonsall (*Derbyshire*), an urban sanitary district of 1,200 inhabitants, obtains an abundant supply of water from springs; the water has not been analysed.

Bootle-cum-Linacre (*Lancashire*). This borough of 16,247 inhabitants is supplied by the Corporation of Liverpool with water derived from one of their pumping works, the well being sunk into the Red Sandstone formation. (*See Liverpool*, p. 368.)

Boston (*Lincolnshire*), a municipal borough containing 14,526 inhabitants, is supplied with water of fairly good quality from streams collected in a reservoir at Miningsby about 13 miles from the town. The hardness is 14°·4, the proportion of organic matter is not large, and there is no evidence of previous sewage or animal contamination. (For analysis, *see* page 52.)

Bournemouth (*Hants*), an urban sanitary district, containing a population of 5,906 in 723 houses, is supplied with water from a gathering ground on Bagshot Beds by a private company. The water flows into a covered subsidence reservoir holding 945,000 gallons, and thence on to filter beds, and is filtered first through coke, and then through another filter charged with 6 inches of fine sand, 6 inches of coarse sand, 4 inches of screened gravel, and 4 inches of coarse gravel. From the filters the water flows into a receiver whence it is pumped to a high service reservoir 2½ miles from and 170 feet above the town capable of holding 200,000 gallons; this reservoir is built above the surrounding ground, and is covered. It is hoped that the necessity to deliver unfiltered water will never arise, but the water can be turned into the service reservoir without being filtered. The supply is intermittent, but none of the mains are charged for less than five hours and some are under pressure for ten hours daily. About 150,000 gallons are delivered to the town daily; the supply is adequate. The rate of charge for water is five per cent. on the rateable value. No extra charge is made for waterclosets. The water has been analysed.

Our sample, the analysis of which will be found at page 42, was collected from a drinking fountain in Lansdowne Crescent. It was clear, soft, and wholesome water, but rather highly charged with peaty matter in solution. It exhibited no evidence of previous sewage or animal contamination, and is altogether a favourable specimen of upland surface water from the Bagshot Beds.

Bowdon (*Cheshire*), an urban sanitary district of 2,200 inhabitants, is supplied by the North Cheshire Water Company, and thus indirectly from the Manchester Corporation Waterworks. (*See Manchester*, p. 373.)

Brackley (*Northamptonshire*), a rural sanitary district of 2,154 inhabitants obtains its supply of water from shallow wells. The water from Mr. W. F. Ramsey's well and the Vicar's well was the best, but even this had been much contaminated with percolations from sewers or cesspools. It contained a considerable proportion of unoxidized animal matters, and was therefore unfit for domestic use.

The samples from the Rev. H. W. Smith's, and Messrs. Weston's and Howard's wells were still more heavily contaminated with impurities from similar sources; indeed they were so rich in nitrogenous matters as to render them capable of producing abundant crops, if employed in the irrigation of land. All the samples were excessively hard. (For analyses, *see* page 80.)

Bradford (*Yorkshire*), a borough of 145,830 inhabitants, is supplied with water on the constant system by gravitation, partly from springs, but chiefly from gathering grounds, 11,000 acres in extent, on the Millstone Grit, whence it is received into seven reservoirs with a united capacity of 885,000,000 gallons. There are three distinct services, viz., a high-level, an intermediate, and a low-level service. The works belong to the Corporation, and the daily supply to Bradford and the district is 6,500,000 gallons. The high-level service is derived from Millstone Grit only, and is therefore a soft water well adapted for manufacturing purposes. It exhibits no evidence of excremental pollution, but contains too much peaty matter in solution to be agreeable for drinking; moreover, not being filtered, it was very turbid with yellowish suspended matter. The intermediate service is also derived exclusively from the Millstone Grit, and is therefore as soft as the high-level service, but being partly spring water it is much more palatable than the latter; indeed it scarcely contains one-third as much organic matter. Unfortunately the spring water is allowed to mix with unfiltered surface water, which renders it turbid as delivered in the town. This water exhibits a moderate amount of previous animal contamination, which, however, probably belongs to the spring water, and consequently, on account of the filtration it has undergone, does not indicate any appreciable risk. The low-level service though derived chiefly from Millstone Grit, comes partly also from Limestone; it is therefore harder than the two other services, but only to a very unimportant extent (less than 1 part in 100,000). It exhibits no evidence of previous animal pollution, and is in other

PART IV. DESCRIPTIVE.

Bradford. Brechin.

respects of a quality intermediate between that of the two other services. Like them it was also, at the time of our visit, turbid with yellow suspended matter.

In addition to those situated in the neighbouring districts of Bolton, Thornton, Clayton, North Brierley, Pudsey, Eccleshill, Calverley, Idle, Tong, Gomersal, Hunsworth and Cleckheaton, there are in Bradford alone 28,000 houses and 800 works supplied for domestic and trade purposes.

The supply is constant, and direct from the mains. Large houses only, where water-closets are in use, have cisterns, and the overflow pipes from these cisterns are connected with the soil pipe. The present supply is adequate for the requirements of the town and district. The domestic rate of charge for water varies from 5 to $7\frac{1}{2}$ per cent. upon the rental, and the rate of charge for supply by meter for manufacturing purposes is from 2*d.* to 1*s.* per 1,000 gallons. In order to prevent waste an officer is specially appointed who periodically inspects the water apparatus and fittings. The waterworks have cost 1,100,000*l.*

The following table contains the results of our analyses of samples from the three services.

COMPOSITION OF WATER SUPPLIED TO BRADFORD.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
BRADFORD.												
High level service, Stubden Reservoir, October 6, 1869.	10·10	**·582**	**·079**	·004	0	·082	**0**	1·02	·9	5·5	6·4	Very turbid; yellowish.
Intermediate service, Manywell's Spring, October 6, 1869.	11·80	**·184**	**·020**	·002	·076	·098	**460**	1·29	·9	5·6	6·5	Turbid; colourless.
Low level service, Heaton Reservoir, October 6, 1869.	13·20	**·396**	**·036**	·003	·026	·064	**0**	1·25	·8	6·3	7·1	Turbid; yellowish.
Deep well in Millstone grit at Messrs. Ingham and Son's mill, October 5, 1869.	55·40	**·150**	**·005**	·028	·038	·066	290	3·23	6·8	7·3	14·1	Clear and colourless.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

At the dye works of Messrs. Ingham and Sons we had an opportunity of becoming acquainted with the water of the deep wells in the Millstone Grit beneath Bradford; these works are supplied from a well 360 feet deep, the influx of water from the first 150 feet being carefully excluded. The water from this well has, when first drawn, a very slight taste of sulphuretted hydrogen, which, however, soon passes off. Though the proportion of organic carbon is rather large, it is in other respects an excellent water, but has double the hardness of the supply furnished by the corporation. Like many other deep well waters it contains a considerable proportion of ammonia, derived in all probability from the reduction of nitrates.

Bradford (*Lancashire*), an urban sanitary district of 8,200 inhabitants, is supplied with water for domestic purposes from the works of the Manchester Corporation, see p. 373.

Braintree (*Essex*), an urban sanitary district containing a population of 4,790, is supplied with water from a well 430 feet deep sunk into the Lower London Tertiaries and chalk beneath the London Clay. The water rises to within 40 feet of the surface; it is pumped to a service tank containing 45,000 gallons placed at the top of a tower about 200 feet high. The supply is constant during the day but is shut off at night. Our analysis, given at page 103, shows this water to have the usual characteristics of that from deep wells sunk beneath the London Clay. It is clear, palatable, wholesome, and of moderate hardness, but it contains a large proportion of saline matter of which the chief constituent is common salt. The proportion of organic matter is very small.

Brechin (*Forfarshire*), a burgh of 7,959 inhabitants, is at present very insufficiently supplied with water chiefly from wells, "the water-yielding stratum lying from 8 to 14 feet beneath the surface," but partly from strictly agricultural lands at Cookston and Maisondieu. The town is rarely supplied from the river. The pipes and fountains are the property of the Commissioners. 16,000 gallons a day are supplied for domestic purposes, which is at the rate of about two gallons per head per day. In the session of 1871, the Police Commissioners, convinced of the total inadequacy of the present supply, "applied to Parliament for an Act confirming a Provisional Order by the Home Secre-
"tary, given after due inquiry, to enable them to obtain an additional supply from a

" stream in the neighbourhood; but they failed in their application. The bill passed " through the Committee of the House of Commons, but was rejected by a Committee " of the House of Lords." The Commissioners are now contemplating a scheme for bringing a copious supply from the *Burn of Mooran*, a distance of about 11 miles from Brechin. This burn is a small tributary of the *North Esk*, flowing from the east side of the hill of Wirren, one of the spurs of the Grampians. The ground drained by the stream is said to consist of clay slate and mica slate. The results of analysis of a sample of this water, given in the table on p. 36 show it to be a good, wholesome, and exceedingly soft water, well adapted for all domestic purposes, but rather too peaty to be quite pleasant to the palate.

The present water supply from Cookston and Maisondieu is a fairly good and very palatable water, of moderate hardness; it exhibits, however, considerable evidence of previous animal contamination, which appears to be due, not to sewage, but to the manure used upon the agricultural lands from which it drains. It contains only a very small proportion of organic matter. A bountiful supply of good water to the town would doubtless tend to reduce the somewhat high rate of mortality which prevails in Brechin. (For analysis of present and proposed supplies, *see* tables pages 36 and 110.)

Brecknock (*Brecknockshire*), a borough of 5,845 inhabitants, is supplied with water from a tributary of the *Terrall*, which is an affluent of the *Usk*. The intake is about 2½ miles from the source of the stream. The water is filtered through layers of sand, gravel, and broken stone. The supply is constant to 935 houses, and it is direct from the main. The works belong to the Local Board of Health and cost 11,100*l*.

Bredbury (*Cheshire*), an urban sanitary district of 3,596 inhabitants, is supplied with water from shallow wells sunk in shale and sand. The district is bounded on two sides by the rivers *Goyt* and *Tame*, both of which, but especially the latter, are in an extremely filthy condition. The well-water has not been analysed.

Bridge of Allan (*Perthshire*).—A rapidly increasing population is here supplied by a private company with water from the *Coxburn* and *Wharry*, upland streams; 350 houses are at present thus supplied on the constant system.

At the time our sample was collected the water was turbid, of a brownish tint, and altogether unfit for domestic use owing to the excessive proportion of peaty matter which it contained. It was soft, and might be used for washing, but was not fit to drink. (For analysis, *see* page 36.)

Bridgend (*Glamorganshire*), an urban sanitary district of 3,539 inhabitants, is supplied with water for domestic purposes by a private company; the works cost from 4,000*l*. to 5,000*l*. The water is obtained from a spring about 2½ miles from town; pumped into two uncovered reservoirs which are built above the surrounding ground and 30,000 gallons of water are delivered (unfiltered) direct from the mains to the district daily. The supply is not adequate. The rate of charge for water for domestic purposes is 5 per cent. on rental. The supply to water-closets if more than one in a house is 6*s*. each per annum. The water was analysed when the Act was obtained by the Company.

Bridgwater, a borough of 12,059 inhabitants, situated on both sides of the *Parrot*, near its entrance into the Bristol Channel, is without any other water supply than that which is obtained from numerous shallow wells. The western side of the town is built for the most part on a bed of gravel; the eastern side on the alluvium, here covering peat. The well from which our sample was taken is in the Market Place on the western side of the river. It is 35 feet deep, and was last cleared out 14 years ago. It supplies many coffee rooms and houses in that neighbourhood. The water consists almost entirely of the soakage from sewers and cesspools, but nearly all the animal matter was oxidised at the time our sample was taken. Its use for dietetic purposes is highly dangerous, and it is much too hard for washing. The well ought to be closed.

Bridlington (*Yorkshire*), a town and fashionable watering-place with a resident population of 6,203 inhabitants, considerably augmented during the season, is supplied with water from springs in the chalk. One of these is at the bottom of the harbour, and the water from it is conveyed to a pump on shore by an iron main; the others are situated outside the town, and are supplied in the usual manner. The harbour-spring is used for shipping, and is also preferred by the inhabitants, whose choice is confirmed by our analyses (*see* page 123). Both waters are, however, of most excellent quality for all dietetic purposes. They are clear, sparkling, and wholesome, and contain only the merest traces of organic matter. They are too hard for washing, but might be softened by Clark's process (*see* page 205.)

Bridport (*Dorset*), an urban sanitary district of 7,666 inhabitants, obtains its supply of water for domestic purposes from shallow private wells, except a very small portion of the district near the harbour, to which the water is conveyed in pipes from a spring. The water has not been analysed.

PART IV. DESCRIPTIVE.

Brierfield. Bristol.

Brierfield (*Lancashire*), an urban sanitary district of 3,100 inhabitants, is partly supplied with water from the wells of the Nelson Urban Sanitary Authority, and partly from springs. The water has not been analysed.

Brighouse (*Yorkshire*), a Local Board of Health district of 7,000 inhabitants, is supplied with water from waterworks belonging to the Corporation of Halifax. (*See Halifax*, p. 344.) The supply is constant and direct from the mains, and 46,000 gallons of water are delivered daily to 700 houses and 12 manufactories, distributed over an area of 403 acres. The volume is at present adequate for the requirements of the town and district. The rate of charge is 1*s*. per 1,000 gallons for trade purposes, for domestic purposes it varies from 7*s*. 6*d*. per annum for houses of from 5*l*. to 7*l*., to 3*l*. 10*s*. for houses of from 91*l*. to 100*l*. gross annual value. No special steps are taken to prevent waste. The water mains and laying the same cost 2,300*l*.

Brighton (*Sussex*), a municipal borough and fashionable watering-place with a resident population of 103,758 persons, greatly augmented during the season, is supplied with water from two deep wells sunk into the Chalk. The Lewes Road well is 100 feet deep, and the water rises to within 25 feet of the surface. The well at Goldstone Bottom is 160 feet deep, and 10 large fissures open into it; one of these is believed to deliver 500 gallons per minute. Both waters are clear, brilliant, palatable, and wholesome. They contain only a minute amount of organic matter, and are of excellent quality for all dietetic purposes. They are too hard for washing, but might be softened by Clark's process (*see* page 205) without losing either their palatability or wholesomeness. For analyses *see* page 99.

The workhouse and its schools are supplied with water of even better quality from a well 1,285 feet deep sunk through the Chalk and Gault into the Lower Greensand. In addition to all the good qualities of the Brighton supply this water is soft, and is therefore useful for washing and cleaning purposes. The supply is however inadequate, owing to an accident in sinking the borehole. For analysis, *see* page 99.

Bristol and Clifton with their 182,552 inhabitants are supplied with water by a private company with a capital of 611,275*l*. The water flows from springs at Chewton Mendip on the side of the Mendip Hills and from a spring at Barrow; the former in the New Red Sandstone with conglomerate, the last in the Mountain Limestone and conglomerate. Water is also obtained when required by pumping from wells at Chelvey, sunk in the New Red Sandstone, two of them 40 feet deep, and a third 196 feet deep, 200 yards from any inhabited place. The whole of the borough of Bristol and portions of surrounding parishes are thus served on the constant system and the supply is declared to be adequate. About three and a half millions of gallons are thus sent daily into the district, a large quantity being used not only in sugar-refining, brewing, and other trade establishments, but in suburban houses, where the gardens make a large demand. We are informed that no fewer than 1,300 establishments are thus supplied by water, the charge being from 6*d*. to 1*s*. 6*d*. per 1,000 gallons according to the quantity consumed. There are two storage reservoirs at Barrow, four miles from Bristol, together 66½ acres in extent, capable of holding 332 millions of gallons; and there are five service reservoirs, together holding 11½ millions of gallons, of which three are covered. Bristol is also to a considerable extent supplied with water from various public and private wells.

The following table contains the results of our analyses of two samples of the Company's water and of a sample of spring water supplying a large drinking fountain in All Saints' Lane:

COMPOSITION OF WATER SUPPLIED TO BRISTOL.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Bristol waterworks supply from main in Clifton Down Hotel, February 8, 1869.	27·24	**·171**	**·025**	·001	·164	·190	**1,330**	1·30	20·2	4·6	24·8	Slightly turbid. Palatable.
Bristol waterworks supply from main at Netham Chemical Works, February 8, 1869.	28·66	**·160**	**·017**	·001	·203	·221	**1,720**	1·30	18·5	5·9	24·4	Slightly turbid. Palatable.
Spring in All Saints' Lane, February 8, 1869.	127·28	**·186**	**·030**	·001	4·712	4·743	**46,810**	7·10	32·2	34·7	66·9	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Taking into consideration that the water supplied by the Company is derived from springs and deep wells the quality is not so good as might be expected, and the analyses indicate some admixture of surface water. Nevertheless both samples are of fairly good quality and the evidence of previous animal contamination which they exhibited is not of such moment as it would have been if the water came from a river or stream. The water is very hard and would be much improved, in this and other respects, by the application to it of Clark's softening process. (*See* page 205.)

The water from the spring in All Saint's Lane consists largely of the soakage from sewers and cesspools. It is a dangerous water and quite unfit for all domestic purposes; nevertheless it is much used for drinking in the neighbourhood, and by the small trading vessels which lie on the "Welsh Back."

Bromley (*Kent*), an urban sanitary district of 10,674 inhabitants, is supplied with water for domestic purposes by the Kent Waterworks Company (*see* p. 274).

Brynmawr (*Brecon*), an urban sanitary district of 7,000 inhabitants, is supplied with water for domestic purposes from a gathering ground of peaty moorland. The water flows into an impounding reservoir; the maximum time the water is stored is two months and the minimum three weeks. The water is filtered through a medium of 2 feet of bolders, 1 foot of gravel, and 6 inches of siliceous sand in layers of 6 inches, and about 80,000 gallons of water is delivered daily. Unfiltered water is delivered to the districts where the filter beds are being cleansed every fourth week. The supply is direct from the mains and is adequate to the requirements of the district. The rate of charge for water is 5 per cent. on the rental. No extra charge is made for supply to waterclosets; the water has been analysed.

Buckingham, the county town of Buckinghamshire, of 3,703 inhabitants, has no public waterworks.

Bulkington (*Warwickshire*), an urban sanitary district of 1,653 inhabitants, has no public waterworks; the supply of water is obtained from private wells.

Burley (*Yorkshire*), an urban sanitary district of 2,271 inhabitants, is supplied with water for domestic purposes from springs at Rumbold Moor on the Millstone Grit formation; the water flows direct from springs unfiltered into storage and service reservoirs, and thence through pipes to consumers. The storage reservoir contains 4,000,000 gallons and the service reservoir 120,000 gallons; both are uncovered, the supply is constant, direct from the mains, and, at present, about 40,000 gallons of water is delivered daily. An extra charge is made for the supply to waterclosets. The water has not been analysed.

Burnley (*Lancashire*), a borough of 40,900 inhabitants, is supplied with water from springs and gathering grounds by gravitation. The gathering ground exceeds 1,000 acres, and the service reservoirs will hold about 54,450,000 gallons. The water is said to be somewhat polluted by sheep kept by farmers on the gathering grounds, and is not filtered. The area of the district served is 1,731 acres, within which 9,070 houses and 200 manufactories and works are supplied on the constant system. The probable daily quantity for both is 1,000,000 gallons. Very few houses within the borough have cisterns attached, and the supply is generally direct from the mains. Where cisterns are attached and pan waterclosets used, there is an overflow pipe connected with the soil pipe, but many sanitary closets are used without any pan, and with a branch direct from the main. The rate of charge for water is 1*s.* in the pound on the rental; this includes the supply to one closet to each house; a charge is made of 12*s.* per annum for each additional closet. The water has been analysed. The waterworks have cost 840,000*l.*

Burslem (*Staffordshire*), a Local Board of Health district of 25,562 inhabitants, is supplied with water by the Staffordshire Potteries Waterworks Company. (*See Staffordshire Potteries Waterworks*, p. 397.)

Burwarton (*Shropshire*) is about to be supplied with spring water from one of the following sources which we have investigated:—

No. 1 was of excellent quality for drinking and all domestic purposes.

No. 2 was almost equally good, and, as it was derived from a spring, the moderate evidence of previous animal contamination which it exhibited may be safely disregarded.

No. 3 contained even less organic matter than the other samples, but was nearly twice as hard and therefore not so well adapted for washing.

The samples are placed in the order of merit in the analytical table, but any village might consider itself fortunate in being supplied with any one of these waters. (For analyses, *see* page 108.)

Bury and District (*Lancashire*), is provided with water by the Bury Improvement Commissioners at a total cost of 387,371*l.*; from a gathering ground of 3,675 acres, all high or mountain land, either pasture or uncultivated, and on the Millstone Grit formation.

PART IV. DESCRIPTIVE.

Bury St. Edmunds. Cambridge.

It is received into six reservoirs of an aggregate capacity of 625,000,000 gallons, from which it is delivered unfiltered at the rate of 1,500,000 gallons daily direct from the mains, on the constant system, to 18,724 houses and 547 works and manufactories. Our analysis of this water is given at page 48.

The water is soft and would be of excellent quality if it were protected from some animal contamination which analysis reveals, and the nature of which is indicated in the following sentence from the return made to us by Mr. William Harper, Clerk to the Bury Urban Sanitary Authority:—"There is a little drainage from a mill and some "houses falling into the Holden Wood reservoir." Such an influx of sewage into a reservoir supplying a large community ought to be strictly prohibited.

Bury St. Edmunds (*Suffolk*), a municipal borough of 14,928 inhabitants, is supplied with water from deep wells sunk into the Chalk. The water is clear, brilliant, palatable, and wholesome, and well adapted for all dietetic purposes. It is too hard for washing, but might be cheaply softened without losing any of its good qualities by Clark's process as described at page 205. (For analyses, *see* page 99.)

Buxton (*Derbyshire*), an urban sanitary district and sanitarium containing a population of 3,717, is supplied with water for domestic purposes partly from the *Watford Brook* and partly from springs on Coombs Moss. The water flows into three reservoirs of an aggregate capacity of 1,900,000 gallons, built in the ground and uncovered. The water is not filtered; the supply is constant and direct from the mains, and 200,000 gallons of water during the season, but out of season only 140,000 gallons, are delivered to the district daily; the supply is adequate, but the mains and branch pipes are too small to distribute it. The rate of charge is 5 per cent. on the rateable value; the supply to one watercloset in each house is allowed, but 5*s*. per annum is charged for every additional closet. Our analysis proves the water to be of very indifferent quality, being turbid and of a brownish yellow colour from peaty matter in solution. It is soft, and therefore useful for washing, but it is quite unfit for dietetic purposes, and ought not to be supplied to a sanatarium like Buxton. (For analyses, *see* page 40.)

Caerleon (*Monmouthshire*), an urban sanitary district of 1,600 inhabitants, obtains its supply of water for domestic purposes from springs and shallow wells. The water has not been analysed.

Calverley (*Yorkshire*), an urban sanitary district of 3,211 inhabitants, is supplied with water from springs and wells. Waterworks to supply only a portion of the township were established in 1856, and belong to W. C. C. Thornhill, Esq., and for the other part of the district in 1866, and belong to the Calverley District Waterworks Company. This latter Company purchases the water it supplies from the Bradford Corporation Waterworks. (*See Bradford*, p. 321.) The rate of charge varies from 6*s*. to 24*s*. per year on houses of the annual rent of 12*l*. and upwards.

Cambridge.—This city, of 30,074 inhabitants, is supplied with water by works belonging to a private company with a capital of 50,000*l*. The water, obtained from the Chalk near the base of the hills at Cherry Hinton, flows from the spring head by an underground brick conduit, and afterwards by iron pipes with turned and bored joints to the pumping station, whence it is pumped to two covered service reservoirs, at the top of the hill, built with brickwork in cement and blue lias lime partly above the surrounding ground, and capable of holding together 1,000,000 gallons. The engines pump 500,000 gallons a day during six days of the week at a cost of 870*l*. a year, including labour, fuel, and materials. The supply is constant. 385,000 gallons are delivered daily to 5,680 houses and 150 business premises, and 63,000 gallons are delivered for trade purposes, and 14,000 gallons daily for street watering. The water is not filtered.

Our analysis given below shows this water to be of most excellent quality for dietetic purposes. It is clear, sparkling, and palatable, and contains only the merest traces of organic matter. As it is spring water the evidence of previous animal contamination which it exhibits may be safely disregarded. The great drawback to this water is its hardness, but this could be remedied by the application to it of Clark's simple process. (*See* page 205.)

Besides the waterworks supply there is a considerable volume of water brought into Cambridge by Hobson's conduit which delivers it into the gutters of some of the streets and into a large drinking fountain in the Market Place. This water is not of unimpeachable quality, as it exhibits evidence of rather a large amount of previous animal contamination. It is however clear and palatable, and contains only a moderate amount of organic matter. It is much harder than the waterworks supply and is quite useless for washing.

Good water may be obtained in and around Cambridge by sinking into the Greensand through a superficial layer of Clay. The water often overflows from these wells, as for

Part IV. Descriptive.

Canterbury. Cardiff.

instance at the running pump in the garden of St. John's College, and the well in the Old Library Court of King's College. The following table contains the results of analysis of several samples of such water. They are all of good quality, but they sometimes contain traces of sulphuretted hydrogen when first drawn, which renders them unpalatable, but the odour and taste soon disappear after the water has been exposed to the air for a few minutes. The water from the Artesian well at Harston, nearly 200 feet deep, four miles from Cambridge, was clear, soft, and nearly free from organic matter. It is altogether a water of most excellent quality for dietetic and all domestic purposes.

Composition of Potable Waters in and around Cambridge.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Cambridge.												
Chalk spring at Cherry Hinton, March 5, 1873.	31·02	**·042**	**·006**	·001	·595	·602	5,640	1·90	17·6	6·3	23·9	Clear.
Same water as supplied by Water Company to the Bull Hotel, March 5, 1873.	33·96	**·051**	**·013**	·001	·644	·658	6,130	1·90	15·5	9·6	25·1	Do.
Fountain in Market Place supplied by Hobson's Conduit, April 10, 1873.	38·12	**·130**	**·021**	·002	·717	·740	**6,870**	2·90	17·6	10·3	27·9	Do.
Deep well running over in Old Library Court of King's College, March 5, 1873.	79·20	**·073**	**·030**	·068	0	·086	240	7·60	17·4	23·3	40·7	Slightly turbid.
Running pump from Greensand in garden of St. John's College, March 5, 1873.	75·52	**·069**	**·021**	·074	0	·082	290	7·60	21·7	18·3	40·0	Turbid.
Artesian well, 200 feet deep, at Harston, March 13, 1873.	28·24	**·028**	**·003**	·050	0	·044	90	1·90	1·1	2·5	3·6	Clear.
Bore hole into Lower Greensand at Oak Tree Coprolite Works, Barton, March 5, 1873.	72·04	**·104**	**·017**	·040	·492	·542	4,930	7·60	18·3	26·0	44·3	Slightly turbid.
Pump at roadside near to Old Barton Toll-gate, March 5, 1873.	85·96	**·079**	**·027**	·074	0	·088	290	8·50	22·9	31·5	54·4	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Canterbury (*Kent*), a city of 20,962 inhabitants, is supplied with water by a private company with a capital of 40,000*l.* The water is derived from two bore-holes into the Chalk at a point above the city and at a distance from any houses. The bore-holes are capable of yielding 60,000 gallons hourly, but the requirements of the city at present amount to only 110,000 gallons daily. The supply is on the constant system to 1,372 houses and 41 factories. The supply is abundant and practically inexhaustible. Proper fittings have been adopted to prevent waste, which have proved eminently successful, and in consequence of this the Company has been able to rescind the rule requiring extra payment for waterclosets. The hard water from the well is here submitted to Clark's softening process (*see* page 205) before distribution to consumers. The quality of this water is unsurpassed by that of any other in Great Britain. Our analyses given at pages 99 and 209, show it to be soft, clear, transparent, palatable, and free from every trace of organic matter. As it is derived from a deep well, the evidence of previous animal contamination which it exhibits, may be entirely disregarded. It is perfectly wholesome and well fitted for dietetic and all domestic purposes.

Canton (*Glamorganshire*), an urban sanitary district of 7,061 inhabitants, is supplied with water chiefly by the Cardiff Waterworks Company and also by several private shallow wells. The water supplied by the Cardiff Waterworks Company is pumped from the river *Ely* into a reservoir situated near the north-eastern boundary of the district; the supply from both sources is adequate, but that obtained from the shallow wells is very objectionable.

Cardiff (*Glamorganshire*), a borough of 39,536 inhabitants, is supplied with water for domestic purposes by the Cardiff Waterworks Company, whose works have cost 116,500*l.* The supply is obtained partly from the river *Ely*, but chiefly from a gathering ground of 2,600 acres on drift overlying the Old Red Sandstone; 1,300 acres of this gathering ground is arable, 900 pasture, and 400 woodland and waste. The gathering ground is manured with stable and farmyard dung and super-phosphates, little or no privy stuff is used thereon. There are four reservoirs, the impounding reservoir contains 65,000,000

PART IV. DESCRIPTIVE.

Cartworth. Castleford.

gallons, and the three service reservoirs contain in the aggregate 4,600,000; these latter are built partially above the surrounding ground and are uncovered; the water obtained from gathering ground is filtered through a medium of sand and gravel 6 feet in thickness; the filter beds require to be cleansed every week, sometimes as often as every other day. No unfiltered water is now delivered; this practice has been discontinued for about four years. The supply of water is constant, direct from the mains, and 1,600,000 gallons are delivered to the town and district daily to 9,800 houses, docks, railways and works for domestic, trade, and sanitary purposes. The supply is adequate. The rate of charge for water is from 5 to 6 per cent. on the rental, and this includes the supply to one watercloset to each house.

Two samples of the water supplied by the Cardiff Waterworks Company were forwarded to us for analysis. In most respects these samples resembled each other very closely, but No. 2 contained a much larger proportion of organic matter than No. 1, and although this organic matter was of exclusively vegetable origin it imparted to the water a peaty flavour, rendering it unpleasant for drinking, and liable to cause diarrhœa.

Sample No. 1 was quite wholesome, and of excellent quality for drinking, cooking, and all domestic purposes except washing, for which it was too hard. Neither sample exhibited any evidence of previous sewage or animal contamination.

The sample of the water supply which we collected in the town was hard, but otherwise of fairly good quality. It was clear and palatable.

A stream called the *Feeder* runs through Cardiff into the harbour, and is much used for the supply of shipping with potable water. It is very highly charged with organic matter, some of which is of animal origin, and it exhibits evidence of recent sewage contamination. It is moderately soft, and might be used for washing, but it is decidedly unwholesome, and altogether unfit for the supply of shipping. The following table contains the analyses of these waters:—

COMPOSITION OF POTABLE WATER AT CARDIFF.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Spring at waterworks, No. 1, Oct. 30, 1873.	25·40	**·240**	**·033**	0	0	·033	**0**	1·60	9·2	12·3	21·5	Clear and palatable.
Ditto No. 2, Ditto.	24·92	**·409**	**·069**	0	0	·069	**0**	1·60	12·4	10·3	22·7	Slightly turbid.
Water supply, Oct. 18, 1872	23·50	**·212**	**·031**	0	·034	·065	**20**	1·40	7·1	12·9	20·0	Clear and palatable.
The *Feeder* at Herbert Street Bridge, Oct. 16, 1872.	15·46	**·694**	**·123**	·030	·037	·185	**300**	1·00	·8	7·0	7·8	Turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Carlisle (*Cumberland*), an urban sanitary district of 31,049 inhabitants, is supplied with potable water from the *Eden* by works belonging to the sanitary authority. The river and tributaries are polluted by the sewage of villages situate above the intake. The water flows into a reservoir capable of holding 843,750 gallons, built of brick-work below the surrounding ground, and uncovered, it is there impounded for a maximum period of 48 hours, and from thence flows on to three filter beds of an united area of 2,300 yards, and through a filtering medium of 18 inches of sand, 18 inches of fine gravel, and 18 inches of coarse gravel; the filter beds are cleansed once a month, and about three-quarters of an inch in depth of the sand is removed at each cleansing, this sand is not used again. Provision is made for taking water direct from the impounding reservoir, if necessary, during the cleansing of the filter beds, but this is not often required as the service reservoir holds *nearly* sufficient water for use during this operation. The water is pumped from the filters to the service reservoir at an annual cost of 1,000*l.*, including labour, fuel, and materials, and 1,061,000 gallons are delivered daily, on the constant system, direct from the mains, to 5,000 houses and 20 manufactories distributed over an area of 1,526 acres. The supply is stated to be abundant. Waste of water is being prevented by the gradual introduction of Guest and Chrimes' and Anderson's single valve water-closet cisterns, Guest and Chrimes' double valve cistern, and by Kennedy's water waste preventer.

Cartworth (*Yorkshire*), an urban sanitary district of 2,077 inhabitants, obtains a supply of water for domestic purposes from springs, the water from which is conveyed by pipes into a service tank and thence distributed to 45 houses direct from the mains; the supply is stated to be adequate. The water has not been analysed.

Castleford. Chipping Wycombe.

Castleford (*Yorkshire*), an urban sanitary district, with a population of 6,268, is supplied with water from a well sunk into the Coal Measures, whence it is pumped into three settling tanks of an aggregate capacity of 66,000 gallons. The water is delivered after eight hours subsidence at the rate of 66,000 gallons daily. The water is somewhat chalybeate, and becomes slightly turbid on exposure to the air, from the deposition of oxide of iron. It also contains a remarkably large proportion of common salt. Its chalybeate character would be entirely destroyed by the addition of lime to it, in the proportion of 1 lb. to each 1,000 gallons. The lime should be first slaked and converted into so called "milk "of lime," or better still into "lime water," before it is added to the chalybeate water. Allowed afterwards to repose for 12 hours in a reservoir, the water would become perfectly clear, a considerable proportion of the organic matter which it contains would be removed, and the hardness would be materially reduced. We collected a sample of water on the 20th September 1869 whilst the well was in an unfinished condition, but the above remarks apply to a sample which was collected on the 2nd March 1871.

The sample of water taken from the same well on Dec. 15, 1871, contained, like the preceding, a moderate amount of organic matter, but the already large proportion of saline matters was nearly doubled, and the proportion of common salt almost exactly so. It contained also a largely increased proportion of ammonia, which indicated that the town sewage found its way to some extent into the well or water-bearing stratum.

The waters from the New Trial Wells, Nos. 2 and 3, are free from all evidence of previous sewage or animal contamination and do not contain an unusual proportion of common salt. They also contain only a moderate proportion of organic elements, but that from No. 2 is chalybeate, and both samples are so excessively hard as to be useless for washing. (For analyses, *see* page 91.)

Cheltenham (*Gloucestershire*).—The town of Cheltenham, embracing the outlying districts of Charlton Kings, Prestbury, and Leckhampton, or a total area of probably nine square miles, and a population exceeding 44,519, is for the most part supplied with water by the Cheltenham Waterworks Company, who derive it chiefly from a number of springs at Leckhampton, beneath the western slopes of the Cotswold range. These springs are thrown out from below the sand beds of the Lower Oolite by the Upper Lias Clay, on which the Cotswolds there lie. The water is in every case received at the spring head into a bricked well, and thence conveyed in pipes to the reservoirs at Leckhampton and Hulett's Hill, capable together of holding 35,000,000 of gallons. It is passed through a small filter bed into these reservoirs, which are 250 feet above the general level of the town. About 300,000 gallons are delivered daily into the town from these reservoirs. The cisterns of more than 4,000 houses are supplied with it on the intermittent system, the water being shut off during the night, special mains being, however, kept always charged for use in case of fire. It is estimated that a population of 28,000 thus receives it at the rate of not more than 12 gallons each daily, so small a consumption being attributed partly to the fact that there is hardly any trade consumption of water in the town and partly to the careful and constant inspection of the house fittings that is maintained by the company's officers. The water is palatable, wholesome, and well suited for all dietetic purposes. It is also much softer than most spring waters from the same source. (For analysis, *see* page 117.) In addition to the springs, which are the principal source of the company's water, there is a pumping station at Sandford mead on the outskirts of the town, and an area of five or six acres in the sand and gravel bed, beneath which are a series of horizontal conduits dug at the depth of 20 feet, which are connected with the pump well, and are thus capable of yielding a considerable supplementary supply in case the spring water should fail. There has not, however, been occasion to make use of this supplementary source for more than three months during the past three years. In addition to the 4,000 houses which receive the Cheltenham company's water, there is a considerable number, especially in the northern and older part of the town, built upon this same sand bed, whose inhabitants, upwards of 10,000, are dependent on their own shallow wells for water. We have taken a sample from the pump in the yard of the Plough Hotel as fairly representing the character of the water which is derived from these wells. The analysis given at page 79 shows this water to consist chiefly of soakage from sewers and cesspools. Though clear and palatable it is a dangerous water for dietetic purposes, and its extreme hardness makes it quite useless for washing.

Chipping Wycombe (*Buckinghamshire*), an urban sanitary district of 5,681 inhabitants, obtains its supply of water for domestic purposes from shallow wells and springs; waterworks are about to be established at High Wycombe by a private company.

Cheshunt (*Hertfordshire*), an urban sanitary district of 7,518 inhabitants, obtains its supply of water for domestic purposes from springs with the exception of a few houses which are supplied by the New River Company (*see* p. 276). The water of the springs has not been analysed.

Chester (*Cheshire*).—This city, of 35,232 inhabitants, is supplied with water by a private company with a capital of 62,000*l.* The water is pumped direct from the *Dee* at a point just above the city, and 40 or 50 miles below the source. The river receives some drainage from the towns and villages on its banks, and those of its tributaries, and also some refuse from oil works and mines. The water is pumped into a subsidence reservoir capable of holding 596,000 gallons, and thence delivered on to six filters together about three-quarters of an acre in extent, whence it flows into a "pure water tank" holding 413,000 gallons, the walls of which are formed of clay puddle, faced inside and outside with Buckley fire-bricks, set in hydraulic mortar, and arched over with similar materials. The water is pumped from thence to a high service "iron" tank on a tower of sufficient height to force water over the highest building in the city. The volume pumped daily amounts to one and a quarter millions of gallons for the supply of 6,000 houses, and 70,000 gallons for the supply of 30 works or manufactories. The water is filtered through a medium consisting of a layer of red sandstone burrs 20 inches, gravel 18 inches, and sand 24 inches. The average rate of filtration is 151·5 gallons per hour per superficial yard. The cleansing of the filters depends upon the state of the river. Sometimes they require cleansing every three or four days, at other times they do not for as many weeks. The sand removed at each cleansing is washed, and the refuse passed into the canal; the company have the power of pumping unfiltered water direct from the river into the mains if necessary, but the necessity has not arisen except on two occasions during the past 12 years, and then it was owing to accidents against which provision has been made for the future.

Our analysis, given at page 46, shows that this water is moderately hard, and that it contains a larger proportion of organic matter than is desirable for dietetic purposes. There was no evidence of previous sewage or animal contamination, but the sample collected by us was turbid and not pleasant to drink.

Chesterfield (*Derbyshire*), a borough of 11,427 inhabitants, is supplied from waterworks belonging to a private company, who receive the water from an upland gathering ground on the Millstone Grit 1,335 acres in extent, of which not more than five per cent. is arable, the remainder being pasture and woodland; two-thirds of the whole being manured by cattle and sheep droppings and by farmyard manure. The water is received into two impounding reservoirs, together 43 acres in extent, and 156 millions of gallons in capacity. Thence it flows unfiltered into a service reservoir containing 6,000,000 gallons, and is thence distributed at the rate of 700,000 gallons daily, for the supply of about 5,000 houses and 50 factories, distributed over an area of about 18,000 acres. The supply is generally constant and direct from the mains, and it is declared to be adequate.

Our analysis given at page 53 shows this water to be considerably contaminated with organic matter, some of which is of animal origin. It would be much improved in palatability by efficient sand filtration, but would still continue to be of suspicious quality. The hardness is moderate.

Childwall (*Lancashire*), an urban sanitary district of 174 inhabitants, obtains its supply of water for domestic purposes partly from the works of the Corporation of Liverpool and partly from wells sunk in the New Red Sandstone.

Chiswick (*Middlesex*), an urban sanitary district of 10,000 inhabitants, is supplied with water for domestic purposes by the West Middlesex and Grand Junction Waterworks Companies. (*See* p. 270.)

Chorley (*Cheshire*), an urban sanitary district of 1,643 inhabitants, is supplied with water partly from the works of the Stockport Water Company and partly from shallow private wells.

Chorley (*Lancashire*), an urban sanitary district, with a population of 16,864, is supplied by gravitation with water by waterworks costing about 40,000*l.*, belonging to the Liverpool Corporation, from reservoirs situate in Chorley and Anglezark, with a capacity of 72,000,000 gallons. The water is said to be unpolluted before entering the reservoirs, and is filtered through broken stone, gravel, and sand. The high service reservoir is built partially above ground, and is not covered. The area of the district supplied exceeds 1,000 acres, including about 3,000 houses and 50 manufactories. The supply is constant, and 400,000 to 500,000 gallons of water are delivered daily for all purposes. The supply is direct from the mains, and is said to be adequate. No special means are taken to prevent waste.

This is a good soft mountain water, but so strongly impregnated with peaty matter as to interfere with its palatability. It exhibits no evidence whatever of previous sewage or animal contamination. (For analysis, *see* page 39.)

Christchurch (*Hants*), a rural sanitary district of 15,415 inhabitants, obtains its supply of potable water from shallow wells. Samples of water from two of these wells were analysed in our laboratory, and the result, given on page 87, shows it to consist chiefly of the soakage from sewers and cesspools.

Christchurch (*Monmouthshire*), an urban sanitary district of 2,408 inhabitants, obtains its supply of water chiefly from the Newport Waterworks Company, and also from private shallow wells.

Clayton (*Yorkshire*), an urban sanitary district of 4,071 inhabitants, obtains its supply of potable water from springs and shallow wells.

Clayton-le-Moors (*Lancashire*).—This urban sanitary district of 5,390 inhabitants is supplied with water from gathering grounds of 250 acres, and reservoirs capable of holding upwards of 50,000,000 gallons. There are 603 houses supplied for domestic purposes, and the number is increasing daily. The supply is constant and direct from the mains. The rate of charge is about 7½ per cent. on the rental; with a minimum charge of 6*s*. 6*d*. per annum. The cost of works has been about 15,000*l*. to the present time.

Clayton, West (*Yorkshire*), an urban sanitary district of 1,531 inhabitants, is supplied with water partly from shallow wells (from this source only in wet weather), but chiefly, by permission of the manufacturers in the district, from four wells and bore-holes sunk on their premises to obtain water for trade and manufacturing purposes.

Cleator Moor (*Cumberland*), an urban sanitary district of 6,000 inhabitants, obtains its supply of water from a gathering ground of about 300 acres on the Skiddaw Slate on the Lower Silurian, about 6 acres of which is peat. The water is conveyed by stoneware pipes into two uncovered reservoirs containing 4,000,000 gallons, built partly above the surrounding ground, and 168,000 gallons of unfiltered water is delivered daily on the constant system, direct from the mains, to 1,150 houses and 12 iron ore pits and blast furnaces for domestic and trade purposes. The supply is not adequate to the requirements of the district. The rate of charge for water is 12*s*. 8*d*. each house (including supply to one watercloset) per annum. The water has not been analysed.

Cleckheaton (*Yorkshire*), an urban sanitary district of 6,583 inhabitants, is supplied with water from the Bradford Corporation Waterworks. The supply is constant and direct from the mains, and 60,000 gallons are delivered daily to 1,000 houses and 120 manufactories, distributed over an area of 1,755 acres. The supply is adequate for the district. The average rate of charge is 10⅝*d*. per 1,000 gallons. To prevent waste a very vigilant inspection is made of the taps and fittings, and persons detected wilfully wasting water are summoned, and on conviction a fine of 5*l*. is inflicted. The waterworks cost 12,000*l*. (*See Bradford*, p. 321.)

Clitheroe (*Lancashire*), a borough of 8,208 inhabitants, obtains water from springs on the moors. Nearly all the houses in the town are supplied. Some manufactories are only partially so. The principal streets are watered daily during the summer and in dry weather. The supply is constant, and direct from the mains, and is said to be adequate.

Congleton (*Cheshire*), a borough, of 11,344 inhabitants, is dependent exclusively upon shallow wells for its water supply. The most esteemed of these is the pump at the Star Inn. We were informed that the well supplying this pump is only three yards deep, that it is affected by drainage when a neighbouring sewer gets stopped up, and that it is sometimes so turbid as to require straining through muslin. It is not, therefore, surprising to find analytical evidence of 10,456 parts of previous sewage contamination in this water. It is not creditable to the authorities that this town should still derive its supply of water from such dangerous sources. The water of Astbury Street well contained urine and fresh sewage. It is an exceedingly dangerous water, and the well ought to be immediately closed. The water from the pump in Wallworth's Yard, the Town pump, and the pump in Garden Street, exhibited strong evidence of sewage contamination, and was not desirable for domestic use. The samples from the pump at Foundry Bank, and the Tanhouse well, were also suspicious waters, but their quality was somewhat better than that of the last category. Finally the water of the Silver Street well and of the pump at Stonehouse Green was of fairly good quality, and might be safely used for domestic purposes. All the samples were too hard for washing. (For analyses, *see* page 76.)

Cornholme (*Lancashire and Yorkshire*), an urban sanitary district of 3,500 inhabitants, obtains water from springs, and each owner thus supplies his own property from this source. The water is not filtered, and has not been analysed.

Cowes, East (*Isle of Wight*), an urban sanitary district of 2,088 inhabitants, is supplied with water from a gathering ground of an area of about 300 acres, 150 acres of which is

PART IV. DESCRIPTIVE.

Crieff. Cupar.

arable and the remainder pasture. Stable, farmyard, and artificial manure are used on the gathering ground; the water flows into a reservoir containing 96,000 gallons built below the surrounding ground and uncovered; this supply is direct from the mains but quite inadequate, especially in the summer months, when the mains are only charged for three hours once a week. The result of our analysis of this water, given on p. 51, shows it to be of very indifferent quality.

Crieff (*Perthshire*), a burgh of 4,153 inhabitants, is supplied partly with water for domestic purposes from natural springs and twenty-eight private wells, 5 feet in diameter, sunk in the Old Red Sandstone to a depth of 20 feet, and also from *Loch Turret*, a natural *loch* or reservoir situated six miles from Crieff, at an elevation of 875 feet above the town. About 36,000 cubic feet of water is supplied from this latter source daily. Dr. Stevenson Macadam, who has analysed the water, says—"it is of "first-class quality for domestic use; it contains a minimum amount of saline matter "and the hardness is so little as to entitle the water to be regarded as soft; the organic "matter is of vegetable origin, and is perfectly harmless in its nature;" and he is of opinion "that alike as a beverage, for cooking purposes, and in washing operations, the "water from *Loch Turret* is of the best quality, and second to none in the kingdom. "Special experiments were made to determine if the water had the power of acting on "lead, and it was found that the liquid was not affected in quality by being stored in "cisterns lined with lead, or by being conveyed through lead pipes."

Crompton (*Lancashire*), an urban sanitary district of 7,302 inhabitants, is supplied with water either by the Corporation of Oldham from their reservoir at Piethorn, direct from mains which are laid through the district, or from shallow wells.

Some of the houses have cisterns to store water gathered from the roofs. In cases where the Oldham Corporation supply the water for domestic purposes they charge 6*l*. 10*s*. per cent. per annum on the gross rental of the dwelling-houses. (*See Oldham*, p. 381.)

Croston (*Lancashire*), an urban sanitary district of 1,518 inhabitants, receives its water supply from private wells and the river. The wells are sunk in gravel to depths varying from 10 to 40 yards.

Cumberworth and Cumberworth Half, Upper Division, (*Yorkshire*), an urban sanitary district of 1,461 inhabitants, obtains its supply of water partly from springs and partly from small rivulets, and the consumers carry it from these sources in cans, tubs, and barrels. The water has not been analysed.

Cupar (*Fifeshire*), a burgh of 5,105 inhabitants, is supplied chiefly with water from numerous public and private wells. There are no waterworks. The Local Authorities suspect that the wells are partly supplied by percolations from the sewers, and the Medical Officer of Health, Dr. J. R. Mackie, states (4th Report) that he considers "the "quantity of chlorides and nitrates found in the well water a very strong proof of sewage "contamination. Many water-closets are connected with cesspools which are emptied "once a year, and some, the watery portion, of the contents percolate into the adjoining "ground."

Our analyses demonstrate that the wells enumerated in the analytical table at page 74, are largely fed by percolations from sewers and cesspools. The only one that can be used with any degree of safety is the Burnside well. The Kirkgate well furnishes an especially dangerous water, containing, as it does, a large proportion of actual or unoxidized sewage matter. It ought to be at once closed. Except that taken from the Kirkgate well, all the waters were clear, colourless, bright, sparkling, and palatable, but taking their origin into consideration, it is not surprising to find that a town, so supplied with potable water, has a high death rate, ranging from 19·5 to 27·5 per 1,000.

The well water has also been analysed by Dr. Stevenson Macadam, who says, "I am "decidedly of opinion that the water from all the wells in Cupar, from samples supplied "to me, is more or less unwholesome, and ought not to be employed for domestic pur-"poses. At ordinary seasons the impurities in the water may not exert a positively "poisonous influence over the inhabitants of Cupar, but I am confident that the daily "use of such water will predispose members of the community to attacks of illness, "especially those of a choleraic nature. I would therefore recommend, in the present "state of the country, that the wells referred to be closed, as far at least as the employ-"ment of the water for drinking and cooking purposes, and that better water be introduced, "by carts or otherwise, for the more pressing dietary wants of the community." The late Professor Penny said: "The analysis of this water shows that it is unhealthy water, "that it contains a notable quantity of dissolved ingredients, and the presence of nitrates "clearly proves that it contains the products of organic matter of an animal nature. "The total amount of organic matter in this water is comparatively small; but, in con-"sequence of its objectionable animal character and origin, I am clearly of opinion that "it is a very objectionable water for habitual domestic and dietetic use. It is also one

PART IV. DESCRIPTIVE. Cwm dû. Darrington.

"of those waters which are very liable to be more seriously polluted at certain seasons "of the year, so that although unobjectionable at one time, there is always a risk that "it may at any other time be highly noxious and unwholesome. I would therefore "recommend that its use should be discontinued." Speaking of other wells in this burgh, he said: "These waters contain so large a proportion of organic and saline "matters, and the quantity of nitrates is so abundant that they are manifestly un-"suitable for habitual domestic and dietetic use, and I have no hesitation in urging that "the wells should be immediately closed."

Cwm dû (*Glamorganshire*), an urban sanitary district of 6,000 inhabitants, obtains its supply of water from springs; it is conveyed by stoneware pipes on which stand-pipes are placed in the streets, cisterns are also placed in different situations to collect the spring water. The inhabitants have to fetch the water from the stand-pipes and cisterns. The supply is said to be adequate to the requirements by the district, except in drought. The water has been analysed.

Dalkeith (*Edinburghshire*), a burgh of 6,386 inhabitants, derives its water supply from three sources, two of which furnish about 30,000 gallons per day; the water is of average quality and of $8\frac{1}{2}°$ and 10° of hardness respectively. The third source furnishes about 20,000 gallons per day; it is of 20° of hardness. Besides these sources, there are also four or five shallow wells, yielding very hard water, but as these, from their position, must be more or less contaminated, the authorities are of opinion that they ought to be shut up. The whole supply of the town amounts to about 50,000 gallons per day, giving an average of about $8\frac{1}{2}$ gallons per head, or, including the suburbs of Eskbank, to which the town's water has been recently introduced, a daily supply of only $7\frac{1}{2}$ gallons per head, which is obviously quite inadequate to the wants of the population. In consequence of the limited supply the water is shut off from the town, from 9 p.m. to 5 a.m. every night, except at one public well; and many houses with waterclosets, but not furnished with cisterns, are wholly without water for eight hours out of every twenty-four, which can scarcely fail to cause the admission of noxious gases into the houses. An Act was recently obtained by the Mid-Lothian Water Company conferring power by which this and other Mid-Lothian towns may be provided with water of excellent quality from one of the head waters of the *Tweed*—the *Manor*, the analysis of which is given at page 37.

Darlington (*Durham*), a borough of 300,000 inhabitants is supplied with water from the river *Tees*. The pumping stations and filter beds are at Tees Cottage, distant two miles from the town. The reservoirs are at Bushell Hill, distant a mile from the town. A volume of about 1,500,000 gallons is pumped from the river daily. The water is filtered through a medium composed of pebbles, gravel, and sand, 5 feet 10 inches in thickness. After filtration it is pumped to a high service reservoir capable of holding 1,000,000 gallons. It is partially built under the surrounding ground and is not covered. The area of district supplied is 3,350 acres, on which there are 4,000 houses and 75 manufactories. The supply is constant, and 1,000,000 gallons for domestic use and 500,000 for trade purposes are delivered to the district daily. The supply is direct from the mains, and the present quantity is said to be adequate for the requirements of the town and district. The rate of charge for water for domestic purposes varies from 1*s*. per quarter on houses of a yearly rent not exceeding 3*l*., up to 10*s*. per quarter for houses not exceeding a yearly rent of 52*l*. a year. For manufacturing purposes, the supply is by meter, the charge varies from 1*s*. per 1,000 gallons for a quarterly consumption not exceeding 30,000 gallons to 3*d*. per 1,000 gallons for a consumption exceeding 3,200,000 gallons. In order to prevent waste an inspector is appointed who periodically inspects the water taps and fittings. The waterworks have cost 60,822*l*. 16*s*. 3*d*.

The water is, to some extent, polluted above the intake, by the sewage of Barnard Castle,—a town of about 4,000 inhabitants,—and by that of the houses and villages between Darlington and Barnard Castle. To this circumstance is probably due the somewhat high proportions of organic carbon and organic nitrogen revealed by our analysis. (*See* page 44.) In other respects the water is of good quality and but moderately hard. Previously to the establishment of these works the town was supplied with water from wells; the authorities state that "an inexhaustible supply of excellent water has been introduced "into our streets, yards, and houses, which has not only changed the aspect of the town, "but has necessarily proved a source of inestimable benefit to the health and comfort to "the inhabitants." The Board of Health will doubtless use its best endeavours to preserve this bountiful supply from being fouled by the filth of the villages situated on the higher reaches of the river. It is also desirable that wells, like that supplying the Blackwell pump (for analysis, *see* page 76) near the centre of the town, should be closed. They are fed almost entirely by soakage from sewers.

Darrington (*Yorkshire*), a village of 512 inhabitants, is supplied with water from shallow wells. The water from the "well in Darrington village, Dec. 22, 1871," consisted chiefly of sewage which had percolated through a few feet of porous earth. It was entirely unfit for human consumption, indeed, it was so rich in nitrogenous compounds derived from decayed animal matters as to render it valuable for fertilization. Land properly irrigated with this water would yield very abundant crops. The water was excessively hard and therefore useless for washing.

The sample from George Fisher's well had been largely contaminated with sewage or animal matter, and although nearly the whole of this had been oxidised and converted into innocuous mineral matters yet sufficient traces remained to render its use for domestic purposes dangerous to health. It was excessively hard and therefore useless for washing. (For analyses, *see* page 74.)

Darton (*Yorkshire*), an urban sanitary district of 5,197 inhabitants, is supplied with potable water partly from the Barnsley Waterworks and partly from shallow wells. The water of the wells has not been analysed.

Daventry (*Northamptonshire*), a borough of 4,051 inhabitants, has a water supply from the Borough Hill spring which flows into a small tank, and is "forwarded twice a week " to part of the town, and thrice to another part for two hours on each occasion, the " inhabitants storing it in tanks on their premises." But the bulk of the people depend for water upon shallow public wells. The present supply is very inadequate.

Dawlish (*Devonshire*), an urban sanitary district of 3,622 inhabitants, is supplied with water from shallow wells. The spring water which it is proposed to bring to Dawlish is of excellent quality, clear, colourless and palatable, and containing but a moderate amount of organic matter. It exhibits no trace of previous animal contamination, and is well fitted for dietetic and all domestic purposes including washing. (For analysis, *see* page 116.)

Deal (*Kent*), a borough of 8,000 inhabitants, is supplied with water from a deep well sunk into the chalk. There are, however, also numerous private and public shallow wells. We have analysed samples of the water supply and of two of the public wells.

The samples of town water supply were of most excellent quality for drinking and cooking, but the water was too hard for washing. Being a deep well water the moderate amount of evidence of previous animal contamination which it exhibited casts no reflection on its salubrity. If submitted to Clark's softening process this water would lose none of its excellence or palatability, and it would then be well adapted for washing and cleaning. (For analyses, *see* page 99.)

The water from the public pump in the Fish Market consisted chiefly of soakage from sewers or cesspools. The large quantities of ammonia and of chlorine which it contained show that a considerable proportion of urine gains access to it. As is usually the case in such wells, much of the sewage matter was oxidised, but there was still left a marked proportion of actual organic matter of disgusting origin. Although the water was palatable and tolerably clear, its use is very dangerous to the public health, and the well ought to be at once closed. It was much too hard for use in washing, and its manure value was about six-sevenths of that of average London sewage.

The water from the well in the Market Place was frightfully polluted by sewage. It was entirely unfit for domestic purposes, and the well should be closed in the interests of the public health. It was also too hard for washing. It was well adapted for the irrigation of crops, its manure value being fully equal to that of average London sewage. (For analyses, *see* page 83.)

Denbigh (*Denbighshire*), an urban sanitary district of 6,322 inhabitants, is supplied with water for domestic purposes by a private company whose works cost 10,400*l*. The water flows from springs issuing from the shale overlying the carboniferous system through an open conduit into an open service reservoir containing about 5,000,000 gallons, and from thence 50,000 gallons of water is delivered to the district daily direct from the mains for domestic and trade purposes. The supply is not adequate to the requirements of the district. The rate of charge for water is 5 per cent. on the rateable value.

Denby (*Yorkshire*), an urban sanitary district of 1,600 inhabitants, obtains a supply of water for domestic purposes from springs in a sparsely populated district.

Denholm Gate (*Yorkshire*), an urban sanitary district of 3,469 inhabitants, is supplied with water partly from springs collected in reservoirs near the town. The district is within the limits and supply of the Bradford Corporation Waterworks, but no water has been obtained from that source.

Denton (*Lancashire*), an urban sanitary district of 5,117 inhabitants, is supplied with water by the waterworks of the Corporation of Manchester. About 900 houses and 40 works and manufactories are supplied, but none is used for watering streets and flushing sewers. The supply is constant, and direct from the mains, and is ample. Rate of charge, 8*s*. per year for cottages. For larger houses 5*l*. per cent. on the amount assessed to the poor's rate. To prevent waste, vigilant inspection is made by the servants of the Manchester Corporation. For the quality of this water see *Manchester*, page 362.

Dewsbury. Duckingfield.

Dewsbury (*Yorkshire*), a borough of 24,773 inhabitants, is supplied with water for domestic purposes from reservoirs connected with gathering grounds 2,000 acres in extent. The works belong to the Corporations of Dewsbury and Batley, and the Local Board of Health of Heckmondwike. The reservoirs are situated at Dunford Bridge, the storage reservoirs are at Broadstone in the parish of Kirkbolton. The district supplied—1,468 statute acres—contains 4,000 houses, and 130 works and manufactories. The supply is constant, and direct from the mains, and about 750,000 gallons are daily delivered to the district,—a quantity which is said to be quite inadequate for the requirements of the town and district, and power has been obtained enabling these towns to bring in a considerable additional volume of water of similar quality (*see Batley*, p. 310.) No steps are taken to prevent waste. The waterworks have cost Dewsbury 97,529*l.* Previously to the establishment of the waterworks the town was supplied from the river, wells, and rainfall.

Dodworth (*Yorkshire*), an urban sanitary district of 2,747 inhabitants, is supplied with water for domestic purposes from the works of the Corporation of Barnsley.

Doncaster (*Yorkshire*).—This borough of 18,768 inhabitants is supplied with water chiefly from the river *Don*. We have analysed two samples of water from sources considered to be available for the supply of the town. The water from the spring in Ravenfield Park was of excellent quality, clear, sparkling, colourless, palatable, of moderate hardness, and well suited for all domestic purposes. Being spring water the previous animal contamination which it exhibited may be safely disregarded. It would require neither filtration nor subsidence before delivery. (For analysis, *see* page 125.) The stream in Ravenfield Park above the fish ponds was much inferior in quality to the spring water, nevertheless, if no sewage or other similar polluting matter gained access to it, the water, though rather hard, was fairly good for town supply, but would require filtration before delivery. (For analysis, *see* page 53.) We presume that much of the latter water is derived from springs, and that it is these which furnish the evidence of previous animal contamination, in which case this evidence may be safely neglected. The water at present supplied from the *Don* is polluted by the sewage of Sheffield, Rotherham, and Barnsley, and its use for dietetic purposes is dangerous.

Dorchester (*Dorset*), an urban sanitary district of 6,915 inhabitants, is supplied with potable water from works belonging to the Corporation which cost 7,500*l.* The water is obtained from a well in a sparsely populated district, sunk in the chalk, the shaft of which is 7 feet in diameter and 135 feet deep, with two 6-inch bore-holes in addition, one 60 feet and the other 30 feet. The water is pumped into a service tank containing about 300,000 gallons, built partially above the surrounding ground and uncovered. About 440,000 gallons of water is pumped and delivered daily direct from the mains, for domestic and trade purposes. The present supply is said to be adequate. The rate of charge for water is 10*d.* in the pound. The water has not been analysed.

Dover (*Kent*), a borough and urban sanitary district of 28,270 inhabitants, is supplied with water from works belonging to the Corporation which cost 44,000*l.* The water is obtained from wells in a sparsely populated district, sunk in the chalk, the shafts of which are 5 feet 6 inches in diameter and 226 feet deep. The water is pumped into service reservoirs, and from thence about 1,200,000 gallons of water is delivered to the district daily for trade and domestic purposes. Samples of this water have been analysed in the laboratory of the Commission, and the result given on p. 99 shows it to be an excellent water for dietetic purposes, but it is too hard for washing.

Drighlington (*Yorkshire*), an urban sanitary district of 5,000 inhabitants, obtains water partly from shallow wells and brooks, and partly from the waterworks of the Corporation of Bradford.

Dronfield (*Derbyshire*), an urban sanitary district of 2,454 inhabitants, obtains a supply of water for domestic purposes from public and private shallow wells. The supply is inadequate, and the sanitary authority are in treaty with the Chesterfield Waterworks Company, and hope to be supplied with potable water from that source before the end of 1875.

Droylsden (*Lancashire*), an urban sanitary district of 6,768 inhabitants, receives its water supply from the Manchester Corporation Waterworks direct from the mains on the constant system. The rate of charge is 8*s.* per year for cottages. For larger houses according to the amount at which they are assessed to the poor rate. (*See Manchester*, p. 373.)

Dukinfield (*Cheshire*), an urban sanitary district of 14,085 inhabitants, is supplied with water from the Dukinfield waterworks, established about the year 1839, and belonging jointly to the Corporation of Stalybridge and the Dukinfield Board of Health. The water is obtained from a gathering ground about 280 acres in extent, consisting of high arable lands in the immediate neighbourhood, and is said to be slightly polluted at certain times of the year by stable manure. The water is not filtered. There are

Part IV. **Descriptive.**

Dumbarton. Dundee.

four reservoirs with an aggregate capacity of 48,209,850 gallons. There are two high-service reservoirs; which, together, contain 25,506,900 gallons; they are partially built above the surrounding ground, and neither of them is covered; the water is not pumped. The district supplied is about 500 statute acres containing 3,000 houses and about 10 manufactories. The supply is constant and about 90,000 gallons are delivered daily. No sewers are flushed from the waterworks. The water is supplied direct from the mains To meet the inadequate supply, the Stalybridge Corporation and the Dukinfield Local Board of Health have been furnished by the Manchester Corporation with about 21,000,000 gallons per year, for the last 12 years. Cottages are supplied at the rate of 6*s.* and 9*s.* per year, each house of a better class at rates varying from 12*s.* to 20*s.* per year. Waterclosets are charged 10*s.* per year; baths 5*s.*; and public-houses and beer-houses, from 20*s.* to 40*s.* per year each. The only step taken to prevent waste is a periodical inspection of fittings. The entire cost of the Dukinfield waterworks was 39,980*l.*, the portion paid by the Dukinfield Local Board of Health was 23,800*l.* The former supply was from wells.

Dumbarton, a burgh of 11,423 inhabitants, derives its supply of potable water from springs and streams. The works were established in 1859, and belong to the Town Council. One of the reservoirs is situated about two miles from the centre of the town, and the other, in course of formation, is about four miles distant. The gathering ground comprises about 300 acres. The supply is constant and by gravitation. The two reservoirs contain 51,000,000 gallons or 204 days' supply. The district supplied—350 acres in extent—contains 700 houses and 16 factories. 250,000 gallons are delivered daily. The water is filtered through 1 foot of broken whinstone, 9 inches of gravel, 1½ inch of perforated tiles, and 2 feet of fine sand. In most cases the supply is direct from the mains, but where there are waterclosets, or bath rooms, the houses are generally furnished with cisterns, and the overflow from these is connected with the soil pipe and thence with the sewer. When the new reservoir is completed the supply will be adequate for the requirements of the town. Previously to the establishment of the waterworks the town was supplied with water from wells and also from the river *Leven*. The improved supply is stated to have had a beneficial effect upon the health of the inhabitants. The rate of charge is 6*d.* in the pound for domestic supply, and 6*d.* in the pound a compulsory rate. In order to prevent waste a superintendent is appointed to make frequent inspection of the works and apparatus. The total cost of the waterworks is 15,000*l.*

Our analysis, given at page 33, shows the water to be clear but of a yellowish colour owing to the presence of a large proportion of peaty matter in solution. The evil occasionally arising from excess of peaty matter in water is described at page 34, under the heading "*Organic Elements.*" With this drawback the water is of good quality. It is entirely free from all evidence of animal pollution, and it is very soft and well adapted for washing.

Dundee, a burgh of 119,141 inhabitants, is supplied with water chiefly from 3,064 acres of gathering grounds at Monikie, about eight miles from the town. The storage reservoirs are said to be capable of holding 661,024,572 gallons. The water is not filtered, but is passed through a series of wire cloth strainers, and is decanted from one reservoir to another. The town service reservoirs are so placed as to command a supply to the greater portion of the town, and the pipe connections are so made that an extra pressure can be had for special purposes from Gazie well, the upper end of the iron mains, and where the aqueduct discharges itself. The high service reservoir, which is at Stob's Muir, is partially built above the surrounding ground and covered over. The area of the district is 5,987 acres containing 6,379 houses, and 136 works and manufactories, to which there is a daily delivery of upwards of 3,000,000 gallons. The supply is constant and direct from the mains; but houses having waterclosets are supplied from cisterns. The rate of charge is 1*s.* 6*d.* in the pound for houses, besides a public rate of 1*d.* in the pound over all kinds of property. Careful inspection is made of taps and fittings in order to prevent waste. The waterworks have cost 49,000*l.* and perpetual annuities of 14,315*l.*

The Monikie water as delivered in Dundee is not a desirable supply for domestic purposes; it exhibits some, though slight, evidence of excremental pollution, and it was, on both occasions when we took a sample, turbid and of a brownish yellow colour from the presence of an excessive proportion of peaty matter. It was found to contain a very large proportion of organic matter, but its hardness was moderate. Even this indifferent water, however, was a great improvement upon that in use before its introduction in 1845, for we are informed that "before the establishment of the waterworks, the town "was supplied by water from wells and rain-water collected in barrels and tanks. The "improved water supply has had a beneficial effect upon the health of the inhabitants. "Stone in the bladder was prevalent in Dundee before the introduction of the present "water supply, but it is now very rare" (For analysis, *see* page 48.)

The town is also partially supplied from a great number of private wells, the water from which is principally used for domestic purposes. The Lady Well spring at the foot of Bonnet Hill is one of the most celebrated of these, and supplies several town wells. Its water is bright, sparkling, and piquant to the palate, but our analysis, the results of which are given at page 110, shows that it is nothing but very thoroughly purified sewage, to the products of decomposition of which it owes its pleasant flavour. At a depth of several hundred feet beneath Dundee, there is a water-bearing stratum yielding a beverage of excellent quality, which is, however, at present used exclusively for manufacturing purposes. At the Bow Bridge Works, there is an artesian well sunk into this stratum to a depth of 238 feet, the water in which rises to within four feet of the surface. At the time of our inspection on the 14th September 1870, the pump drawing from this well had been at work only for 10 days, and the water was still turbid from the presence of minutely divided mineral matter. This water contained only a very small proportion of organic matter; it was colourless, palatable, and admirably adapted for drinking, but rather too hard for washing. The moderate amount of previous sewage or animal contamination which it exhibited may be safely disregarded in the water from a well of this great depth. The noxious constituents of sewage being almost certainly not dissolved but in suspension, the chance of their penetration through such a thickness of strata is infinitely small. (For analysis, *see* page 89.)

Not only is the quality of the water supplied to Dundee for domestic purposes far from good, but the quantity is quite inadequate to the wants of the town; and, accordingly, the Police Commissioners have obtained powers to bring in an additional supply from the Loch of Lintrathen, which is situated upon high ground about 16 miles from the town. It is very desirable that the Monikie water should be abandoned altogether for domestic purposes, the gathering ground is yearly becoming more cultivated, whilst a railway has been opened through the centre of it, giving easy access to town manure. The water might still be used for watering streets and flushing sewers, and, perhaps, for some manufacturing purposes.

Dunfermline (*Fifeshire*), a city and royal burgh of 14,963 inhabitants, is supplied with water by gravitation from springs and surface drainage, stored in reservoirs. The water-works were established in 1850, and belong to the Corporation. The area of the gathering ground is about 350 acres. There are two reservoirs situated at Craigluscar about 24 acres in area, and containing about 56,000,000 gallons. The water is said to be unpolluted before entering the reservoirs; it is filtered through a medium of sand and gravel 2½ feet in depth, and flows into the high service reservoir containing 200,000 gallons, which is built entirely above the surrounding ground, and is covered. The supply is constant, except in dry weather, to about 2,000 houses and 30 factories, and about 300,000 gallons of water are delivered daily. The houses are furnished partly with cisterns, and the overflow pipe is generally connected with the soil pipe from the waterclosets. The present supply is inadequate in droughty seasons. The rate of charge for water is 1*s.* 3*d.* in the pound on rents of 5*l.* and under, 1*s.* 6*d.* in the pound on rents above 5*l.*, and 6*d.* per 1,000 gallons to works. To prevent waste, general supervision is made of the taps and fittings. The waterworks cost 30,000*l.* The water has been analysed by Dr. Stevenson Macadam, who says, "The Craigluscar water is "an excellent town water. It contains a comparatively small portion of saline matter, "a minute amount of organic matter, which is however of vegetable or plant origin, "and is practically harmless. I have no doubt that this water is first class for cooking "purposes and washing operations. I can confidently recommend it as superior water "for household and manufacturing use."

Dunkeld (*Perthshire*), a burgh of 783 inhabitants, has enjoyed for the past five years a supply of water brought by the Duke of Athole from a burn in the hills about three miles distant. Our analysis of this water (*see* page 36), shows it to be of excellent quality; it was, on the occasion of our inspection, clear, colourless, and palatable. It contained a moderate proportion of vegetable organic matter, was very soft, and exhibited no evidence of previous animal contamination, it was, therefore, admirably adapted for drinking and all domestic uses.

Dunstable (*Bedfordshire*), a borough of 4,558 inhabitants, including a district of about 3 square miles, is supplied by the Dunstable Gas and Water Company, who obtain water from a well 7 feet in diameter and 60 feet deep sunk into the chalk with a 12-inch bore-hole 90 feet in addition thereto, whence it is pumped by a pair of 8-horse power engines. The water is not filtered, and 25,000 gallons are daily delivered, direct from the mains, on the constant system, for domestic and trade purposes. The supply is said to be adequate. The water has been analysed by Dr. Letheby, who says, "The results of "analysis show that the Dunstable water is very much like that supplied to London "from the deep chalk wells of the Kent Waterworks Company, and, although a little "hard, is nevertheless regarded as an excellent water for domestic purposes."

PART IV. DESCRIPTIVE.

Durham. Eastbourne.

Durham, containing 14,833 inhabitants, is supplied with water both from private wells, and, on the constant system, from the river *Wear*. The pumping station of the Durham Waterworks Company at Shincliffe is about one mile and a half above the city where the reservoir capable of holding 800,000 gallons is situated, and about 480,000 gallons are thus delivered daily to 3,700 houses and 80 manufactories and other works. The water is subjected to filtration before it leaves the works, but the operation was not being quite satisfactorily performed when we took our sample at the County Hotel, as the water was slightly turbid. The river is stated to be polluted by "hush"—the débris from the washing floors of lead works, and by sewage from Bishop Auckland and other small towns higher up the stream; there was, however, but small evidence of this pollution in our sample, which shows the water to have been, on that occasion, of good quality, considering its source (for analysis *see* page, 44); indeed a comparison of the water, before and after filtration, indicates a much greater improvement than is usually effected by that process, which is perhaps accounted for by the circumstance that the filters are of the unusual depth of nine feet. The filtering medium is composed of a layer of broken grit stones two feet deep, fine layers of course and fine gravel, each six inches deep, and a layer of clean washed river sand four feet six inches deep. Although we do not consider that water taken from a river subject to direct sewage contamination is a safe supply for a town, yet it is greatly to be preferred to that of the shallow wells of the city, if the well of the Medical Officer be, as described to us, one of the best. This water, though clear and sparkling, is shown by our analysis (*see* page 73) to be little else but the percolations from sewers and cesspits; 100,000 lbs. of it contain the inorganic remains of as much excrementitious matter as is present in 62,360 lbs. of London sewage, whilst the large proportion of chlorine which it contains, shows that a good deal of urine mixes with it; indeed the pump is in a back yard close to a privy and ashpit, and the waste water from the pump trough passes down a sewer-grid close to the pump. With such arrangements, it is impossible to prevent the surrounding earth from becoming soaked with excrementitious matters, and although, in this case, the well itself is a few yards distant, under an adjoining dining room, the soakage obviously gains free access to its water.

Dunbar (*Haddingtonshire*), a royal burgh of 3,320 inhabitants, is supplied with water obtained from *Spott Spring*. The waterworks were established in 1765, and belong to the Corporation. The reservoirs are situated at Spott and at Dunbar. The high service reservoir contains 10,000 gallons, is situated 10 feet above ground, and is covered. There are about 180 houses supplied with water. The supply is only furnished from three to four hours daily, and the volume supplied is from two to three gallons per head. The majority of the houses have cisterns, the overflow pipe from which is connected with the soil pipe from the watercloset. The present quantity is totally inadequate for the requirements of the town and district; an extension of the supply is being arranged for, and it is proposed to obtain it from springs on the Lammermoor Hills. The rate of charge for water is 5*d*. in the pound on the rental, in addition to a progressive rate of 3*d*. in the pound for private pipes; commencing at 3*s*. 3*d*. on 3*l*. rentals. To prevent waste extraordinary vigilance is used by the police water inspector, who cautions the inhabitants against waste. The waterworks cost 3,800*l*. The suburb of Belhaven is supplied with water from private wells. Dr. Stevenson Macadam speaks very unfavourably of the water from the wells, characterising it as "unwholesome, and "ought to be prohibited. The habitual use of it for domestic supply must be attended "with considerable risk to health;" and recommending the introduction of purer water.

East Acton (*Middlesex*), an urban sanitary district of 3,151 inhabitants, is supplied with water by the Grand Junction Metropolitan Water Company. (For analysis of water, *see* page 271.) Shallow wells are also used. The water from one of these consisted chiefly of oxidized sewage or soakage from cesspools. The oxidation at the time the sample was taken was tolerably complete, so that but little animal organic matter remained; nevertheless, there is always imminent risk that such water may become dangerously contaminated, and it ought therefore never to be used for dietetic purposes. (For analysis, *see* page 88.)

Eastbourne (*Sussex*), an urban sanitary district of 10,500 inhabitants, is supplied with water from a well 10 feet in diameter and 100 feet deep sunk into the Lower Greensand, whence it is pumped by engines of together 75 horse-power, to two service reservoirs holding respectively 1,000,000 and 2,000,000 gallons of water. The reservoirs are lined with bricks and flints in cement on concrete and are quite water-tight. About 500,000 gallons of water are supplied daily, on the constant system, to 1,600 houses over an area of 5,000 acres.

The results of analysis given at page 97, prove this water to be palatable, and nearly free from organic matter. It is an excellent water for dietetic purposes, but is too hard for washing. By the application to it of Clark's softening process (*see* page 205) its hardness would be reduced to one third of its present amount. Being a deep well water the moderate evidence of previous animal contamination which it exhibits may be safely disregarded.

East Molesey. Edinburgh.

East Molesey (*Surrey*), an urban sanitary district of 2,408 inhabitants, is supplied with water for domestic purposes by the Lambeth Water Company (*see* Lambeth Water Company, p. 273).

Eastwood (*Nottinghamshire*).—This township of 2,540 inhabitants obtains its supply of water chiefly from shallow wells. The water here had all the characteristics of a moderately deep spring water of great hardness. It exhibited some evidence of previous sewage or animal contamination, but if inspection showed that this pollution did not occur between the springs and reservoir, it might be safely disregarded and the water considered wholesome. It was too hard to be used for washing. (For analysis, *see* page 126.)

Eccleshill (*Yorkshire*), an urban sanitary district of 5,621 inhabitants, is supplied with water for domestic purposes by the Bradford Corporation Waterworks. The supply is constant except during a long drought in summer, and direct from the mains, and 50,000 gallons of water are delivered daily, for domestic and trade purposes, to 993 houses and 21 manufactories, distributed over an area of 1,200 acres, and is adequate at present for the requirements of the district. The rate of charge for domestic purposes is 2*s.* 2*d.* per quarter and upwards according to the annual value of the houses; and for trade purposes from 7*d.* to 1*s.* 6*d.* per 3,000 gallons according to the quantity of water consumed. To prevent waste frequent inspection is made of the taps and fittings. The waterworks cost 3,800*l.* (*See Bradford,* p. 321.)

Edmonton (*Middlesex*), an urban sanitary district of 13,859 inhabitants, obtains a supply of potable water from shallow private wells. Arrangements are being made with the New River Company to supply a portion of the district from their works (*see* New River Company, p. 276). The water of the shallow wells has not been analysed

Edinburgh.—This city is supplied with water from springs and streams impounded on pastoral lands. The waterworks were established in 1819, and belong to the Edinburgh and District Water Trustees appointed by the corporations of Edinburgh, Leith, and Portobello, under the Edinburgh and District Water Company's Act of 1869. Two reservoirs and springs are situated on the south side, and three reservoirs and springs on the north side of the Pentland Hills. The reservoirs are constructed at Glencorse, Loganlee, Clubbiedean, Torduff, and Bonally. These reservoirs contain in the aggregate 665,350,000 gallons. Besides supplying the city, they provide 280 cubic feet per minute of compensation water for mills. The water is filtered before delivery in Edinburgh. The covered service reservoir is situated on the Castle Hill, and holds 1,500,000 gallons. The district supplied—4,480 acres—contains 41,686 tenements, and 5,047 shops, and 300 to 400 factories. The supply is intermittent and is at the rate of about 550 cubic feet per minute for all purposes, 14 per cent. being used for manufactories. In dry seasons no water can be spared, either for flushing sewers or for watering streets. The houses are supplied with cisterns, and the overflow pipe is generally connected with the soil pipe of the watercloset. Waste is prevented by constant inspection by officers of the corporation. Previously to the establishment of the waterworks, the city was supplied from the springs of Swanston and Comiston, the maximum yield of which is 54 cubic feet per minute, and the minimum 10½ cubic feet per minute. The improved water supply is stated to have had a most beneficial effect upon the health of the inhabitants.

The water from the various sources above mentioned arrives at Edinburgh in four distinct pipes, named respectively the Crawley pipe, the Swanston pipe, the Collinton pipe, and the Comiston pipe. The Crawley pipe conveys, in addition to spring water, the filtered supply from the Glencorse and Loganlee reservoirs; the Swanston pipe transmits the water of the Bonally reservoirs; the Collinton pipe conveys the supply from the Torduff and Clubbiedean reservoirs; whilst the Comiston pipe is the conduit for the water of the Comiston springs. We have analysed samples of water flowing from these four pipes, and the results are given in the following table. We have also examined samples of water taken from the Loganlee and Torduff reservoirs as well as from the Harperrig reservoir, which last is only used for compensation to mill-owners. The Crawley water, as delivered in Edinburgh was, on both occasions when we examined it analytically, of fairly good quality for all domestic purposes. It contained, on April 6th, 1870, a smaller proportion of organic matter than it did on September 22nd, 1868, owing probably to its being mixed, at the former date, with a larger proportion of spring water, to which is no doubt due the slight amount of previous animal contamination exhibited by it on that occasion. It was, however, at the later date, turbid as it flowed from the pipe into the service reservoir on the Castle Hill. The Swanston water appears to vary in quality between very wide limits. On September 22nd, 1868, it contained a large proportion of peaty matter, which rendered it somewhat bitter to the taste, whilst its hardness was about equal to that of the Crawley water. On April 6th, 1870, it was

PART IV. DESCRIPTIVE.

Edinburgh.

clear, colourless, and palatable and contained but a very minute quantity of organic matter; it exhibited, however, a small amount of evidence of previous animal contamination, and was markedly harder than on the previous occasion, in fact, it had now all the characters of a spring water of excellent quality. The Collinton water also varies in quality in like manner. On September 22nd, 1868, it was a fairly good impounded surface water, suitable for all domestic purposes, but containing a slightly larger proportion of organic matter than that present in the Crawley water. On April 6th, 1870, the pipe was delivering an excellent spring water, containing only a very minute proportion of organic matter. The hardness on both days was moderate and nearly equal. On the two occasions when our samples were collected, the Comiston pipe was delivering spring water containing, on September 22nd, 1868, a moderate proportion of organic matter, and on April 6th a very minute proportion of this impurity. The water has nearly double the hardness of the Crawley supply. On both occasions it exhibited strong evidence of previous animal contamination, which led us to visit the locality in which the springs take their rise. We found that this water was collected from eight different springs rising in highly cultivated land. The water from these springs is conducted into a common tank, whence it is discharged into the Comiston pipe. Three pipes known as the Hare, the Fox, and the Plover, respectively, deliver the water from these springs into the tank. The Hare pipe delivers the water of one spring only, which rose in the midst of a potato field. The Fox pipe brings the produce of four springs, which rose, at the time of our visit, in fields of barley and potatoes. The water delivered by the Plover pipe is derived from three springs, one of them situated near a farmstead and cottages, and the others in wheat and turnip fields. We collected a separate sample from each of the three pipes and submitted them to the test for previous animal contamination. As might be anticipated from their surroundings, all these samples exhibited strong evidence of previous animal contamination.

In connexion with the Edinburgh water supply, the following table contains the analytical results yielded by the water impounded in the Loganlee, Harperrig, and Torduff reservoirs. These results show how very inferior is the quality of the surface drainage from the slopes of the Pentland Hills; and, when compared with those yielded by the samples collected from the Crawley and Collinton pipes, they also demonstrate the great improvement which is effected in such water by filtration. The sample drawn from the Loganlee reservoir was brown, slightly turbid, and undrinkable on account of the large proportion of peaty matter which it contained.

The present supply is totally inadequate for the requirements of the district, and application was made to Parliament in the session of 1871 for powers to bring in a bountiful supply from St. Mary's Loch in the *Tweed* basin. The bill passed the House of Commons, but was rejected by a Committee of the House of Lords. The composition of this and other waters available for the supply of Edinburgh, in the *Tweed* basin, is given in the following analytical table. The *South Esk*, near Gladhouse Mill, has also been proposed as a source of additional supply, but our analysis of this water, the results of which are contained in the table below, shows that it is not fit for this purdose. It contains an excessive proportion of peaty matter in solution, which gives it a brown tinge and imparts to it a bitter taste.

A comparatively small volume of water is obtained from private wells in Edinburgh, but this is stated to be used exclusively by brewers. The sample which we collected from a well near Holyrood Palace was greatly contaminated with sewage; it contained also a notable quantity of arsenic. If used in brewing, it is fortunate that this water is weil boiled before it is consumed as a beverage.

COMPOSITION OF WATER SUPPLIED TO OR AVAILABLE FOR EDINBURGH.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
EDINBURGH. *Present Supply.*												
Water supply from Crawley, September 22, 1868.	11·28	**·187**	**·031**	·001	0	·032	**0**	1·04	·7	5·3	6·0	Clear.
Water supply from Crawley, April 6, 1870.	9·94	**·162**	**·012**	0	·053	·065	**210**	1·06	1·2	5·2	6·4	Turbid.
Water supply from Swanston, September 22, 1868.	12·70	**·378**	**·059**	·001	0	·060	**0**	1·39	0	6·2	6·2	Clear.

COMPOSITION OF WATER SUPPLIED TO OR AVAILABLE FOR EDINBURGH—*continued.*

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
Water supply from Swanston, April 6, 1870.	13·48	·067	·007	0	·062	·069	300	1·26	4·5	5·6	10·1	Clear.
Water supply from Colinton, September 22, 1868.	14·10	·203	·042	0	0	·042	0	·89	4·4	4·8	9·2	„
Water supply from Colinton, April 6, 1870.	13·60	·053	·009	·001	0	·010	0	·95	5·0	4·8	9·8	„
Water supply from Comiston, September 22, 1868.	22·58	·085	·017	·001	·744	·762	7,130	1·89	2·8	7·6	10·4	Turbid.
Water supply from Comiston, April 6, 1870.	22·94	·029	·010	·001	·852	·863	8,210	2·00	3·5	8·1	11·6	Clear.
Water from well near Holyrood Palace, April 16, 1869.	92·54	·326	·175	·056	·950	1·171	9,640	7·95	27·9	8·3	36·2	Arsenic = ·01.
Loganlee reservoir, Pentland Hills, June 13, 1871.	8·88	·638	·034	·005	0	·038	0	·95	0	4·7	4·7	Brown and slightly turbid.
Torduff reservoir, 50 feet from surface, June 9, 1871.	13·30	·333	·039	·006	·009	·053	0	1·08	2·7	6·0	8·7	Colourless, slightly turbid.
Available sources for new supply.												
The *South Esk* at Gladhouse Mill, June 16, 1871.	9·86	·682	·052	·004	0	·055	0	·90	0	5·7	5·7	Brownish and very turbid.
The *Tala* near its source, September 24, 1870.	4·02	·105	·017	·002	0	·019	0	·63	·6	1·7	2·3	Clear and colourless.
The *Tala* near its source, April 3, 1871.	2·92	·080	·008	0	0	·008	0	·67	·4	1·7	2·1	Do.
The *Megget* flowing into St. Mary's Loch, June 20, 1871.	4·22	·405	·020	·001	0	·021	0	·70	·3	2·2	2·5	Yellow and slightly turbid.
St. Mary's Loch at the head, April 3, 1871.	4·90	·310	·018	0	0	·018	0	·65	0	2·6	2·6	Slightly yellow and turbid.
St. Mary's Loch one mile from the head, September 24, 1870.	4·74	·293	·023	0	0	·023	0	·64	·3	2·3	2·6	Do.
St. Mary's Loch at foot, September 24, 1870.	4·48	·254	·019	0	0	·019	0	·72	·1	2·0	2·1	Colourless and clear.
The *Heriot* near its source, September 24, 1870.	8·12	·085	·010	0	0	·010	0	·85	1·8	4·3	6·1	Do.
The *Heriot* near its source, April 1, 1871.	7·30	·099	·015	0	0	·015	0	·89	1·1	4·6	5·7	Do.
The *Manor* tributary of the *Tweed* February 22, 1873.	3·52	·043	·011	·001	0	·012	0	·65	0	1·5	1·5	Do.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The best of these waters for dietetic and all domestic purposes is that furnished by the *Manor*, one of the head waters of the *Tweed*. We know of no better water than this in Great Britain. It is clear, clourless, palatable and soft, and contains only traces of organic matter. It is free from any evidence of previous sewage or animal contamination. The worst sample in the above series of waters from available sources is that furnished by the *South Esk* at Gladhouse Mill: it is quite unfit for domestic use.

Elland (*Yorkshire*), an urban sanitary district of 7,525 inhabitants, is supplied with water for domestic purposes from the Halifax Corporation Waterworks. The supply is constant and direct from the mains, and 60,000 gallons of water are delivered daily to 900 houses supplied for domestic purposes, and 42 manufactories for trade purposes. The quantity of water supplied is adequate for the requirements of the district. The rate charged by the Halifax Corporation Waterworks is 6*d.* per 1,000 gallons. To prevent waste an inspector is engaged to examine the fittings and taps constantly. The water mains cost 5,180*l.* (*See Halifax*, page 350.)

Ely (*Cambridgeshire*) is a city of 8,162 inhabitants, and is supplied with water from the river *Ouse* which is abstracted from the river just above Ely, and about 20 miles below Cambridge, the sewage of which latter city passes direct into the *Cam*, which joins the *Ouse* several miles above Ely.

Before delivery the water is filtered through sand, coarse gravel, and wood charcoal, and, as the sample submitted to analysis had undergone this process, the following remarks apply to the filtered water.

The sample was clear, colourless, and palatable; but it was, nevertheless, appreciaoly contaminated with soluble sewage matter, and exhibited considerable evidence of previous sewage pollution. This water could not be used for domestic purposes without risk to health; it is not, in our opinion, suitable for the supply of a town. It is so excessively hard as to be almost useless for washing. (For analysis, *see* page 52.)

Enfield (*Middlesex*), an urban sanitary district of 16,054 inhabitants, is supplied with water from works belonging to the sanitary authority, which cost 16,000*l.*; the water is

PART IV. DESCRIPTIVE.

Epsom.

obtained from two bore-holes into the chalk, one 90 and the other 250 feet deep. The water is pumped from thence into two service reservoirs containing about 322,000 gallons, and 270,000 gallons of water is delivered unfiltered daily direct from the mains, intermittently. The supply is inadequate. The rate of charge for water is 1*s*. 2*d*. in the pound on the rateable value. The water has not been analysed.

Epsom (*Surrey*), an urban sanitary district of 6,276 inhabitants, is supplied with 170,000 gallons of water daily, which is delivered on the constant system during the day to about 930 houses situated within an area of 600 acres. This suppy is derived from two wells sunk through 62 feet of various strata into the chalk. The one well is 50 feet deep with a bore-hole 34 feet further; the other 46 feet deep has a bore-hole 140 feet in addition. There are storage and service reservoirs together capable of holding 182,000 gallons.

Exeter (*Devonshire*).—This city, of 34,648 inhabitants, derives its water from the *Exe*, abstracted by conduit pipes at a point close to its junction with the *Culm* 45 miles from its source and 1 mile 5 furlongs and 70 yards from the pumping station at the works on Pynes' Leat. The river water is pumped, by water and auxiliary steam power, about 150 feet high into two open reservoirs (lined with limestone on concrete set in blue lias mortar) together capable of holding 4,400,000 gallons, whence it flows on to filter beds together about 1 acre in extent. About 862,000 gallons are pumped daily, and delivered for domestic, trade, and sanitary purposes to 7,000 houses, three breweries, and the railway station, within an area of about 1¼ miles square. The houses are supplied with cisterns and a few receive their water direct from the mains.

The river *Exe* above its junction with the *Culm* was, on May 26, 1870, a soft and unpolluted stream, containing but a small proportion of organic matter, and exhibiting no evidence of previous animal contamination.

A second sample, collected on September 26, 1871, from the same place also contained a very small proportion of solid impurity and a moderate amount of organic matter, chiefly, if not entirely, of vegetable origin. It was soft, and therefore well adapted for washing and cleaning operations, and for all manufacturing purposes, except the brewing of pale ale. It exhibited some slight evidence of previous sewage or animal contamination, the source of which ought to be ascertained. In all other respects it was a water of excellent quality for drinking and all domestic purposes. Being a river water, subject to turbidity, it would be necessary to filter it before delivery to consumers. A third sample, collected on October 22, 1871, was not quite so good; it contained a larger proportion of organic matter, and exhibited somewhat more evidence of previous sewage or animal contamination. The admission of the sewage of Tiverton into the *Exe* ought to be jealously watched by the Sanitary Authority at Exeter. (For analyses, *see* page 48.)

Failsworth (*Lancashire*), an urban sanitary district of 5,685 inhabitants, is supplied with water on the constant system by the Oldham Corporation Waterworks. (*See Oldham*, page 381.) The supply is direct from the mains, and is quite adequate to the requirements of the district. The rate of charge is 6½ per cent. on the annual rental of the property.

Fairfield (*Derbyshire*), an urban sanitary district of 1,020 inhabitants, obtains a supply of water for domestic purposes from springs conveyed by a closed conduit into a service tank containing about 400,000 gallons, built partly above the surrounding ground, and uncovered. The supply is inadequate to the requirements of the district. The water has not been analysed.

Farnley Tyas (*Yorkshire*), an urban sanitary district of 601 inhabitants, is supplied with water from private wells. The supply is adequate. The water has not been analysed.

Farnworth (*Lancashire*), an urban sanitary district of 13,550 inhabitants, receives its water supply from the waterworks of the Corporation of Bolton. (*See Bolton*, page 320.) The supply is direct from the mains and the charge is 9*d*. per 1,000 gallons.

Farsley (*Yorkshire*), an urban sanitary district of 3,800 inhabitants, is supplied with water by the Calverley District Waterworks Company, who purchase the water from the Bradford Waterworks Company. (*See Bradford*, p. 321.) The works were established in 1864. The supply is constant, adequate, and direct from the mains, to about 500 houses and 3 mills. The rate of charge for water for trade purposes, is 1*s*. 6*d*. per 1,000 gallons. To prevent waste, inspectors are appointed to examine fittings, taps, and meters.

Faversham (*Kent*), an urban sanitary district containing 7,319 inhabitants, obtains water from a Company with a capital of 9,000*l*. The Company supply 650 houses within an area of two square miles on the constant system direct from the mains with 140,000 gallons of water daily, derived from a well seven feet in diameter and 114 feet deep sunk in the Chalk. The water is not filtered but pumped into two reservoirs capable of containing 200,000 gallons and thence distributed.

Filey (*Yorkshire*), an urban sanitary district of 2,259 inhabitants, is supplied with potable water by a private company from springs; the water is conveyed into service reservoirs by earthenware pipes. About 50,000 gallons is delivered daily for domestic purposes direct from the mains on the constant system. The supply is stated to be adequate. The rate of charge for water is $7\frac{1}{2}$ per cent. on the rateable value. The water has not been analysed.

Flint (*Flintshire*), an urban sanitary district of 4,277 inhabitants, is supplied with water by a private company from springs; the water is conveyed by earthenware pipes a distance of three-quarters of a mile from spring to a reservoir partly built above ground and uncovered. The water is not filtered, and about 24,000 gallons are delivered daily direct from the mains. The supply is not adequate. The water has not been analysed.

Flockton (*Yorkshire*), an urban sanitary district of 1,116 inhabitants, obtains water for domestic purposes from springs. The water has not been analysed.

Folkestone (*Kent*), an urban sanitary district containing 12,694 inhabitants, is supplied by a private Company, whose works cost 43,182*l.*, with water which is obtained in part from springs issuing at the base of a steep Chalk down above the Gault at the Cherry Gardens, about two miles from Folkestone, and partly from four wells 10 feet in diameter sunk through clay into the Greensand below the Gault to a depth of about 40 feet. These wells and pumping engines are situated about half a mile nearer to Folkestone than the springs just mentioned. The springs flow at once into two uncovered reservoirs, capable of holding 7,500,000 gallons. Wells Nos. 2, 3, and 4 are pumped into well No. 1, from which the water is lifted into the reservoirs at Cherry Gardens. In winter the chalk springs yield sufficient water, and no part of the supply is derived from wells, but in summer the springs fall off greatly, and the chief portion of the water is obtained from the wells, which are said to yield an aggregate volume of upwards of 500,000 gallons daily. The quantity supplied is between 500,000 and 600,000 gallons daily distributed to 1,890 houses situated in the town and parish of Folkestone and district of Sandgate.

The camp at Shorncliffe is supplied from a separate upland reservoir with about 65,000 gallons daily. The houses are provided with cisterns, and the water is laid on in districts, each district being supplied during two hours.

The water is not filtered before delivery, and the supply is intermittent.

We have inspected these works on two occasions, viz., on the 28th of February 1873, and again on the 9th of August 1873. On the first occasion we collected samples of the spring water as it entered and as it left the storage reservoirs; whilst on the second occasion samples from each of the wells, Nos. 2, 3, and 4, were collected together with specimens of, 1st, the mixed water as it left the lower storage reservoir on its way to the town; and, 2nd, as it was running in a constant stream from a drinking fountain in the office of Mr. Richard Hart, the Secretary of the Water Company. As wells Nos. 2, 3, and 4 delivered into well No. 1, no separate sample of the water yielded by the latter could be obtained. The results of the chemical examination of these waters are given in the following analytical table:—

COMPOSITION OF WATER SUPPLIED TO FOLKESTONE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
FOLKESTONE WATER SUPPLY.												
Supply from chief spring running into reservoir at Cherry Garden House, Feb. 28, 1873.	32·14	**·025**	**·004**	0	·313	·317	2,810	2·90	21·3	5·0	26·3	Clear.
Same water as it leaves the storage reservoir, Feb. 28, 1873.	32·16	**·059**	**·030**	·003	·393	·425	3,630	2·80	17·8	6·1	23·9	Slightly turbid.
Supply at Secretary's Office, Aug. 9, 1873.	42·26	**·095**	**·018**	0	0	·018	0	4·50	24·5	7·7	32·2	Slightly turbid.
Greensand well, No. 2, Aug. 9, 1873.	48·96	**·107**	**·021**	0	0	·021	0	5·60	28·7	10·4	84·1	A few floating particles.
Ditto No. 3, Aug. 9, 1873 -	41·14	**·091**	**·021**	·004	0	·024	0	4·20	24·6	7·0	31·6	Slightly turbid.
Ditto No. 4, Aug. 9, 1873 -	40·50	**·120**	**·016**	·013	0	·027	0	4·20	22·9	8·1	81·0	Slightly turbid.
Supply as it leaves the lower reservoir, Cherry Gardens, Aug. 9, 1873.	37·78	**·186**	**·041**	·005	·023	·068	0	4·30	19·3	7·6	26·9	A few floating particles.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

On these results we have to remark:—

1st. That although the samples both from the springs and the wells were very hard, they were otherwise of most excellent quality. The moderate amount of evidence of

PART IV. DESCRIPTIVE.

Folkestone.

previous animal contamination exhibited by the spring water is of no importance, and has no bearing upon the wholesomeness of the water. These waters are all wholesome and palatable, and contain but mere traces of organic matter.

2nd. By storage in the open reservoirs the water becomes slightly softer, but at the same time contracts a marked amount of organic impurity. On the 28th February the water leaving the reservoir contained a proportion of organic elements (organic carbon and organic nitrogen) three times as great as that which it held in solution at the spring. On the 9th of August the proportion was also largely increased, but owing to the different composition of the five kinds of water then supplying the reservoir in unknown volumes, the exact amount of the increase could not be precisely determined; taking, however, the average composition of the affluent waters and comparing it with the composition of the effluent water from the reservoir, the proportion of organic matter in the effluent is double that present in the affluent water. Nevertheless the original purity of the water is so great that, even after this deterioration in the reservoirs, it must be pronounced to be on both occasions when we examined it of fairly good quality.

There were not wanting visible causes sufficient to account for the deterioration of the water during its sojourn in the storage reservoirs. There are two houses and some cow sheds situated near to and above the storage reservoirs, and the so-called "Cherry "Gardens" near these houses are, as we were informed, to some extent a place of public resort, and there is no sufficient fence around the springs and reservoirs to prevent trespassers from gaining access to the water. On the occasion of our first visit, we noticed that ducks were kept upon the reservoirs, and that sheep were admitted to pasture upon the grassy banks sloping down to the water's edge. Hard water from springs and wells, when exposed to sunlight is very prolific of confervoid growths, and such growths were noticed in the reservoirs on both occasions.

3rd. The temperature of the water entering the storage reservoirs averaged 52°·3 Fahr., but on the 9th of August the temperature of the water leaving them and entering the mains was 63°·5 Fahr., whilst that being delivered in the town was no less than 65°·8 Fahr. At this temperature the best water is vapid and unpalatable.

4th. The sample of water taken at the office of the secretary of the water company on the 9th of August differs very markedly in many respects from the water which was found to be entering the main at the reservoir about an hour and a half later. We are unable to offer any explanation of this difference.

With reference to the complaints which have been made to the Local Government Board, about the quality of the water supplied to Folkestone, we have to say that the only defect in the water at its source is its somewhat excessive hardness. Any other defects which have been noticed must have arisen from the modes of storage and distribution. To remedy all such defects, the following things are necessary :—

1. The softening of the water by Clark's process.
2. Its storage is covered reservoirs.
3. Its delivery on the constant system.

The method of softening water by lime, commonly known as Clark's process, has long been in practical and successful operation. The water supplied to Canterbury, Tring, Aylesbury, Caterham, Redhill, and other places has been for many years treated in this way with the best results, and repeated chemical analyses have shown that the waters delivered to the above towns, though excessively hard at their sources, are unsurpassed in purity, and usefulness for all domestic purposes by any water in the United Kingdom. The water supplied to Folkestone both from the springs and wells, is admirably adapted for this softening operation. If the water which was being delivered on the 9th of August of more than 32 degrees of hardness had been submitted to this process, it would have retained less than eight degrees of hardness. By being thus softened, it loses none of its original palatability, whilst it is much more pleasant for personal ablution. A great saving in soap and soda also results when it is used instead of hard water for the washing of linen. The patent for Clark's process expired some years ago.

The necessity for covered storage reservoirs is not so obvious. It is usual to leave reservoirs uncovered, when the latter, like these, are situated at a distance from the town, but it must be borne in mind that the soft surface water collected from gathering grounds, which is usually impounded in such reservoirs, does not deteriorate from the growth of confervae to anything like the extent which obtains in the case of hard spring well and waters. Water of the latter character ought never to be exposed to light before delivery. The Kent Water Company which delivers such water to a portion of the metropolis, employed some years ago an open reservoir at Deptford, and complaints of the quality of the water were loud and frequent; but since the reservoir was covered, the water which has been examined monthly has been almost absolutely free from organic taint. Open reservoirs at a distance from towns are quite admissible, and perhaps in some cases desirable, but hard spring or well water deteriorates from the moment when it enters such reservoirs.

The disadvantages of the intermitent over the constant system of supply are so obvious that comment upon this proposed improvement is unnecessary, and we will only mention that the access of sewer gas, coal gas, and even of sewage itself to the interior of water mains, when the latter are empty is very likely to occur, especially in a hilly town like Folkestone. As the water is drawn off from the disconnected main a partial vacuum is occasioned, and the liquids or gases surrounding a defective pipe are inevitably sucked in.

Forfar, a burgh of 11,031 inhabitants, is supplied with water for domestic purposes from wells sunk by owners of private property to a depth of from 20 to 30 feet in the sand and gravel overlying the Old Red Sandstone. A list of fifty-seven of these wells will be found in our 4th Report (Rivers of Scotland), Vol. II., Part IV., Sect. 1.

This stratum of sand and gravel forms an excellent intermittent filter for the sewage and surface soakage of the town, and the sample of water which we obtained from the East Town End well, the analysis of which is given at page 71, closely resembles the best samples of sewage, purified by intermittent filtration, which we have examined. Although the purification of the sewage is in this case satisfactory, the use of even such cleansed excrementitious matter for drinking and cooking can scarcely fail to be the means of propagating zymotic disease, although the water may be, as in this instance, clear, sparkling, and palatable. In the higher parts of the town the well water appears to be much less contaminated; thus our sample from the West High Street well exhibited only very moderate evidence of previous sewage or animal contamination, and contained but a minute proportion of unoxidized organic matter. It was bright, clear, and palatable, and a fairly good shallow-well water. Both its softness, and the small proportion of chlorine which it contained, absolve this water from the charge of any serious amount of excremental pollution. It is very desirable, however, that no part of a town of this size should any longer be dependent upon its own surface soakage for its water supply. (For the analysis of this water, *see* page 71.)

Frome (*Somersetshire*), an urban sanitary district of 9,752 inhabitants, is supplied with water for domestic purposes from wells and springs. The supply is inadequate. A Waterworks Company has been established and has commenced sinking a well.

The chief present supply is from a fountain at the foot of the churchyard; the water is brought in a brick drain from a spring in the cellar of a house at some little distance. The burial ground is, however, above the level of the fountain, and it is not known how its drainage water is disposed of. Our analysis (*see* page 118) shows considerable anterior animal pollution, which, as indicated by the comparatively small proportion of chlorine, does not appear to have been entirely derived from sewage. The proportion of organic matter actually left in the water was very small; nevertheless the evidence of so much previous pollution relegates it to the class of suspicious waters. Moreover it is too hard for domestic purposes. This water, however, is greatly superior to a sample which we drew from a shallow well in the Blue House School, (for analysis, *see* page 81,) and which contained unoxidised sewage matters, besides exhibiting a very large anterior pollution of the same kind. The use of this water by the boys is dangerous; the well ought to be carefully examined, and if the access of foul liquids to it cannot be prevented it ought to be closed.

We are indebted to Messrs. Cruttwell and Daniel, of Frome, for the samples of water from springs at Whitburn and Egford near Frome. One of these is said to gush with considerable force out of the side of a Chalk hill, and would be well adapted for supplying the town with water. The analysis given in the table at page 121 shows this water to be soft and of excellent quality, both for domestic and manufacturing purposes. It is clear, sparkling, and palatable, and contains but a very small proportion of organic matter. From its chemical composition, we infer that this water springs from the Greensand, which crops out about two miles from Frome. The other spring is from the Oolite, and has all the excellent qualities of oolitic spring water. (For analysis, *see* page 118, and for the description of Oolitic spring water page 120.)

These waters being from deep-seated springs the evidence of previous animal contamination which they contained need not be regarded. The Oolite spring, if it were not so hard, would be a good water for domestic use; it contained but a very small proportion of organic matter.

The water of the Upper Greensand spring was, however, of still better quality; it was very soft, and in every respect a most excellent water both for domestic and manufacturing purposes. By boiling for half an hour the former water became as soft as the latter.

Fulstone (*Yorkshire*), an urban sanitary district of 2,052 inhabitants, is supplied with water for domestic purposes from springs adjacent to the village. The supply is not adequate. The water has not been analysed.

Fulwood (*Lancashire*), an urban sanitary district of 3,079 inhabitants, is supplied with

PART IV. DESCRIPTIVE.

water by the Preston Corporation Waterworks. The supply is constant and direct from the mains. The rate of charge is 5 per cent. on the rental. (*See Preston*, p. 387.)

Gainford.

Gainford (*Durham*).—This township of 820 inhabitants is supplied with water from shallow wells. We have examined several samples from wells in this town. These waters had all been derived to a large extent from sewage. Those from the well in Hornsby's Yard, in Pearson's Yard, and Mr. Nicholson's well contained considerable quantities of fresh or unoxidized sewage, and were consequently dangerous and utterly unfit to drink. The waters from Messrs. Adamson's and Metcalf's wells were similarly polluted with fresh sewage, but to a less extent. Their use for drinking would, however, be attended with much risk to health as they were little else but sewage which had filtered through a few feet of porous earth. The water of St. Mary's well was the only one of the series which might be drunk without much risk, the sewage with which this water had been contaminated to a considerable extent, having undergone such complete oxidation that mere traces of its organic constituents remained in the water. Probably the well is much deeper than those from which the other samples were drawn.

All these waters were excessively hard and therefore quite useless for washing. (For analyses, *see* page 72.)

Galashiels, a burgh of 10,312 inhabitants, is supplied with water partly from 139 public and private wells sunk to a depth of from 15 to 20 feet in the gravel on which the town is built, and partly by a private company which has been in existence about 16 or 18 years. The water delivered by this company is collected from about 200 acres of gathering ground, most of which is pasture land, but some is cultivated. Artificial manures and lime are employed on the land, but town refuse is used "on a very small "part of a field near the lower reservoir." It is believed to be impossible to exclude the drainage water of the cultivated land. The company has no control over the occupiers of the land within the gathering ground so as to restrain them from putting town refuse upon the land. The supply is intermittent. Between the months of April and October it is given for eight hours a day in one part of the town and for 16 hours in other parts of the town. The consumers mostly use cisterns, or "they get the water the best way "they can." There is not a sufficient quantity of water to give a constant supply.

The sample of this water, which we collected at the house of Mr. Robert Stewart, Town Clerk, was clear, colourless, palatable, and moderately soft, but it exhibited very marked evidence of previous animal contamination. In our opinion this supply is inadequate, both in quantity and quality, for the wants of the town.

There are two reservoirs situated about a mile from the town; one contains 4,460,000 gallons, the other 139,000 gallons. The area of the gathering ground is about 200 acres. The water is not filtered, and is not used in watering streets. The rate of charge for water by the private company is 1*s*. in the pound on the rental. In order to prevent waste, the fittings are kept in as good order as possible. The waterworks costs 3,000*l*.

The shallow wells furnish bright, colourless, and sparkling water of moderate hardness, but they all exhibit considerable evidence of previous excremental pollution. The well at the river side opposite the skinnery is the best of the three we have analysed, and as it contains but a very minute proportion of organic matter, it may be used for domestic purposes with very little risk. Sandy's well is also a tolerably good shallow-well water, but the water of Mr. Thompson's well is not of good quality; a watercloset and a privy are situated within a few feet of this well. We were informed that the skinnery well and Sandy's well were each used by about 500 people, and that Mr. Thompson's well supplied about five families.

(For the analysis of the water supply *see* page 48, and for that of the shallow well waters, page 69.)

Galston (*Ayrshire*), a burgh of 4,727 inhabitants, is supplied with water from 19 public and 14 private wells, 3 feet to 6 feet in diameter, and 10 to 30 feet in depth, which give an abundant supply of water in winter, but are deficient in summer. The wells were all sunk previously to the adoption of the Police Act, and some of them are 100 years old. In the lower part of the town, where the wells are shallow, they are sunk through alluvial soil and gravel to the level of the water in the river. In this part of the burgh the river overflows its banks, and here there has been more disease than in the other portions of the town, and epidemics have been more frequent and severe, especially in 1849, when Asiatic cholera prevailed. In the higher portions of the town, where the wells are sunk through boulder clay into the rock, and where they are not subject to the overflowing of the river, the inhabitants were almost entirely free from cholera.

Garston (*Lancashire*), an urban sanitary district of 8,500 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 368.) The supply is partly by cisterns and partly direct from the mains. The rate of charge is 9*d*. in the pound on the assessable value of the premises supplied.

Glasgow.

Glasgow.—The city of Glasgow, containing 530,000 inhabitants, is bountifully supplied with water by gravitation from Loch Katrine and Gorbals. The Gorbals waterworks were established in 1847, and the Loch Katrine works at the end of 1859. Both are the property of the Corporation. Loch Katrine is situated in the Highlands of Perthshire, 34 miles north of Glasgow, whilst the reservoirs at Gorbals are about seven miles south of the city. The area of the gathering grounds at Loch Katrine and subsidiary lochs is 47,808 acres, but of this area, 22,800 acres—the drainage area of Loch Katrine—alone contribute to the supply of Glasgow, the remainder being utilized for compensation water only. The area of gathering ground at Gorbals is 2,560 acres. The available contents of Loch Katrine are 5,623,000,000 gallons. The water is not filtered before delivery. The Gorbals water is filtered through 2 feet of Arran sand, 1½ inch perforated tiles, and 1 foot 6 inches of gravel and large stones. The area of the district supplied extends 12 miles from north to south, and the same distance from east to west. The supply is constant, and the average volume of water delivered daily in 1869 for domestic and sanitary purposes was 20,000,000 gallons; sold by meter to 750 manufactories 3,000,000 gallons, and for other purposes not domestic, 3,000,000 gallons; total, 26,000,000 gallons. On some days in the summer of 1870, as much as 31,000,000 gallons were delivered. The works have cost 1,672,810*l*. The steps taken to prevent waste are supervision by eight inspectors, but the fittings generally are bad, and an inspection of each house is made only once in 18 months. Previously to the establishment of the waterworks the city was supplied from the *Clyde*. Our analysis (*see* page 36) shows that the high reputation which the Loch Katrine water enjoys is well deserved. It contains less than 1¾ grain of total solid impurity in a gallon; of this nearly a grain is common salt, and the remainder contains a moderate proportion of peaty organic matter. It is palatable and generally clear and colourless when seen in a decanter, and analysis shows it to be free from all suspicion of excremental pollution. It is exceedingly soft, and therefore well adapted for washing and cleansing purposes.

The Gorbals water is inferior in quality to that of Loch Katrine, nevertheless it is wholesome and soft. Our sample was clear, but of a yellowish colour owing to the presence of rather a large proportion of peaty matter, which constitutes the only defect of this water. Though five times as hard as the water of Loch Katrine, it is still a soft water. It is quite free from all evidence of excremental pollution. (For analysis, *see* page 37.)

Dr. William Gairdner, the Medical Officer of Health for Glasgow, said in his evidence before us (Vol. II., Fourth Report, Part III., Q. 2694, 2695), that in his opinion the water supply of Glasgow is unexceptionable; and in answer to the question, "An opinion has been expressed that very soft water is a bad thing; do you concur in "that?" he replied, "I think there is no foundation for that at all."

A large number of the better class of houses have cisterns, and the overflow pipe is almost always connected with the soil pipe of the watercloset. The charge for water is 9*d*. in the pound upon the rental within the municipality, and 1*s*. in the pound beyond; also a public rate on all property within the municipality of 1*d*. in the pound. There is reason to believe that diarrhœal diseases in general have a low rate of mortality in Glasgow. The last epidemic of cholera produced an exceptionally small mortality considering the state of the population in a sanitary point of view. (*See* page 153.)

Besides our own analysis quoted above the water supply from Loch Katrine is subjected to a monthly chemical examination by Professor G. Bischof, of the Andersonian University Glasgow. His results are contained in the following table:

COMPOSITION OF WATER SUPPLIED TO GLASGOW FROM LOCH KATRINE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.									REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.	
GLASGOW WATER SUPPLY FROM LOCH KATRINE.										
May 12, 1873	3·16	·204	·017	·001	0	·018	0	·66	·8	Clear and colourless.
June 16, 1873	3·30	·181	·016	·001	0	·017	0	·71	·8	Clear and colourless.
July 18, 1873	3·20	·192	·008	·001	0	·009	0	·79	1·0	Clear and colourless.
August 1, 1873	2·90	·209	·011	·001	0	·012	0	·76	1·0	Clear and colourless.
September 1, 1873	3·80	·156	·047	·001	0	·048	0	·82	1·3	Clear and colourless.
October 14, 1873	5·60	·256	·028	·001	0	·029	0	·59	·5	Turbid. Yellow.
November 24, 1873	2·13	·177	·035	·002	0	·037	0	·66	·3	Slightly turbid. Yellow.
January 15, 1874	3·60	·154	·021	·001	0	·022	0	·68	·4	Clear and yellowish.
February 5, 1874	3·84	·251	·008	·001	0	·009	0	·71	·3	Clear and yellowish.
March 10, 1874	2·09	·185	·007	·001	0	·008	0	·71	·1	Clear and slightly yellowish.
April 1, 1874	3·32	·169	·003	·001	0	·004	0	·71	·1	Clear and slightly yellowish.
May 5, 1874	3·40	·235	·011	·001	0	·012	0	·63	·1	Clear and slightly yellowish.

These numbers show that whilst the proportion of peaty matter occasionally rises higher than is desirable, the water is always wholesome and free from every trace of evidence of previous sewage or animal contamination.

Glossop (*Derbyshire*), a borough of 17,600 inhabitants, is supplied with water obtained from streams and springs. The waterworks established in 1865 are now enlarged, and belong to Lord Edward George Fitzalan Howard, of Glossop Hall. The reservoirs are situate at Swineshaw. About three-fourths of the inhabitants are supplied with water from this source.

Gloucester (*Gloucestershire*), a city and urban sanitary district of 18,330 inhabitants, derives its supply of potable water partly from a gathering ground of 1,500 acres, 1,400 acres of which is pasture and wood, and 100 acres is arable, and partly by springs thrown out by the *Lias* 5½ miles from the town. The water flows from springs into subsidence and impounding reservoirs containing 62,100,000 gallons, and thence into service reservoirs containing 54,000,000 gallons. The water is not filtered; 500,000 gallons are delivered daily on the constant system to 3,900 houses and 80 manufactories for domestic, trade, and sanitary purposes; the present supply is adequate. The rate of charge for water is 5 per cent on rental for domestic and 1*s.* per 1,000 gallons for trade purposes. Our analysis of it (*see* page 46) reveals no evidence of excremental pollution; but the water is hard, and contains a somewhat large proportion of organic elements; it would be greatly improved in both these respects by being subjected to the liming process described at page 205. Its hardness would be thereby reduced from 19½° to 3½°. The water was turbid and needed filtration at the time our sample was taken.

Godmanchester (*Huntingdonshire*), an urban sanitary district of 2,363 inhabitants, obtains its supply of water for domestic purposes from springs and wells. The water has not been analysed.

Golcar (*Yorkshire*), an urban sanitary district of 6,030 inhabitants, obtains a supply of water chiefly from springs, which flow into stone troughs; the inhabitants have to go a considerable distance to obtain water from these troughs. In the summer season they have to rise very early in order to collect a sufficient quantity for their daily wants. On Saturdays this is, of course, a double hardship. A few years ago the steward of Lord Scarborough kindly offered a site for a reservoir, and a supply of water for the same, if the Local Board would be at the expense of constructing the works, but this they declined to do. Subsequently a Mr. Taylor constructed a reservoir on his own property, and he now gratuitously supplies a great number of people with water. The Local Board have received the following memorial from the ratepayers:—"To the "Local Board of Health for the township of Golcar. The memorial of the inhabitants "of the township of Golcar, being owners and ratepayers, showeth that on the 25th day "of August 1864, a request, in writing, signed by 90 ratepayers, was presented to "your Board praying that measures might be taken to ensure a continuous supply of "pure water to the inhabitants, and the memorial further showeth that many of the "inhabitants have suffered from the want of water for the last two years, especially "during the summer months, so much so as to necessitate their going considerable "distances, as well as during the night time, to obtain a sufficient supply; also that during "the last year zymotic diseases have extensively prevailed in this township, *i.e.*, diseases "which are usually regarded as of a preventible character, and are mainly attributable to a "deficient and impure supply of water, so much so that for the year ending February 1st, "1870, out of a total number of deaths registered for the township of Golcar, viz., 136, "one-fourth of the deaths resulted from the several fevers partaking of the typhoid, "the gastric, and scarlatina forms, and one-sixth of the whole number from scarlatina, "in addition to 10 deaths from diarrhœa. Your memorialists therefore submit that the "foregoing state of things ought no longer to be allowed to exist, but that the Local "Board of Health should take the matter into their most serious consideration, inasmuch "as the law gives them the power not only to obtain a pure and sufficient supply of "water, but to execute works for the proper drainage of the township, measures "calculated to secure, in the opinion of your memorialists, beyond everything else, the "health and the lives of the inhabitants."

Gravesend (*Kent*), a borough of 19,995 inhabitants, is supplied with water by the Gravesend and Milton Waterworks Company from a well 9 feet in diameter and 200 feet deep sunk into the Chalk. The water is pumped into a service reservoir built above the surrounding ground but not covered; 250,000 gallons of water are delivered daily in summer and 200,000 in winter, to 3,000 houses, distributed over an area of about two square miles. The supply is intermittent, the houses being provided with cisterns.

Our analysis, given at page 100, shows this water to be hard, but otherwise of most excellent quality for drinking and cooking. It contains but the merest trace of organic matter, and the evidence of previous animal contamination which it exhibits may be safely disregarded, as the water is derived exclusively from a deep well. By the application to it of Clark's process (*see* page 205) the hardness would be reduced from 28° to 8°, and it would then be in all respects one of the best waters in the kingdom. PART IV. DESCRIPTIVE. Greaseley. Greenock.

Greaseley (*Nottinghamshire*).—This township of 7,282 inhabitants derives its supply of water from shallow wells and brooks. We have examined several samples from tanks, pumps, and the *Nethergreen Brook.*

The water from Morley's pump consisted essentially of percolated sewage. It contained a considerable proportion of unoxidized animal organic matter and could not be used for domestic purposes without great risk to health. It was moreover excessively hard. (For analysis, *see* page 76.) The water from the soft water pump in Morley's Yard contained only a small proportion of organic elements, but it exhibited evidence of some previous contamination with animal organic matter which, however, was not sewage. It was tolerably soft and was, on the whole, the best water in the Greaseley series for domestic purposes, but, being slightly turbid, it ought to be filtered before use for drinking. (For analysis, *see* page 29.) Brigg's soft water cistern contained water excessively and permanently hard, derived chiefly from sewers or cesspits. Its domestic use would be attended with great risk to health. (For analysis, *see* page 29.) Elias Paxton's well yielded water which had been much contaminated with urine and animal matters, a considerable proportion of which was still present in an unoxidized condition. It was also excessively hard and quite unfit for domestic use. (For analysis, *see* page 76.) The *Nethergreen Brook* water was of fair quality. It was of about the hardness of *Thames* water and had been slightly contaminated with animal matters, the source of which ought to be ascertained. It would be desirable to filter it before use. (For analysis, *see* page 53.)

Great Bookham (*Surrey*). This township of 1,089 inhabitants is supplied with water from shallow wells, samples of which we have submitted to analysis. The water of the well in sand, 12 feet deep, consisted chiefly of the soakage from sewers and cesspools. It was quite unfit for human consumption. (For analysis, *see* page 83.) The sample from Mr. Barclay's Chalk well was of excellent quality for drinking or cooking. It contained but mere traces of organic matter. It was too hard for washing but admirably adapted for Clark's softening process, which would reduce its hardness to little more than one sixth of its present amount. (For analysis, *see* page 101.) The water from the well in Eastwick Lane was considerably polluted by actual sewage which must gain access to the well near the surface. If this surface soakage could be prevented the water would probably be as good as the previously mentioned sample. At the time the sample was taken it was unfit for domestic use. (For analysis, *see* page 106.) The water from the well in Tanner Lane, was also polluted by so large a proportion of organic matter as to render it quite unsuitable for human consumption. (For analysis, *see* page 106.) The water from Mr. Wood's well was excellent, though somewhat inferior to that of Mr. Barclay's well. It was a little softer, but for washing it would be greatly improved by being submitted to Clark's process of softening. These remarks, however, apply only to the filtered water. As the sample reached us it was very muddy and entirely unfit for any domestic use. (For analysis, *see* page 101.) The well in sand, 18 feet deep, yields a water which, as received by us, was very muddy, and even after filtration, polluted with a large proportion of organic matter. The spring seems to be fed chiefly by sewage. It was too hard for washing and could not be softened by Clark's process. It was therefore quite unfit for dietetic and all domestic purposes. (For analysis, *see* page 83.)

Great Crosby (*Lancashire*), an urban sanitary district of 3,000 inhabitants, is supplied with water partly from the waterworks of the Corporation of Liverpool (*see Liverpool*, p. 368), and partly from private wells.

Great Harwood (*Lancashire*), an urban sanitary district of 4,907 inhabitants, is supplied with water principally by small wells and rain-water cisterns attached to the houses.

Greenock (*Renfrewshire*), a borough of 60,000 inhabitants, obtains its supply of water by gravitation from gathering grounds which consist of hill and pasture land with peat moss resting upon whinstone. There are 16 storage reservoirs with an aggregate capacity of 3,269,261,400 gallons, or 211 days' supply. The water was only partially filtered in 1870, but for the future all the water supplied for domestic purposes would be filtered through 2 feet of broken whinstone, 6 inches of gravel, and 2 feet of sand from the Isle of Arran. The supply is constant, and, according to the return made to us, amounts to 51 gallons per head per diem for domestic purposes alone, or 258 gallons per head per diem for all purposes. The latter quantity, however, appears to include compensation water to millowners. It is considered that when certain new works are completed, the supply will be adequate for the town and district. Prior to 1869 no steps were taken to prevent waste. The works were established in 1773, and have cost up to the present time 345,000*l.* They belong to the water trustees of Greenock. The area of the district supplied is 2,445 acres; houses, 11,344, for domestic purposes; works 40 by meter, and 37 without meter. About 10,917,000 gallons of water are delivered daily to mills for power; 1,500,000 to public works for trade purposes; and 3,060,000 to inhabitants for domestic purposes; total, 15,477,000. The streets are watered with salt water pumped from the river. There are 2,097 houses furnished with cisterns; the overflow pipes from which are connected with the soil pipe, and thence with the sewer. The rate of charge for water is a public rate of 2*d.* in the pound on the rental, and a domestic rate of 1*s.* in the pound; and to manufactories and works by meter, from 7*d.* to 3*d.* per 1,000 gallons, according to the quantity taken. Our analysis (*see* page 33) shows the water to be very peaty; but it was soft and otherwise of good quality. It exhibited no trace of excremental pollution, but was, when our sample was taken, slightly turbid and of a yellowish colour. There are now no private wells in Greenock.

Notwithstanding the very high rate of mortality which has prevailed for many years in this town, there is no Medical Officer of Health. Dr. John Macdougal, who has practised for seven years in Greenock, stated in his evidence given before us upon the sanitary condition of the town, that he considers it to be one of the most unhealthy places in the United Kingdom. The town has a pretty good supply of water, and is well drained, but there is much overcrowding and great poverty. In his opinion nothing short of putting the people into more roomy houses and making them less poor would have the effect of improving their health.

Greetland (*Yorkshire*), a Local Board of Health district of 4,114 inhabitants, is supplied with water chiefly by the Halifax Corporation, and partly by springs and wells. The supply is constant and direct from the mains, and 28,000 gallons of water are delivered daily to 408 houses and 9 manufactories. The supply is adequate for the requirements of the town and district. The charge for water is 2*d.* per week for 347 houses under the yearly rent of 7*l.* 10*s.*, at the rate of 3*d.*, 40 houses under 12*l.*, and 15 houses above 12*l.* at 4*d.* per week, 5 beershops at 1*l.*, and one public-house at 2*l.* per annum. To prevent waste the water inspector constantly examines the fittings and taps. The water mains cost 1,440*l.* 8*s.* 4*d.* (*See Halifax, below.*)

Gorton (*Lancashire*), an urban sanitary district of 21,606 inhabitants, receives its supply of water from the Manchester Corporation Waterworks. (*See Manchester*, p. 373.)

Guiseley (*Yorkshire*), an urban sanitary district of 3,185 inhabitants, is supplied with water from wells sunk into the Red Sandstone. The works were established in 1861 and belong to a private company. The reservoir containing 130,000 gallons is situated at a considerable elevation above the town, it is built below the level of the surrounding ground and is covered. Since the works were established it has been found necessary to sink another well at a lower elevation than the reservoir; from this water is pumped into the reservoir. The water is said not to be polluted, and is not filtered; it is pumped from a well sunk in the Old Red Sandstone, 8 feet in diameter and 18 feet deep with a bore-hole 3 inches in diameter. The water is supplied to 400 houses distributed over an area of 1,525 acres; it is supplied direct from the mains which are only charged two hours daily in summer. The present supply is inadequate to the requirements of the town and district. The rate of charge is 2½*d.* per week on rentals under 8*l.*, and 3*d.* per week for rentals above 8*l.* No steps have been taken to prevent waste.

Gunthwaite and Ingbirchworth (*Yorkshire*), an urban sanitary district of 753 inhabitants, with an area of 1,977 acres, containing 90 dwellings, is supplied with water from a spring and rivulet.

Halifax (*Yorkshire*), a borough of 65,800 inhabitants, is supplied with water by gravitation works belonging to the Corporation. They cost about 40,000*l.*, and consist of reservoirs at Ogden and Mixenden, with 8,000 acres of gathering ground, situate on the range of Millstone Grit hills between Lancashire and Yorkshire. The reservoirs contain about 658,000,000 gallons, of which about 2,000,000 gallons per day are discharged as compensation water, and 3,700,000 gallons daily are used in Halifax. The water is soft and of excellent quality, both for domestic and manufacturing purposes; but to the water drinker its good qualities were effectually concealed, when our sample was taken, behind a cloud of suspended matters, which a sand filter would at once remove. Filtration would make this one of the finest potable waters in the kingdom. (For analysis, *see* page 39.) In the borough there are 13,000 houses supplied for domestic purposes, and manufactories and works for trade purposes. The supply is constant and direct from the mains; cisterns are provided only for the supply of waterclosets. About 3,600,000 gallons of water are delivered to the district daily. The supply is said to be adequate to the requirements of the town; but the Corporation are constructing extensive works so as to enable them to double the present supply. The rate of charge for water varies from 6*s*. 6*d*. to houses under 5*l*. annual rental; up to 4*l*. to houses of 100*l*. a year; and 4 per cent. of the rental is charged on all houses above 100*l*. a year. Waterclosets and baths in houses are charged at from 5*s*. to 7*s*. 6*d*. each per annum. Works and manufactories are supplied for trade purposes by meter according to consumption, varying from 6*d*. to 10*d*. per 1,000 gallons. In order to prevent waste a general inspection, from house to house, is made of fittings and taps.

PART IV. DESCRIPTIVE.

Ham Common. Hardingstone.

Ham Common (*Surrey*), an urban sanitary district of 1,450 inhabitants, is supplied with water for domestic purposes by the Southwark and Vauxhall Water Company. (*See Southwark and Vauxhall Water Company*, p. 271.)

Hamilton (*Lanarkshire*), a burgh of 11,498 inhabitants, is supplied with water by gravitation from a reservoir situated about three miles from the town. The gathering ground upon which the water is collected is in great part arable land. Part of the soil is peaty. At the time our sample was taken, the water had been in the reservoir for several months. It was slightly turbid, brownish, and not pleasant to drink on account of the large proportion of organic matter which it contained. When first collected in the reservoir, it doubtless exhibited evidence of previous animal contamination, but this had entirely disappeared when our analysis was made. The water was not good, but it would be much improved by the operation of two additional filters, which were being made at the time of our visit. (For analysis, *see* page 37.) The storage reservoir contains 55,885,056 gallons, or 248 days' supply. The works were established in 1857 and belong to the Town Council. The supply is constant, and the consumption about 21 gallons per head per day for all purposes. Waste is prevented by inspection of fittings and cutting off the water from premises where waste is permitted. The district supplied (604 acres) contains 1,100 houses. About 225,000 gallons are delivered daily for trade and domestic purposes. The water is supplied direct from the mains, and the present quantity is said to be adequate to the requirements of the town. The public rate of charge for water on all the rentals is 5*d*. in the pound. The domestic rate chargeable for water introduced into houses is 6*d*. in the pound on the rental. The waterworks have cost 13,829*l*. Before the establishment of the present waterworks, the town was supplied by public and private wells, and the improved water supply is said to have had a beneficial effect upon the health of the inhabitants: this we can readily believe if the water furnished by the shallow well at Hamilton Palace may be taken as a specimen of the well water which was previously used in the town. This well is fed by the soakage of sewers and cesspools, and its water might be used with advantage for the irrigation of land; it would prove more highly fertilizing than the sewage in the adjacent *Cadzow Burn*. (For analysis, *see* page 74.) In his evidence before us, Dr. William Naismith, the Medical Officer of Health for Hamilton, informed us that the town had been frequently and severely visited by cholera. In 1832 there were 111 cases and 63 deaths, the population being then about 9,000. There was a very severe epidemic of cholera in 1848–49, and the potable water was at that time obtained entirely from wells, a great many of which were near to middens and cesspools and liable to infiltration. There were then 440 cases of cholera, and 251 deaths, besides 754 cases of diarrhœa. Thus the cholera attacks were 46 per 1,000 and the deaths 26 per 1,000. In a population like that of London, this would be equal to 138,000 attacks and 78,000 deaths. The next cholera epidemic in Hamilton occurred in the year 1854; it was much milder. There were 86 attacks and 44 deaths, besides 128 cases of diarrhœa. In the year 1857 the new water supply was introduced. During the last cholera epidemic of 1866 only two fatal cases occurred in Hamilton. A few of the private wells were still in use in that year. The medical officer is of opinion that the contagion of typhoid fever is conveyed by means of the excrements of the patients. He says "I think the connexion between the "escape of excrementitious matters from patients of that kind into wells, and the "outbreak of the same fever among those using the water of those wells, has been quite "established." A severe epidemic of typhus prevailed in Hamilton from October 1865 to May 1866. A considerable proportion of the population of Hamilton consists of Irish, who live crowded together, amidst much filth, in courts and alleys.

Hampton Wick (*Middlesex*), an urban sanitary district of 2,207 inhabitants, is supplied with water for domestic purposes by the Grand Junction Water Company. (*See Grand Junction Water Company*, p. 270).

Hardingstone (*Northamptonshire*), an urban sanitary district of 2,300 inhabitants, obtains its supply of potable water partly from the Northampton Water Company and partly from shallow wells sunk in a gravelly subsoil, *too near privies;* the supply

PART IV. DESCRIPTIVE.

from this latter source is highly polluted. For analysis of Northampton water supply, see p. 95.

Harrow. Hawick.

Harrow (*Middlesex*), an urban sanitary district of 5,010 inhabitants, obtains its supply of water for domestic purposes partly from works of a private company, which cost 11,000*l.*, and partly from private wells. The company derives water from two wells sunk into the chalk, the shafts are 6 feet 3 inches in diameter and 135 and 194 feet deep respectively, with 12 and 15 inch bore-holes in addition 220 feet deep. The wells are sunk in a sparsely populated district; the water is not filtered, and 150,000 gallons are delivered daily to about 500 houses. The supply is adequate to the requirements of the district. The rate of charge for water is 6 per cent. on the rental. Our analyses of potable water of this district will be found on page 103, and our remarks on its quality on page 295.

Hartlepool (*Durham*), a borough of 13,166 inhabitants, is supplied with water by a private Company with a capital of 86,000*l.* who take their water partly from bore-holes in a limestone quarry near the town, and partly from an upland gathering ground of 4,000 acres, of which 664 acres are on magnesian limestone at Hart, two miles westward of Hartlepool, and 3,445 acres are at Hurworth, about eight miles from Hartlepool, in a colliery district, the surface there being generally strong clay. There is an impounding reservoir capable of holding 22 millions of gallons at Hurworth, and two service reservoirs at Hart capable of holding 23 millions of gallons. The water is not filtered. About 4,000 houses and 65 works within an area of 3,750 acres are thus supplied with 1,450,000 gallons daily, viz., 850,000 gallons for domestic use, 585,000 gallons for trade purposes, and 10,700 gallons for sanitary purposes. The supply is constant and direct from the mains.

Harwich (*Essex*), is a borough of 6,079 inhabitants. An attempt is now being made to supply this town with water from a bore-hole driven into the chalk. The sample of this water which we examined was not of unexceptionable quality, apparently through a leakage into the borehole, of some water from a neighbouring horse pond. It also contained 5·07 per cent. of sea water, but this would not be an insuperable objection if the surface soakage were excluded. The water would always be much too hard for washing and cleansing purposes. (For analysis, *see* page 106.)

Havant (*Hampshire*), an urban sanitary district of 2,634 inhabitants, is supplied with water for domestic purposes partly by the Portsmouth Waterworks Company from springs issuing from the chalk, and partly by private shallow wells. (For analysis of the supply from the Portsmouth Waterworks, *see* p. 123.)

Hawes (*Yorkshire*), a township of 1,843 inhabitants, is supplied with water from springs and wells, several samples of which we have submitted to analysis. With the exception of the sample from the Town Head well and Mr. H. Whaley's spring, all were good, wholesome, and palatable waters, those from Dyer's Garth well and Blackburn Sike being, for shallow well waters, of exceptionally excellent quality. The Holme well furnishes good water, but the Town Head well was somewhat contaminated with recent sewage. All the waters would be improved by being submitted to Clark's process. (*See* page 205.) All, except that from the pump in the Cattle Market would then be soft and well adapted for washing. (For analysis of pump in Cattle Market, Dyer's Garth well, Blackburn Sike, and White Hart well, *see* page 72; for that of the Holme well, page 113; and for those of the Town Head well, Mr. H. Whaley's spring, and Spilliam Green spring, page 126).

Hawick (*Roxburghshire*), a burgh of 11,700 inhabitants, is supplied with water from a mountain stream, conveyed into a reservoir, capable of holding four days' supply, near to the stream, and flows from thence by gravitation to a high service reservoir, situate on the hill side above the town. The works were established in September 1865, and belong to the Corporation. The rate of charge is 7*d.* in the pound on the rental. Tenants, into whose houses the water is not introduced, pay 2*d.* in the pound on the rental, and the owners 1*d.* in the pound. The police acting as inspectors report any waste coming to their knowledge, and the persons so causing waste are proceeded against under the Act. The waterworks cost upwards of 9,000*l.* The supply is constant, and 280,000 gallons are delivered to the town daily. The water is not filtered before delivery, and is consequently sometimes, though rarely, a little muddy. It was clear, colourless, wholesome, and palatable when our sample was taken. It contained only a very small proportion of organic matter, exhibited no evidence of excremental pollution, and was of moderate hardness. The supply is so abundant that a stream of it is always running in the gutters. The improved water supply is said to have had a most beneficial effect upon the health of the inhabitants. Mr. Donald Macleod, a medical practitioner in the town, stated in his evidence before us that, in his opinion, moderately soft water is the healthiest water to use for general household purposes. (For analysis, *see* page 42.)

Notwithstanding this abundant supply of good wholesome water, some springs and private wells are still used in the town. We took samples from two of these, viz., from Mr. John Scott's well in Teviot Crescent, and from a spring at the cemetery, opposite to Mr. J. Laing's house. Mr. John Scott's well is sunk to the depth of 20 feet in gravel, close to a number of privies. The water was clear, colourless, and palatable, but contained the products of the decomposition of animal matters; there was, however, only a very small proportion of unoxidised organic matter left in it. (For analysis, *see* page 69.) The spring at the foot of the cemetery contained a larger proportion of the products derived from animal matter, and also a slightly larger amount of unoxidised organic matter; nevertheless, the water was clear, colourless, and sparkling. (For analysis, *see* page 109.) Taking their origin into account, both these waters must be regarded as of suspicious quality.

Haworth (*Yorkshire*), an urban sanitary district of 2,884 inhabitants, is supplied with water by the waterworks of the Local Board of Health, the water is obtained chiefly from springs, but to a small extent from gathering grounds. The reservoir, situated near the village of Haworth contains 194,600 gallons. The water is said to be unpolluted before entering the reservoir, is not filtered, and is not pumped. The area supplied—360 acres—contains 491 houses. The supply is intermittent and direct from the mains, but it is scarcely adequate to the requirements of the town and district. The rate of charge for water is 3*d.* in the pound on the assessment. The waterworks were constructed in 1854, and cost 3,050*l.* The water has not been analysed.

Haydock (*Lancashire*), an urban sanitary district of 5,286 inhabitants, obtains water for domestic purposes chiefly from shallow wells. Messrs. Richard Evans and Company (who are owners of many cottages) have sunk a well from it. The occupiers of their cottages are supplied with water. The water has not been analysed.

Hayle (*Cornwall*), an urban sanitary district of 2,500 inhabitants, is supplied with water by works belonging to the sanitary authority obtained from a gathering ground of about three square miles area, the whole of which is cultivated, and farmyard manure is used thereon. The water flows into a reservoir containing about 1,000,000 gallons, built partially above the surrounding ground, and uncovered. The water is not filtered, and 15,000 gallons are delivered daily for domestic purposes on the constant system, partly direct from the mains, and partly through cisterns. The rate of charge for water is $2\frac{1}{2}$ per cent. on the rateable value.

Heage (*Derbyshire*), an urban sanitary district of 2,195 inhabitants, is supplied with water for domestic purposes from private shallow wells, and also shallow wells sunk at different parts of the district, at the expense of the Local Board. The supply is stated to be adequate for the requirements of the district. The water has not been analysed.

Heaton (*Yorkshire*), an urban sanitary district of 1,673 inhabitants, is supplied with water from forty private shallow wells situated in various parts of the township. The water has not been analysed.

Heaton Norris, an urban sanitary district of 3,299 inhabitants, is supplied with water by the Stockport Water Company. (*See Stockport*, p. 399).

Heavor (*Derbyshire*), an urban sanitary district of 4,988 inhabitants, obtains water for domestic purposes from a well 270 feet deep, pumped direct into the mains, owing to the inadequacy of the supply, and about 16,000 gallons are delivered daily direct from the mains to about 600 houses, unfiltered, on the intermittent system. The water has not been analysed.

Hebden Bridge (*Yorkshire*), an urban sanitary district of 4,500 inhabitants, is supplied with water chiefly from springs. We have analysed several samples of water available for the supply of this district. With two exceptions all these waters were of excellent quality and well adapted for all domestic uses. The sample from the spring at Wood Top was one of the purest waters we have ever examined. (For analysis, *see* page 113.) The two exceptions were the samples from the wells in Foster Mill Lane and Royd Terrace, but even these have only a slight suspicion of sewage contamination attaching to them, and may be safely used if they are derived from springs or from wells not less than 30 feet deep. (For analysis of Lister spring and Wood Top spring, *see* page 113; of the remaining samples, page 72.)

Heckmondwike (*Yorkshire*), an urban sanitary district, containing 8,300 inhabitants, is supplied with water from gathering grounds exceeding 2,000 acres in extent. The whole of the volume of the stream is abstracted, impounded, and stored, with the exception of the 2,000,000 gallons which is daily passed down the streams as compensation to the millowners; Dewsbury is entitled to use 750,000 gallons; Batley, 500,000; and Heckmondwike, 250,000 gallons a day. The service reservoir for the town of Heckmondwike is situated at Stancliffe, just out of the township, and it contains 1,000,000

PART IV. DESCRIPTIVE.

Helston. Hillmorton.

gallons; it is partially built above the surrounding ground and covered. The water is collected from the moorlands at or near Woodhead, partly in the counties of Lancashire and Yorkshire, far away from any source of pollution. The water is not filtered, but flows by gravitation to a high service reservoir, and thence into the township. The area of district supplied is 693 statute acres, including 1,800 houses and 60 manufactories. The supply is constant, except in time of drought. In summer, water is obtained from mills having deep wells for the purpose of watering the streets. The supply is direct from the mains, and is very deficient for three or four months in the summer. The rate of charge for water varies from 8*s*. 8*d*. per year, on houses of the value of 5*l*. 10*s*., to 2*l*. 6*s*. a year on houses of the value of from 70*l*. to 80*l*.; and for trade purposes 6*d*. per 1,000 gallons. The steps taken to prevent waste are constant supervision, by an inspector, of the fittings and taps; and parties detected in wasting the water are summoned, and, on conviction, are fined. The waterworks have cost Heckmondwike 30,494*l*. 1*s*. 9*d*. (For quality of the water *see Batley*, page 310.)

Helston (*Cornwall*), a borough of 3,797 inhabitants, is supplied partly by natural springs and partly by shallow wells, into streets and houses. There are no waterworks connected with the borough. We have examined two samples of water from this town. The shallow well supplying the iron pump in Meneage Street is largely fed by the soakage from sewers or cesspools. It is a dangerous water. The spring water of Five Wells Shoot is much worse and is quite unfit for dietetic purposes. It is however of moderate hardness and might be used for washing. (For analysis, *see* pages 70 and 110.)

Hepworth (*Yorkshire*), an urban sanitary district of 1,111 inhabitants, obtains its supply of potable water from shallow private wells. The supply is stated to be adequate. The water has not been analysed.

Hereford (*Herefordshire*), a city and urban sanitary district of 20,000 inhabitants, is supplied with water for domestic purposes, abstracted from the *Wye*, and pumped into a service reservoir containing about 4,000,000 of gallons; the water is filtered and 1,000,000 gallons are delivered on the constant system direct from the mains daily. The present supply is stated to be adequate. Our analysis given on p. 48 shows this water to be turbid, brown, and highly charged with peaty matter. It is scarcely fit for drinking, but it is soft and well suited for washing. It exhibited no evidence of previous animal contamination.

Heywood (*Lancashire*), an urban sanitary district of 21,248 inhabitants, is supplied with water by a private company from a watershed of 1,260 acres three miles from the town, where it is stored in reservoirs of an aggregate capacity of 506,000,000 gallons, from whence it flows on to filter beds and thence into service reservoirs containing about 338,000,000 gallons. The water is said to be unpolluted; it is filtered through layers of rubble stone, gravel, and sand. The district supplied (Heywood and Middleton) contains 7,000 houses, and 150 manufactories. The supply is on the constant system and amounts to 700,000 gallons daily for domestic, trade, and sanitary purposes. The rate of charge is 10*s*. per annum for cottages, under 7½ per cent. on houses under 40*l*. annual rental; 6½ per cent. on houses under 60*l*.; 6 per cent. on houses under 80*l*.; 5 per cent. on houses under 150*l*. per annum. To prevent waste, inspectors are appointed to examine taps and fittings. The works cost 85,000*l*.

Higher Bebington (*Cheshire*), an urban sanitary district of 2,865 inhabitants, is supplied with water by the Wirral Waterworks Company. The water is pumped to high service reservoirs on Prenton Hill; one of them is built entirely above, and the other is altogether underground. (*See Oxton*, page 382.) Some houses have cisterns, and others are supplied direct from the mains. The supply is adequate.

Hillmorton (*Warwickshire*), a parish of 1,094 inhabitants, derives its supply of water for drinking and domestic purposes from shallow wells, numerous samples of which we have submitted to investigation. The only sample which could, in any way, be considered as fit for human consumption was that from Dandy well; but even this had been previously contaminated to an extent that would be caused by the admixture of 10 per cent. of average London sewage. The high proportion of chlorine in this well shows that its contamination was caused chiefly by liquid manure, as distinguished from solid excrementitious matters. It was a tolerably soft water, and of all the samples the best adapted for washing and cleansing purposes. As a potable water, however, it ought only to be used provisionally until a better supply can be obtained, because the large proportion of ammonia indicates that the source of contamination is not far from the well. The samples from the Upper Public well, Lower Street, and the Bottom Public well, Lower Street, closely resembled each other both in the amount of organic impurity which they contained, and in the extent of their previous sewage or manure contamination, although they differ rather widely in their relative quantities of mineral constituents. The water of both these wells was derived to a very large extent from sewage and from the drainage of privies, cesspools, and manure heaps; the upper well receiving its contamination chiefly from the washings of solid excrements, whilst that of the bottom well was more largely derived from urine and slop water. The water of both these wells had filtered through a thicker stratum of soil than that of the Dandy well, and hence the animal organic matter, although nearly four times as great in quantity at first, was more completely oxidized before it reached the well. The upper well water was but moderately hard, but that from the bottom well very hard. It is needless to add that the use of these waters for domestic purposes must be attended with great risk to health. The water from the well in Pryse's yard and Dunkley's well was still more frightfully polluted, the latter being derived entirely from liquid manure only slightly inferior in strength to average London sewage. Nearly 6 per cent. of this liquid manure was in the fresh or unoxidized condition; a half-pint glass of this water therefore contained rather more than a desert spoonful of actual sewage of the strength of London sewage. But it was in the sample from the well in Pryse's yard that excrementitious pollution reached its climax. This water was derived entirely from liquid manure of double the strength of average London sewage, and it still contained, at the time when the analysis was made, a quantity of this liquid manure in a fresh or unchanged condition, equal to rather more than a table spoonful of average London sewage in a half-pint glass of the water. In using the water of these two wells the people of Hillmorton are simply drinking their own liquid excrements and slop water after filtration through a few feet of earth. The liquid which they thus imbibe under the name of "spring or well water" is much worse than London sewage filtered through five feet of gravel. We have as yet met with only one sample of water so polluted as that from Pryse's well, it was the water from a well in the Rue Traversine in Paris, situated in the midst of cesspools; the water from that well (which is used only, we believe, for making bread) was derived from liquid manure *thrice* as strong as London sewage. The water from the well in Mr. Billington's yard, though palatable, contained a notable proportion of actual sewage matter, and had received a large amount of soakage from sewers or cesspools. It cannot, therefore, be used for domestic purposes without serious risk to health. (For analyses, *see* page 79.)

Hinderwell (*Yorkshire*), an urban sanitary district of 2,599 inhabitants, obtains its supply of water for domestic purposes from springs, streams, and wells. The water has not been analysed.

Hindley (*Lancashire*), an urban sanitary district of 10,627 inhabitants, is supplied with water from shallow wells. There are no waterworks.

Hollingworth (*Cheshire*), an urban sanitary district of 2,347 inhabitants, obtains a supply of potable water from springs. The supply is said to be adequate. The water has not been analysed.

Holme (*Yorkshire*), an urban sanitary district of 7,624, inhabitants, is supplied with water from a stream and from springs. The supply is said to be adequate for the requirements of the district. The water has not been analysed.

Holm Cultram (*Cumberland*), an urban sanitary district of 4,087 inhabitants, obtains a supply of water for domestic purposes from shallow private wells. The water has not been analysed.

Holywell (*Flintshire*), an urban sanitary district of 3,540 inhabitants, obtains water from private wells; the supply is inadequate and a company has been established (Holywell and District Waterworks Company), and it is proposed to convey the water from the celebrated St. Winifred's Well to Holywell for the supply of the town and district. (For analysis of this water, *see* page 112.)

Honley (*Yorkshire*), an urban sanitary district of 4,700 inhabitants, is supplied with water for domestic purposes from eighteen public wells and surface springs. The supply is adequate, but not well distributed. The water has not been analysed.

Hoole (*Cheshire*), an urban sanitary district of 1,720 inhabitants, obtains a supply of water for domestic purposes, partly from the Chester Waterworks Company, and partly from private wells. The supply is said to be adequate. The water of the wells has not been analysed. (For an analysis of the Chester water, *see* p. 46.)

Horbury (*Yorkshire*), an urban sanitary district of 4,000 inhabitants, is supplied with water for domestic purposes partly by public and private shallow wells. The supply is very insufficient, and the local authority have obtained powers to take water from a neighbouring township. Steps are being taken to execute the necessary works. We have analysed several samples of these well-waters with the following results:—The only samples which, in the absence of a better supply, may be used for domestic purposes without great risk to health are those from Mr. Mortimer's well and the Hall Cliffe well. Although the well at the Wool Packs Inn exhibited no evidence of *previous* sewage contamination, the high proportion of chlorine which it contained convinces us that this evidence had become obliterated, and that this water was, originally, drainage of fully the strength of London sewage. It contained, moreover, a large proportion of *actual* or unoxidised sewage matter. Its use for domestic purposes is, therefore, highly dangerous to health. The remaining samples were merely sewage which had soaked through a few feet of porous earth. Mr. Johnson's well at Quarry Hill contained a moderate proportion of actual or unoxidised sewage matter, whilst Captain Hartley's cottage well and kitchen well contained much actual or unoxidised sewage matter. It is needless to add that these waters were utterly unfit for human consumption. All the samples were excessively hard, and therefore not adapted for washing. They were tasteless, colourless, and inodorous. (For analyses, *see* page 73.)

Horncastle (*Lincolnshire*), an urban sanitary district of 4,858 inhabitants, has no waterworks, but a supply of potable water is obtained, partly from the rivers *Bain* and *Waring* which flow through the district, and partly from shallow wells. The water has not been analysed.

Hornsea (*Yorkshire*), an urban sanitary district of 1,700 inhabitants, is supplied with water for domestic purposes from private wells. The supply is inadequate and the sanitary authority are about to construct waterworks and sewage works for the district.

Hornsey (*Middlesex*), an urban sanitary district of 12,592, is supplied with water for domestic purposes by the New River Company. (*See* p. 276.)

Hornsey, South (*Middlesex*), an urban sanitary district of 8,000 inhabitants, obtains its supply of potable water from the New River Company. (*See* p. 276.)

Horsforth (*Yorkshire*), an urban sanitary district of 5,500 inhabitants, obtains a supply of potable water from stream and springs. The water is not filtered, and the supply is said to be adequate.

Hoyland Swaine (*Yorkshire*), an urban sanitary district of 748, obtains its supply of potable water from private wells. The supply is said to be adequate. The water has not been analysed.

Huddersfield (*Yorkshire*).—This borough of 70,250 inhabitants is supplied with water for domestic purposes by waterworks established under Acts of Parliament passed in 1828 and 1845. The supply powers extend, however, only to the central portions of the borough, and the sources of supply are from springs at Longwood. Further extensive works, authorised by the Huddersfield Water Act, 1869, are now in progress. The source of supply of the new works is from springs and gathering ground at Meltham and Marsden, about eight miles south of the borough. The original works were established in 1828, although there existed previously some small works established by the Ramsden family, who are the principal proprietors of the district. The waterworks now belong to the Corporation. The reservoirs of the existing works, capable of holding 69,000,000 gallons, are situated at Longwood, and the area of the gathering ground of the existing works and those now in progress, is 5,000 statute acres. The water is said to be unpolluted before entering the reservoirs, and is not filtered. The high service reservoir (Spring Street) holding 392,713 gallons, is built entirely above the surrounding ground, and is not covered. The district supplied (2,000 acres) contains 12,000 houses and 80 works and manufactories. The supply is constant during the winter months, and intermittent during the summer months (the mains then being charged on an average 8 hours per diem). The average volume of water delivered in the district daily is 750,000 gallons. The supply to cottages under 10*l*. rental is direct from the mains. Houses of the higher class are furnished with cisterns, the overflow pipes of which are generally connected with the soil pipes; but, under the new Act of 1869, the overflow pipes are not to be connected with the soil pipes, but to project through the walls outside the buildings. The present supply is said to be inadequate for the town and district. The rate of charge for water varies from 4*s*. for houses under 2*l*. rateable value, up to 45*s*. for houses of the rateable value of 50*l*. The supply to works and manufactories is by meter, and the rate varies from 1*s*. 6*d*. per 1,000 gallons for 15,000 gallons per quarter, to 1*s*. per 1,000 for from 60,000 to 100,000 gallons per quarter. In order to prevent waste, a periodical inspection is made of the taps and fittings.

The water is of excellent quality (*see* analysis, page 114), clear, colourless, and palatable. It contains only a very small proportion of organic matter. Its hardness is moderate, and it is well adapted for dietetic and all domestic purposes.

Hugglescote (*Leicestershire*), a township of 2,327 inhabitants, derives its water from springs and shallow wells. We have submitted samples of several of these to analysis, the results of which will be found at pages 76 and 116. William Griffin's spring in Donington affords water of good quality for drinking and culinary purposes, but too hard for washing. As this is a spring water the moderate amount of previous animal contamination may be disregarded, it arises from manured land and not from sewage. (For analysis, *see* page 116). The remaining samples consisted chiefly of soakage from sewers or cesspools, and were therefore unfit for human consumption. They were also too hard to be used for washing. (For analysis, *see* page 76).

Hurst (*Lancashire*), an urban sanitary district of 5,432 inhabitants, is supplied with water chiefly by the Corporation of Ashton-under-Lyne, from waterworks belonging to that Corporation. (*See Ashton-under-Lyne*, p. 305.)

Hurworth (*Durham*), a township of 1,357 inhabitants, obtains its water from springs and shallow wells. The sample from the spring at Cross Bank Hill was an excellent water in all respects but one;—its hardness, which was greater than desirable, and being nearly all permanent could not be much diminished by boiling. This drawback, however, only affects its use for washing; it was a perfectly safe and wholesome water. (For analysis, *see* page 116.) The only other samples fit for human consumption were Mr. Broughton's pump and the pump at the west end of the village. The latter sample was the softest of the series, but unless the well be deep the amount of animal contamination places it amongst the suspicious class of waters. The remaining class consisted chiefly of sewage which had percolated through a porous soil (*see* column headed "previous sewage or animal contamination"). The numbers in this column were confirmed by the high proportions of chlorine, which unmistakably disclosed the fact that these waters had been mixed with a large proportion of urine. Even the water from the pump near the churchyard had received its contamination chiefly from urine and but little, if at all, from decaying corpses. These highly contaminated samples contained, moreover, a good deal of unoxidized animal matter, and their use for domestic purposes would be attended with great risk to health. London sewage filtered through five feet of gravel would be a better water than these samples. (For analyses, *see* page 76.)

Hyde (*Cheshire*), an urban sanitary district of 14,360 inhabitants, is supplied with water from a gathering ground. There are five small reservoirs. The water is to some extent polluted, owing to its coming from cultivated land, having dwelling houses and farmsteads upon it. It is not filtered. The area of the district supplied is about 2,000 acres. There are from 4,500 to 5,000 houses supplied direct from the mains in addition to works and manufactories. In dry seasons, the town and district often suffer very severely from the inadequate and sometimes the total stoppage of the supply. Occupiers of dwelling houses are charged at the rate of 5 per cent. upon the annual rental of their premises.

Hythe (*Kent*), an urban sanitary district of 3,289 inhabitants, obtains its supply of potable water from springs issuing from the lower greensand, which flows through earthenware pipes into a covered reservoir holding about 40,000 gallons; the water is not filtered; and about 20,000 gallons are delivered on the intermittent system to about 400 houses daily. The supply is inadequate to the requirements of the district.

Idle (*Yorkshire*), an urban sanitary district of 6,253, obtains its supply of potable water from the Calverley District Water Company, who purchase their supply in bulk from the Bradford Corporation (*see Bradford*, page 321.)

Ilfracombe (*Devon*), an urban sanitary district and fashionable watering place of 4,681 inhabitants (largely augmented in the season), is supplied with water for domestic purposes from streams. Waterworks were established in 1849, and belong to the Local Board of Health. The water flows direct from streams into a reservoir about a mile from the town. The area of the reservoir is 3½ acres, average depth 20 feet. The water is said to be not polluted before entering the reservoir; is filtered through sand and gravel, and flows by gravitation into the town; 800 houses are supplied with water for domestic purposes, but no manufactories. The supply is intermittent and the houses are both furnished with cisterns and supplied direct from the mains; the overflow pipes from the cisterns are connected with the soil pipes. The present supply is adequate for the requirements of the town and district. In order to prevent waste periodical inspection is made of the fittings. The waterworks cost 6,000*l.* Previously to the establishment of the waterworks the district was supplied with water from private wells. There has been no marked improvement in the health of the inhabitants, as far as can be ascertained from the waterworks supply. The water is clear, colourless, and of moderate hardness. It is also of fairly good quality for dietetic purposes. (For analysis of this water, *see* p. 35.)

Ilkeston (*Derbyshire*), an urban sanitary district of 10,000 inhabitants, is supplied with water from wells, the river, and by a private company; waterworks were established in 1855. The reservoirs are situated at Pimlico and at Little Hallam, one in the centre of the town, and the other a mile distant. The area of the gathering ground is about

PART IV. DESCRIPTIVE.

Ilkley.

Inverness.

1,000 acres. The water is filtered through gravel and sand, and pumped to a high service reservoir. The high service reservoir contains 75,000 gallons; is built above the surrounding ground, but is uncovered. The supply is constant and direct from the mains, and 790 houses are supplied for domestic purposes. The present supply is adequate for the requirements of the district. The rate of charge for water is 2*d.* a week for cottages, and other houses in proportion. Previously to the establishment of the waterworks the district was supplied with water from wells, and rain water collected in cisterns. The water has not been analysed.

Ilkley (*Yorkshire*), an urban sanitary district of 2,511 inhabitants, obtains its supply of water for domestic purposes from springs. The works belong to the Sanitary Authority, and cost 11,000*l.* The water is not filtered, and 40,000 gallons are delivered daily on the constant system to about 400 houses and baths. The supply is said to be adequate. The water is of most excellent quality for dietetic purposes. It is also of moderate hardness, and therefore suitable for washing. (For analysis of this water, *see* page 113.)

Ilminster (*Somerset*), a town of 2,431 inhabitants, is supplied with water from shallow wells and springs. We have analysed a sample from a public spring in the town. The water from this spring would naturally fall under the category of suspicious or doubtful waters owing to the large amount of evidence which it exhibited of previous sewage or animal contamination, but as it contained only a minute trace of organic matter, and was derived from a deep-seated spring, it might be used for drinking and cooking purposes with reasonable safety. It had doubtless percolated through highly manured soil in its passage downwards into the Lias from which it issued, and hence the evidence of previous animal contamination. Great care should be taken that no town sewage or soakage gains access to the spring. The water was clear, bright, and palatable, and no infusoria were found in the sample examined. It was, however, a water which would be likely to favour the development of animalculæ on standing for some time in contact with the air. It was too hard for washing, and on this account also somewhat objectionable for other domestic purposes. (For analyses, *see* page 117.)

Ince-in-Mackerfield (*Lancashire*), an urban sanitary district of 14,000 inhabitants, is supplied with water for domestic purposes from works belonging to the Sanitary Authority which cost 22,000*l.* The water is obtained from two wells sunk in the New Red Sandstone. The shafts of the wells are 6 feet in diameter, and 150 feet deep, with trial boreholes 3 inches in diameter, and 150 feet below bottom of wells. The wells are sunk in a sparsely populated district. The water is not filtered, and about 120,000 gallons are delivered daily direct from the mains, on the intermittent system, to 2,300 houses and 12 works for domestic and trade purposes. The supply is adequate.

Inverness.—This burgh of 14,469 inhabitants is supplied with water abstracted from the river *Ness*. The works were established in 1830, and belong to the Inverness Gas and Water Company. The reservoirs, containing 390,000 gallons, are situated on high ground, immediately above the town, and 450,000 gallons are pumped from the river daily. The high-service reservoir is built entirely above the surrounding ground, but is not covered. The district supplied (1,363 acres) contains 2,000 houses and 10 manufactories. The supply is constant, and 414,000 gallons are delivered in the district daily for domestic and 36,000 for trade purposes. The majority of the houses are supplied with cisterns, and the rest draw direct from the mains. The overflow pipes from the cisterns are invariably connected with the soil pipes. The rate of charge for water for domestic use is 1*s.* in the pound on the rental, or 6*d.* per 1,000 gallons by meter, and 6*d.* per 1,000 gallons for trade purposes. In order to prevent waste, periodical inspections of the pipes, taps, and fittings are made by men employed by the company. The waterworks have cost 13,906*l.*

The intake is about a mile above the town, but below Holm Mill, from which a considerable quantity of woollen dye and fulling waste is discharged into the watercourse. The excrements of the workpeople at this mill, though ostensibly kept out of the stream, we found to be in close proximity to the mill lade, which is on the same side of the river as the intake of the water company. The water filters through a gravel bank on its way from the river to the pump well, whence it is raised to uncovered service reservoirs on a neighbouring hill. This filtration not only removes all suspended matter, but slightly reduces the proportion of peaty matter in the water, as shown in columns headed organic carbon and organic nitrogen in the analytical table below.

The water supplied to the town is very soft, and free from all evidence of excremental pollution, but it is too peaty to be pleasant for drinking, and the sanitary authorities will do well to take precautions against the fouling of the stream at Holm Mill. Most of the houses have cisterns, the rest are supplied direct from the mains. The overflow pipes from the cisterns are invariably connected with the soil pipes.

PART IV. DESCRIPTIVE.

Inverness. Ivybridge.

The water acts violently upon bright lead, but not at all upon the tarnished metal. We have seen leaden water pipes which were said to have been in use for many years in Inverness, and there was not the slightest evidence of corrosion upon the interior surface.

The Medical Officer of Inverness, Mr. F. M. B. Stewart, says (Fourth Report., Vol. II., Part I., Sec. 4):—

"I am of opinion that the water is very good, and that the effect upon the health of the inhabitants "is also highly beneficial. I consider the supply defective; the water is cut off one day every week. "Serious complaints were made last summer about the scanty supply. The water (from its peaty "nature, I suppose) causes diarrhœa in persons coming to town for about a week or 10 days. I do "not consider that the supply can ever be satisfactory until it is got by gravitation from the hill "lochs. The water being forced by machinery up to a considerable height, there is a serious risk of "the machinery breaking, and thus causing a deficient supply."

A few shallow wells are still used in Inverness; one of them supplying a public pump situated in Well Street, about 100 yards from the river, was described to us as sometimes contaminated and discoloured, we therefore took a sample of the water and submitted it to analysis. The results, contained in the following table, show that at the time of our visit the water of this well was clear, colourless, and wholesome.

COMPOSITION OF POTABLE WATER AT INVERNESS.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Water supply, March 8, 1872	3·20	**·349**	**·044**	·001	0	·045	**0**	·95	·4	2·3	2·7	Clear and palatable.
Pump in Well Street, March 8, 1872	15·60	**·139**	**·006**	0	·033	·039	**10**	4·20	·3	7·6	7·9	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Ipswich (*Suffolk*), an urban sanitary district of 42,839 inhabitants, is supplied with water partly from works belonging to a private Company, and partly by private shallow wells. The water obtained by the Company is derived partly from springs, and partly from a well sunk and bore-hole into the chalk. The springs flow into a service reservoir containing 600,000 gallons, supplying the low level part of the town, and the water of the well is pumped into another service reservoir holding 600,000 gallons, to supply the high level part of the town. The reservoirs are built partly above the surrounding ground, and are covered. The water is not filtered, and 800,000 gallons are delivered to the district daily, direct from the mains, on the constant system, to about 8,000 houses and 12 manufactories. The water obtained from both of these sources is of excellent quality for dietetic purposes, but it is too hard for washing. (For analyses, *see* pp. 100 and 123.) About 10,000 of the population obtain their supply of potable water from shallow private wells. Eleven of these wells, supplying about 100 houses, have been reported as polluted, and proceedings are now pending (December 1874) against the occupiers under the Sanitary Laws Amendment Act, 1874. The rate of charge for water is 5 per cent. on the rental.

Irvine (*Ayrshire*), a royal burgh of 6,886 inhabitants, is supplied with water from 14 public wells, which belong to the Corporation, and by private wells. The wells are $4\frac{1}{2}$ feet in diameter and are sunk in sand to an average depth of 10 feet. There is said to be an abundant supply of water.

Ivybridge (*Devonshire*) is supplied with water from the river and from wells. We have examined samples of river and well water from this village with the following results:— The two samples from the river *Erme* were first-class waters, wholesome, and fit for all domestic purposes. They were very soft, and contained but a small proportion of organic matter of vegetable origin. The sample from above Harford Bridge was slightly better than the other taken about two miles nearer the district to be supplied. Being river water and slightly turbid, it would be desirable, wherever it be abstracted, that it should be subjected to sand filtration before delivery. (For analyses, *see* page 33.) The waters from Mr. Boon's well and Mr. Bryant's well were seriously and recently contaminated with urine; they were consequently quite unfit for human consumption, but were soft and well adapted for washing and cleansing purposes. The samples from the wells at Mr. Allen's cottages and at Mr. Sherwell's cottages were of fairly good

Part IV. Descriptive.

Jedburgh. Kelso.

quality and could be used for drinking purposes with but little risk to health, if the wells be carefully guarded from the admission of surface impurities. They were also tolerably soft and therefore adapted for washing and cleansing. The water from the well adjoining Mr. Head's premises was by no means bad, although its quality was not quite satisfactory. The well is either shallow or it receives some slight surface soakage. If the latter, steps should be taken to exclude it. It was soft and well adapted for washing. (For analyses, *see* page 70.) The water from the artesian well adjoining Mr. Allen's premises was one of the best in Great Britain. It contained only the merest trace of organic matter and was very soft. It was therefore admirably adapted for drinking, cooking, and all domestic purposes. The slight evidence of previous animal contamination which it exhibited need not be regarded, as the water came from a deep source. (For analysis, *see* page 89.)

Jedburgh (*Roxburghshire*), a town of 3,321 inhabitants, derives its water supply from springs. The yield of the springs is very variable; in 1870 it was as low as 36,000 gallons a day; it sometimes rises to 90,000 gallons a day. The works were established in 1868, and belong to the Police Commissioners. The high-service reservoir is situated on the hill side above the town; it is built below the surrounding ground, and is covered. The maximum supply to the inhabitants is 53,000 gallons daily and is intermittent; waste is prevented by vigilant inspection of the fittings and taps. Most of the houses are furnished with cisterns, a few only being supplied direct from the mains. The overflow pipes from the cisterns are connected with the soil pipes, and thence with the sewers.

The district supplied (421 acres) contains 333 houses and six manufactories. The rate of charge for water is 1*s.* 2*d.* in the pound on the rental. The waterworks have cost about 4,996*l.*

The water is hard, but otherwise of very excellent quality. It is clear, colourless, and palatable, and contains but a very minute proportion of organic matter. It exhibits some evidence of previous animal contamination; but as it is spring water, this may safely be disregarded. Previously to the introduction of the present supply, the town derived its water by pumping partly from springs and partly from the river *Jed*. It is stated that the introduction of the new supply has not been attended by any change in the health of the inhabitants. Mr. John Hume, a medical practitioner in Jedburgh, said in his evidence before us, that he considered a moderately hard water to be the most wholesome for domestic use. (For analysis, *see* page 111.)

Johnstone (*Renfrewshire*), a burgh of 8,000 inhabitants, receives its water from the Paisley Waterworks Commissioners, which supply was introduced into the town in 1869. The area of district supplied is about 300 imperial acres, containing 466 houses, and 13 manufactories or works. 200,000 gallons of water are delivered every 24 hours into the town. The houses are not furnished with cisterns, but are supplied direct from the mains. The quantity is adequate, and the rate of charge for water is the same as in Paisley. The steps taken to prevent waste are vigilant inspection of the fittings and taps, and no outside taps or wells are allowed unless self-acting. (*See Paisley*, p. 383).

Kearsley (*Lancashire*), an urban sanitary district, is supplied with water from the Bolton Corporation Waterworks. (*See Bolton*, page 320.)

Keighley (*Yorkshire*), an urban sanitary district of 20,000 inhabitants, is supplied with water chiefly from springs, and also from gathering ground. The works were first established in 1816, and extended in 1869, and belong to the Local Board of Health. The area of the gathering ground is 2,320 acres. There are two small service reservoirs situate in the high part of the town, in which the water from the springs is collected. The other reservoirs are the Chedoles and the Bullytree; these have a united capacity of 256,250,000 gallons. The water is said to be unpolluted before entering the reservoirs, it is not filtered, and is not pumped. The high service reservoir is situated at Black Hill, and contains 2,000,000 gallons; it is built partially under the surrounding ground, and is not covered. The supply is intermittent, and direct from the mains, and is adequate for the requirements of the town and district. The rate of charge extends from 4*s.* per annum for houses rated under 21*l.* to 24*s.* for houses rated at 22*l.* 10*s.* and upwards. Strict watch is kept to prevent waste, and offenders are summoned or the supply is cut off. The waterworks cost 150,000*l.* The water is said to be very soft, and almost equal to that supplied to Glasgow from Loch Katrine.

Kelso (*Roxburghshire*), a borough of 4,564 inhabitants, is supplied with water partly from the river *Tweed* and partly from springs. The supply from springs has been in existence for a long series of years, that from the river was established in 1863. The works belong to the Commissioners of Police. The tank for the spring water contains 6,000 gallons, and is situated in Horse-market Street, and the water is distributed thence by gravitation. The reservoir for the *Tweed* water is placed on high ground at Angry Flat, about half a mile from the town. About 100,000 gallons of water are daily pumped from the river at Windy Gowl into a subsidence reservoir capable of containing 250,000 gallons, and the water is afterwards filtered. The spring water is clear, colourless, wholesome, and palatable; it contains only a very minute proportion of organic matter, but it is hard. (For analysis, *see* page 114.) The *Tweed* water is soft and contains a moderate proportion of organic matter, except in time of flood, when we presume the pumping is discontinued. Its use for domestic purposes is undesirable because it has received the sewage of Peebles, Selkirk, Galashiels, and other places before it reaches the intake. (For analysis, *see* page 48.) The district supplied is 1,140 acres in extent and contains 500 houses. The supply of spring water is constant; that from the *Tweed* 14 hours per day; and 30,000 gallons of spring, and 100,000 gallons of *Tweed* water are delivered to the district daily. The supply is said to be adequate to the requirements of the district. The rate of charge is 11*d.* in the pound on the assessment. In order to prevent waste, periodical inspection is made of the taps and fittings. The waterworks have cost 6,000*l.*

PART IV. DESCRIPTIVE. Kendal. Kilmarnock.

Kendal (*Westmoreland*), a borough of 13,442 inhabitants, is supplied with water for domestic purposes from waterworks established in 1846, which belong to the Kendal Waterworks Company and have cost 16,000*l.* The water is obtained from gathering grounds, from springs, and from streams. The reservoirs, capable of holding 18,500,000 gallons, are situated about one mile from the town. The area of the gathering ground is 200 acres. The water from streams filters through the river bank—a natural bed of gravel and sand, into filtering wells, a short distance from the river channel. The area of the district supplied is 230 acres containing 2,300 houses and 100 manufactories. The supply is constant, and 300,000 gallons of water are delivered to the district daily for trade and domestic purposes. The houses are supplied direct from the mains. The rate of charge for water is 1*s.* 3*d.* in the pound on the rateable value. In order to prevent waste, a general supervision is made of the taps and fittings. The waterworks have cost about 16,000*l.* Shallow wells are also now used to a considerable extent. Before the establishment of the present waterworks, the inhabitants are said to have suffered severely from gravel on account of the hardness of the water; but the improved supply has had a beneficial effect upon their health, the disease having nearly disappeared. Our analysis of the company's water (*see* page 36) shows it to be soft, and of good quality, but slightly turbid. A sample of a shallow well water from the pump in the King's Head Hotel yard was shown by our analysis (*see* page 69) to be frightfully contaminated by soakage from neighbouring privies, piggeries, and stable yards. Though a favourite well, its water was quite unfit for dietetic purposes.

Kidderminster (*Worcestershire*), a borough of 19,463 inhabitants, is supplied with water for domestic purposes from shallow private wells and by casks carried in carts from a neighbouring polluted river. The volume of water from this source has fortunately been greatly diminished by the sinking of artesian wells at the various carpet manufactories to obtain water for trade purposes. The supply is filthy and altogether inadequate for the requirements of the population. The town stands on New Red Sandstone, which supplies the deep wells of the manufactories with potable water of excellent quality, as is seen from the analytical results yielded by our sample from the deep well in Messrs. Brenton and Lewis's mill, furnishing 100,000 gallons per day. (*See* page 93.) One of the two shallow wells, which were pointed out to us as yielding water of average quality, was situated in Mr. Alderman Tovey's courtyard, it was only 5 feet deep and contained a liquid which was very similar in composition to that which we have obtained in our laboratory, by allowing London sewage to soak slowly through 5 feet of gravel. The drinking of such water, especially in periods of epidemic disease, cannot but be fraught with great risk to health. The other well, from which we drew a sample, contained water which analysis shows to have had a like origin, but the animal matters had been somewhat more oxidized than those in the water of Alderman Tovey's well, consequently the present pollution was less, whilst the previous contamination was greater. (For analyses of these shallow well waters *see* page 76.) We do not remember to have visited a town of this size in which the water supply has been so completely neglected. The splendid water in the New Red Sandstone immediately beneath the town ought to render easy to the inhabitants of Kidderminster a remedy for this state of things.

Kilmarnock (*Ayrshire*), a burgh of 23,709 inhabitants, is supplied with water partly by gravitation from impounding reservoirs situated in an elevated position two miles north-east of the town, and partly from shallow wells. The drainage area is about 1,250 acres, and the storage reservoir holds 62,500,000 gallons, or 89 days' supply. Before delivery the water is filtered through fine sand, coarse sand, and gravel. The works were esta-

PART IV. DESCRIPTIVE.

Kinross. Kirkintilloch.

blished in 1850, and belong to the Corporation. The district supplied (1,000 acres) contains 5,000 houses and 38 works. The supply is constant and direct from the mains, but it is stated to be totally inadequate, especially for the higher districts of the town, and powers were obtained in the year 1871 to augment the quantity. At present it amounts to 27 gallons per head per day for all purposes. Some waterclosets draw direct from the main. This is a bad arrangement, as regurgitation may take place. Previously to the establishment of the waterworks the town was supplied from wells and the river *Kilmarnock*. It is stated that the improved water supply has had a most beneficial effect on the health of the inhabitants. Analysis shows (*see* page 44) that the quality of this water is very similar to that of the river itself above the town; it is only slightly less peaty and three degrees softer. Our sample was of a yellowish colour but clear, and it exhibited no evidence of previous animal contamination. Though not very palatable, it is greatly to be preferred to the well waters still used in the town. The Cross well, which is in the centre of the town and much used for drinking, is largely fed by sewer and surface soakage; 100,000 parts of the water exhibit 32,820 parts of previous sewage contamination, and although there are but traces of the animal matter left unoxidised, the use of water having such an origin must be attended with much risk during the prevalence of epidemics in the burgh. Far more dangerous, however, is the water obtained from a well in High Street, said to be much used in the neighbourhood. We found the water to consist chiefly of imperfectly filtered sewage; it was very turbid, and contained a considerable proportion of unoxidised animal matter. This well ought to be at once closed. (For analyses of these well waters, *see* page 74.)

Kinross (*Kinrosshire*), a burgh of 1,926 inhabitants, is supplied with water for domestic purposes from natural springs and private wells sunk in the Old Red Sandstone; there are no other waterworks.

Kirkburton (*Yorkshire*), an urban sanitary district of 3,700 inhabitants, in supplied with water from springs and wells. The present supply is not adequate to the requirements of the district. The water has not been analysed.

Kirkaldy and Dysart (*Fifeshire*), a parliamentary and royal burgh of 21,385 inhabitants, is supplied with water for domestic and other purposes from streams. It is collected in reservoirs, and conveyed thence by gravitation. The waterworks were established in 1869, and belong to the Commissioners. The principal reservoir is situated about 12 miles north of the town, and the Commissioners are obliged to send 750 gallons per minute from thence into the watercourses, as compensation water to the mills. The water for the supply of the district, is conveyed from the principal reservoir to the service reservoir, situate about four miles from the town. The area of the gathering ground is 1,836 acres. The area of the principal reservoir is 160 acres, and of the service reservoir, 10 acres. The compensation reservoir will contain 200,000,000 gallons, and the service reservoir 21,000,000 gallons. The water flows, before entering the reservoir, through a pastoral country, and is not considered to be much polluted. The water is filtered first through a medium of clean sharp sand, gravel, and broken clay pipes. The service reservoir is built principally above ground, and is not covered. The area supplied is 1,200 acres, and it contains 568 houses and 68 works. The supply is constant, and about 500,000 gallons for domestic purposes, and 74,000 gallons for trade purposes are delivered daily. Most of the houses are furnished with cisterns, and the overflow pipes from the cisterns are in some instances connected with the soil pipes. The present quantity is more than adequate for the requirements of the district. The rate of charge for this water is 1*s.* 4*d.* in the pound upon the rental, in addition to a public rate of 3*d.* in the pound. The rate for works is 4*d.* to 6*d.* per 1,000 gallons. To prevent waste, a strict investigation of the taps and fittings is made regularly. The waterworks cost 50,000*l.*

Kirkheaton (*Yorkshire*), an urban sanitary district of 2,646 inhabitants, is supplied with water from shallow wells and springs in all parts of the district. The present supply is not adequate. The water has not been analysed.

Kirkintilloch (*Dumbartonshire*).—Although this town contained in 1871 a population of 6,700, it has no extra-urban water supply, but is dependent upon private shallow wells. The governing body state that they have not executed any public works, such as water or sewerage works; it is therefore not surprising to find that the mortality is high, and that it has reached 30·7 per 1,000. The wells from which the inhabitants derive their potable water are, for the most part, frightfully polluted by excrementitious matters. (*See* our analyses at page 74.) Out of four which we examined, there was only one, the water from which could be used for domestic purposes without great risk to health. This well is situated in a field at the end of Kerr Street. It is sunk to a depth of 25 to 30 feet in gravel and sand, and is surrounded by cultivated fields, upon which nightsoil is probably to some extent used as manure. The depth of water in the well is from 3 to 4 feet. The water was colourless, but slightly turbid. It contained a moderate amount of organic matter, partly of animal origin, and exhibited decided evidence of previous animal contamination. This water can only be recommended for use in default of a more wholesome supply, but it is much better than the beverage yielded by the following pumps:—Whitelaw's well, east, is an open well in a garden, about 7 feet deep and containing about 4 feet of water. It is not near a privy, but the garden from which the water soaks is probably heavily manured. The water was clear, nearly colourless, and moderately hard. It contained a large proportion of animal organic matter in solution, and exhibited strong evidence of anterior pollution. Mr. Findlay's pump yielded a clear and nearly colourless water, containing a very large proportion of animal organic matter, and exhibiting evidence of previous pollution with animal refuse equal to that which would be produced by adding $27\frac{3}{4}$ gallons of average filtered London sewage to $72\frac{1}{4}$ gallons of pure water. The well is about 12 feet deep, and close to two very offensive middens. Of the shallow wells of Kirkintilloch, that known as Freeland Place well is probably the worst. It is an open well in a corner, and an open street drain comes down to the same corner, and flows directly into the well whenever a neighbouring grid gets stopped up. When our sample was taken the water was very muddy from mineral and organic matter in suspension. There was also a considerable proportion of animal organic matter in solution, and the evidence of previous pollution showed that the water had been contaminated with a proportion of animal matter equal to that added to $62\frac{3}{4}$ gallons of pure water when $37\frac{1}{4}$ gallons of average filtered London sewage are mixed with it. The water is too hard for washing. Dr. Stewart, the Medical Officer of Health, informed us that a violent epidemic of cholera raged in Kirkintilloch in 1854, that eleven deaths occurred in a street near to this well, and that the victims all used this water. In one case a woman, whom he saw carrying a pitcher from this well, died of cholera four hours afterwards. In the interests of the public health, this well ought to be at once filled up, and no time ought to be lost in providing the inhabitants of Kirkintilloch with a wholesome supply of water, so that the use of the remaining wells may be dispensed with.

Kirklington-cum-Upslan (*Yorkshire*), an urban sanitary district of 300 inhabitants, obtains a supply of water for domestic purposes from shallow wells in a subsoil of gravel and sand. The water has not been analysed.

Kirriemuir (*Forfarshire*).—This burgh or barony of 4,145 inhabitants has no waterworks, neither is there a burgh surveyor, waterworks engineer, or medical officer of health.

Knaresborough and Tentergate (*Yorkshire*), an urban sanitary district of 5,205 inhabitants, is supplied with water by a private company from the river *Nidd.* The works cost 12,000*l.* The water is pumped from the river into an open subsiding reservoir built entirely above the surrounding ground, and capable of holding 257,000 gallons, from thence it flows on to filter beds, and filters through a coarse and fine gravel and river sand in layers to a depth of six feet, and 90,000 gallons are delivered daily to about 1,376 houses, direct from the mains. The supply is adequate to the requirements of the district. A sample from the river, considering the season of the year at which it was taken, contained but a moderate proportion of organic matter. It exhibited no evidence of previous sewage or animal contamination, but was slightly turbid and should be filtered before being supplied for domestic use. It was a good, wholesome, soft, and palatable water, well adapted for all domestic purposes. (For analysis, *see* page 39.)

Knighton (*Radnorshire*), an urban sanitary district of 1,646 inhabitants, obtains its potable water from springs, conveyed from thence by pipes into covered service tanks, built partially above ground, and holding 27,000 gallons. The supply is direct from the mains, and is said to be adequate. The water has not been filtered.

Lanark, a burgh of 5,099 inhabitants, is supplied with water from springs and from private wells. The waterworks belong to the Town Council. The reservoirs are situate about a mile to the east of the town. The high service reservoir, containing 160,000 gallons, is built entirely under the ground, and is covered. The private wells of the town are sunk into the Old Red Sandstone, from 20 to 35 feet deep. The area of the district supplied is 400 acres, containing 730 houses, and four manufactories. The supply is constant, except in drought, when the mains are only charged for a few hours during the day. Some of the houses are furnished with cisterns, and others are supplied direct from the mains. Vigilant inspection of fittings is undertaken to prevent waste. Our sample of the waterworks water was taken from a standpipe opposite the Clydesdale Hotel. It was slightly turbid, and, for spring water, contained a large proportion of organic matter indicating pollution from surface water. It was soft and well adapted for washing. As the water exhibits considerable evidence of previous animal contamination, the source of the surface water should be examined. (For analysis, *see* page 126.)

Lancaster (*Lancashire*), an urban sanitary district of 17,034 inhabitants, is supplied with potable water from springs on the Bleasdale Fells issuing from the Millstone

PART IV. DESCRIPTIVE.

Langholm. Leeds.

Grit formation; the water flows direct from springs through a closed conduit into covered service reservoirs situate 250 feet above the lowest part of the town, and is not filtered. From thence 700,000 gallons of water are delivered daily, on the intermittent system, for domestic and trade purposes, partly direct from the mains and partly through cisterns. The waterworks belong to the sanitary authority, and cost about 45,000*l.* We have analysed a sample of this water, and the result given on page 39 proves it to be a most excellent potable water, suitable for every domestic purpose, and, on account of its softness, well adapted for use in the laundry and lavatory.

Langholm (*Dumfriesshire*), a burgh or barony of 3,275 inhabitants, is supplied with water obtained from mountain springs. The works were established in 1856, and belong to the Commissioners of Police. The storage reservoir is situated at an elevation on the eastern side of the town. The high-service tank contains 23,000 gallons. The water is said to be unpolluted before entering the tank, is not filtered, and is not pumped. There are a few wells to private houses. The water is supplied on the constant system to about 50 houses distributed over an area of 40 imperial acres, and about 20 gallons per head are delivered to the inhabitants daily. The houses are furnished with cisterns, the waste pipe from which is connected with the soil pipe from the waterclosets. The supply of water is adequate for domestic purposes. The rate of charge is 4*d.* in the pound for domestic purposes, and 6*d.* in the pound when used for baths and waterclosets To prevent waste constant inspection is made of the fittings and taps. The waterworks cost about 800*l.* The water has not been analysed.

Lathorn (*Lancashire*), an urban sanitary district of 3,659 inhabitants, obtains a supply of water for domestic purposes chiefly from private wells, but partly from springs. There are no waterworks. The water has not been analysed.

Launceston (*Cornwall*), a borough and urban sanitary district of 3,500 inhabitants, is supplied with water for domestic purposes from natural springs diverted, and flowing into reservoirs about two miles from the town. The works were established in 1854, and belong to the Local Board of Health. The reservoirs contain 175,000 gallons. The water is said to be not polluted before entering the reservoirs, and is filtered through sand. The reservoirs are partially built above ground, and are all covered. The supply is intermittent as regards the very high portions of the town, but constant in the lower parts, and about 60,000 gallons are delivered to the district daily for domestic purposes. The houses are partially supplied with cisterns, and in such case the overflow from the cisterns is connected with the sewers. The present supply is adequate for the supply of the district. The rate of charge for water varies from 1*s.* 9*d.* in the pound for houses of the net annual value of 1*l.* 10*s.* to 10*d.* in the pound for houses of the annual value of 13*l.* 6*s.* 8*d.* The waterworks have cost 6,225*l.* Previously to the establishment of the waterworks, the inhabitants obtained their supply of water from wells which are now abandoned.

Leamington (*Warwickshire*), an urban sanitary district of 20,917 inhabitants, is supplied, on the constant system, with water from the river *Leam*, the intake being above the town, but below the influx of sewage from Southam and other smaller places, and of drainage from cultivated land. The water is very hard, (*see* analysis page 50) and was not, when our sample was taken, efficiently filtered. Considering its source, its quality was not otherwise bad, but the previous sewage or animal contamination which it exhibits renders its character suspicious, and many of the inhabitants prefer to drink the water of shallow wells. We took a sample of one of these, the water of which had a high reputation for purity and brilliancy. Analysis shows (*see* page 76) this well to be fed entirely by sewage, and although the organic matters were nearly all oxidised, we cannot but condemn this use, for dietetic purposes of water which has so recently had such a disgusting origin.

Leeds, a borough of 272,629 inhabitants, is supplied with water on the constant system from gathering grounds at Eccup, from the river *Wharfe* at Arthington, and from the river *Washburn* at Leathley. The works belong to the Corporation, and have cost 535,620*l.* The chief works are a storage reservoir at Eccup containing 257,000,000 gallons; the Westwood reservoirs and filter beds containing 22,000,000 gallons, the Woodhouse reservoir of 6,000,000 gallons capacity, and the pumping stations at Arthington and Headingley. The Eccup reservoir receives the drainage of 1,200 acres. This water and that taken from the *Washburn* are said to be free from pollution, but the river *Wharfe* receives, above the intake, some of the sewage of Otley, Burley, Ilkley, and Addingham; the water from this source is therefore filtered through sand 18 inches deep. Our sample was taken from the main in the Great Northern Railway station supplied from the reservoir at Eccup. It exhibited no previous sewage or animal contamination, was of moderate hardness (8·3 parts in 100,000) and clear, but contained rather a large proportion of peaty matter. (For analysis, *see* page 39.)

PART IV DESCRIPTIVE. Lees. Leith.

The area of the district supplied is 21,572 acres; containing 56,908 houses, and 2,500 works and manufactories. The supply is constant, and 6,000,000 gallons of water are delivered to the district daily for trade and domestic purposes. From April to October 17,862,000 gallons are used for watering streets. The sewers are not flushed. The supply of water is direct from the mains, except to large houses, which have cisterns. The waste pipes from cisterns are not connected with soil pipes, but either have an outlet on to the sinkstones or into the pan of the waterclosets. The present supply is adequate for the requirements of the town and district. The rate of charge for houses for domestic purposes is 1*s.* in the pound on the rental; that to manufactories for trade purposes is 6*d.* per 1,000 gallons. In order to prevent waste an assistant inspector is occupied constantly in inspecting taps and fittings. The waterworks have cost 535,620*l.*

Lees (*Lancashire*), an urban sanitary district of 2,919 inhabitants, is supplied with water by the Oldham Corporation Waterworks. (*See Oldham*, p. 381.)

Leicester (*Leicestershire*), a borough of 95,220 inhabitants, is supplied by a private company with water from a brook flowing through Bradgate Park; the reservoirs in which it is impounded are situated five miles from the town. We have repeatedly analysed this water with the following results:

COMPOSITION OF WATER SUPPLIED TO LEICESTER.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	REMARKS.
Leicester water supply, Nov. 1867.	23·70	·506	·020	·001	·001	·022	0	—	—	—	13·4	Clear and yellow.
Ditto at Haymarket, Aug. 30, 1871.	23·58	·579	·072	·002	·048	·122	180	1·45	11·0	11·0	22·0	Slightly turbid. Slightly yellow.
Ditto at Woodgate, Aug. 30, 1871	21·62	·679	·089	·002	·010	·101	0	1·55	10·0	8·9	18·9	Slightly turbid. Yellow.
Ditto at St. Nicholas Square, Aug. 30, 1871.	26·32	·485	·075	·001	·005	·081	0	1·48	15·8	9·0	24·8	Slightly turbid. Slightly yellow.
Ditto at Haymarket, Oct. 5, 1871.	22·10	·620	·093	·003	·083	·178	530	1·55	9·4	11·8	21·2	Slightly turbid. Brownish.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

All the samples contained an unusually large quantity of organic matter, which was however chiefly if not entirely of vegetable origin. The sample collected in Woodgate contained the largest, and that collected in St. Nicholas Square the smallest, proportion of organic matter. This organic matter tinges the water of a yellow (and in the second sample from the Haymarket of a brownish) colour, and certainly renders it unpalatable and possibly unwholesome. Both samples from the Haymarket exhibited evidence of previous contamination with animal matter; the others exhibited nc such evidence. All the samples, except that collected in 1867, were somewhat turbid and required filtration before use for drinking. They were all hard and not well adapted for washing. The second sample from the Haymarket was somewhat worse in quality than the first, as it contained more organic matter and exhibited stronger evidence of previous animal contamination.

On the assumption that all the water supplied to Leicester comes from one reservoir, the considerable differences in the composition of the three samples collected on August 30, 1871, indicate that the mains were in a very foul condition and required thorough flushing out and cleansing.

Leigh (*Essex*).—This parish of 1,688 inhabitants is supplied with water from shallow wells, the water from several of which we have analysed with the following results. The waters from the Bay pump and the Strand pump were remarkable for containing a large proportion of alkaline salts, of which chloride of sodium was a prominent ingredient. In other respects these waters were of fair, though not quite unimpeachable, quality. The water from the Bay pump was very soft. The water from the Churchyard well contained rather a large proportion of organic matter which appeared to be of animal origin. It also exhibited previous contamination with animal matters to a dangerous extent and was moreover excessively hard. It was entirely unfit for domestic use. (For analyses, *see* page 88.)

Leith (*Edinburghshire*).—This burgh of 44,721 inhabitants is supplied with water

PART IV. DESCRIPTIVE.

Leominster. Leyland.

by the Edinburgh and District Water Trustees. The supply is intermittent. (*See Edinburgh*, p. 339.)

Leominster (*Herefordshire*), a borough of 5,863 inhabitants, is supplied with water from a well 7 feet 6 inches in diameter, and 60 feet deep with a bore-hole 110 feet deep, sunk through gravel into the Old Red Sandstone formation. About 100,000 gallons are pumped daily, and supplied direct from the mains, unfiltered, to 700 houses situate within an area of about two square miles.

Leslie (*Fifeshire*), a burgh of barony of 3,768 inhabitants, is supplied with water from springs, situated three miles from the town, and about 200 feet above the level of the service reservoir. The works were established in 1834, and belong to the Leslie Waterworks Company. The water is said to be unpolluted before entering the high service reservoir. The high service reservoir is a leaden tank containing about 7,000 gallons, and is built entirely above the ground, and covered. The district supplied is the burgh of Leslie and the village of Prinlaws, but no works or manufactories. The supply is constant, and 36,000 gallons a day are supplied for domestic purposes. There are only 15 houses in the district which have waterclosets, and these are furnished with cisterns. The supply is adequate for present requirements of town and district. The rate charged per annum for water is 8*d.* per individual above 12 years of age. To prevent waste, the superintendent of the water company inspects the fittings and works periodically. The waterworks cost 600*l.* The water has been analysed by Dr. Stevenson Macadam, who states that it is excellent for general domestic purposes. The quality and quantity of saline ingredients dissolved in the water are similar to those found in all good town waters. The hardness of the water is only 5°·5, and consequently it is entitled to rank as a soft water. The organic matter is a mere trace, and is of a vegetable origin.

Leven (*Fifeshire*), a burgh or barony of 2,501 inhabitants, is supplied with water abstracted from the *Leven*. The works were established in November 1867, and are the property of the Police Commissioners. The reservoir is situated about a mile from the town. The water is said to be unpolluted, and it is not filtered, it flows from the reservoir by gravitation into the town. The service reservoir contains about 35,000 gallons, it is partly built above the ground, and is uncovered. The area supplied—140 acres—contains 132 houses. The mains are fully charged, and 50,000 gallons are delivered to the district daily for domestic purposes. The houses having waterclosets are furnished with cisterns, and the remaining houses are supplied direct from the mains; the quantity is adequate for the inhabitants of the town and district. The rate of charge for the water is 10*d.* in the pound. No steps are taken to prevent waste. The waterworks cost 229*l.* 7*s.* 11*d.*

Levenshulme (*Lancashire*), an urban sanitary district of 2,500 inhabitants, is supplied with water by the Manchester waterworks. (*See Manchester*, page 373.)

Leyland (*Lancashire*), an urban sanitary district of 3,839 inhabitants, derives its water from shallow wells. This village is a type of many others in the districts which we have visited. It has a Local Board of Health, which, according to its own return, has executed no sanitary works and keeps no record of the rate of mortality. Leyland is situated on a sandy porous soil, through which the liquid contents of the cesspools and privies rapidly soak into the adjoining shallow wells. On this account the sinks, gullies, and cesspools, do not require to be connected with sewers.

"There is generally one privy, midden and ash pit to each house. They are cleansed when thought to require it by the owners or occupiers of the property at no cost to the Local Board, and this district being in a great measure an agricultural one, the refuse is put upon the land."

Such being the conditions under which water collects in the subsoil of this village, it is not surprising that our analysis of a sample, drawn from a well, situated only a few yards from two privies, contained a considerable amount of organic matter, and no less than 24,360 parts of previous sewage or animal contamination in 100,000. The water in these wells consists in fact chiefly of the house slops and liquid excrement of the inhabitants diluted, to some extent, with the rain water which falls upon the surrounding highly cultivated soil. The potable water used in Leyland is but little better than that which we obtained in our experiments by filtering London sewage through 15 feet of sand, as is seen from the following comparison of analytical results:—

	100,000 lbs. of Leyland water contained.	100,000 lbs. of filtered London sewage contained.
Total solid impurity	54·40 lbs.	56·40 lbs.
Organic carbon	·325 „	·537 „
Organic Nitrogen	·056 „	·107 „
Previous sewage or animal contamination.	24·360 „	25·050 „

The supply of such villages as this with pure water is often a problem of considerable difficulty since the number of inhabitants is too small to permit the execution of expensive works for such an object. In the utilization for domestic purposes of the pure water of a river basin, such outlying districts ought not to be altogether overlooked; they are often scourged by fever, as was recently the case at the neighbouring village of Walton-le-Dale, where, as given in evidence before us, a similar pollution of shallow well water prevailed.

There is a spring of excellent water issuing from the drift on the outskirts of the village. It is clear, colourless, palatable, and wholesome, and contains only a very small proportion of organic matter. The evidence of previous animal contamination which it exhibits need not be regarded. It is too hard for washing. (For analysis, *see* p. 125.)

Lincoln.—This city of 26,766 inhabitants is supplied daily with 400,000 gallons of water, which flows from impounding reservoirs on to filters, and thence into mains. Of this about one-third goes to works and manufactories, and the remainder, 260,000 gallons, is supplied to 5,079 houses, being at the rate of about ten gallons a head. The water is derived, partly from springs and partly from a gathering ground of 2,000 acres, which is one third of it cultivated and the remainder woodland. From this land the water is received into a storage reservoir and thence flows on to three small filter beds. The Corporation have also power to take water from the *Witham*, which flows close by the pumping station. The sample of this water which we collected on July 12th, 1873, was not of good quality. It was turbid, contained a large proportion of organic matter, and exhibited some evidence of previous sewage or animal contamination. The hardness was moderate. (For analysis, *see* page 52).

Linlithgow, a burgh of 3,690 inhabitants, has no waterworks, strictly speaking; nevertheless water is brought to public fountains from springs outside the town. There are no reservoirs, and the water is introduced into about 12 houses only. There is no water rate, the supply being free to the inhabitants, and no steps are taken to prevent waste. The present supply is stated to be adequate for the requirements of the town if properly husbanded and stored, but during the last three years it has visibly diminished. The sample, which we collected from the public fountain in front of the Council Hall, was of excellent quality for drinking and cooking purposes, but rather too hard for washing. It was colourless and palatable, and contained but a very minute proportion of organic matter. (For analysis, *see* page 114.) By the application of Clark's softening process to this water, its hardness would be reduced to one third of its present amount. The death rate in Linlithgow (population 3,690) varies from 18·5 to 22·5 per 1,000 per annum.

Linthwaite (*Yorkshire*), an urban sanitary district of 5,047 inhabitants, is supplied with water for domestic purposes from about 240 private shallow wells. The Board have constructed a service reservoir, containing 450,000 gallons, at Milnbridge for receiving water from springs; they have also erected in different parts of the district 13 stone troughs and public tanks for distributing water to the inhabitants. The water is said to be unpolluted before entering the reservoir, it is not filtered, and is not pumped. The supply is adequate for the requirements of the district. The inhabitants are not charged for the water. The waterworks cost 480*l.* The water has not been analysed.

Litchurch (*Derbyshire*), an urban sanitary district of 11,087 inhabitants, is supplied with water for domestic purposes by the Derby Waterworks Company. The supply is constant, direct from the mains, and the water is filtered.

Liskeard (*Cornwall*), a borough and urban sanitary district of 4,700 inhabitants, is supplied with water for domestic purposes from a spring which rises in the centre of the town called Pipe Well, four public wells or pumps, and wells or pumps belonging to private houses, but principally by the Liskeard Waterworks Company. The Company derives its water from a series of springs which rise at Poke Tor, Penhale, and Tremar Coombe, in the parish of St. Cleer, called the *Tremar* stream. The water from these springs is conveyed into reservoir by pipes; also from springs which rise at Sibly Back, Cryllay, and Headrifton, in St. Cleer, called the *Cryllay* stream, the water from which runs in an open conduit about two miles from the springs, and by pipes for three miles into the reservoir. The waterworks were established in 1860. The reservoirs are situated on St. Cleer Down, in the parish of St. Cleer, about two miles from Liskeard. The reservoirs contain 545,500 gallons. It is believed that the water is not polluted to any extent; it is not filtered, but strained through copper wire strainers, and flows by gravitation into the town. The water-bearing stratum of the public wells is Killas. Pipe Well is a running stream, the source of which cannot be exactly ascertained.

PART IV. DESCRIPTIVE.

Little-borough. Liverpool.

Ladye Well is 9 feet deep; Dean Well is 28 feet deep; Castle Street well is about 26 feet deep; and Barn Street well is about 75 feet deep. About 760 houses in the town are supplied by the Liskeard Waterworks Company for domestic use. The remaining houses are supplied by public or private wells, or pumps. Five manufactories are supplied by the waterworks company. The supply from the waterworks is constant, and direct from the mains, and about 200,000 gallons are supplied to the district daily for domestic purposes. The overflows from the cisterns and waste pipes are connected with the sewers. The supply is quite adequate for the requirements of the town and district. The rate of charge for the water varies from 4*s.* 4*d.* per annum for houses of the annual value of 4*l.*, to 70*s.* for houses of the annual value of 100*l.* We have examined several samples of water from this town and the results of our analyses are given at pages 70 and 110. These analyses prove, firstly, that the water supplied by the Liskeard Waterworks Company, though not quite clear and bright, was of good quality and perfectly wholesome; secondly, that the Pipe Well water, though not actually contaminated at the time our sample was taken, was in imminent danger of sewage pollution, and a considerable proportion of it consisted of sewage very perfectly purified (chemically) by filtration through a porous stratum. We are not surprised to learn that an outbreak of typhoid fever has occurred near this well; thirdly, the shallow-well water from Castle Well is similar in quality to the Pipe Well water, but the sample from Dean Well exhibits considerably less evidence of previous sewage or animal contamination and might be used for domestic purposes without much risk to health.

Littleborough (*Lancashire*), an urban sanitary distrct of 8,700 inhabitants, is supplied with water for domestic purposes from the Rochdale Corporation Waterworks. (*See Rochdale*, page 389.)

Little Crosby (*Lancashire*), an urban sanitary district of 432 inhabitants, obtains its supply of potable water from shallow wells. The water has not been analysed.

Little Hulton (*Lancashire*), an urban sanitary district of 4,805 inhabitants, obtains an inadequate supply of potable water from shallow private wells and ponds. The supply is inadequate, especially in drought. Arrangements are about to be made with Corporation of Bolton to supply the district with water. The water of the wells has not been analysed.

Little Lever (*Lancashire*), an urban sanitary district of 4,204 inhabitants, is supplied with water for domestic purposes from the Bury and District Waterworks. (*See Bury and District Waterworks*, page 325.)

Litherland (*Lancashire*), an urban sanitary district of 2,214 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool, below.*)

Little Woolton (*Lancashire*), an urban sanitary district of 1,128 inhabitants, is supplied with water partly from the waterworks of the Corporation of Liverpool (*see Liverpool, below*), and partly from private wells.

Liverpool.—This borough of 493,405 inhabitants is supplied with water, partly by gravitation, and partly by pumping from deep wells in and near the town, sunk into the New Red Sandstone which underlies Liverpool and its suburbs, and extends beneath the estuary of the Mersey to the Cheshire shore. The gravitation works are situated on the slopes of Rivington Pike, distant about 33 miles from Liverpool.

The pumping stations at present in use are Green Lane, Bootle, Windsor, Dudlow Lane, and Water Street. The Water Street station was, at the time of our visit of inspection, about to be abandoned on account of the increasing impurity of the water. Three stations, viz., Hotham Street, Soho, and Bevington Bush, have already been closed for the same reasons at the annexed dates* :—

Hotham Street - - - -	1866
Soho - - - - -	1866
Bevington Bush - - -	1857

Although these wells are closed as sources of supply, we were enabled with the ready assistance of the hydraulic engineer, the late Mr. Duncan, to procure samples of two of them, the results of the analysis of which are included in the following table:—

* These wells appear, however, to have been occasionally used at later dates, for in a pamphlet by Mr. Charles H. Beloe, Chairman of the Liverpool Water Committee, it is stated that, "The following stations "are rarely or ever used for supplying the town, except during protracted drought, the water from these "wells being bad, and the machinery old and expensive to work,—

"Bevington Bush Station, "Soho Station,
"Hotham Street Station, "Water Street Station,
"Devonshire Place Station."

COMPOSITION OF POTABLE WATERS SUPPLIED TO LIVERPOOL.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			Temperature Centigrade.	Distance from Town Hall in a direct line.	Depth of Well and Bore-holes.	Yield in Gallons per Day.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.				
												°	Yards.	Feet.	
Bevington Bush Well, May 21, 1868. Closed.	86·70	**·135**	**·038**	·005	8·678	8·721	**86,510**	12·61	11·5	24·0	35·5	—	1,460	149	—
Soho Well, May 21, 1868. Closed.	59·98	**·066**	**·024**	·001	2·195	2·220	**21,640**	7·51	3·9	16·2	20·1	—	1,540	123	—
Bootle Extension Well, May 21, 1868.	34·40	**·091**	**·027**	·001	·418	·446	3,870	3·18	0	13·7	12·6	10·4	5,350	312	1,600,000
Green Lane Well, May 21, 1868.	26·40	**·020**	**·020**	0	·416	·436	3,840	2·68	4·0	9·6	13·6	11·0	5,060	370	3,000,000
Dudlow Lane Well, May 21, 1868.	19·64	**·004**	**·000**	·003	·679	·681	6,490	2·61	·5	6·5	7·0	—	6,820	245	700,000
Ditto, Oct. 18, 1873	16·92	**·142**	**·080**	0	·527	·607	4,950	3·00	0	7·0	7·0	—	—	—	—
Windsor Well, May 21, 1868.	32·00	**·076**	**·033**	0	·411	·444	3,790	2·87	2·1	12·8	14·9	11·2	3,230	453	900,000
Water Street Well, May 21, 1868.	51·42	**·018**	**·013**	·001	1·975	1·989	**19,440**	7·94	1·6	11·6	13·2	16·0*	2,340	156	300,000
Kensington service reservoir, containing mixture of about one-third Green Lane Well water and two-thirds Rivington Pike water, May 22, 1868.	12·92	**·057**	**·021**	·001	·133	·154	1,010	1·59	·5	5·7	6·2	13·0	—	—	—
Rivington Pike water, unfiltered, as it passed on to filter beds, June 4, 1869.	8·48	**·243**	**·031**	·004	0	·034	**0**	1·53	·1	3·6	3·7	—	—	—	—
Ditto, as issuing from sand filters, June 4, 1869.	9·66	**·210**	**·029**	·002	0	·031	**0**	1·53	·3	3·7	4·0	—	—	—	15,500,000

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

* Condensing water of engine is allowed to mix with supply, and hence this comparatively high temperature.

These analyses are very instructive as illustrations of the way in which a dense population affects the water even of deep wells. The Bevington Bush, Soho, and Water Street wells, sunk into a soil carrying a dense population, are, notwithstanding their great depth, highly charged with oxidised animal refuse. They are in this respect but little superior to the much shallower wells of London as is seen from the following comparisons :—

	Previous sewage or animal contamination.
Liverpool Deep Wells.	
Bevington Bush well - - -	86,510
Soho Well - - - -	21,640
Water Street well - - -	19,400
London Shallow Wells.	
Pump in Aldgate - - - -	70,000
„ in the Temple - - -	25,690
„ near St. Martin's Church - -	48,790
„ in Idol Lane - - -	63,200
„ in Royal Institution - -	43,240

The water from some of the closed wells in Liverpool was distributed to certain portions of the town during the cholera epidemic of 1866; but Dr. Trench, the Medical Officer of Health, has not been able to trace any connexion between the supply of this water and the outbreak of cholera in Liverpool in that year, see Vol. II. (Minutes of Evidence), Part III., Q. 1873. It is satisfactory to know that these wells are now permanently closed (*see*, however, foot note, p. 368), and that the Water Street well, which is but little better as regards anterior animal contamination, will also soon be abandoned.

With one exception, the remaining wells yield, at the present time, water of excellent quality. They all necessarily contain the drainage from cultivated land, but this has been so thoroughly oxidised and purified by percolation through a porous and well aerated rock, that but very minute quantities of organic matter (represented in the above analyses by organic carbon and organic nitrogen) have escaped decomposition. The waters are not excessively hard, but nearly the whole of the hardness is permanent, that is, it is not removed by boiling; indeed, the water of the Bootle Extension well became somewhat harder by boiling. They all exhibit a considerable amount of alkalinity.

The exception just alluded to is the Dudlow Lane well, which shows a somewhat higher degree of previous animal contamination than is desirable. In other respects, however, this water is the best of the series; it contains much less solid impurity, and is far softer than any of the other well waters, whilst the organic matter with which it was previously contaminated has been so completely oxidised as to leave but the faintest trace behind. This is one of the very few waters which we have found containing no appreciable amount of organic nitrogen. At the time of our visit (May 21st, 1868) this well was not completed, and the water was therefore probably not in a normal condition. We have examined it again since the works were finished, but find that the quality of the water has deteriorated.

The water derived from the gathering ground upon Rivington Pike is of excellent quality, and, except as regards organic matter, is greatly superior to that of any of the New Red Sandstone wells. It has a hardness of only 3·97 degrees, whilst the well waters vary from 6·96 to 14·87 degrees. It contains only 9·66 parts of solid impurity in 100,000 parts, whilst the well waters (excluding those of the closed wells) contain from 19·64 to 51·42 parts. On the other hand, the Rivington water holds in solution much more organic matter than the well waters; this organic matter is, however, essentially of a vegetable (peaty) nature, as is shown by the comparatively small proportion of nitrogen as compared to carbon which it contains, and by the entire absence, from this water, of any evidence of previous animal contamination.

The great difference in the proportion of organic nitrogen to organic carbon in the Rivington, as compared with the well water, is seen from the following comparison:—

	Organic Nitrogen.		Organic Carbon.
Bootle Extension well - - -	1	:	3·37
Green Lane well - - -	1	:	1·00
Windsor well - - - -	1	:	2·30
Water Street well - - -	1	:	1·38
Rivington Pike water - - -	1	:	7·24

Before leaving the works at Rivington Pike, the water, contrary to the usual practice in such cases, is submitted to a thorough filtration through sand,—a process which, as seen from an inspection of the above analytical table, effects a marked improvement in its quality by reducing the amount of organic matter, although it slightly increases the total solid impurity and hardness. This increase is obviously due to the solution of the sand and fragments of millstone grit composing the filter beds, but the very slight deterioration thus produced scarcely detracts from the substantial improvement effected. To ascertain the amount and nature of the organic matter thus removed by mere adhesion to the substance of the filters we submitted to analysis two portions of sand, one of which had just been taken from a filter bed, whilst the other consisted of a portion of the same sand which had been washed and made ready for use again. 100,000 parts of the sand contained—

	Organic Matter.	Organic Carbon.	Organic Nitrogen.	N. : C.
As removed from the filter bed	1523·40	314·160	38·640	1 : 8·13
After washing - -	804·41	94·921	16·973	1 : 5·59

It cannot be doubted that a considerable amount of organic matter undergoes oxidation and destruction during the passage of the water through the sand, but independently of this it appears, from the above analytical numbers, that one ton of dry sand washed after previous use is capable of removing from water and retaining 16·1 lbs. of peaty matter.

It follows from what we have said of each water separately that the mixture of Green Lane well-water and Rivington Pike water distributed from the Kensington service reservoir to the greater part of Liverpool must be of excellent quality; it is perfectly clear and transparent, contains but a small amount of solid impurities, and possesses only 6·19 degrees of hardness; and although it exhibits 1,010 parts of previous sewage or

Liverpool. Llanfrechfa, Upper.

animal contamination, this, as we have already stated, implies but an infinitesimal amount of risk, since it is all contained in the water of a deep well, none of it being derived from the surface water of Rivington Pike.

The whole of Liverpool is now abundantly supplied upon the constant system, but the demands of an increasing population fully keep pace with the increase of water which is from time to time obtained. The Corporation are already extending to their utmost capacity the works at Rivington Pike; a new source of supply is therefore only a question of time.

The service reservoirs are in Prescot, Kensington, Aubrey Street, Park Hill, Atherton Street, Dudlow Lane, Woolton Hill; and the aggregate area is $37\frac{1}{3}$ acres; with an aggregate capacity of 114,553,000 gallons. The water is not pumped, but abstracted from streams, and the total drainage from the watershed is taken. A daily volume of 6,465,000 gallons is sent down the streams as compensation, and 10,347,743 sent to Liverpool as per average of 1867. The area of the gathering ground is 10,000 acres. The impounding reservoirs are at Roddlesworth, Rake, Anglezark, Chorley, and Rivington. The area of the whole, with the filter beds, is 549 acres, greatest depth 78 feet, and capacity 3,268,000,000 gallons. The Goit is $3\frac{1}{2}$ miles long, and of an average width at bottom of 21 feet. In ordinary work 14,000,000 gallons pass through the filters daily.

The water is not polluted, and it is filtered through the following media—2 feet 6 inches of sharp river sand, 6 inches of clean gravel $\frac{1}{8}$ inch diameter, 6 inches of clean gravel $\frac{1}{4}$ inch diameter, 6 inches of clean gravel $\frac{1}{2}$ inch diameter, 6 inches of clean gravel 1 inch diameter, 6 inches of clean gravel 2 inches diameter, 6 inches broken stones 4 inches diameter, 12 inches broken stones 6 inches diameter.

The water, after filtration at Horwich, flows from the clear-water tank through a main 44-inch diameter, and 18 miles in length, to the service reservoir at Prescot; to break the pressure on this length there are two small reservoirs, one at Aspull and the other at Mountry House. From Prescot the line is continued by two pipes, one 44 inches in diameter and the other 36 inches in diameter, to old Swan, a distance of 5 miles, and thence to the service reservoirs at Kensington, Aubrey Street, Park Hill, and Dudlow Lane; these supply the lower part of the town; the upper part is supplied from the high-service reservoir at Everton, into which the water is pumped by a Cornish engine, while the neighbourhood of Mossley Hill and Woolton Hill are served by the Woolton Hill reservoir, which is filled from Dudlow Lane by a Bolton and Watts' condensing engine. The area of the service reservoirs is 4,418 feet; the maximum depth is 10 feet; and the capacity is 250,000 gallons. The high-service reservoir is built to a height of 100 feet above the ground and roofed. The total cost of pumping is 1*l.* 3*s.* $5\frac{1}{2}$*d.* per million gallons.

The service reservoirs are built partially above ground, and covered. The pumping machinery; is at Bootle,—2 Bolton and Watts' condensing engines and 1 Cornish engine in course of erection. At Green-lane,—2 Cornish engines and 1 Bolton and Watts' condensing engine. At Windsor,—1 Cornish engine. At Water-street,—1 Bolton and Watts' condensing engine. And at Dudlow Lane,—1 single-acting Cornish engine and 1 Bolton and Watts' condensing engine.

The area of the district supplied is 60 square miles. The total number of assessments for 1867 was 99,284. There are 775 works and manufactories supplied by meter, many of these are very trifling quantities supplied for power only. The most considerable supplies are to sugar houses, railway stations, and breweries. Originally constant supply was given, at present intermittent. The mains are charged usually from 12 to 15 hours daily. Street watering is done from March to October. Flushing drains and sewers is constantly carried on by a staff of men for the purpose.

Part of the town is supplied direct from the mains, and part from cisterns. It is now compulsory for all new property to be provided with cisterns, and that the overflow pipe be carried outside the premises, and not directly connected with the soil pipe or sewer. The supply is inadequate. A special staff of men is employed to make house to house inspection of all water fittings and appliances. The former supply was from springs and wells. The cost of the waterworks was about two millions (2,000,000*l.*).

Llandilo (*Carmarthenshire*), an urban sanitary district of 1,400 inhabitants, obtains its supply of water for domestic purposes from springs which flow into a service reservoir, and is thence distributed on the intermittent system direct from the mains. The supply is said to be adequate. The water has not been analysed.

Llandovery (*Carmarthenshire*), an urban sanitary district of 1,861 inhabitants, obtains a supply of potable water from shallow wells. The water has not been analysed.

Llanfrechfa, Upper (*Monmouthshire*), an urban sanitary district of 2,900 inhabitants,

Part IV. Descriptive.

Long Sutton. Malpas.

obtains its supply of potable water from shallow wells. The water has not been analysed.

Long Sutton (*Lincolnshire*), an urban sanitary district of 2,729 inhabitants, is supplied with water for domestic purposes from private shallow wells, there are also two public shallow wells. The water has not been analysed.

Longwood (*Yorkshire*), an urban sanitary district of 4,055 inhabitants, is supplied with water from springs and shallow private wells, the supply is inadequate. The water has not been analysed.

Lower Bebbington (*Cheshire*), an urban sanitary district of 3,139 inhabitants, is supplied with water for domestic purposes by the Wirral Waterworks Company. (*See Oxton*, page 382.)

Luddenden Foot (*Yorkshire*), an urban sanitary district of 2,968 inhabitants, is supplied with water from shallow wells sunk only two feet into the ground in different parts of the district. The people carry the water from the wells nearest to their dwellings. The supply is adequate for the requirements of the inhabitants. The water has not been analysed.

Ludgvan (*Cornwall*), an urban sanitary district of 2,960 inhabitants, obtains its supply of water for domestic purposes from wells and springs. The water has not been analysed.

Lymm (*Cheshire*), an urban sanitary district of 4,561 inhabitants, is supplied with water from wells on private property, and by a spring in the village. The water has not been analysed.

Macclesfield (*Cheshire*), a borough of 35,571 inhabitants, is supplied with water by gravitation from reservoirs at Langley, principally fed by springs and streams, passing through a conduit to filtering beds, and thence into a service reservoir. The new works came into operation in 1850, and belong to the Corporation. The reservoirs are situate, one at the Macclesfield Common and the other at Langley. The gathering ground is 2,000 acres. The reservoirs hold 177,555,000 gallons. The water is said to be unpolluted before entering the reservoirs, and is filtered through a medium of small boulders, rough gravel, fine gravel, coarse sand, and fine sand. The high service reservoir holds 2,000,000 gallons; it is only partially built above ground, and not covered. The area of the district supplied is 1,000 acres. 8,637 houses are supplied for domestic purposes; forty silk mills, eight breweries, and eight dye-houses, for trade purposes. The supply is constant, and about 1,000,000 gallons is delivered to the district daily. The houses are in very few instances furnished with cisterns; and where cisterns are allowed the over-flow pipe does not communicate with any pipe belonging to a sewer or soil pipe, but opens on to the surface. The supply is said to be adequate. No house is charged less than 5*s.*, the rest about 1*s.* in the pound. Water is supplied to manufacturers and others for 6*d.* per thousand gallons. Men employed by the Corporation are always looking after the mains, service pipes, and taps. The waterworks cost 50,000*l.* Our analysis (*see* page 48) shows that there is some, though very slight evidence of previous animal contamination in the water which ought to be traced to its source. It was also turbid. In other respects the water is of excellent quality, containing, for surface water, a moderate proportion of organic matter. It is soft and therefore well adapted for washing and for manufacturing purposes.

Maidenhead (*Berkshire*), a borough of 6,173 inhabitants, is supplied with water chiefly from shallow wells. We have examined two samples with the following results:— The water from the shallow well collected May 23, 1872, though palatable and tolerably clear, consisted almost entirely of soakage from sewers and cesspools, and it contained a very appreciable quantity of unoxidised sewage matter. Its use for drinking or cooking would be dangerous, and it was too hard to be used for washing. It was well adapted for the irrigation of land and would procure luxuriant crops without the use of any other manure. The other shallow well is situated near the railway station and its water is equally polluted and dangerous. We know of no town in Great Britain where an improved water supply is more imperatively called for. (For analyses, *see* page 83.)

Malpas (*Cheshire*).—This township of 123 (*Horton-by-Malpas*) inhabitants is supplied with water from private wells. We have examined samples from the town well and from Mrs. Holland's pump. The first sample from the town well exhibited considerable evidence of previous sewage or animal contamination, and moreover contained a small quantity of actual or unoxidized sewage; its use in that condition would be attended with risk to health. The second sample was, so far as mineral constituents were concerned, very similar to the first, but it contained no actual or unoxidized sewage, and the proportion of organic impurity was little more than one-fifth as great as that found in the previous sample. If the well can be always as effectively protected from contamination as it was when the last sample was taken, it will yield water of excellent quality. The second sample was colourless and palatable, but it contained a few suspended particles which ought not to be present in well water if the sample be carefully taken. The water from Mrs. Holland's pump was frightfully contaminated both with actual sewage and the products of its decomposition. It was in fact sewage which had filtered through a few feet of earth. It was very dangerous water, and the well ought, in the interest of the public health, to be at once closed. It was rather turbid, but inodorous and palatable. Being harder, it was not so well adapted for washing as the water from the town pump. (For analyses, *see* page 76.)

Malmesbury (*Wiltshire*), an urban sanitary district of 3,000 inhabitants, is supplied with water partly from works of a private company, and partly from private wells.

Malton (*Yorkshire*), an urban sanitary district of 8,168 inhabitants, is supplied with water from a well 6 feet 6 inches diameter, and 12 feet deep, sunk in the Oolite, in a sparsely populated district. The water is pumped into an uncovered service reservoir built partially above ground, holding 225,000 gallons, and from thence 150,000 to 180,000 gallons of unfiltered water for domestic and trade purposes is delivered daily, on the constant system, direct from the mains, to 1,403 houses, and 62 works. The supply is adequate at the present time (August 1874), the dryest season experienced in this district, the water level in the well after being lowered by pumping, about 10 inches remains permanent. The water has not been analysed.

Manchester (*Lancashire*).—This city of 355,665 inhabitants is supplied with water from waterworks belonging to the Corporation. The supply is obtained from an upland gathering ground with its streams, including springs. The Corporation commenced to supply water in 1851. The works belong to the Mayor, Aldermen, and Citizens of Manchester. The storage reservoirs are situate in the valleys of the river *Etherow*, and on the *Arnfield* and *Hollingworth* brooks, in the township of Tintwistle, in Cheshire, and Padfield, in Derbyshire; and the service reservoirs are situate at Godley, Denton, Gorton, and Prestwich. Beyond the volume required to be sent down the rivers for the millowners on the *Etherow*, or about 14,000,000 gallons per day, the quantity of water now abstracted from the river, streams, and springs, and supplied to the district, is about an average throughout the year of 14½ millions of gallons per day. The area of the gathering ground is 19,300 statute acres. The 11 storage reservoirs contain in all 4,599,000,000 gallons. The water is unpolluted before it enters the reservoir, and is not filtered but is passed through brass wire strainers 60 strands to an inch before it enters the mains. Nevertheless even in the case of a water of such undoubted purity, we would recommend filtration, since even the best waters from gathering grounds are liable at times to be turbid, and although turbidity in these cases has not the significance which it possesses when the muddy water is derived from sources exposed to excremental pollution, yet the use, for drinking purposes, of water containing suspended matters is reasonably objected to by consumers and may even drive them in some instances to the use of clear and sparkling water derived from dangerous sources. The area of district supplied is 84 square miles. 137,250 houses are supplied for domestic purposes, and 9,416 works and manufactories by agreement for trading purposes only. The supply is constant; but during the excessive and unprecedented drought of 1868 the service mains were, for a limited period, shut off from 6 p.m. to 6 a.m. For watering streets, 846,000 gallons per week for four and a half months in the year. The supply is generally direct from the main, but baths and waterclosets are supplied from cisterns. If from the cistern, the overflow pipe is brought through the external wall of the premises to prevent waste and fouling of the water. The present supply is adequate to the requirements of the town and district. The public rate of charge for water is threepence in the pound on the poor's rate assessment on all property within the city, and payable by the owner, besides a domestic rate of 9*d.* in the pound on the same assessment on all dwelling-houses in the city. Beyond the city the charge is 1*s.* in the pound on the rental of all dwelling-houses. Water for trading purposes is charged according to special agreement, and either with or without meter, both in and out of the city. To prevent waste, a staff of watermen is constantly looking over the piping in the streets, and a staff of sub-inspectors and plumbers examining the piping and fittings inside houses and other premises. Our analyses of this water given at page 39 show that occasionally, as on the 29th January 1870, it is derived chiefly from springs. At other times it is chiefly upland surface water containing a moderate proportion of organic matter. It is at all times wholesome and, as a rule, palatable. Only on one occasion, Oct. 9, 1871, did we find the proportion of peaty matter somewhat excessive. It is very soft and therefore admirably adapted for washing and manufacturing purposes. In addition to supplying

PART IV. DESCRIPTIVE.

Machynlleth. Merthyr Tydfil.

the city of Manchester, the Corporation supply Salford and 31 townships beyond containing a population of 394,335 or a total of 750,000 persons.

Machynlleth (*Montgomeryshire*), a rural sanitary district of 2,042 inhabitants, obtains its supply of water from private shallow walls. For analyses of the water, *see* p. 69.

Madron (*Cornwall*), an urban sanitary district of 2,927 inhabitants, obtains its supply of potable water from streams and shallow wells. The water has not been analysed.

Margate (*Kent*), a borough of 11,956 inhabitants, is supplied with water by a private Waterworks Company with a capital of 20,000*l.*, from a well 10 feet in diameter, and about 50 feet deep with a bore-hole 20 feet into the Chalk. From this well the water is pumped by three engines of 15 horse-power each, into two reservoirs of high and low level service respectively, both built above the surrounding ground and uncovered. About 500,000 gallons of water are pumped daily, and 2,200 houses are supplied direct from the mains. The houses, it is stated, are not generally supplied with cisterns; but the company compel the provision of cisterns in the case of all new water-closets.

Marsden-in-Almondbury and Marsden-in-Huddersfield (*Yorkshire*), an urban sanitary district of 2,811 inhabitants, is supplied with water for domestic purposes from a tributary of the *Colne* and from springs. The supply is inadequate to the requirements of the district; some of the inhabitants have to carry water for a distance of half a mile. The water has not been analysed.

Masham (*Yorkshire*), an urban sanitary district of 2,208 inhabitants, obtains its supply of potable water from springs and wells, and it stated the supply is adequate.

Matlock (*Derbyshire*), an urban sanitary district and sanitorium of 2,700 inhabitants, greatly augmented during the season, is supplied with water for domestic purposes by a private company, who obtain it from springs. The water is conveyed by earthenware pipes into three reservoirs of an aggregate capacity of 100,000 gallons; from thence 73,000 gallons of water is daily delivered unfiltered, intermittently, direct from the mains, to 255 houses and four hydropathic establishments. There are also a great many private shallow wells. The supply is inadequate to the requirements of the district. The water has not been analysed.

Melrose (*Roxburghshire*), a burgh or barony of 1,405 inhabitants, is indebted to his Grace the Duke of Buccleuch for a supply of excellent water from a reservoir on the slope of one of the neighbouring Eildon Hills, fed by springs. The water is clear, colourless, and palatable. It is of moderate hardness, and contains only a mere trace of organic matter. As it is spring water, some evidence of previous animal contamination, which it exhibits, may be safely disregarded. The supply is constant. A few shallow wells are still used in the town. (For analysis, *see* page 109.)

Meltham (*Yorkshire*), an urban sanitary district of 4,229 inhabitants, is supplied with water from springs. The waterworks belong to the Local Board of Health. The reservoir is situated at Town Slack, and contains 612,562 gallons. The water is said to be unpolluted before entering the reservoir, and is not filtered. The supply is constant, and direct from the mains, and is delivered to 450 houses, distributed over an area of 1,000 acres, and is adequate for the supply of the town and district. The rate of charge is 3*d.* in the pound on the rateable value. To prevent waste, the waterworks inspector makes constant inspection of the taps and fittings. The waterworks cost 2,500*l.* The water has not been analysed.

Merthyr Tydfil (*Glamorganshire*), an urban sanitary district of 52,778 inhabitants, is supplied with water for domestic purposes from the river *Taff Vechan* at the foot of the Breconshire Beacon Hills, about seven miles from Merthyr, where it is received direct from the river into straining basins, connected by pipes with the filtering beds at Penybryn. The works were established in 1861 and belong to the Local Board of Health. The impounding compensation reservoirs are situated at Pentwyn. The service reservoir and pumping station at Penybryn one mile from Merthyr, and the service reservoir at Dowlais Top. The area of the gathering ground is seven square miles, and about 1,000,000 gallons are abstracted from the river daily. The contents of the impounding compensation reservoir is 396,615,000 gallons, of Penybryn reservoir 500,000 gallons, of Dowlais reservoir 300,000 gallons, and of the tanks and filter bed at Penybryn 1,200,000 gallons. The water is not polluted before entering the reservoirs, it is filtered through sand 2 feet in thickness, and gradually through layers of gravel 3 feet in thickness. About 253,000 gallons per day are pumped to Dowlais Top reservoir for the supply of a portion of the district which is too elevated to be supplied by gravitation. The height pumped is 283 feet. The high-service reservoir is partially built above ground and is covered. The area of the district supplied is about 1,095 acres including Cefn-Coed. The supply is constant and direct from the mains, and about 1,000,000 gallons of water is distributed to the district daily for trade and domestic purposes to 10,200 houses, three ironworks, two gasworks, and 48 works and factories. The present supply is adequate for the requirements of the district. The waterworks have cost 83,600*l.* Previously to the establishment of waterworks the inhabitants were supplied with water from wells and springs. The health of the district has been greatly promoted by an unlimited supply of pure water. It is of excellent quality for dietetic purposes and is sufficiently soft for washing. (For analysis of this water *see* page 44.)

Mexborough (*Yorkshire*), an urban sanitary district of 5,000 inhabitants, obtains its supply of water for domestic purposes from shallow wells. The supply is inadequate to the requirements of the district; during drought in summer water is carried about the district in barrels. The water has not been analysed.

Middlesborough (*Yorkshire*), a borough of 50,000 inhabitants, is supplied with water for domestic purposes by the Stockton and Middlesborough Waterworks Company. The water is abstracted from the *Tees* above Darlington. The waterworks were established in 1851. The area supplied is 2,100 acres containing 7,000 houses and 80 manufactories. The supply is constant, and 5,000,000 gallons are delivered to the district daily for domestic and trade purposes. 50,000 gallons of water are used daily from May to August for watering the streets. The supply is direct from the mains, and is at present adequate for the requirements of the town and district. The rate of charge for water is rather more than 5 per cent. per annum on the rental. In order to prevent waste very vigorous inspection is made of the taps and fittings. (*See Stockton,* p. 399.)

Midgley (*Yorkshire*), an urban sanitary district of 3,065 inhabitants, is supplied with water from shallow wells and streams.

Milton next Sittingbourne (*Kent*), an urban sanitary district of 3,000 inhabitants, obtains its supply of water for domestic purposes from wells. The supply is inadequate, and it is stated that the sanitary authority contemplate constructing waterworks. The water has not been analysed.

Moffat (*Dumfriesshire*), a burgh of 1,730 inhabitants, is supplied with water on the constant system from springs situated 3 miles from, and 150 feet above, the town. The works were established in 1867, and belong to the Commissioners of Police. The water is conveyed by pipes 6 inches in diameter into a high-service reservoir, which is built partly above ground, and is covered. The area supplied—176 imperial acres—contains 410 houses. The houses are generally supplied with cisterns, and the overflow pipe from the cistern is connected with the soil pipe. The present supply is adequate for the requirements of the town and district. The rate of charge for water is 1*s.* in the pound on the yearly rent. No special means have been taken to prevent waste. The water-works cost 3,657*l.* The water has been analysed by Dr. Stevenson Macadam, who says, "I have carefully tested a sample of water received from the town of Moffat, and "the water is clear, transparent, and colourless, and possesses an agreeable taste. It "contains only 3·72 grains of saline and organic matter dissolved in an imperial gallon, "of which 3·34 grains are saline matter, and 0·38 grains organic matter. The hardness "of the water is only 2°, and accordingly it ranks as a soft water. It contains no "metallic or other impurities, and can be safely conveyed through leaden pipes. I am "of opinion that the water under examination is of a first class quality for culinary "purposes and for washing operations, and that it is eminently suited for introduction "into the town for general domestic use."

Monk Bretton (*Yorkshire*), an urban sanitary district of 2,090 inhabitants, obtains its supply of potable water from shallow wells. The supply is very insufficient in quantity. The water has not been analysed.

Monks Coppenhall (*Crewe*), (*Cheshire*), an urban sanitary district of 17,810 inhabitants, is supplied with water by the London and North-western Railway Company, from a reservoir at Whitmoor, about 14 miles from the town. There are 2,809 houses supplied on the constant system. The quantity consumed averages, in winter, 55,000 gallons, in summer, 85,000 gallons, including 6,000 gallons per day for watering the streets during the dry months. The supply is direct from the mains. The rate of charge is 5 per cent. on the rateable value. No means are taken to prevent waste. The Local Board have only had to pay the cost of laying mains within their district, which amounts to 4,850*l.* The water is supplied by the railway company to the Board at 6*d.* per 1,000 gallons.

Monmouth (*Monmouthshire*), a borough of 5,874 inhabitants, is supplied with water pumped from the *Wye* into reservoirs, and thence delivered, at the rate of 100,000 gallons a day, on the intermittent system, directly from the mains, to about 460 houses. Cottages are charged at the rate of 2*d.* a week, and houses from 5 to 6 per cent. on their rental.

PART IV. DESCRIPTIVE.

Montrose. Musselburgh.

Montrose (*Forfarshire.*)—This burgh of 15,789 inhabitants is supplied with water for domestic purposes from springs and wells within about three miles of the town. One-sixth of the volume is obtained from a spring derived from the Old Red Sandstone formation in Glenskenno, and five-sixths from a well sunk in the river silt, at Kinnaber in the valley of the *North Esk*. The supply from the spring was obtained by the Corporation about 135 years ago, and that from the well about 14 years ago. The works belong to the Police Commissioners. A daily volume of 260,000 gallons is pumped 130 feet by water power to a high service reservoir, having an area of 588 superficial yards, and a depth of 3 yards, and containing 300,000 gallons. The spring water reservoir contains 36,000 gallons. The water is stated to be unpolluted before entering the reservoirs, and is not filtered. The high service reservoir is partially built above ground, and is covered with a slate roof. The well is 25 feet in diameter, and 20 feet deep. The area supplied, two square miles, contains 1,000 houses, and 24 manufactories. The mains are constantly charged, and 300,000 gallons of water is supplied to the district daily for trade and domestic purposes. Cisterns are only supplied to houses having waterclosets, and the overflow pipe from the cisterns is connected with the soil pipe. The present supply is adequate for the requirements of the town and district. The rate of charge for water for domestic purposes is 3*d*. in the pound on the rental, and from 3*d*. to 5*d*. per 1,000 gallons for trade purposes. Our analysis (*see* page 53) shows the Kinnaber water to contain only a moderate proportion of organic matter. Its hardness is also not excessive, but it exhibits evidence of considerable anterior contamination by sewage or animal matter. As it is a river water, an investigation into the source of this previous contamination should be made.

The spring in Glenskenno yields water of excellent quality for drinking and cooking, but it is harder than is desirable for washing. It is clear, colourless, and palatable, and contains only a very minute proportion of organic matter. Being spring water, the evidence of previous animal contamination which it exhibits may be safely disregarded, because the exhaustive filtration to which such water has been subjected in passing through great thicknesses of soil or rock affords a sufficient guarantee that all noxious constituents have been removed. Our sample of this water was taken from a stand-pipe opposite the entrance to the Star Hotel in High Street, and we were informed that the water consisted of a mixture of about one-twentieth of Glenskenno water and nineteen-twentieths of the Kinnaber water. The analytical results (*see* page 111) show, however, that this information was erroneous. If there was any admixture of Kinnaber water, it must have been in but small proportion. To prevent waste, men are appointed to inspect the taps and fittings. The waterworks cost 9,000*l*.

Morley (*Yorkshire*), an urban sanitary district of 10,000 inhabitants, is supplied with water for domestic purposes from the Leeds Corporation Waterworks. The reservoir containing 1,500,000 gallons, is situated at Churwell. The water is said to be unpolluted before entering the reservoir, and is filtered. The supply is constant and direct from the mains, and 100,000 gallons are delivered daily to 1,200 houses and 15 manufactories, distributed over an area of 1,400 acres; the present supply is adequate for the requirements of the town. The rate of charge for water for domestic purposes varies from 8*s*. 8*d*. a year for houses not exceeding 3*l*. yearly value, up to 2*l*. a year for houses from 50*l*. to 60*l*. yearly value; for trade purposes the charge is by meter, and varies from 1*s*. 3*d*. per 1,000 gallons for the quarterly consumption of 5,000 gallons, down to 9*d*. for the quarterly consumption of 500,000 gallons. No steps are taken to prevent waste. The waterworks cost 20,000*l*. (*See Leeds*, p. 364.)

Mossley (*Lancashire, Yorkshire and Cheshire*), an urban sanitary district of 10,578 inhabitants, is insufficiently supplied from small private waterworks, and from wells; a Bill is now before Parliament for a better supply.

Moss-side (*Lancashire*), an urban sanitary district of 6,000 inhabitants, is supplied with water by the waterworks of the Corporation of Manchester. (*See Manchester*, p. 373.)

Mountain Ash (*Glamorganshire*), an urban sanitary district of 7,500 inhabitants, is supplied with water for domestic purposes from private works (not under the Waterworks Clauses Act) belonging to Messrs. Nixon, Taylor, and Company, who obtain the water from streams. The water is delivered direct from the mains and is stated to be adequate.

Much Woolton (*Lancashire*), an urban sanitary district of 4,644 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 368.)

Musselburgh (*Edinburghshire*), a burgh of 7,517 inhabitants, formerly obtained water for domestic purposes from the river *Esk*, but owing to the gross pollution of that river by paper mills, its water has for many years been entirely unfit for drinking or cooking, and the town has in consequence been compelled to resort exclusively to shallow wells sunk in a bed of gravel resting upon clay. Many of the houses have private wells, and there are eleven public wells, with pumps attached, maintained by the Corporation. We have examined the water from three of the latter, and the results of our analyses are contained in the table on page 74. Bicker's well is 10½ feet deep, and gives a clear, bright, and palatable water, which consists chiefly of soakage from the streets, gutters, and sewers. Dr. Alexander Macdonald Sanderson, the Medical Officer of Health at Musselburgh, stated in his evidence before us, that the excrementitious matters "are thrown out into the streets and into the gutters." This water not only contains a large proportion of the inorganic remains of oxidised animal refuse, but also a considerable amount of organic matter of animal origin. It is a dangerous water. Carry's well is a private well 10 feet deep, situated in the yard of the Musselburgh Arms Hotel. We were informed that before the year 1866, it was considered to be the best well in the town, but in that year ten people who drank of the water were attacked by cholera, and five of them died. The well was then closed. Our analysis shows that this well is fed almost exclusively by sewage and similar foul water, which has simply been to a considerable extent purified by soakage through a few feet of gravel. The water which we obtained from it was clear, bright, and palatable. Newbiggen well in Wonder street is 10½ feet deep, and furnishes water which is similar in all respects to that of the two wells already described. Though bright and sparkling, it was found to contain a considerable amount of unoxidised sewage matter. It is difficult to imagine a more disgusting and dangerous state of things than that which here prevails in reference to what is called potable water, and it is satisfactory to know that the people of Musselburgh have the prospect of soon being relieved from the necessity of drinking their own drainage, as the Corporation are contemplating the construction of waterworks for the supply of the town. The third public well (Cran's well, Esk-side, Fisherrow), yields water of excellent quality, containing only a minute proportion of organic matter, and exhibiting no trace of previous sewage or animal contamination. The water was also of moderate hardness, and therefore suitable for all domestic purposes. The well is close to the river, and much deeper (28 feet deep) than any other in Musselburgh. Unfortunately, the supply from it is very scanty; it dries up in summer, and is frequently pumped dry. It is stated to be "the favourite well," and its water is fetched "from all parts of the town." The Medical Officer states that in the cholera outburst in Musselburgh in 1866 there were only one or two cases about Cran's well, "and they occurred in a street farther "up, called South Vennel." The people at South Vennel got their water chiefly from Campy well in the High Street. Although Musselburgh occupies a healthy position on the shore of the Frith, and contains only 7,517 inhabitants, the mortality has been in several years above 30 per 1,000, and in the year 1865 it was no less than 32·4 per 1,000. In his evidence before us, the Medical Officer of Health stated that the diseases which have principally prevailed in the town are scarlatina, diarrhœa, choleraic diarrhœa, cholera, fever, and chest diseases. An Act was obtained in 1871 for a better supply, but up to this date (June 1874) no other supply has been introduced.

PART IV. DESCRIPTIVE.

Nantwich. Newark.

Nantwich (*Cheshire*), an urban sanitary district of 6,673 inhabitants, has been partially supplied by gravitation from Baddiley Mere, at a distance of 4½ miles from the town. The gathering ground is about 600 acres. There are two reservoirs capable of holding 14,000,000 gallons. The water is filtered through gravel, stones of various sizes, and coarse sand, which form a filtering medium 6 feet deep.

Nelson (*Lancashire*), an urban sanitary district of 5,694 inhabitants, is supplied with water from the *Walverden* stream, from springs, and from gathering grounds. The waterworks are the property of the Local Board, and cost about 20,000*l.*; the reservoirs are situate on and adjoining the *Walverden* stream. The gathering ground is 1,800 acres, and two reservoirs have been provided capable of holding 2,000,000 gallons. The district is 1,850 acres in extent. The water is supplied direct from the mains, and 140,000 gallons are delivered daily to 2,293 houses and 26 works, for domestic and trade purposes. The supply is said to be adequate. The water has not been filtered.

Nether Thong (*Yorkshire*), an urban sanitary district of 1,025 inhabitants, is supplied with water for domestic purposes from the river and from springs. The supply is not adequate in droughty seasons. The water has not been analysed.

Newark (*Nottinghamshire*), a borough with a population of 12,195, is supplied with water abstracted from the *Trent* at a point about two miles above the town. The water filters through the gravel into a series of tunnels or culverts, dug alongside of the river for a distance of 50 yards, and is pumped in a filtered condition into the service reservoir holding 500,000 gallons, situated on high land and built above the surrounding ground at some distance from the town, and thence delivered, on the constant system, direct from the mains. Our sample collected on July 11, 1873, was slightly turbid, and exhibited

PART IV. DESCRIPTIVE.

Newbiggin-by-the-Sea. Newnham.

some evidence of previous sewage or animal contamination. It was also very hard, but was otherwise palatable and of fairly good quality, containing only a moderate proportion of organic matter. (For analysis, *see* page 77.)

Newbiggin-by-the-Sea (*Northumberland*). — This urban sanitary district of 1,135 inhabitants is supplied with water from wells. The samples from the well sunk by the Local Board and from Mr. Duncan's well were very hard, and contained excessive quantities of saline constituents. They were also much contaminated with organic matter which appeared to be of animal origin. They were both unfit for domestic purposes, the use of the former being especially dangerous. The water from the pump at the end of Woodhorn Lane was softer, but exhibited considerable evidence of previous sewage contamination, and was still very hard. (For analysis, *see* page 73.)

Newbury (*Berkshire*), a borough of 6,602 inhabitants. "There are no waterworks "within the borough, or in the vicinity thereof. The water in use is obtained from "wells. One section of the town being on gravel over chalk, the other on peat. The "wells are mostly in the dense part of the borough, and in many places in close "contiguity to privies and cesspools."

Newcastle-on-Tyne (*Northumberland*).—This borough of 133,678 inhabitants is supplied with water chiefly from an upland gathering ground. A population of 43,153 families, or upwards of 200,000 persons, together with nearly 600 works and manufactories, are thus supplied with 8,000,000 gallons daily. Of this quantity 300,000 gallons are devoted to street cleaning and sanitary purposes; 3,000,000 are employed in factories and works; and 4,700,000 gallons daily constitute the domestic supply, which thus amounts to about 20 gallons a head per diem. The whole of the supply is by gravitation in the first instance; but pumping engines are employed at several stations within the district, extending over no less than 95 square miles, throughout which the Company's service ramifies, in order to command the higher localities which are above the gravitation level. The cost of the works of the Newcastle and Gateshead Water Company has amounted to 618,000*l.* The Company have, in addition to their gathering ground of 17,300 acres, the power of pumping from the river *Tyne*, a mile westward of the village of Newburn, which may be used in case of need, but which has not been used during the past three years. The gathering grounds—17,000 acres, extending from Harlow Hill to Thockington—are, to the extent of three-fourths of their area, in pasture; one-fourth is arable land, receiving periodical dressings of farmyard manure in the course of ordinary cultivation; but no refuse of privies, middens, or ashpits is said to be used within the district. There are no fewer than nine storage reservoirs, together capable of holding upwards of 1,000,000,000 gallons, equal to four months' requirement. The water is continually flowing from various streams within the district of the gathering ground into subsiding reservoirs, and thence into these impounding storage reservoirs, from which it passes outwards through screens of copper gauze (48 strands per inch) into the service mains. Three filter beds with an area of about 6,000 square yards, and a filtering medium of broken freestone, rough and fine gravel, and rough and fine sand 3 feet 6 inches in depth are employed, but only a portion of the water passes through them, that portion being the river water exclusively at such times as the *Tyne* water is being pumped; but, as already stated, this water has not been used for several years past. The supply is constant and direct from the mains, very few houses having cisterns. Continuous inspection of the fittings is made to prevent waste; double valves are used to cisterns of water-closets and screw down taps. The annual cost of pumping, including labour, fuel, and materials, is 3,884*l.*

Our analysis of this water given at page 43 shows it to contain a moderate proportion of organic matter, some of which appears to be of animal origin. The evidence of previous animal contamination has, however, been obliterated by long storage in the companies' reservoirs. The water is of rather more than moderate hardness.

New Malden (*Surrey*), an urban sanitary district of 416 inhabitants, is supplied with water for domestic purposes by the Lambeth Water Company. (*See* p. 273.)

Newmilns (*Ayrshire*), a burgh or barony of 3,028 inhabitants, is supplied with water from 6 public wells, 18 private wells, and 2 stand-pipes, and also from the river. The wells are from 10 to 40 feet deep, and from 3 to 10 feet in diameter; they have been sunk during a series of years, and belong to the Police Commissioners. The burgh is situated on the eastern out-crop of the Carboniferous basin. The supply of water is chiefly derived from a stratum of sand and gravel on a level with the bed of the river, the water, indeed, being merely the river water filtered. There is no rate of charge for the water. The wells are maintained out of the rates. The present supply is inadequate to the requirements of the town.

Newnham (*Gloucestershire*), a rural sanitary district of 1,982 inhabitants, is supplied with water from shallow wells. We have analysed samples from several of these wells and, with one exception, the waters were entirely unfit for human consumption by reason of their excessive previous pollution by animal matters; they were little better than filtered sewage. The well in Sailor's Square was especially dangerous, as it contained a considerable amount of unoxidised sewage matter. For other domestic purposes all the waters were unfit on account of their excessive hardness. The exception above alluded to is Mr. M. F. Carter's well, the water from which may be considered tolerably safe. If it were softened by Clark's process, it would be also fairly good for every domestic purpose. Its total solid impurity would be reduced from 58·16 to 17·36 parts in 100,000, and its hardness from 48·6 to 7·8 parts in 100,000. (For analyses, *see* page 77.)

Newport. Newtown and Llanllwchaiarn.

Newport (*Monmouthshire*), an urban sanitary district of 26,955 inhabitants, is supplied with water from springs and gathering ground. The waterworks were established in 1846, and belong to the Newport and Pllgwenlly Waterworks Company. The reservoirs are situated in Ynisybw and Stow Hill. The area of gathering ground is about 1,000 acres. The reservoirs contain about 80,000,000 of gallons. The water is not polluted before entering the reservoirs and is not filtered. The water is pumped, to supply the higher levels of the district, into a reservoir containing 90,000 gallons, which is partially built above the ground, and is covered. The area of the district supplied is about 1,000 acres. The supply is direct from the mains on the constant system, and 1,500,000 gallons are delivered daily to 3,900 houses for domestic purposes, and 50 manufactories for trade purposes. The present supply is scarcely adequate. The company have just obtained a new Act for further extensions (Royal assent 22nd June 1872). The charge for water is 5 per cent. on the rental where supplied by gravitation; and 6 per cent. when pumped. The waterworks have cost to the present time about 53,000*l*. Previously to the establishment of the waterworks, water was obtained from shallow wells. The improved water supply has had a beneficial effect upon the health of the inhabitants. The water has not been analysed.

Newport (*Isle of Wight*), an urban sanitary district of 6,744 inhabitants, is supplied by the Newport and Carisbrooke Water Company with water for domestic purposes, from springs issuing from the Chalk into the service reservoir, which is built of brick-work and arched over. The water flows from reservoir into pipes, and is thus distributed to 700 houses direct from the mains on the constant system. The higher parts of the town are not adequately supplied. The water is of most excellent quality for dietetic purposes, but it is too hard for washing. (For analysis, *see* p. 123.)

Newquay (*Cardiganshire*), an urban sanitary district of 1,421 inhabitants, obtains its supply of water "from rainfall collected in cisterns, springs, and a well."

Newquay (*Cornwall*), a rural sanitary district of 1,121 inhabitants, is supplied with water from wells. We have submitted to analysis samples from some of these wells. With the exception of the water from the Fort pump and the Town pump all the samples were turbid and ought to be filtered before use for drinking. If the samples were carefully taken, this turbidity indicates the access of some surface water to the wells, unless the pumps were of the Abyssinian description. Actual contamination by organic matter only occurred in the waters from the pumps near Mrs. Dyer's and Dr. Clarke's houses, and even in these cases but to a moderate extent. When filtered, the waters from Messrs. Treffry's and Bocking's pumps were reasonably safe waters. The samples from the Fort pump and the Town pump, although free from present or actual contamination, exhibited strong evidence of past pollution with animal matter. This matter was almost completely oxidised and destroyed at the time the analysis was made, but it may not always be so, and consequently these waters should be avoided as suspicious or doubtful. All the samples were very hard and therefore useless for washing. (For analyses, *see* page 71.)

Newton Heath (*Lancashire*), an urban sanitary district of 19,500 inhabitants, is entirely supplied with water by the Manchester Corporation Waterworks, with the exception of a very few houses in the agricultural portion of the district, the occupiers of which houses obtain the water from wells. (*See Manchester*, page 373.)

Newton-in-Mackerfield (*Lancashire*), an urban sanitary district of 9,000 inhabitants, is supplied with water from private wells and pumps. The wells are sunk in the New Red Sandstone. The present supply is very inadequate in the Earlestown end (west) of the district, and the water is very hard.

Newton Moor (*Cheshire*), an urban sanitary district of 7,000 inhabitants, is partly supplied with water for domestic purposes by the Hyde urban sanitary authority, who purchase the water in bulk from the Manchester Corporation, and partly by springs the property of Messrs. J. and I. Ashton; the supply is said to be adequate. (For analysis of the water supplied by the Manchester Corporation, *see* p. 373.)

Newtown and Llanllwchaiarn (*Montgomeryshire*), an urban sanitary district of 5,000 inhabitants, has no waterworks, but is supplied with water for drinking and culinary purposes from springs and from wells about 20 or 30 feet deep, and for other domestic purposes from the river *Severn*. The river water is soft and otherwise of excellent quality, and an abundant supply brought into the town from this source would be a great boon to the inhabitants, who must, at present, either carry this water considerable distances, or resort to but moderately deep wells sunk in the midst of privies and cesspools. The authorities consider that the health of the town suffers from this cause, and its frequent visitation by epidemics of cholera and typhoid fever supports this opinion. The annual rate of mortality per 1,000 has, in some years, been as high as between 29 and 30, which is excessive for a town of 5,000 inhabitants. There is, however, much over-crowding in some parts of the town, and we have everywhere found that the conditions included under that term are the most potent causes of sickness and a high rate of mortality. At the time our samples were taken, the water of these wells, although exhibiting a considerable amount of previous animal contamination, contained remarkably small proportions of organic matter (*see* analyses, p. 108), showing that the animal and sewage matters had been almost entirely oxidised and destroyed during their percolation through the porous soil. Indeed the water of the spring which fed the Lady Well was, as our analysis proves, of almost unsurpassed purity; and, if carefully guarded from excremental pollution, would be a real treasure to the neighbourhood; but the well supplied by this spring is surrounded by privies and filthy surface drains, and is therefore never secure from pollution. The natural spring which supplies the pump in the Canal Road rises in a manured meadow about 100 yards from the nearest houses. The pump in Pump Court is surrounded by privies and middens of a very filthy description, which must continually imperil the purity of the water (*see* analysis, page 69). It is in contemplation to supply the town with water from an affluent of the *Severn*. The water from the upper part of this stream entering the *Severn* near Newtown was of excellent quality for all domestic purposes. It was palatable, contained but a very small proportion of organic matter, which was moreover of vegetable origin, and it was quite free from any trace of animal contamination. It was very soft and therefore well adapted for washing and manufacturing purposes. (For analysis, *see* page 35.)

Normanton (*Yorkshire*), an urban sanitary district of 6,000 inhabitants, obtains its supply of water for domestic purposes from shallow wells; the supply is very inadequate, and the sanitary authority are about to obtain a public supply from a colliery in the district. The water has not been analsyed.

Northallerton (*Yorkshire*), an urban sanitary district of 2,663 inhabitants, obtains its supply of potable water from private wells. The water has not been analysed.

North Bierley (*Yorkshire*), an urban sanitary district of 14,433 inhabitants, is supplied with water partly from wells, and partly by the Waterworks Company, who obtain their water from the Bradford Corporation Waterworks. The district was first supplied from this source in 1864, and from 40,000 to 60,000 gallons are intermittently delivered daily direct from the mains to 2,620 houses and 25 works for domestic and trade purposes. The supply is inadequate to the requirements of the district. The reservoirs belong to the Bradford Corporation Waterworks, and the water mains belong to the North Bierley Waterworks Company, and cost 18,000*l*. (*See Bradford*, p. 321.)

North Darley (*Derbyshire*), an urban sanitary district of 1,520 inhabitants, "finds its "supply of water for domestic purposes partly from the *Derwent* and partly from private "wells and springs, as best suits the convenience of each inhabitant. The sanitary "authority have under consideration measures for making public provision for the "supply of the more densely populated parts of the district."

North Owram (*Yorkshire*), an urban sanitary district of 4,100 inhabitants, obtains its water from shallow private wells and springs. The supply is inadequate to the requirements of the district. The water has not been analysed.

Northwich (*Cheshire*).—This urban sanitary district of 1,214 inhabitants is supplied with water by a private company from *Wade Brook*, abstracted at a point about one mile from the boundary of the district. The water is filtered through gravel, sand, and charcoal into a reservoir, and then pumped to a high service uncovered reservoir, holding 44,000 gallons. The rate of charge is 1*s*. in the pound on the rental, or 1*s*. per 1,000 gallons by meter. 210 houses are supplied, and the mains are kept charged 12 hours daily. The water is not of good quality, but is perhaps the best obtainable within a moderate distance. Being a running water, the evidence of 320 parts of previous animal contamination exposes it to suspicion, the water which furnishes that evidence may be derived from a deep seated spring, in which case the evidence may be disregarded, but the brook above the intake ought to be carefully examined to ascertain if any sewage or soakage from privies or cesspools gains access to the stream. (For analysis, *see* page 53.)

Nottingham (*Nottinghamshire*).—This borough of 90,000 inhabitants is supplied with water by a private company from wells in the New Red Sandstone. We have analysed several samples of water from a spring and from deep wells in and near this town.

The samples from Mr. Thackray's and Mr. Fisher's wells contained but a very small proportion of organic matter, yet their previous heavy contamination with animal matters rendered them undesirable sources of supply for domestic purposes. Their hardness also rendered them unsuitable for washing. The water of Mr. Thackray's well is used only for manufacturing purposes, but that from Mr. Fisher's well partially supplies the suburb of Radford. The wells are contiguous, and situated in a densely populated district. (For analyses, *see* page 93.)

The Bagthorpe well is one of the chief sources of the water delivered in Nottingham. It also supplies the Lunatic Asylum. It is sunk 120 feet deep into the New Red Sandstone, and yields about 3,000,000 gallons daily. Our analyses of three samples of this water (*see* page 93), prove it to be of most excellent quality for dietetic purposes,—clear, sparkling, palatable, and wholesome. For washing and manufacturing purposes it is too hard.

The *Trent*, near Nottingham, is neither suitable nor safe for the supply of a town, as it is much polluted by sewage and manufacturing refuse above the intake.

In the Bulwell Forest, near Nottingham, there issues from the Bunter Pebble Beds a copious spring of magnificent water,—clear, brilliant, and wholesome, which might be drawn upon for a supplementary supply if the deep wells should fail to yield an adequate quantity. (For the analysis of this water, *see* page 116.)

At the suggestion of Mr. M. D. Tarbotton, the Borough Engineer, the company have recently sunk a new well at Bestwood Park outside the town, and have obtained an abundant supply of excellent water.

Oakworth (*Yorkshire*), an urban sanitary district of 5,683 inhabitants, obtains its supply of water for domestic purposes from springs. The water has not been analysed.

Ogley Hay (*Staffordshire*.)—This parish of 1,824 inhabitants is supplied with water from shallow wells. We have analysed five samples from this place. Samples Nos. 1 and 5 were good wholesome waters well adapted for drinking and all domestic purposes. Nos. 2 and 3 were suspicious waters which had been heavily contaminated with sewage and which might at any moment become dangerous to health, although they were not so at the time the samples were taken. No. 4 consisted almost entirely of the soakage from sewers and cesspools. It was a very dangerous water and its use for domestic purposes ought to be at once abandoned. It was too hard to permit of its use for washing. (For analyses, *see* page 73.)

Oldham (*Lancashire*), a borough of 82,619 inhabitants, is supplied with water from the sources of the rivers *Irwell* and *Medlock*, stored in impounding reservoirs, situate at Strinesdale, about two miles east of the town, and at Piethorn, about four miles east of Rochdale. The works belong to the Corporation. The gathering ground is 2,700 acres. The reservoirs are eight in number, and the united capacity is 742,000,000 gallons. The water is stated to be unpolluted before entering the reservoirs, and is not filtered. The area supplied is 13,000 acres, containing 22,000 houses and 400 manufactories. The supply is constant, and a volume of from 2,500,000 to 3,000,000 gallons is delivered to the district daily. The water is drawn direct from the mains. The rate of charge for water for domestic purposes is 6½ per cent. on the rent. The charge for manufacturing purposes is from 8*d*. to 3*d*. per 1,000 gallons. The present supply is barely sufficient. To prevent waste, periodical inspection is made of taps and apparatus. The waterworks cost 229,000*l*. The quality of the water is excellent (*see* analysis at page 39); it is soft, contains but little organic matter, and exhibits no trace of previous animal contamination. Unfortunately, however, the quantity of this water is not adequate to the wants of the population, and shallow wells are still to some extent used for domestic purposes. We inspected one of these known as Nook pump, situated in the higher part of the town. It supplies about 300 houses, and is said never to fail. The well is 23 feet deep in a sandstone rock of the Coal Measures, which here crops out at the surface. There is a stone quarry close by, in which a pool of water stands at the same level as the water in the well. The street sewer runs close to the well, and a very offensive privy, used by 13 people is within 10 or 12 yards of it. The analysis, in the table at page 73, of the sample taken at the time of our visit shows 10,100 parts of previous sewage or animal contamination. In his evidence before us, Mr. Thomas Platt, surgeon of Oldham, stated that scarlatina had prevailed in the neighbourhood of this well. The use of potable water derived from such a source cannot but be attended with great risk.

Openshaw (*Lancashire*), an urban sanitary district of 12,000 inhabitants, receives its water supply from the works of the Manchester Corporation. There are 2,241

PART IV. DESCRIPTIVE.

houses supplied on the constant system and direct from the mains. The supply is adequate. (*See Manchester*, p. 373.)

Ormesby. Oxton.

Ormesby (*Yorkshire*), an urban sanitary district of 6,500 inhabitants, is supplied with water for domestic purposes by the Stockton and Middlesborough Waterworks Company. (*See Stockton*, p. 399, and *Middlesborough*, p. 375).

Ormskirk (*Lancashire*), an urban sanitary district of 6,127 inhabitants, obtains its water from wells. The water is pumped to a tank on a tower 75 feet high situated on the highest point of land in the neighbourhood of the town; the tank contains 107,000 gallons. The greatest available head of water, where mains are laid, is 123 feet, the least 74 feet. The well is 60 feet in depth, and the bore-hole is 90 yards deep by 6 inches in diameter. The district includes about three and a half miles of service mains, and 1,050 houses. The service mains are kept charged, 12 hours at full pressure, and 12 hours at half pressure. The daily volume of water delivered is 200,000 gallons. The houses are not supplied direct from the mains but through cisterns. The rate of charge is 5 per cent. on the rateable value, or 6*d*., 9*d*., and 1*s*. per 1,000 per meter. To prevent waste daily inspection is made of the taps. The cost of the works was 9,280*l*.

Orrell (*Lancashire*), an urban sanitary district of 3,561 inhabitants, obtains its supply of potable water from shallow wells sunk in a gravel subsoil. Samples of water from several of these wells have been analysed and the results proved the water to be totally unfit for dietetic purposes, moreover for washing purposes the water is too hard.

Oswaldtwistle (*Lancashire*), an urban sanitary district of 10,500 inhabitants, is supplied with water from streams from a gathering ground of 277 acres, and reservoirs of an aggregate capacity of 82,364,750 gallons. There are 1,600 houses supplied for domestic purposes, and 28 manufactories for trade purposes. The supply is constant, and direct from the mains, and is said to be ample, and 50,000 gallons of unfiltered water is delivered in the district daily.

Ovenden (*Yorkshire*), an urban sanitary district of 7,374, obtains its supply of water for domestic purposes from springs, it is said that the supply is adequate. The water has not been analysed.

Over Darwen (*Lancashire*), an urban sanitary district of 22,000 inhabitants, obtains water from streams. The waterworks, established in 1847, now belong to the Sanitary Authority. The reservoir is situate about a mile from the town. The area of the gathering ground is 504 acres. Eamsdale reservoir contains 116 millions of gallons. The water flows into a high-service reservoir, and is not filtered. The area supplied—5,000 statute acres—contains 3,861 houses and 47 mills; the supply is constant, and a volume of 800,000 gallons is daily delivered. About 60 houses are furnished with cisterns; these have ball taps to prevent waste. The Company are applying to Parliament in the present Session for powers to construct additional reservoirs to supply a higher level. To prevent waste, constant inspection is made of taps and fittings. The water is soft, but it is subject to sewage pollution, and always contains rather a large proportion of organic matter. (For analysis, *see* page 39.)*

Oxenhope (*Yorkshire*), an urban sanitary district of 2,328 inhabitants, is stated to be abundantly supplied with water from a river and streams flowing through the district. There are no waterworks. The district is a wide one, with a scattered population. The water has not been analysed.

Oxton (*Cheshire*), an urban sanitary district of 3,000 inhabitants is supplied with water from the Wirral Waterworks Company. The reservoir is on Prenton Mount, about a mile from the Oxton township boundary. The pumping station is situated in the valley at a distance of 1,672 yards from the reservoir. The well is sunk in the upper and middle Bunter divisions of the New Red Sandstone. The shaft is 30 feet long, 9 feet wide, and 130 feet deep from the surface, the bore-hole is 18 inches in diameter, and 237 feet deep below the bottom of the shaft. The high-service reservoir contains 700,000 gallons, it is built entirely above the surrounding ground, and is roofed over; 500,000 gallons per diem of water are pumped into it by two Cornish engines of 10 h. p. each, with lifting ram pumps at bottom, and forcing ram pumps from top of well to reservoirs. The area supplied—3¼ square miles nearly—contains about 500 houses and cottages; the supply is constant, adequate, and direct from the mains, and 43,000 gallons are delivered daily for domestic purposes only. The rate of charge is 6 per cent. on the amount of rent. To prevent waste inspection of taps, service pipes and mains is made once a month; nevertheless a great waste occurs. The waterworks for Oxton and the districts of Upper and Lower Bebington, New Ferry, Rock Ferry, and Noctorum, cost upwards of 40,000*l*. At the time of our visit (May 1868), this water, though clear and palatable, was polluted

* Since these remarks were written on our analysis of the sample of the potable water supplied to Over Darwen a severe outbreak of typhoid fever has occurred, produced by the sewage polluted water supply.

by a considerable proportion of organic matter, probably from surface soakage into the well from cultivated land. (*See* analysis, page 105.) In other respects, it was similar in quality to the waters supplied from similar wells to Birkenhead, Tranmere, and Wallasey; and, with proper precautions, there is no reason why it should not be, in all respects, equal to these waters.

Padiham and Hapton. Peebles.

Padiham and Hapton (*Lancashire*).—This urban sanitary district of 6,675 inhabitants is supplied with water from gathering grounds on the Millstone Grit. It contains a large proportion of organic matter, which appears to be chiefly, if not entirely, of vegetable origin. It is probably wholesome though not palatable, and would be much improved by filtration. It exhibits no evidence of excremental contamination, and is soft and well adapted for washing and cleansing operations. (For analysis, *see* page 39.)

Panteg (*Monmouthshire*), an urban sanitary district of 2,761 inhabitants, obtains its supply of water for domestic purposes from wells; the present supply is said to be adequate for the requirements of the district. The water has not been analysed.

Paisley (*Renfrewshire*), a burgh of 50,000 inhabitants, is supplied with water from streams and gathering grounds. The works were established in 1835, and belong to the Corporation. There are three storage reservoirs:—Stanley reservoir, situated about two miles south of Paisley, contains 222,100,543 gallons; Rowbank reservoir, about eight miles to the south-west, contains 486,558,703 gallons; and Harelaw reservoir, about three miles to the south-east, has a capacity of 97,588,187 gallons. The total storage capacity is, therefore, 806,247,433 gallons, or 293 days' supply. The water is delivered on the constant system at the rate of about 50 gallons per head per diem. The water is said to be unpolluted before entering the reservoirs; it is filtered through sand and gravel six feet deep. The capacity of the high service tank is 437,500 gallons; it is built partially above the ground, and is covered. The area of the district—3,000 acres—contains 10,460 houses, and 150 works and manufactories. The rate of charge for water is 1*s.* in the pound upon the rental for domestic purposes, in addition to 2*d.* in the pound public water rate, and for manufacturing purposes from 3½*d.* to 5*d.* per 1,000 gallons. To prevent waste, vigilant inspection is made of the taps and fittings. The waterworks cost 137,000*l.* The volume of water is said to be adequate for the present requirements of the town. Before the establishment of the works, the town was supplied from the river *Cart* and from private wells. The improved supply is stated to have had a beneficial effect upon the health of the inhabitants. Previously to the establishment of these works, stone in the bladder was of frequent occurrence, but it is now never heard of. The amount of fever is less than formerly, and cholera has never appeared since the town was fully supplied. The water of the Harelaw reservoir is partly used for compensation, and the rest of it discharges into the Stanley reservoir, consequently the direct supply to the town is from two reservoirs only. We have collected and analysed samples from both sources, and we find that the supply from both is soft and free from evidence of excremental pollution; but the water from the Stanley reservoir is much superior in quality to that of the Rowbank reservoir; the latter, though clear, was brownish from the presence of an excessive proportion of peaty organic matter, and it was in consequence not pleasant to drink. The superior quality of the supply from Stanley reservoir appears to be due to a considerable proportion of spring water which is there impounded. One small tributary of the Rowbank reservoir is very peaty, and the quality of the water in this reservoir would be much improved if this peaty stream were diverted and used only as compensation water for the mills below. (For the analysis of these waters, *see* page 37.)

Peebles (*Peebleshire.*)—This burgh of 2,622 inhabitants is supplied with water from mountain streams and springs. The works were established in 1845, extended under the General Police Act in 1867 and subsequent years, and belong to the Commissioners of Police. There are three reservoirs, two situate about a mile, and the other about five miles, from Peebles. The water is soft and quite free from evidence of previous contamination. (*See* analysis, page 37.) It is of good quality for all domestic purposes, but it was slightly turbid when our sample was taken, and would be much improved if filtered before delivery. The area of the district—500 acres—contains 564 houses. The supply is constant, and 150,000 gallons of water are delivered in the burgh daily. The houses are generally furnished with cisterns, and the overflow pipes from the cisterns are connected with the soil pipes. The present supply is more than adequate to the requirements of the burgh. There is no rate of charge for water. The cost is defrayed by police assessment of 8*d.* in the pound. To prevent waste, inspection is made of the taps and fittings. The waterworks cost 5,000*l.* The shallow well at Peebles railway station yields a clear, colourless, and palatable water: it is, however, situated within 30 yards of a cesspool, and the water exhibits strong evidence of previous excremental pollution. It is also said to be occasionally muddy, and cannot therefore

PART IV. DESCRIPTIVE.

Pemberton. Penzance.

be recommended for drinking or cooking. It might, however, be used for washing, as its hardness is not great. (For analysis, *see* page 69.)

The *Tweed* above Peebles is a clear, colourless, wholesome, and soft water in dry weather, but our sample taken on March 13th, 1872, shows (*see* page 37) that it is liable to become contaminated with peat during floods.

Pemberton (*Lancashire*), an urban sanitary district of 10,374 inhabitants, obtains its supply of potable water "from shallow wells, springs, and ponds; the quality however is "very inferior. This summer (1874) the inhabitants of this large and increasing district "have suffered severely from an inadequate supply of water." The water has not been analysed.

Pennington (*Lancashire*), an urban sanitary district of 5,424 inhabitants, is supplied with water from private wells in the New Red Sandstone. The volume is stated to be adequate.

Penrhyn (*Cornwall*), an urban sanitary district of 3,636 inhabitants, is supplied with water for domestic purposes from gathering grounds and from wells. (For analysis of one of the latter, *see* p. 71.) The waterworks were established in 1847 and belong to the Falmouth Waterworks Company. The reservoirs are situated at Antronmoor, about a mile from the town. The water is said to be not polluted before entering the reservoirs and is not filtered. The supply is constant and direct from the mains to about 600 houses and two manufactories for domestic and trade purposes distributed over an area of 289 acres. The overflows from the cisterns to waterclosets are connected with the drains, but not with the soil pipe. The present supply is adequate for the requirements of the town and district. The rate of charge for water is 1*s*. in the pound on the gross rental. Previously to the establishment of the works, the inhabitants obtained their supply of water from wells and running streams. Our analysis of the water supplied from gathering grounds given on p. 47 shows it to be soft but contaminated with products derived from manured land.

Penzance (*Cornwall*) an urban sanitary district and watering place of 10,312 inhabitants, greatly augmented during the season, is supplied with water for domestic purposes abstracted from streams just beyond the boundary of the borough. Waterworks were established in 1850, and belong to the urban sanitary authority. About 2,000 gallons of water are abstracted from the streams, and conveyed into reservoirs about two miles from the town containing 6,000,000 gallons. The water is polluted by cattle to some extent before entering the reservoirs; it is not filtered and is not pumped, but flows by gravitation into the town. The area of the district supplied is 472 acres, and the number of houses 2,216, besides a railway station, gasworks, and iron foundry. The supply is constant, and 200,000 gallons are delivered to the district daily for trade and domestic purposes. Most of the houses are supplied from mains direct; some of the waterclosets have cisterns, the overflows from which are connected with the sewers, but are trapped. There has been an ample supply of water for the last few years, but considerable inconvenience was experienced two years ago on account of the drought. The rate of charge for water varies from 4*s*. 4*d*. per annum on houses of a rateable value not exceeding 4*l*. up to 29*s*. 8*d*. for houses of a rateable value not exceeding 42*l*. The waterworks cost 7,836*l*. 4*s*. 11*d*. Previously to the establishment of the waterworks the town was supplied with water from streams and private wells.

COMPOSITION OF WATER SUPPLIED TO PENZANCE.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	REMARKS.
Water as supplied to the town June 9, 1871.	11·20	**·152**	**·045**	0	·124	·169	**920**	4·35	0	3·0	3·0	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

This water is polluted by the drainage from manured land, and at the time our sample was taken, it was not safe for dietetic purposes. It was very soft, and therefore well adapted for washing.

The Madron and Alverton springs, near Penzance, yield water of excellent quality for dietetic and all domestic purposes. As they are deep seated springs and unpolluted, the previous animal contamination which they exhibit need not be regarded. (For the analyses of these spring waters, *see* p. 110.)

PART IV. DESCRIPTIVE.

Perth.

Plymouth.

Perth (*Perthshire*), a city of 25,000 inhabitants, obtains its water for domestic purposes from two sources. That part of the city which lies on the west side of the river is supplied by a private company from a tank formed upon Moncrieff Island in the river *Tay*. The river water arrives at this tank by natural filtration through a bed of gravel, containing 14,444 cubic yards, and as the river here is tidal, though fresh, the water undergoes to some extent the process of intermittent filtration, by which its quality is greatly improved, the proportion of organic elements being thereby reduced two thirds. On the other hand, the hardness is nearly doubled; nevertheless it is still a very soft water, having only three degrees of hardness. It exhibits no evidence of previous animal contamination, and is clear, colourless, and palatable, and well fitted for all domestic purposes. The local authorities complain of the precarious nature of the supply; they say:—" The water is pumped by two 12 nominal horse-power engines,— " both of which are 40 years old, and constantly needing repair,—working 22 hours " daily, to a high service reservoir which contains 481,751 gallons. The number of " inhabitants supplied is 23,500, and the total volume of water pumped per day is about " 500,000 gallons. Of these 86,000 gallons are supplied to the railway, and 414,000 " gallons are used for domestic, manufacturing, and other purposes, being about 15⅔ " gallons per head of the population, for all purposes. The small size of the reservoir " and the want of reserve engine power are matters of very serious importance. The " reservoir is scarcely ever full, except occasionally on Saturday nights. It takes the " two engines in the present state of matters to keep the daily draught upon them for " the supply of the town; in short, the consumption proceeds almost as fast as the " engines can pump, and the supply is withdrawn from the pipes ere it reaches the " reservoir; at present there is no surplus available for additional population or " contingencies." The houses are partly supplied by cisterns and partly from the mains direct. The rate of charge for water is 8*d*. in the pound on the rental for houses, and 2*d*. for shops. No efficient means are taken to prevent waste. The waterworks cost 16,000*l*. That part of the town situated on the east side of the river is chiefly supplied by the Bridgend Water Company from sources which are contaminated by agricultural operations. The water, though colourless, was slightly turbid, and exhibited marked evidence of previous animal contamination, besides containing a considerable proportion of organic matter, some of which appeared to be of animal origin. It was also more than twice as hard as the supply on the west side of the river. Our analyses of these waters yielded the following results:—

COMPOSITION OF WATER SUPPLIED TO PERTH.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.												REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness.				
									Temporary.	Permanent.	Total.		
Water supply from the *Tay*, Sept. 15, 1870.	5·72	**·119**	**·018**	0	0	·018	**0**	·85	·1	2·8	2·9		Clear and palatable.
Ditto from Bridgend Water Company, Sept. 15, 1870.	16·02	**·191**	**·036**	0	·242	·278	**2,100**	1·55	1·4	6·2	7·6		Slightly turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Petworth (*Sussex*), a rural sanitary district of 2,114 inhabitants, obtains its water from works belonging to Lord Leconfield, partly from the river at a point about three-quarters of a mile below the entrance of the town drainage:—" This water is used but little for " drinking purposes,"—and partly from a spring in Petworth Park, which flows into two conduits in the town. Both of these supplies are unfiltered, and are furnished to the inhabitants without cost. The town is also partly supplied with water from private wells.

Phillack (*Cornwall*), an urban sanitary district of 4,165 inhabitants, obtains its supply of potable water from shallow wells. The water has not been analysed.

Plymouth (*Devonshire*), an urban sanitary district and naval arsenal of 68,758 inhabitants, considerably augmented from time to time by a floating population, is supplied with potable water from the *Mew* abstracted at a point about 3½ miles from its source; the water flows into four service reservoirs, capable of holding, in the aggregate, 11,540,000 from which 8,000,000 is delivered unfiltered, daily, on the constant system, in some cases direct from the mains, to 8,000 houses and 90 manufactories for domestic and trade purposes. The supply is said to be adequate except in very severe drought. The works were first established in 1855 and belong to the Corporation of Plymouth. Our analysis,

PART IV. DESCRIPTIVE.

Pollokshaws. Port Glasgow.

given on page 107, proves this water to be of most excellent quality for dietetic and all domestic purposes. It was however turbid, and would therefore require filtration before use for drinking.

Pollokshaws (*Renfrewshire*).—This burgh of 8,921 inhabitants is supplied with water from the Glasgow Corporation Waterworks, and the water was first introduced into this burgh in 1854. There are very few houses supplied with cisterns. The volume is adequate for the requirements of the district. The rate of charge is 1*s*. per pound on the rental. The steps taken to prevent waste are inspection by the servants of the Corporation. Before the present supply was introduced into the burgh, it derived its water chiefly from wells and the river *Cart* now totally unfit for any use whatever. The improved water supply is stated to have had a beneficial effect upon the health of the inhabitants. (*See Glasgow*, p. 346.)

Pontefract (*Yorkshire*), a borough of 5,372 inhabitants, is supplied with water for domestic purposes by public and private wells. The waterworks are the property of the Street Commissioners. The well of the Waterworks Company at Tanshelf is 7 feet in diameter, and sunk into the Magnesian Limestone a depth of 40 feet; 7,000 gallons of water are pumped each hour, and for 10 hours each day. The service reservoir contains 18,000 gallons; it is built partially above ground, and is not covered. The area of the district supplied is 2,050 statute acres. Houses 211 for domestic purposes, 10 works, and 21 malt kilns for trade purposes. The supply is direct from the mains which are only kept charged for 16 hours a day, and 90,000 gallons of water are supplied daily for domestic and trade purposes to 216 houses and 43 works and malt kilns, distributed over an area of 2,050 acres. The supply is adequate, but there is insufficient storage room. The rate of charge for water for houses rated at 20*l*. and upwards is twenty shillings a year; above 10*l*. and under 20*l*., fifteen shillings; below 10*l*., ten shillings a year; for malt kilns, 1*s*. 6*d*. per quarter of barley malted per year, and for steam boilers, ten shillings a year. Persons detected in wasting water are summoned before the magistrates. The waterworks cost 2,800*l*. We have analysed this water as also samples from a new borehole at the waterworks, from Baghill well and from other sources. All these samples exhibited much *past*, but comparatively little *present*, pollution. They might all be used at present for drinking with safety; but waters which, like that from the spring in Waterham's field, from the new bore-hole at the waterworks, and the water supply, have been derived to a considerable extent from soakage from sewers or cesspits, or from very heavily manured land, can never be considered either desirable or permanently safe. If the Baghill well be not less than 60 feet deep we should consider the use of the water from that source as nearly free from risk on the ground of pollution; but all the samples were too hard for habitual use. Water with so much permanent hardness is apt to form urinary concretions. This excessive hardness also renders all the waters useless for washing. (For analysis of water from the Baghill well, *see* page 75; from the new bore-hole, page 91; the water supply, page 92; and from the spring in Waterham's field, page 115.)

Pontypool (*Monmouthshire*), an urban sanitary district of 5,000 inhabitants, is supplied with water for domestic purposes principally from springs by gravitation, by the Pontypool Gas and Water Company The supply is constant and direct from the mains, and is adequate for the requirements of the town and district. The rate of charge for water varies from 1*s*. 6*d*. to 2*s*. per quarter. Previously to the establishment of the waterworks the inhabitants were supplied with water from shallow wells and springs.

Poole (*Dorsetshire*), a borough of 10,031 inhabitants, is supplied with water by a company with a capital of 8,600*l*., who obtain it from "springs found by excavation from "4 to 10 feet below the surface in running sand." It is first collected in earthenware pipes into receiving tanks, and thence through iron pipes to filter-beds and reservoirs. The sands are those of the Plastic Clay formation, and there are three separate areas thus drained, amounting in all to about 10 acres, nine-tenths of which are rough pasture ground, about an acre being garden land. The water is filtered through two small filter-beds, and received into three covered brick reservoirs holding about 200,000 gallons; and 650 houses, including eight used for trade purposes, are supplied on the constant system direct from the mains, within an area of about 1,500 acres, at the rate of 50,000 gallons daily.

Port Glasgow (*Renfrewshire*).—This burgh of 10,805 inhabitants is supplied with water by gravitation from mountain streams. The waterworks belong to the Commissioners of Police. The reservoirs are situated at Leperston, about four miles from Port Glasgow. The area of the gathering ground is 225 acres, and the storage reservoirs contain 61,500,000 gallons, or 118 days' supply. The water is said to be unpolluted before entering the reservoirs; it is filtered through a medium of broken whinstone 1 foot 7 inches, gravel 3½ inches, perforated tiles 1½ inches, and sand 2 feet. The area supplied is 640 imperial acres, contains 575 houses, and 18 public works. Almost all the houses draw direct from the mains. The quantity is said to be adequate for the requirements of the town and district. The supply is constant, and amounts to about 48 gallons per head per diem for all purposes. Waste is prevented by vigilant inspection of the fittings and taps. Previously to the establishment of the present works, the town derived its water from mountain streams collected in two or three tanks and a small reservoir, and from private wells. The water was unfiltered. It is believed that the improved water supply has had a very beneficial effect upon the health of the inhabitants. The rate of charge is 1*s.* in the pound on the rental. The waterworks cost 15,121*l.*

Port Glasgow has been visited by cholera at each return of the epidemic. The last attack was in 1866, when shallow wells were still used, together with unfiltered water from manured land. The worst cholera epidemic in Port Glasgow was that of 1853–4, when the number of deaths was very large. Dr. James Grieve, the medical officer, says that the present water supply "is very good and very soft; at times there is a slight "discolouration, but very slight and only occasionally." Mr. James Morris Gale, M. Inst. C.E., who designed and carried out the waterworks, states in his evidence that the gathering ground "is principally hill pasture, with a little cultivated ground, upon "trap and whinstone, nearly all whinstone.—With respect to hardness, the water is "very similar to the Gorbals water, and probably as to organic matter it also corre-"sponds very much." The water is clear, palatable, and wholesome, but it contains rather more organic matter than is desirable. Our analysis, given at page 33, shows that it exhibits no evidence of previous sewage or animal contamination.

Portland (*Dorsetshire*), an urban sanitary district of 9,130 inhabitants (exclusive of the garrison and convict establishment), obtains its supply of water for domestic purposes from shallow private wells; the supply is inadequate. The water has not been filtered.

Portobello (*Edinburghshire*).—This burgh of 5,481 inhabitants is supplied with water by the Edinburgh and District Water Trustees. The supply is intermittent. (*See Edinburgh*, p. 339.) The houses are furnished with cisterns, and the overflow pipes from them are connected with the soil pipes. Previous to the delivery from present source, the inhabitants obtained water from wells; they also used rainwater collected in tubs and tanks. The rate of charge for water is 7*d.* in the pound on the rental. The improved supply is said to have had a beneficial effect on the health of the inhabitants.

Poulton, Bare, and Torrisholme (*Lancashire*), an urban sanitary district of 3,005 inhabitants, is supplied with water for domestic purposes by the Lancaster Corporation Waterworks. The supply is constant, and 81,600 gallons are delivered daily, partly direct from the mains and partly through cistern, to 650 houses for domestic purposes; the supply is said to be adequate. (For analysis of this water *see Lancaster*, p. 39.)

Prescot (*Lancashire*).—This urban sanitary district of 5,990 inhabitants is principally supplied by the Liverpool Corporation Waterworks. (*See* p. 368.)

Preston (*Lancashire*), a borough of 86,000 inhabitants, is supplied with water principally gathered from Longridge Fell, and conveyed by gravitation conduits into reservoirs; a portion is also conveyed by a conduit from the river *Loud* to the reservoirs. The waterworks were first established in 1832, remained the property of a private company until 1854, when they were purchased by the Local Board of Health, and have since been considerably improved and extended. The reservoirs are situate to the north-east of Preston at distances of from three to eight miles from the town. The area of gathering ground is 2,878 acres; rather more than one half is upon limestone. There are seven reservoirs and the combined capacity is 264,857,902 gallons. The water is said to be unpolluted before entering the reservoir or tank; it is not filtered. The service reservoir gives a pressure sufficient to reach the top story of the highest building in the borough, and contains 52,173,000 gallons; it is built partly above the surrounding ground, and is not covered. The water is supplied direct from the mains to 17,930 houses in Preston, 394 in Ashton, 130 in Fulwood, and 490 in Longridge; also to about 500 manufactories. The supply is constant, and 751,412 gallons are daily delivered for trade, and 2,305,500 gallons for domestic purposes. To prevent waste constant inspection is made of the waterclosets, pipes, and taps. The waterworks cost 235,000*l.* The Corporation, to whom the works belong, have just obtained powers to take a further supply from one of the sources of the river *Hodder*, and the works are in progress. The water at present supplied is on the whole good; it is beyond all suspicion of excremental contamination, but it contains a somewhat large proportion of peaty matter, and is also rather hard. It is believed that both these defects will be remedied by admixture of water from the new source of supply. The quality would be considerably improved by sand filtration. (For analysis, *see* p. 39.)

Prestwich (*Lancashire*), an urban sanitary district of 6,820 inhabitants, is supplied with water by the Manchester Corporation, and by the Bury and District Waterworks Company. (*See* p. 373 and p. 325.)

PART IV. DESCRIPTIVE.

Pudsey. Ripon.

Pudsey (*Yorkshire*), an urban sanitary district of 14,000 inhabitants, is supplied with water for domestic purposes by the Calverley District Waterworks Company, who obtain their water in bulk from the Bradford Corporation Waterworks. (*See Bradford* p. 321). The supply is intermittent and direct from the mains to 1,000 houses and 48 manufactories daily for domestic and trade purposes, and is said to be scarcely adequate to the requirements of the district.

Queensbury (*Yorkshire*), an urban sanitary district of 7,500 inhabitants, is supplied with water for domestic purposes from shallow private wells, and from a public fountain erected at the sole expense of Messrs. John Foster and Son. The water has not been analysed.

Quorndon (*Leicestershire*), an urban sanitary district of 1,517 inhabitants, obtains its supply of potable water from shallow private wells sunk in a subsoil of gravel and sand. The water has not been analysed.

Radcliffe (*Lancashire*), an urban sanitary district of 11,446 inhabitants, is supplied with water for domestic purposes by the Bury and District Waterworks Company. (*See* p. 325.)

Rainford (*Lancashire*), an urban sanitary district of 3,336 inhabitants, has no waterworks; the supply of potable water is obtained from shallow private wells The water has not been analysed.

Ramsbottom (*Lancashire*), an urban sanitary district of 4,204 inhabitants, is supplied with water by the Bury and District Waterworks Company. (*See* page 325.)

Rastrick (*Yorkshire*), an urban sanitary district of 5,893 inhabitants, is supplied with water for domestic purposes partly by shallow private wells, and partly from the Halifax Corporation Waterworks. (*See Halifax*, page 350.) The supply is constant, direct from the mains, and 60,000 gallons are delivered daily to 880 houses and 20 manufactories for domestic and trade purposes distributed over an area of 1,290 acres. The supply is said to be adequate.

Ravensthorpe (*Yorkshire*), an urban sanitary district of 3,100 inhabitants, is supplied with water for domestic purposes by the Dewsbury, Batley, and Heckmondwike Waterworks Company. The supply is constant, except in dry weather, and direct from the mains, and 21,000 gallons of water are delivered daily to 680 houses and 4 manufactories, distributed over an area of 360 acres; and this volume is at present adequate for the requirements of the district. The scale of charges for domestic purposes varies from 17*s*. 4*d*. for houses of the annual value of 5*l*. 10*s*., to 3*l*. for houses of the annual value of 50*l*. The rate for warehouses, shops, and offices of the value of 5*l*. varies from 8*s*. per annum to 1*l*. 10*s*. for warehouses, shops, and houses of the annual value of 100*l*. No special steps are taken to prevent waste. The water mains cost 2,700*l*. (*See Dewsbury*, p. 335.)

Redcar (*Yorkshire*), an urban sanitary district of 1,943 inhabitants, obtains its supply of potable water from springs flowing through iron pipes to a reservoir holding 90,000 gallons, and thence to a service reservoir holding 22,000 gallons placed 200 feet above the town. The supply is constant and direct from the mains, and 30,000 gallons of water is delivered daily; the supply is said to be adequate. The water has not been analysed.

Redruth (*Cornwall*), an urban sanitary district of 10,685 inhabitants, is supplied with by water obtained by driving adits into the Granite formation; the water is thence conveyed mains into the streets, and the inhabitants have to fetch it from stand-pipes placed on the by mains. The water is not filtered. The present supply is inadequate for the district. Before the water was obtained from its present source the inhabitants had to collect the rainfall for their domestic wants The water has not been analysed.

Richmond (*Surrey*), an urban sanitary district of 15,110 inhabitants, is supplied with water by the Southwark and Vauxhall Waterworks Company, but without, as alleged, any Parliamentary or other powers on the part of that company so to do. For remarks on the quality of the Southwark and Vauxhall Company's water, *see* page 272.

Ripley (*Derbyshire*), an urban sanitary district of 7,000 inhabitants, obtains its supply of potable water from shallow private wells; the supply is quite inadequate, and the urban sanitary authority have entered into a contract for a well to be sunk and works constructed to supply the district with water.

Ripon (*Yorkshire*).—This borough of 6,806 inhabitants is supplied with water by the Corporation from the river *Ure;* private wells are also used.

Owing to the expense of pumping, the Corporation are about to obtain a new source of supply by gravitation, and we have analysed several samples of water from springs and rivers selected by the Corporation for that purpose. No. 1 was water from a spring from the Millstone Grit; it was clear, colourless, soft, and very palatable. It was for domestic and all purposes one of the best waters known to us, and would require neither filtration nor subsidence before delivery to consumers. No. 3 was from the river *Laver* partly supplied by No. 1, and taken 9½ miles below the point at which the latter issues. It was the next in order of merit. It was nearly as soft as No. 1, but contained more than four times as much vegetable organic matter, and was therefore not quite so palatable. Moreover it was not quite clear, and ought therefore to be submitted to filtration or subsidence before distribution.

No. 2 was from the *Kex Beck*, and taken about eight miles from its source. It was considerably inferior to No. 3; it was nearly four times as hard, and the organic matter which it contained was more highly nitrogenised. In palatability it was similar to No. 3, and, like it, would require filtration or subsidence before distribution.

No. 4 was the present supply from the *Ure*, taken at about 40 miles from the source of the river. Though a fairly good water, it was inferior to all the others in palatability and in regard to organic impurity. It was softer than No. 2, but three times as hard as No. 3, and more than four times as hard as No. 1.

All the samples were free from any evidence of previous sewage or animal contamination, and they were all wholesome.

In making their selection of a new source to replace No. 4, the Corporation of Ripon will probably find some difficulty in deciding between No. 1 and No. 3, owing to the greater expense which would be incurred in the supply of No. 1.

Perhaps the following considerations, based upon the sanitary aspect of the question, may be of some assistance to them.

No. 1 being spring water will almost certainly preserve its good qualities unimpaired for centuries, whilst No. 3 may at any time become polluted by agricultural operations, house drainage, or the establishment of paper mills, or other factories upon the banks of the stream. Moreover No. 1 is more palatable than No. 3 and its supply could offer no inducement to the inhabitants to resort to the palatable but unwholesome water of shallow wells in Ripon. Extended experience is leading more and more to the conclusion that the best and most wholesome water for the supply of towns is spring or deep well water. This is the case even if it be hard, but a soft spring water like No. 1 is a prize not often within the reach of a town. (For analyses, *see* pages 39, 46, 53, and 113.)

Rishworth (*Yorkshire*), an urban sanitary district of 1,200 inhabitants, obtains its water from shallow private wells. The supply is said to be adequate for the district. The water has not been analysed.

Roath (*Glamorganshire*), an urban sanitary district of 9,000 inhabitants, is supplied with water for domestic purposes by the Cardiff Waterworks Company; the supply is stated to be abundant. (*See Cardiff*, p. 327.)

Rochdale (*Lancashire*).—This borough of 64,000 inhabitants is supplied with water, by waterworks belonging to the Corporation, obtained from catchwater drains and springs on Brown Wardle Common, running into five artificial reservoirs. The united capacity of these reservoirs is nearly 150,000,000 gallons. The water is very soft, contains but a small quantity of organic matter which is entirely vegetable, and exhibits no previous animal contamination. Though not filtered, it is in every respect a first-class water. (*See* analysis, page 39.) The gathering ground is about 700 acres in area.

The area supplied is comprised within a circle of between three and four miles in diameter, and contains about 13,000 houses. The supply is constant, and direct from the mains, and about 750,000 gallons, nearly all for domestic purposes, are delivered to the district daily. The waterworks cost about 7,000*l*., and annuities amounting to 7,459*l*. 4*s*. A spring near the churchyard, which supplies the Town Clerk's office and some of the low-lying parts of the town, is, however, preferred for drinking by many of the inhabitants, although it is strongly impregnated with the inorganic remains of decayed organic matter. It exhibits a previous animal contamination of no less than 17,818 parts in 100,000, derived almost certainly from the drainage of the neighbouring burial ground. Common decency, not to speak of risk to health, requires that the use of this water should be discontinued. (For analysis, *see* page 114.)

Rochester (*Kent*), a borough of 18,352 inhabitants, is supplied with water by a private company who obtain it from two wells sunk in the Chalk 7 feet in diameter, and 83 and 103 feet deep respectively, with an adit at the bottom of the shaft 1,700 feet in length, and three bore-holes in addition 12 inches in diameter, and 150, 283, and 248 feet deep respectively. The wells are situated in the village of Luton, a sparsely populated district. The water is pumped direct into the mains, and the supply is constant to 6,679 houses for domestic purposes; the supply to works, Government establishments, watering streets, and sanitary purposes is measured by meter.

Roxby-cum-Risby (*Lincolnshire*), an urban sanitary district of 374 inhabitants, has no waterworks. A supply of potable water is obtained from private shallow wells; there being one of such wells to each house in the district. The water has not been analysed.

Royton. St. Helens.

Royton (*Lancashire*), an urban sanitary district of 7,794 inhabitants, receives its water supply partly from the Oldham Corporation Waterworks (*see Oldham*, p. 381), but chiefly from private shallow wells.

Runcorn (*Cheshire*), an urban sanitary district of 12,443 inhabitants, is supplied with water by a limited company, under Act of Parliament, 26 May 1865, from a well sunk into the New Red Sandstone, and also, to a limited extent, from private shallow wells. There is also a public fountain fed from a neighbouring spring, which is much used by the inhabitants. The water is hard, but in other respects its quality is not bad. (For analysis of the fountain water *see* page 116.)

Rusholme (*Lancashire*), an urban sanitary district of 7,600 inhabitants, receives its supply of potable water from the works of the Corporation of Manchester. The supply is constant and direct from the mains to about 1,500 houses, distributed over an area of 1,160 acres. It is stated that "the supply is adequate for domestic purposes, but there "ought to be a much greater quantity delivered for flushing sewers and sanitary pur- "poses." (*See Manchester*, p. 373.)

Ruskington (*Lincolnshire*), an urban sanitary district of 1,156 inhabitants, obtains a supply of water for domestic purposes from shallow private wells sunk in a subsoil of gravel and sand. The water has not been analysed.

Ruthin (*Denbighshire*), an urban sanitary district of 3,300 inhabitants, is supplied with water by the Ruthin Water Company, abstracted from a gathering ground of 240 acres on the Upper Silurian formation, about 40 acres of which is manured with farm-yard dung. The water flows into an uncovered reservoir holding 2,000,000 gallons; the water is delivered unfiltered, "but it ought to be" direct from the mains on the constant system to 266 houses for domestic purposes. The supply is stated to be adequate; the works cost 7,500*l*.

St. Albans (*Hertfordshire*), a borough of 8,303 inhabitants, is supplied with water by a private company, who pump about 90,000 gallons daily from a well 200 feet deep, with three bore-holes 50 feet deeper into the Chalk. The company supply at present 750 houses, both on the constant and intermittent systems, within an area of 600 acres.

St. Austell (*Cornwall*), an urban sanitary district of 4,000 inhabitants, is supplied with water for domestic purposes from springs in the granite, about a mile and a half from the town. The water is collected in a reservoir, and flows from thence through mains to the town. The waterworks were established in 1766, and belong to the governing body. The reservoir contains 300,000 gallons. The water is not polluted before entering the reservoir, and is not filtered. The supply to the waterclosets is by cisterns, and for domestic purposes direct from the main, and 150,000 gallons of water is delivered daily to 660 houses and 12 manufactories distributed over an area of 186 acres. The present supply is adequate for the requirements of the district. The rate of charge for water varies from 5*s*. on houses the rateable value of which does not exceed 5*l*., to 4*s*. for houses the rateable value of which does not exceed 50*l*. The waterworks have cost about 1,000*l*. Our analysis, given on page 107, shows this water to be clear, potable, nearly destitute of organic matter, and of most excellent quality for dietetic purposes. It is also very soft, and therefore, well adapted for washing.

St. Columb (*Cornwall*), an urban sanitary district of 1,113 inhabitants, obtains its supply of potable water partly from springs and partly from stream. The water flows into an impounding reservoir holding 500,000 gallons, and is thence distributed direct from mains to consumers. The supply is said to be adequate to the requirements of the district. The water has not been analysed.

St. Helens (*Isle of Wight*), an urban sanitary district of 3,500 inhabitants, obtains its water for domestic purposes partly from shallow wells and partly from the Ryde Corporation Waterworks, but the supply from this latter works is to be discontinued, and the sanitary authority are seeking another source of supply.

St. Helens (*Lancashire*), a borough of 45,000 inhabitants, is supplied with water from works the property of the Corporation. The impounding reservoir of the gravitation waterworks for trade supply, and also the pumping station and service reservoir of the potable water, are situated in the township of Eccleston just beyond the borough boundary. The pumping station is 150 feet above the town. The gathering ground of the gravitation works has an area of 300 acres, and the reservoirs contain 8,106,000 gallons. The water flowing into these reservoirs is polluted by organic impurities incidental to highly cultivated ground; it is not filtered. The wells, 8 and 10 feet diameter, are sunk to a depth of 210 feet, with 6-inch and 18-inch bore-holes in addition, 63 and 99 feet deep respectively, through the middle division, and to a depth of 18 feet into the lower division "Bunters" of the New Red Sandstone; and 27,500 gallons of water per hour is pumped constantly day and night, into a service reservoir,—containing 456,000 gallons, partially built above the surrounding ground and covered,—by two Cornish engines (duplicates) of 50 h.p., each with two sets of main pumps delivering the water in single lifts into the service reservoir. The area supplied—12,075 acres—comprises 7,000 houses and about 100 manufactories. The supply is intermittent, direct from the mains, and 650,000 gallons of water for domestic, and 800,000 gallons for trade purposes are delivered daily. The rate of charge for domestic purposes is 10*d.* in the 1*l.* on the yearly value of the house, and for trade purposes 7*d.* per 1,000 gallons. The supply is inadequate. The waterworks cost 77,396*l.* The potable water is one of the best in Great Britain (*see* analysis, page 93) for dietetic purposes. Analysis failed to detect even a trace of organic matter in it. It is clear, palatable, and wholesome, and its hardness is not great. It is New Red Sandstone water of the very best quality.

St. Ives (*Cornwall*), an urban sanitary district of 6,965 inhabitants, is supplied with water for domestic purposes from three streams; the water is conveyed into large covered tanks on the outskirts of the town. The waterworks were established about 30 years ago, and belong to the Corporation. The tanks contain about 55,000 gallons. 350 houses are supplied with water for domestic purposes, and the remainder of the inhabitants obtain their water from public stand-pipes in the streets. The supply is constant, and direct from the mains, and 88,000 gallons of water is daily delivered to 350 houses distributed over an area of 80 acres for domestic purposes. The present supply is inadequate for the requirements of the district. The rate of charge for water varies from 3*s.* per annum upon houses rated at 6*l.*, up to 10*s.* per annum upon houses rated at 20*l.* Previously to the establishment of the waterworks the inhabitants obtained their supply of water from wells. The water has not been analysed.

Sale (*Cheshire*), an urban sanitary district of 5,573 inhabitants, is supplied with water chiefly by shallow wells, but partly by the North Cheshire Waterworks Company, who purchase their water in bulk from the Manchester Corporation. (*See Manchester*, p. 373.)

Salford (*Lancashire*).—This borough of 124,825 inhabitants is supplied with water in bulk by the Corporation of Manchester, and the quantity delivered is recorded by meters. The area, 1,329 acres, of which about 700 acres are covered with buildings and roads and is supplied with water, leaving about 600 acres not yet built upon. There are about 15,000 houses in the Salford district supplied for domestic purposes besides 176 works or manufactories. The supply is constant, except in cases of excessive drought, and about 1,500,000 gallons are delivered daily, of which 1,100,000 may be considered as for domestic purposes, and 400,000 as for business purposes. The amount paid to the Corporation of Manchester for the delivery of 1,500,000 gallons daily is 6,500*l.* per annum. In some few cases the houses are furnished with cisterns, but the great majority are supplied direct from the mains. The supply is adequate. The charge is 10*d.* in the pound on the rent for dwelling houses, 9*d.* in the pound for houses and shops, and 1*s.* for beer houses and public houses. Cottages of 10*l.* and under are compounded for by the owner, who is allowed a discount of 25 per cent. To prevent waste, inspectors are employed, whose duty it is to make a systematic and periodical inspection of the water fittings throughout the district. (*See Manchester*, p. 373.)

Salisbury (*Wiltshire*), an urban sanitary district of 12,903 inhabitants, is supplied with water for domestic purposes from a well sunk in the Chalk, 8 feet in diameter, and 50 feet deep, with a 6-inch bore-hole in addition 40 feet deep. The well is sunk in a sparsely populated district; 600,000 gallons of water is pumped daily; the supply is intermittent, but direct from the mains, to 2,588 houses distributed over an area of 598 acres. The supply is said to be adequate.

Sandbach (*Cheshire*), an urban sanitary district of 5,259 inhabitants, has no public water supply and is dependent on private shallow wells; besides which there are several natural springs about the town which are said to yield good water, and these, together with the wells, furnish a sufficient supply for the inhabitants. The water has not been analysed.

Sandgate (*Kent*), an urban sanitary district of 1,840 inhabitants, obtains its supply of potable water from springs issuing from the Upper Greensand. The water flows into a reservoir holding 24,700 gallons, from thence unfiltered through cast-iron mains for distribution to about 300 houses; the supply is direct from the mains, and is said to be adequate.

Sandown (*Isle of Wight*).—This urban sanitary district and watering place of 2,350 inhabitants, augmented in the season to about 4,000, is supplied with water from the *Yar.* The water is taken into a reservoir about 1,600 yards from the river, and is polluted both by sewage and other animal matters, and is inadequate to the requirements of the district. The sample taken from the reservoir close to the entrance to the main by which Sandown is supplied, was much polluted with organic matter, some of which was of animal origin. This water was quite unfit for all domestic purposes except washing.

Scammonden. Sheffield.

Its use for drinking must be attended with great risk to health. Sand filtration would improve its quality, but it would still be a dangerous water. The sample from the river *Yar* from which water is pumped into the reservoir, though of somewhat better quality than the preceding at the time the samples were taken, was still a dangerous water for domestic use. Although it contained less actual sewage than the former, it exhibited much more evidence of *previous* sewage contamination. (For analyses, *see* page 50.)

Scammonden (*Yorkshire*), an urban sanitary district of 912 inhabitants, is supplied with water for domestic purposes from springs. The water has not been analysed.

Scarborough (*Yorkshire*), a borough and fashionable watering place with a resident population of 24,259, greatly augmented during the season, is supplied with water from springs at Cayton Bay in the Coralline Oolite, whence it flows into a subsiding reservoir, and is pumped to a service reservoir 222 feet square and 15 feet deep situate on the hill, built of brickwork in cement on concrete above surrounding ground and uncovered, and is thence delivered at the rate of 603,433 gallons daily. The quantity delivered during 1872 for trade and sanitary purposes was 24,013,000 gallons. An additional supply is also now obtained from a well sunk at Cayton into the Coraline Oolite, the water from which is pumped to the service reservoirs. There is also a deep well into the same stratum at the Grand Hotel. All these waters are clear, palatable, and of most excellent quality for dietetic purposes (*see* analyses, pages 96 and 119), but for washing they require to be softened by Clark's process (*see* page 205). The water from the well at the Grand Hotel smells of sulphuretted hydrogen when it is first delivered by the pump, but the odour soon vanishes.

Scholes (*Yorkshire*), an urban sanitary district of 1,086 inhabitants, is supplied with water for domestic purposes from shallow private wells. The water has not been analysed.

Selkirk (*Selkirkshire*), a burgh of 5,000 inhabitants, derives its potable water from a well 20 feet in diameter and 20 feet deep, sunk in gravel and sand, and situated close to the river *Ettrick*. During 12 hours daily, the pumps raise 5,000 gallons per hour to a covered high-service reservoir of 112,500 gallons capacity, placed 300 feet above the level of the river. The works were established in 1865, and belong to the Commissioners of Police. The water is constantly supplied to 230 houses and also to 14 public fountains erected in the streets of the burgh for the gratuitous use of the inhabitants. The present supply is said to be adequate for the requirements of the town and district, although it only amounts to 11 or 12 gallons per head per day. Waste is prevented by the vigilant inspection of taps and fittings. Previously to the establishment of the waterworks, the town was supplied from private wells and from a loch about a quarter of a mile distant from the burgh, the water from which was conveyed to a public tank situate in the market place. The improved supply is said to have had a beneficial effect upon the health of the inhabitants, although there are some parts of the town especially unhealthy, caused by overcrowding and inefficient accommodation. Our analyses of the river and well water given at pages 37 and 69 show conclusively that the well is supplied by infiltration from the river, and they also demonstrate the great purifying effect which passage through even a few feet of sand and gravel exerts upon river water. The most objectionable impurity in river water is organic matter, expressed in the analytical tables by organic carbon and organic nitrogen; and it will be seen on comparing the numbers in the columns so headed, that the proportion of organic matter in the river water is reduced more than two-thirds during the passage of the water through the filtering material. There is, however, a slight though unimportant admixture of the subsoil water of the town with the contents of the well, as is seen from the increase in the proportion of chlorine and the appearance of some slight evidence of previous animal contamination. The water is clear, colourless, palatable, soft, and wholesome, and well adapted for all domestic purposes.

Shanklin (*Isle of Wight*), an urban sanitary district of 2,400 inhabitants, obtains its supply of water for domestic use from springs issuing from the Chalk and Greensand flowing through earthenware pipes into tanks holding about 100,000 gallons. The water is not filtered and about 20,000 gallons are delivered daily, intermittently, direct from the mains to about 300 houses within an area of 240 acres. The supply is said to be inadequate to the requirements of the district.

Sheffield (*Yorkshire*), a municipal borough of 239,947 inhabitants, is supplied with upland surface water by a private Company from gathering grounds on the Millstone Grit, impounded in six reservoirs holding in the aggregate 1,538,000,000 of gallons, from thence it flows unfiltered into uncovered reservoirs holding 25,000,000 of gallons built partially above surrounding ground. The supply is constant partly direct from the mains and partly through cisterns, and 5,500,000 gallons are delivered daily to about 50,000 houses and 700 works and manufactories within an area of 9,345 acres. The supply is said to be adequate for a much larger population. The waterworks cost 1,129,484*l.* Our analysis of a sample of the water (*see* page 40), taken direct from a main in the town, shows it to be turbid and rather peaty, but otherwise of fairly good quality. It is soft and therefore well adapted for washing and manufacturing purposes.

Sheffield, South Yorkshire Asylum.—We have examined two samples from this Institution. The water from Jacob's well was one of the worst we have ever seen. It was very muddy and offensive to the smell and swarmed with vibrios, bacteria, and other living organisms. It also contained large proportions of organic elements and ammonia in solution. The evidence of a much larger proportion of previous animal contamination had probably disappeared by the process of putrefaction which rapidly destroys this evidence. It is needless to say that this water was utterly unfit for domestic purposes, indeed its use for drinking would be attended with great risk to health. (For analysis, *see* page 73.) The sample from Sampson's spring on the other hand, was of excellent quality. It was very soft, contained but mere traces of organic elements, and was in every respect admirably adapted for all domestic purposes. Its composition showed that it was from a deep-seated spring and hence the evidence of a moderate amount of previous animal contamination is of no consequence. (For analysis, *see* page 114.)

Shelf (*Yorkshire*), an urban sanitary district of 3,063 inhabitants, is supplied with water from very shallow private wells. The district is included in the water supply area of Bradford, under an Act passed last session, and it is expected that the district will be supplied from that source in about two years. The present supply is inadequate to the requirements of the district. The water has not been analysed.

Shelley (*Yorkshire*), an urban sanitary district of 1,751 inhabitants, obtains a supply of potable water from private shallow wells and springs. The water has not been filtered.

Shepley (*Yorkshire*), an urban sanitary district of 1,507 inhabitants, is supplied with water from a stream and from private wells. The water has not been analysed.

Shipley (*Yorkshire*), an urban sanitary district of 11,757 inhabitants, is supplied with water from springs. The waterworks were established in 1855, and belong to the Local Board of Health. The reservoirs are situated at Eldwick, near Bingley, and at Baildon Bank, Baildon. The area of gathering ground is 1,300 acres. The three reservoirs have an united capacity of 36,000,000 gallons. The water is said to be unpolluted before entering the reservoirs: it is not filtered, and is not pumped. The high service reservoir is built level with the surrounding ground, and is not covered. The supply is constant and direct from the mains, and 3,000,000 gallons are delivered to the town daily, for trade and domestic purposes, to 1,963 houses and 45 manufactories, distributed over an area of 1,330 acres. The present supply is adequate for the town and district. The rate of charge for houses varies from 8*s.* 8*d.* to 46*s.* yearly. To prevent waste periodical inspection is made of the fittings and taps. The waterworks cost 29,800*l.*

Shirley (*Hants*), an urban sanitary district of 5,339 inhabitants, obtains its water for domestic purposes from shallow private wells. The water has not been analysed.

Shrewsbury (*Shropshire*), a borough of 23,300 inhabitants, is supplied with water from the *Severn* by a private company whose works cost 34,559*l.* at a pumping station by the river side above the town. Two engines of 20 and 40 horse-power deliver nearly 500,000 gallons daily, during seven or eight hours of each 24, to the houses within an area of three square miles. The water is unfiltered and not of good quality; it is delivered into cisterns in the houses, the supply not being direct from the mains. A quantity of excellent and wholesome spring water from the New Red Sandstone is also brought into the town from a distance of about a mile on the south-west side. The following are the analytical results yielded by these waters:—

COMPOSITION OF WATER SUPPLIED TO SHREWSBURY.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Water supplied to Shrewsbury from the *Severn*, May 10, 1871.	13·92	**·240**	**·035**	·003	·555	·592	**5,250**	2·75	3·0	4·9	7·9	Turbid.
Water supply from spring, May 19, 1873.	38·48	**·040**	**·016**	·001	·449	·466	4,180	2·30	20·4	10·9	31·3	Clear.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Silsden. Somerton.

Silsden (*Yorkshire*), an urban sanitary district of 2,700 inhabitants, is supplied with water from private shallow wells and small streams. These wells are sunk in gravel, and are only about two feet deep; the water of which has not been analysed. The supply is inadequate, and the sanitary authority have arranged with the Corporation of Bradford to supply the district with water from their works. (*See Bradford*, p. 321.)

Sittingbourne (*Kent*), an urban sanitary district of 6,147 inhabitants, is supplied with water for domestic purposes partly from shallow wells and partly from waterworks belonging to the sanitary authority derived from a well sunk in the Chalk, 6 feet in diameter, 160 feet deep, with a 12-inch bore-hole in addition 239 feet deep. The well is sunk in a sparsely populated district, and 12,000 gallons of unfiltered water is delivered daily on the constant system direct from the mains to 367 houses and 28 works for domestic and trade purposes. The waterworks cost 6,500.

Skelmanthorpe (*Yorkshire*), an urban sanitary district of 2,953 inhabitants, obtains its supply of water for domestic purposes from private wells; the supply is said to be adequate. The water has not been analysed.

Skipton (*Yorkshire*), an urban sanitary district of 6,078 inhabitants, is supplied with water for domestic purposes from gathering grounds by the Skipton Waterworks Company. The area of the gathering ground is about 230 statute acres. There are three reservoirs, with a united capacity of 2,625,192 gallons. The area supplied—730 acres—contains 1,160 houses. The water is said to be filtered through sand and gravel, but at the time our sample was taken, this operation must have been either omitted or very imperfectly performed, as the water was then being delivered in a very turbid condition. Our analysis (*see* page 43) shows the water to be peaty, and some of it comes from pasture land, but it is not exposed to further excremental pollution, and is otherwise of fair quality. The supply is intermittent in dry seasons, being only turned on, at such times, for 8 to 12 hours daily. It amounts on the average to about 25 gallons per head, inclusive of that used for manufacturing purposes. This quantity is stated to be very inadequate for the requirements of the town; indeed in the summer of 1870 it entirely failed, and water had to be got from the *Eller Beck;* but the higher parts of the town were for a period of three months without even this impure water. Powers are therefore now being sought to bring in a new and softer supply of 300,000 gallons daily from the Millstone Grit by gravitation. The water is supplied direct from the mains; only a few houses have cisterns, the overflow pipes from which are connected with the soil pipes. The rate of charge is 5 per cent. on the rental. This charge is about to be increased, owing to recent expenditure of the Company in Parliamentary proceedings. The waterworks cost 6,274*l.*

Slaithwaite (*Yorkshire*), an urban sanitary district of 2,730 inhabitants, is supplied with water from springs. The supply is inadequate. The water has not been analysed.

Somerby (*Rutland*).—This parish of 512 inhabitants derives its water from shallow wells. The town well supplying the end of the village furnished a fairly good water for drinking but it was harder than desirable for washing. Plant's pump water was inferior to the last, but still it was as good well water as is usually met with near human habitations. It was excessively hard and quite unfit for washing. If these wells were carefully guarded from surface soakage their water might be drunk with but very slight risk to health. The remaining samples were little else than sewage which had percolated through a porous soil into the wells. On this ground they were entirely unfit to be drunk, and, by reason of their excessive hardness, they were useless for washing. (For analyses, *see* page 79.)

Somerton (*Somerset*).—This parish of 2,302 inhabitants is supplied with water from wells and streams. We have analysed several samples of water collected from these, and, except the following, all the samples were turbid, and therefore, on this account alone, unfit to drink without previous filtration:—Well near Town Hall; Ringer's well; Mr. Erith's Well. Of the entire series, all but the following were dangerous and unfit for domestic use on account of the large proportion of previous or actual sewage contamination which they exhibited:—Brook above entrance of first sewer; Well near Town Hall; Deep well at Mr. Ord's Brewery; Mr. Erith's well. Of these the water from the "brook above entrance of first sewer" was of suspicious character, and could only be used for drinking with inconsiderable risk, after the brook had been closely inspected and found to have no sewage or drainage from houses or from highly manured land passing into it. Even then we should not consider it a desirable water. The water from the Town Hall well was of better quality, as it contained a much smaller proportion of organic matter; it was the safest water for drinking purposes in the series, but it was very hard and consequently not suitable for washing or cleaning operations. The next in point of quality was the deep well water at Mr. Ord's brewery, but this contained nearly twice as much organic matter as the

Town Hall well, and was moreover still harder. (For analysis, *see* page 95.) The water from the well at Mr. Erith's was little inferior to the last-named sample as regards organic matter, and was softer, but it exhibited a larger proportion of previous animal contamination, which was shown to be chiefly urine by the large proportion of chlorine which the water contained. It was not a desirable water, but amongst a series so highly polluted it may be regarded as a comparatively good and safe beverage. The following wells should be at once closed; they are fed almost exclusively by sewage, and the drinking of the water from them is highly dangerous to health:—Well in Kirkham Street; Well near Walton's Lodging House; Well at Cook's Holes; Ringer's Well; Well in Langport Road. (For analyses, *see* page 79.) If the three samples, the analysis of which is given in the following table, represent the same brook at consecutive points of its course, it becomes considerably fouled before it reaches the point represented by the second sample; but below the drain from Mr. Ord's brewery it has become manifold more polluted both by dissolved and suspended organic matter. Below this point the stream must become very offensive in warm weather.

PART IV. DESCRIPTIVE.

Soothill. Southam.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											Suspended Matters.		
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
Brook above entrance of first sewer, January 17, 1871.	40·40	**·272**	**·040**	·003	·636	·678	**6,060**	2·80	21·2	7·9	29·1	Slightly turbid.		
Brook just below dam forming sheep-washing place, January 17, 1871.	52·40	**·462**	**·095**	·017	·867	·976	**8,490**	3·85	24·8	8·7	33·5	4·04	1·82	5·86
Brook just below drain from Mr. Ord's Brewery, January 17, 1871.	58·60	**1·587**	**·398**	·006	·261	·664	**2,340**	3·90	28·1	8·9	37·0	3·84	4·74	8·58

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Soothill Nether (*Yorkshire*), an urban sanitary district of 4,927 inhabitants, obtains a supply of water from the Dewsbury Corporation Waterworks at 1*s.* 6*d.* per 1,000 gallons. These works supply upwards of 9,000 gallons daily direct from the mains, to 600 houses and 2 manufactories, distributed over an area of 563 acres. The mains are only charged from two to three hours per day. The present supply is inadequate for the requirements of the district. (*See Dewsbury*, p. 335.) No steps are taken to prevent waste. The water mains cost 2,481*l.* 4*s.* 4*d.* The water has not been analysed.

Soothill, Upper (*Yorkshire*), an urban sanitary district of 3,500 inhabitants, is supplied with water for domestic purposes partly from shallow private wells, and partly from the Halifax Corporation Waterworks. (*See Halifax*, p. 350.)

Southampton (*Hampshire*), an urban sanitary district of 53,741 inhabitants, is supplied with water for domestic purposes abstracted from the *Itchen* which is polluted by part of the sewage of Winchester eight miles above the intake. The water flows into five reservoirs, and thence partly filtered 2,250,000 gallons are delivered daily on the constant system direct from the mains to 9,500 and 150 manufactories for domestic and trade purposes. The supply is said to be adequate.

Southborough (*Kent*), an urban sanitary district of 3,471 inhabitants, obtains its supply of potable water from shallow private wells. The water has not been analysed.

South Darley (*Derbyshire*), an urban sanitary district of 605 inhabitants, obtains its supply of water for domestic purposes from private wells. The supply is inadequate, especially in drought. The water has not been analysed.

Southam (*Warwickshire*).—This rural sanitary district of 1,785 inhabitants is supplied with water from wells and springs. All the samples were very hard and therefore but ill adapted for washing or cleansing purposes. The waters from the well at Park Lane Cottages and Reynold's well had been frightfully polluted by excrementitious matters. They were indeed simply the urine and slops of the inhabitants which had percolated through a porous soil. We need not say that the use of these waters for domestic purposes is very dangerous. (For analyses, *see* page 80.) Of the rest, Holywell Spring was the best, and if carefully protected from the admission of surface

PART IV. DESCRIPTIVE. South Ouram. Spalding.

drainage might be regarded as reasonably safe. (For analysis, *see* page 127.) The same remarks apply in a mitigated degree to the waters from Martin's well and Market Hill well, but Burnell's well (for analyses, *see* page 80) and the Town Well Spring (for analysis, *see* page 127) contained such large proportions of ammonia as to indicate that their previous animal contamination was very recent, and we consider, therefore, that these waters could not safely be used for drinking. All the samples were turbid and would require filtration before use for drinking. The cause of this turbidity ought to be investigated; well waters are usually perfectly clear, and any muddiness in them generally indicates the admission of surface water.

South Owram (*Yorkshire*), an urban sanitary district of 3,091 inhabitants, is supplied with water for domestic purposes from shallow private wells and springs. The supply is not adequate to the requirements of the district. The water has not been analysed.

Southport (*Lancashire*), a borough of 18,085 inhabitants, is supplied with water by the Southport Waterworks Company, from a well sunk in the New Red Sandstone to a depth of 192 feet, and with a bore-hole of 30 feet. The works were established in 1854. The water is filtered, and 600,000 gallons are pumped daily into the covered service reservoir at Scarisbrick capable of holding 1,000,000 gallons, and also a covered one at Aughton, containing 960,000 gallons, the water from this reservoir was turned into a tank at Scarisbrick to reduce the pressure; there is now a reducing valve, and the water flows direct to Southport unfiltered. The supply is constant over the district, with a pressure of 150 feet. The waterclosets have cisterns with overflow to outside of houses and not into soil pipes. The supply is ample. The rate of charge for waterclosets is 8*s.* per annum; houses, 5 per cent. on rent: garden, 8*s.* per rood, and 6*d.* per 1,000 gallons to the Corporation. Legal proceedings are taken to prevent waste. The waterworks first cost 17,000*l.*, and this has since increased to 70,000*l.* Private wells are not now extensively used; percolation from drains and increase of population in the district has seriously affected the character of the water supplying the shallow wells. It is stated that analysis has shown the water from these wells to be unfit for dietetic purposes.

South Stockton (*Yorkshire*), an urban sanitary district of 7,714 inhabitants, is supplied with water by the Stockton and Middlesborough Waterworks Company established in 1858. The pumping stations are on the river *Tees*, at Tees Cottage, about three miles west of Darlington. There is a reservoir near the "Fighting Cocks," about midway between Darlington and Stockton. The water is supplied to 1,300 houses and 10 manufactories distributed over an area of 325 acres. The supply is constant, adequate, and direct from the mains, and 290,000 gallons for trade, and 168,000 gallons for domestic purposes are delivered to the district daily. The rate of charge for water, for trade purposes, is 3*d.* per 1,000 gallons to large consumers, and up to 1*s.* per 1,000 gallons to small consumers, and for domestic purposes, 5*l.* to 6*l.* per cent. on the rental. To prevent waste an inspector is constantly employed examining the fittings. (*See Stockton*, p. 399.)

Sowerby (*Yorkshire*), an urban sanitary district of 6,079 inhabitants, is supplied with water from shallow wells and streams.

Sowerby Bridge (*Yorkshire*), an urban sanitary district of 7,041 inhabitants, is supplied with water from the Halifax Corporation Waterworks. The supply is constant, direct from the mains, and 100,000 gallons are delivered daily to 1,000 houses and 100 manufactories; the present supply is adequate, and the rate of charge is 1*s.* per 1,000 gallons. The water mains and fittings cost 9,000*l.* No steps are taken to prevent waste. (*See Halifax*, p. 350.)

Soyland (*Yorkshire*), an urban sanitary district of 3,264 inhabitants, is supplied with water for domestic purposes from shallow private wells. The supply is said to be adequate. The water has not been analysed.

Spalding (*Lincolnshire*), an urban sanitary district of 9,111 inhabitants, is supplied, to the extent of about two thirds of its population, with water by a local company, who pump about 100,000 gallons daily from a neighbouring watercourse on to filter beds, and thence to a tank capable of holding nearly 40,000 gallons at a level of 80 feet above that on which the town is built. The water, derived from springs some 20 miles away, rising between the Oolitic rock and the Oxford Clay, travels in one of the numerous water channels of the fen country to the spot whence it is pumped. New works are at present being constructed to bring water seven or eight miles from an artesian well at Bourne, correspond-

Part IV. Descriptive.

Speenhamland. Stalybridge.

ing to that of the large natural spring there, of which an analysis is given on page 118. This water is clear, palatable, wholesome, and of excellent quality for dietetic purposes, but it is too hard for washing. Its hardness would be reduced to one-third its present amount by the application of Clark's process to it, *see* page 205. A considerable proportion of the inhabitants of Spalding still draw their water either from the shallow wells sunk into the gravel on which the town is built, or direct from the river *Welland* at low water. There are 12 public wells, provided with street pumps, thus used. Some of them provide water which is only used for washing purposes; and it is impossible that any of them, sunk into the porous subsoil over which the ancient town of Spalding stands, can be trustworthy as supplying wholesome drinking water.

Speenhamland (*Berkshire*), an urban sanitary district of 1,101 inhabitants, is said to be abundantly supplied with potable water from shallow private wells. The water has not been analysed.

Staffordshire Potteries Waterworks, with a capital of 221,268*l.*, supply 28,000 houses and 210 works and manufactories, within an area of 10 square miles, delivering about three millions of gallons daily within the district. The water is obtained (1) from a well 12 feet in diameter sunk 135 feet deep, with a 6-inch bore hole in addition 90 feet deep, in the Conglomerate of the New Red Sandstone, at Wall Grange, and thence pumped to a storage reservoir, from which it flows into service reservoirs for distribution; and (2) from springs at the weir near Longton, in the New Red Sandstone, flowing direct into a service reservoir. There are eight service reservoirs together capable of holding upwards of 4,000,000 gallons, these are lined with clay puddle and protected against percolation, all situated in high districts and four of them are covered; there are also three pumping stations with three pumping engines of 120 horse-power each. The water is generally supplied direct from the mains during about 10 hours each day. The supply is adequate for present wants, but a further quantity is about to be provided. Our analyses given below prove these waters to be of most excellent quality for all dietetic purposes. They are clear, brilliant, wholesome, and palatable, and their hardness is moderate considering their source.

Composition of Water supplied by the Staffordshire Potteries Company.

Results of Analysis, expressed in parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Springs at Wall Grange pumping station, Sept. 30, 1873.	18·42	·049	·007	0	·193	·200	1,610	1·40	7·1	6·3	13·4	Clear and palatable.
Deep well at Mier pumping station, Oct. 3, 1873.	25·44	·053	·011	·001	·320	·332	2,890	1·50	9·6	7·3	16·9	Clear and palatable.
Sutherland reservoir supplied by springs, Oct. 3, 1873.	22·92	·052	·007	0	·467	·474	4,350	1·60	7·7	7·7	15·4	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Stalybridge (*Lancashire and Cheshire*), a borough of 21,042 inhabitants, is supplied with water from the Dukinfield Waterworks, and also from waterworks constructed under "*The Ashton-under-Lyne and Stalybridge* (*Corporation*) *Waterworks Act*, 1864." (*See Ashton-under-Lyne*, p. 305.) The reservoirs are at Dukinfield.

The gathering ground is about 280 statute acres. There are four reservoirs with a total capacity of 48,209,850 gallons.. The water is obtained from the high arable lands in the immediate neighbourhood of the reservoirs, and is slightly polluted at certain times of the year by stable manure. The water is not filtered. There are two high service reservoirs, of the aggregate capacity of 25,506,900 gallons. They are partially built above the surrounding grounds and neither of them is covered. There are no wells.

The area of the district supplied is about 500 statute acres. There are about 5,000 houses supplied for domestic purposes, and 10 cotton mills for drinking purposes only. The supply is constant, and about 100,000 gallons is supplied to the district daily.

The water is drawn direct from the mains. When supplied by meter, it is at the rate of 1*s.* per 1,000 gallons; cottages at the rate of 6*s.* and 9*s.* per year; houses of a better class at rates varying from 12*s.* to 20*s.* per year each. Waterclosets are charged 10*s.* per year each, baths 5*s.*, and public-houses and beer-houses from 20*s.* to 40*s.* per year each. To meet the inadequate supply, the joint committee of the Stalybridge

PART IV. DESCRIPTIVE.

Stamford. Stirling.

Corporation and Dukinfield Local Board of Health have been furnished by the Manchester Corporation with about 21,000,000 gallons per year for the last 12 years. Waste is prevented by a periodical inspection of fittings, the borough being divided into districts, and men appointed to examine and repair the fittings. The entire cost of the Dukinfield waterworks was 39,980*l.*, the portion paid by the Stalybridge Corporation was 16,700*l.*

Stamford (*Lincolnshire*), an urban sanitary district of 7,846 inhabitants, is supplied to a considerable extent with water from the Wothorpe spring, thrown out by the Lias Clay from beneath the iron stone beds of the Lower Oolite. A large part of the town is still dependant on private wells. The spring at Wothorpe yields about 100,000 gallons in the 24 hours, and is received into a reservoir capable of holding upwards of 300,000 gallons, whence it is laid on to the houses of about three quarters of the population. The supply is constant to stand-pipes in the streets, but intermittent to dwelling-houses. The spring water yielded the following results on analysis :—

Composition of Wothorpe Spring Water.

Results of Analysis, expressed in parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Spring at Wothorpe, Dec. 3, 1873	46·48	**·070**	**·017**	0	1·026	1·043	9,940	2·70	26·3	8·1	34·4	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

These results show the water to be clear, palatable, and wholesome. It contains but a small proportion of organic matter, but it is very hard and should be softened by Clark's process (*see* page 205). It would then be equally palatable and well adapted for washing.

Standish-with-Langtree (*Lancashire*), an urban sanitary district of 3,698 inhabitants, obtains its supply of potable water from springs and wells. The supply is said to be adequate.

Stirling (*Stirlingshire*), a burgh of 14,276 inhabitants, is supplied with water for domestic purposes from streams and springs collected in three reservoirs with a united capacity of about 63,000,000 gallons on the Touch Hills, about four miles from Stirling. The supply is constant; and about half a million gallons per day, or 36 gallons per head, are used for domestic purposes. The works are under the control of a body of thirteen commissioners, of whom seven are members of the town council, and six elected by the ratepayers. The water is supplied by gravitation to 1,543 houses and 20 manufactories and is not filtered before delivery. The better classes of houses have cisterns; in others the supply is direct from the mains. The overflow pipe from the cisterns is in most cases connected with the soil or waste pipe. The present quantity is said to be adequate, although there was a scarcity in the very dry summer of 1870. Waste is prevented by a house-to-house visitation made by two inspectors. The waterworks cost 25,000*l.* Before the construction of the waterworks, a supply of about two gallons per head per day was brought from two springs in the Touch Hills, which supplied sixteen public standpipes called wells. There were also a number of private wells sunk behind dwelling-houses; these have all been closed since the construction of the new waterworks in 1848.—"The improved water supply has been of very great benefit to the "community, but Stirling was not an unhealthy town previously." The death rate ranges from 19·9 to 29 per 1,000 per annum. Our analysis given at page 33 shows this water to be light brown, turbid, and rather unpalatable. It contained an excessive proportion of peaty matter, but exhibited no evidence of previous animal contamination. It was soft and well adapted for washing. The Butt well, a large natural spring issuing below the cemetery is much used, as is also St. Ninian's well, a most abundant spring on the lower side of the town. The first of these appears to be slightly polluted, probably by the cemetery, the second is good clear and wholesome water containing mere traces only of organic matter. Both samples are of somewhat more than moderate hardness. (For the analyses of these waters, *see* page 114.)

PART IV. DESCRIPTIVE

Stockport. Stretford and Moss Side.

Stockport (*Cheshire and Lancashire*), a borough of 53,014 inhabitants, is supplied with water by a private company with a capital of 269,000*l.*, who obtain their water, to the extent of 850,000 gallons daily, from a gathering ground situate at Lyme Park, Disley, eight miles from Stockport, which is nearly all pasture. They have also the power to take 1,000,000 gallons daily from the Manchester Corporation Waterworks, and their daily draught on this source is at present about 300,000 gallons daily. The water is received into an impounding reservoir at Lyme Park, about 12 acres in extent, and capable of holding 73,000,000 gallons, and is then filtered. There is another at Alderley Edge, and a further storage reservoir, capable of holding 80,000,000 gallons, is now being made at Lyme. 1,150,000 gallons of water are supplied daily to 13,500 houses and 370 factories, within an area of 60 square miles, and on the constant system. The water of the river is undoubtedly entirely unfit for domestic or almost any other purposes, fouled as it is by the refuse of printworks containing arsenic. The Water Company, however, alleges that it has ceased to supply river water altogether since the year 1859, when arsenic was actually found in the cistern of one of its customers. The water which we saw delivered to a public swimming bath in the town had a very repulsive appearance, and on the whole the supply of this large town cannot be said to be in a satisfactory condition, although our analysis given on p. 44 shows that a sample which we collected on the 27th July 1868 was of fairly good quality for dietetic and all other domestic purposes.

Stockton-on-Tees (*Durham*), a borough of 30,000 inhabitants, is supplied with water on the constant system by the Stockton and Middlesborough Waterworks Company. The water is obtained from the river *Tees*, the pumping station being at Tees Cottage above Darlington. The source of supply is therefore identical with that from which the Local Board of Health of Darlington obtain water, and our remarks upon the risk of pollution to which the upper part of the *Tees* is exposed, are therefore equally applicable to the water delivered at Stockton and Middlesborough.

The water is polluted before entering the reservoirs by the sewage of Barnard Castle (containing about 4,000 inhabitants), by Staindrop, Gainford, and several other villages on its bank, also by lead washings and refuse from dyeworks and fellmongers' premises. The water is filtered, and the filtering medium is composed of gravel and sand six feet in thickness. The area supplied—2,695 statute acres—contains 5,600 houses and 50 manufactories. The supply is constant, and direct from the mains, and 1,000,000 gallons is delivered for trade, and 1,000,000 gallons for domestic purposes in the district daily. The rate of charge for water for houses not exceeding 4*l.* per year to houses not exceeding 100*l.* a year varies from 1*s.* 6*d.* to 15*s.* a quarter; for trade purposes, for any supply not exceeding 5,000 gallons per quarter, 7*s.* 6*d.* per quarter; and for the next 5,000 gallons up to 640,000 gallons, the price varies from 1*s.* to 5*d.* per 1,000 gallons. Special rates are made for day and night supplies to iron works and other manufactories. In order to prevent waste constant inspection is made of the taps and fittings. The total cost of the works was 295,000*l.* Our analyses (*see* page 44) exhibit the condition of the water at the Company's works before and after filtration, from which it is seen that, not only are the suspended impurities removed, but an appreciable diminution, even of the organic matters in solution, is effected. The water, at the time our sample was taken, was of unimpeachable quality; it was clear and bright and nearly as palatable as deep well or spring water. Its hardness was rather more than moderate $12\frac{1}{4}°$; but by boiling for half an hour or by the addition of quicklime in the proportion of 7 cwts. to each 1,000,000 gallons, we find that it can be softened to $3\frac{1}{2}°$; it thus becomes better adapted for washing, cleansing, and manufacturing purposes, whilst it is at the same time rendered more palatable for drinking. The supply is twenty-four gallons daily per head of population for domestic purposes. Some of the inhabitants of Stockton prefer to drink the water from wells sunk upon their own premises, but these contain the remains of much animal matter, and, if not carefully protected from surface soakage, constitute dangerous sources of potable water. Two examples of water from wells of this description about 90 feet deep are given in the analytical table on page 78. The water was slightly turbid in both cases, and this circumstance together with the, for deep well water, very high proportions of organic elements (organic carbon and organic nitrogen) point unmistakably to the flow of surface drainage into the upper part of the shafts of these wells.

Street (*Somersetshire*), an urban sanitary district of 2,500 inhabitants, obtains its supply of potable water from wells. The supply is said to be adequate. The water has not been analysed.

Stretford and Moss Side (*Lancashire*), an urban sanitary district with 11,845 inhabitants, with an area of 420 acres containing 790 houses, receives its water supply from

PART IV. DESCRIPTIVE.

Stroud. Sudbury.

the waterworks of the Manchester Corporation. The supply is chiefly direct from the mains. (*See Manchester*, p. 373.)

Stroud (*Gloucestershire*), a Local Board district of 7,001 inhabitants, is supplied with water to a small extent from wells, but chiefly from waterworks belonging to the Board of Health, called the Upper and Lower Works. The reservoirs are situated, two on Stroud Hill, above the town, and one near the Cross in the middle of the town. The upper works are only supplied from gathering grounds. Pipes are carried along the sides of the hills in the Fuller's Earth clays to an extent of 2,000 by 100 yards. The capacity of one of the upper reservoirs is 1,680,000 gallons; that of the other is about 900,000 gallons, and the capacity of the lower reservoir is 37,000 gallons. The water is said to be unpolluted before entering the reservoirs. Only the water of the upper reservoir is filtered, and that through a rough gravel filter in the bottom. The water is not pumped. The only supply of water obtained from wells is from those owned by private persons, except in the instance of a well sunk by the Local Board to obtain water for watering the streets. All the wells are sunk in Inferior Oolite to the level of the water-bearing clays of the Upper Lias, or the lower part of the supra-liassic sands. The area supplied—110 acres—contains 900 houses, and 9 manufactories. The hours of supply vary in summer and winter from one to two or three hours; and about 50,000 gallons of water on the average are delivered to the district daily. Houses of the better class are furnished with cisterns, but the cottages are generally without cisterns. In the former cases the waste pipe is usually connected with a sewer. The present supply is scarcely adequate for the requirements of the town. Additional storage was obtained last year, and it is hoped that the supply will be in future sufficient. Hitherto the upper portion of the town has not had more than half the proper supply during the summer months. The rate of charge varies according to the rental of the houses from 4*s.* to 30*s.* per year; an additional charge of 5*s.* for stables and coachhouses. To prevent waste the fittings are constantly inspected. The lower streets are supplied from Gainer's well, a copious spring thrown out by the Lias about half way down the hill. We have analysed this water, and find it to be of not quite unimpeachable quality for dietetic purposes, and too hard for washing. (For analysis, *see* page 119.) The supply to the upper part of the town is of bad quality; it is highly charged with organic matter partly of animal origin, and it is excessively hard. It is quite unfit for domestic use. Both waters would be reduced to moderate hardness by the application to them of Clark's softening process. (*See* page 205, and for analysis, page 50.) We have also examined several samples from sources available for the supply of Stroud. The spring at Chalford (for analysis, *see* page 118) would furnish an abundant and excellent supply, especially if it were softened before delivery by the addition, to each 60,000 gallons, of 1 cwt. of quicklime previously slaked and diffused through about 500 gallons of water. The Chalford spring water would thus be reduced from 24½° to 3½° of hardness.

Sudbury (*Derby*).—This village is about to be supplied with water from one or more of the following sources:—(1.) The water of the spring near the village which was of excellent quality for drinking and culinary purposes. It contained only a minute proportion of organic matter. As it was spring water the evidence of a moderate amount of previous animal contamination which it exhibited may be safely disregarded. For washing it was harder than is desirable, but as rain water can usually be employed for this purpose in the country, this defect would probably not be of much consequence. It was, moreover, considerably softer than any water supplied to London. (2.) The water from the spring in coppice, which contained only a moderate amount of organic matter, but this organic matter was highly nitrogenised,—a circumstance which indicates an animal origin. It was also very hard and therefore unfit for washing. Although it could not be condemned as bad, it was decidedly inferior in quality to the preceding sample. The evidence of *previous* animal contamination was less than it was in the foregoing sample, but as this evidence is liable to be diminished in many ways, it must always be regarded as a minimum and must never be used for comparison. The samples from (3.) "Hunting Gate and Reservoir" and from (4) "Coppice and Reservoir" were both of excellent quality for dietetic and all domestic purposes. They were palatable and contained only a very small proportion of organic matter. The latter sample was the better as regards comparative freedom from organic matter, but it contained some evidence of previous animal contamination which may, however, be safely disregarded. Neither sample was inordinately hard. The results of analysis are given in the following table:—

COMPOSITION OF WATER SUPPLIED TO SUDBURY.

RESULTS OF ANALYSIS, EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Spring near village, July 6, 1872 -	20·30	**·056**	**·014**	0	·354	·368	3,220	1·30	9·3	7·0	16·3	Slightly turbid. Palatable.
Spring in coppice, June 17, 1873 -	19·60	**·097**	**·069**	·001	·221	·291	1,900	1·60	18·8	6·9	25·7	Clear and palatable.
Hunting gate and reservoir, March 23, 1874.	22·12	**·079**	**·013**	·003	·037	·052	70	1·45	7·3	6·9	14·2	Slightly turbid. Palatable.
Coppice and reservoir, March 23, 1874.	21·60	**·057**	**·007**	·005	·228	·239	2,000	1·40	6·6	7·0	13·6	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Sudbury (*Suffolk and Essex*).—This borough of 6,908 inhabitants obtained its supply of water for domestic purpose from shallow wells. With a view to get a better supply, samples from the following sources were sent to us (through the Local Government Act Office) for analysis, and the Corporation have since carried out waterworks. The waters from Webb's well, Prior's well, and bore-hole No. 5, May 13, 1870, contained only very small quantities of organic matter, but in this respect that from Prior's well was the best. The sample from Webb's well exhibited evidence of a large amount of previous animal contamination, which, as shown by the moderate proportion of chlorine, had probably arisen from solid manure as distinguished from sewage; the water must however be regarded as slightly suspicious. The water from the Bore-hole No. 5 improved considerably between May 13, 1870, and April 5, 1872, in consequence of the protection of the bore-hole from surface percolation. The water collected at the latter date contained but a very small proportion of organic matter, and being a deep well water may be used with safety, although it exhibited some evidence of previous animal contamination. It was too hard for washing, but might be softened from 38 to 8 degrees of hardness by the application to it of Clark's process. (For analyses, *see* page 100.)

Sunderland (*Durham*).—This borough of 98,242 inhabitants is supplied with excellent water, on the constant system, from deep wells sunk into the Dolomite. The water contains but mere traces of organic matter, and it has about the same degree of hardness as water from the limestone; but the hardness is permanent, and therefore not removeable by boiling or by the addition of lime. As Dolomite is a double carbonate of lime and magnesia, it was to be expected that both these alkaline earths would be present in the water; analysis confirms this supposition and shows that 100,000 lbs. of this water contain 5·89 lbs. of lime, and 3·96 lbs. of magnesia. As the wells are deep, the evidence of original animal contamination exhibited by the water is of no importance. (For analysis, *see* page 92.)

Surbiton St. Mark's (*Surrey*), an urban sanitary district of 7,641 inhabitants, is supplied with water for domestic purposes by the Lambeth Water Company. (*See Lambeth Water Company, p.* 272.)

Sutton Bridge (*Lincolnshire*), an urban sanitary district of 1,526 inhabitants, obtains its supply of water for domestic purposes from shallow wells. The water has not been analysed.

Swansea (*Glamorganshire*).—This borough and urban sanitary district of 51,702 inhabitants is supplied with water partly from an upland gathering ground and partly from springs. The old works were purchased in 1853, and the new works commenced in 1862, and finished in 1867, and belong to the Corporation. The reservoirs are situated near Velendu, on the river *Lliw*. The area of the gathering ground is 1,860 acres, and a volume of 1,500,000 gallons is abstracted from the river daily. The *Lliw* reservoir contains 300,000,000 gallons, and the Cwm Donkin reservoir contains 6,800,000. The water is not polluted before entering the reservoirs, is not filtered, is not pumped, but flows by gravitation into the district. The supply is intermittent in summer, but constant in winter, and 1,940,000 gallons are delivered daily, direct from the mains, to about 7,000 houses and 95 works and factories for domestic and trade purposes, within an area of 4,000 acres; the supply is not adequate to the requirement of the district. The waterworks cost 169,000*l*. The water from the river *Lliw* is sometimes rather peaty, but otherwise soft, wholesome, and of excellent quality. The springs yield water which is in every respect of most excellent quality.

Part IV.
Descriptive.

Swindon.
Old and New
Teddington.

We have also received from the Borough Engineer the following samples:—

The water from Lliw Colliery shaft was much polluted both by dissolved and suspended organic impurities and was quite unfit for domestic purposes.

The water from the brook near Lliw reservoir was of excellent quality, well fitted in every respect for drinking and all domestic purposes.

Sample A. from Sketty Hall was probably a well water. It was generally of good quality but rather hard. It exhibited, however, considerable evidence of *previous* animal contamination, the import of which it is impossible to tell without more information about the well.

Sample B. from Sketty Hall was probably a brook water. It was of moderate hardness and would be of fairly good quality if it did not exhibit some evidence of previous sewage or animal contamination. Our analyses of these waters are given in the following table:—

Composition of Potable Waters at Swansea.

Results of Analysis, expressed in parts per 100,000.

DESCRIPTION.	Dissolved Matters.											Remarks.
	Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Water supply from springs, June 21, 1871.	4·80	**·037**	**·012**	·001	·007	·020	0	1·55	·3	3·2	3·5	Slightly turbid.
Ditto from gathering ground, Oct. 17, 1872.	4·84	**·205**	**·025**	0	·010	·035	**0**	1·10	·1	2·2	2·3	Turbid.
Water from Lliw Colliery shaft, July 1873.	39·24	**·570**	**·183**	·170	0	·323	**1,080**	·80	4·3	10·6	14·9	Suspended matter:— Mineral 294·4; Organic 36·2; Total - 330·6
Water from brook near Lliw reservoir, July 1873.	5·04	**·120**	**·022**	·004	·020	·045	**0**	1·70	0	2·2	2·2	Turbid.
Sketty Hall, sample A., July 1873	26·32	**·060**	**·022**	0	·356	·378	**3,240**	2·80	10·0	7·4	17·4	Slightly turbid.
Sketty Hall, sample B., July 1873	14·40	**·151**	**·045**	0	·107	·152	**570**	2·60	0	8·7	8·7	Very turbid.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Swindon, Old and New (*Wiltshire*), urban sanitary districts containing together 11,120 inhabitants, are supplied with water for domestic purposes by a private company whose works cost 23,671*l*. The water is obtained from springs in the Greensand thrown out by the Gault, and flows direct into reservoirs holding about 20,000,000 of gallons, from whence it is pumped to supply 1,650 houses and the manufacturing works of the Great Western Railway Company, on the intermittent system, direct from the mains. The supply is inadequate, especially in drought.

Swinton and Pendlebury (*Lancashire*), an urban sanitary district of 14,052 inhabitants, receives its supply of water from the Manchester Corporation Waterworks. (*See Manchester*, p. 373.)

Tarporley (*Cheshire*), an urban sanitary district of 2,652 inhabitants, is supplied with water exclusively from shallow wells. The water has not been analysed.

Taunton (*Somerset*), an urban sanitary district of 15,466 inhabitants, is supplied with water by a local company, who collect it from a gathering ground five miles from the town, and thence deliver it by gravitation. Our sample was drawn from a tap in the kitchen of No. 6, Cann Street, occupied by the company's turncock. The water was slightly turbid, but palatable and suitable for washing. For dietetic purposes its quality was suspicious, unless it can be shown that the previous sewage contamination which it exhibits is not present in the surface water. (For analysis, *see* page 48.)

Tavistock (*Devon*), a rural sanitary district of 7,725 inhabitants, is supplied with water for domestic purposes partly from shallow wells and partly from works belonging to the Duke of Bedford, which cost 7,000*l*. The water is obtained from springs and flows into reservoirs holding 395,000 gallons partially built above the surrounding ground, from thence is delivered on the constant system to 751 houses within an area of 150 acres, direct from the mains. The supply is said to be adequate for the domestic requirements of a larger population. The rate of charge for water is $2\frac{1}{2}$ per cent. on the rateable value of the houses. Our analysis, given on page 110, proves the water to be of excellent quality for dietetic and all other domestic purposes. The spring supplying Tavistock Union Workhouse is of even still better quality.

Teddington (*Middlesex*), an urban sanitary district of 4,053 inhabitants, is supplied with water for domestic purposes by the Grand Junction Water Company. (*See Grand Junction Water Company*, p. 271.)

PART IV. DESCRIPTIVE.

Tenbury Wells. Todmorden.

Tenbury Wells (*Worcestershire*), an urban sanitary district of 1,210 inhabitants, is supplied with water from shallow private wells.

Tenby (*Pembrokeshire*), an urban sanitary district of 4,000 inhabitants, obtains its supply of potable water from springs. The supply is inadequate and new works are in course of construction. The water will be obtained partly from springs and partly from gathering ground, and will flow through iron pipes into reservoirs holding about 4,600,000 gallons, built partially above the surrounding ground, from thence on to filter beds, and into pipes for distribution on the constant system, direct from mains, to the consumers. The water has not been analysed.

Tewkesbury (*Gloucestershire*), a borough of 5,409 inhabitants, is supplied with water of bad quality drawn from the *Severn*, a mile above the town, filtered and pumped into a reservoir. Our sample was taken on the premises of Mr. Savory, ironmonger, Tewkesbury. A portion only of the inhabitants are at present thus provided. Many shallow wells furnish the bulk of the supply. The water contained much peaty matter, which gave it a brownish colour and rendered it rather unpleasant for dietetic purposes. It was of moderate hardness. (For analysis, *see* page 50.)

Thetford (*Norfolk*), a borough of 4,166 inhabitants, obtains its supply of potable water from wells. We have analysed samples from some of these wells and found that only one was fit for human consumption, viz., the water from the pump at the Railway Hotel which contained but mere traces of organic matter. Even this water exhibited evidence of considerable previous animal contamination, but the small proportion of chlorine which it contained showed that this contamination had been derived from manured land and not from sewage. The other well waters had been very heavily contaminated with sewage or soakage from cesspits, and as they contained a considerable proportion of unoxidized sewage matter they cannot be used for domestic purposes without great risk. The water of the pumps at the Bell Inn and at Mr. Barnard's house were especially dangerous. (For analyses, *see* page 84.) The *Snarehill* river and the *Lesser Ouse* above the town were too impure for drinking and too hard for washing. (For analyses, *see* page 52.)

Thornhill (*Yorkshire*), an urban sanitary district of 5,285 inhabitants, is supplied with water for domestic purposes from the waterworks belonging to the Corporation of Dewsbury, at the rate of 1*s*. 6*d*. per 1,000 gallons. The water is supplied direct from the mains which are only charged from two to three hours a day, and 9,000 gallons of water are delivered daily to 387 houses and 6 manufactories, distributed over an area of 2,565 acres. The quantity is not adequate for the requirements of the town and district. No steps are taken to prevent waste. The water mains cost 1,850*l*. The water has not been analysed.

Thornton (*Yorkshire*), an urban sanitary district of 5,674 inhabitants, is supplied with water for domestic purposes by the Bradford Corporation Waterworks. The water is delivered to 495 houses and 5 manufactories, distributed over an area of 100 acres. The supply is constant, and direct from the mains, and about 15,000 gallons are delivered daily to the district. This quantity is at present adequate for the requirements of the town and district. The rate of charge for water is, for cottages 2*d*. a week; a higher rate for a better class of houses; and 8*d*. per 1,000 gallons for mill purposes. To prevent waste the taps and fittings are constantly inspected. The waterworks cost 4,710*l*. 1*s*. 4*d*. (*See Bradford*, p. 321.)

Thurlstone (*Yorkshire*), an urban sanitary district of 2,639 inhabitants, obtains a supply of water from springs flowing out of the Millstone Grit formation. The supply is said to be adequate. The water has not been analysed.

Thurmaston (*Leicestershire*), an urban sanitary district of 1,200 inhabitants, obtains its supply of potable water from private shallow wells. The water has not been analysed.

Thurstonland (*Yorkshire*).—This urban sanitary district of 1,001 inhabitants, is supplied with water from springs and wells.

Tickhill (*Yorkshire*), an urban sanitary district of 1,915 inhabitants, obtains its supply of water for domestic purposes from private wells and stream. The water has not been analysed.

Tipton (*Staffordshire*), an urban sanitary district of 29,445 inhabitants, is supplied with potable water by the South Staffordshire Waterworks Company. The result of our analysis of this water will be found on page 105. It shows that the water is somewhat, though slightly, polluted, probably by soakage from cultivated land. It is too hard for washing.

Todmorden (*Lancashire and Yorkshire*), an urban sanitary district of 11,998 inhabitants, is principally supplied with water from shallow wells and springs, but impounding reservoirs have been constructed by millowners for manufacturing purposes, and a supply is obtained from these sources by the tenants or workpeople of the manufacturers to whom the reservoirs belong. The present quantity is not adequate to the requirements of the district. The water has not been analysed.

Tong Street.
Tranmere.

Tong Street (*Yorkshire*).—This urban sanitary district of 3,740 inhabitants is supplied with water from the Bradford Corporation Waterworks. (*See Bradford*, p. 321.)

Torquay (*Devonshire*), an urban sanitary district and fashionable watering place, with a resident population of 22,000, much increased during the season, is supplied with water from a stream rising on Dartmoor, the whole water of which is diverted, at two miles from its source, into an impounding reservoir holding 80,000,000 of gallons, and it flows thence into three service reservoirs, capable of holding about 2,500,000 gallons. The minimum flow of the stream is said to be 151,000 gallons daily, but this was after an unprecedented drought of five months duration. The water is delivered daily, at the rate of 600,000 gallons, in an unfiltered state, to about 2,000 houses within an area of 1,200 acres. The supply is intermittent. All houses are required to have cisterns. This water, which is also suplied to Newton Abbott where we took a sample, is of inferior quality. It contains a large proportion of organic matter which is chiefly if not altogether of vegetable origin. There is also some evidence of previous animal contamination which should be traced to its source. It was slightly turbid when our sample was taken, but it was very soft and well adapted for washing. Better water than this ought to be supplied to a great sanitarium like Torquay. The waterworks cost 68,306*l*. (For analysis, *see* page 47.)

Torrington, Great (*Devon*), an urban sanitary district of 3,529 inhabitants, is supplied with water for domestic purposes by a private company obtained from springs and stream impounded in a reservoir holding about 5,000,000 of gallons; thence it flows on to filter beds and through mains, from whence it is supplied direct to 158 houses and 12 manufactories for domestic and trade purposes. The supply is said to be adequate. The water has not been analysed.

Totnes (*Devon*), an urban sanitary district of 4,073 inhabitants, is supplied with water from springs about half a mile from the town, situated about 340 feet above high-water mark, and the water was conveyed in 1865 in iron pipes from the spring head to a reservoir containing 186,624 gallons. The water is not polluted before entering the reservoir, is not filtered, and flows by gravitation into the town; the reservoirs are built above the surrounding ground, and covered. The supply is intermittent in order to husband the water and prevent waste; only about 6,000 gallons daily is all that can be prudently let off from the reservoir in the summer months. The supply is direct from the mains for the few persons who have it laid on to their houses, and from five public stand-pipes in different parts of the town. The present supply is inadequate. The rate of charge for water is 10*d*. in the pound on the rateable value of the houses where the service is laid on. The waterworks have cost 1,205*l*. The water has not been analysed.

Tottenham (*Middlesex*), an urban sanitary district of 23,000 inhabitants, is supplied with water from a well 60 feet deep and 8 feet in diameter, sunk into the chalk with four bore-holes of 6-inch, 9-inch, and 18-inch respectively. The water is pumped into two service reservoirs containing 454,000 gallons built partially above ground and covered, from thence it is delivered unfiltered, chiefly direct from the mains on the intermittent system, to about 3,000 houses at the rate of about 24 gallons per head. The supply, it is said, would be adequate if properly distributed.

Tow Law (*Durham*), an urban sanitary district of 4,968 inhabitants, is supplied with potable water by the Weardale and Shilden Waterworks Company, whose gathering ground of 3,000 acres of moorland lies on the Millstone Grit formation.

Toxteth Park (*Lancashire*), an urban sanitary district of 6,450 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 368.) The houses usually have cisterns. Rate of charge, 5 per cent. on the rental, with extra charges for stables, carriages, and gardens.

Tranmere (*Cheshire*), an urban sanitary district of 15,717 inhabitants, is supplied with water from works established in 1860, and belonging to the Board. The reservoir is situate in Greenway Road, and the pumping station in Fountain Street. The well is sunk in the New Red Sandstone, and is 9 feet diameter, and 128 feet deep, with a bore-hole 130 feet of 15-inch below bottom of well, and a separate bore-hole, 250 feet of 9-inch, and 50 feet 4-inch diameter below bottom of well. The volume of water pumped is 50,000 gallons per hour when at work. The service reservoir contains 588,550 gallons, and the high level tank 40,861 gallons. The service reservoir is entirely under ground, the high-level tank is above the ground, and both are covered. The pumping machinery consists of condensing engine, and ram, of 30 horse-power. The area supplied is 1,059 acres, over which are distributed 3,021 houses, and 15 manufactories: the mains extend to portions of the district not yet built upon. The supply is said to be adequate, constant, and chiefly direct from the mains, and 360,000 gallons of water are delivered to the district daily. The charge is 9*d*. in the pound on the rateable value of the premises. To prevent waste, a house-to-house examination is daily made by an inspector. The waterworks cost 38,250*l*. Our analysis, given at page 94, shows this water to be absolutely free from organic matter. It is clear, palatable, wholesome, and well fitted for all dietetic purposes. It is also of moderate hardness.

Trawden. Upholland.

Trawden (*Lancashire*), an urban sanitary district of 2,129 inhabitants, obtains its supply of potable water from streams and shallow wells. The supply is inadequate, and the sanitary authority are making arrangements for constructing works; the water will be taken from springs in the immediate neighbourhood.

Trowbridge (*Wiltshire*), an urban sanitary district of 11,500 inhabitants, is very inadequately supplied with water for domestic purposes from private wells; the water of these is said to be of very indifferent quality; and the waterworks have been in course of construction for some time by a joint stock company, but they are still incomplete. We visited the waterworks, which are at a short distance from the town, and found that the company had sunk a well into the Lias 160 feet deep, at the bottom of which was a bore-hole 18 inches in diameter and 40 feet deep. In sinking the shaft a salt spring was tapped and afterwards stopped out, but we were informed that some water came in at about 20 feet from the surface. Our analysis, given at page 105, shows the water to be excessively hard, and to contain a considerable proportion of common salt (6 lbs. in 1,000 gallons, 3 oz. in this volume of water being about the usual proportion in good potable water), besides a rather large proportion of organic elements.

Truro (*Cornwall*), a borough of 10,899 inhabitants, has no waterworks, but is supplied by public and private wells within the town, varying in depth from 9 to 70 feet. "None " of the wells are near cesspools or dung pits, but drains in some cases are within " 10 feet, but they are carried through earthenware pipes." We collected and analysed a sample from the principal public pump situated in the middle of Boscawen Street. The well is 25 feet deep. There is a good deal of oxidized sewage percolates into this well, and the water, as shown by its analysis, the results of which are given at page 71, was somewhat turbid and of suspicious quality. As this is probably one of the best wells of the town, the water supply of Truro must be pronounced very unsatisfactory.

Tunbridge Wells (*Kent and Surrey*), an urban sanitary district and fashionable watering place, of 19,410 inhabitants, is supplied with about 200,000 gallons of water daily from springs in the Hastings Sand, which are brought through iron pipes to a subsiding reservoir holding 400,000 gallons, whence the water flows, unfiltered, into two service reservoirs, built partially above the surrounding ground and covered, capable of holding about three days' supply. Two 40-horse power engines distribute the quantity named to 2,036 houses within an area of about 3,200 acres. The supply is intermittent, and the houses are furnished with cisterns. Our analysis, given at page 121, shows this water to be almost free from organic matter, and otherwise of most excellent quality for dietetic and all domestic purposes. It is clear, palatable, and wholesome. The evidence of previous animal contamination which it exhibits may be safely disregarded, it is doubtless due to the neighbouring highly manured hop grounds. The water is very soft and therefore well adapted for washing.

Tyldesley-with-Shakerley and Rusholme (*Lancashire*).—These urban sanitary districts of 14,008 inhabitants are supplied with water by the waterworks of the Corporation of Manchester. In Tyldesley-with-Shakerley there are 960 houses supplied for domestic purposes, and 9 manufactories. The supply is constant, and 30,000 gallons are supplied, but the Manchester Waterworks are prepared to supply 300,000 gallons daily. The supply is adequate, is partly from the mains and partly from cisterns. The rate of charge is 7½ per cent. on annual rent. No steps are taken to prevent waste. The mains and fittings cost 5,862*l*. 6*s*. 8*d*. In Rusholme all the houses in the district are supplied for domestic purposes. The supply is direct from the mains, is constant and ample. The rate of charge for water is 5*l*. per cent. on the rental. The Corporation of Manchester employ inspectors to prevent waste. (*See Manchester*, p. 373.)

Tynemouth (*Northumberland*), a borough of 38,941 inhabitants, is supplied by the North Shields Waterworks Company, with a capital of 68,248*l*., with water derived from springs and shafts in the Coal Measures and Magnesian Limestone. The water is filtered. There are three pumping stations, and 530,000 gallons are delivered daily, nearly all on the constant system, and direct from the mains, to about 40,000 people within an area of 6 square miles.

Upper Thong (*Yorkshire*), an urban sanitary district of 2,419 inhabitants, is supplied with water for domestic purposes by private wells. The supply is not adequate to the requirements of the district. The water has not been analysed.

Upholland (*Lancashire*), an urban sanitary district of 4,157 inhabitants, obtains its supply of water from shallow wells and a spring outside the village. The water has not been analysed.

Uxbridge. Wallingfen.

Uxbridge (*Middlesex*), an urban sanitary district of 7,500 inhabitants, is supplied with water from works, costing 16,000*l.*, the property of the Local Board of Health. There are two wells sunk into the Chalk, 7 feet 6 inches in diameter and 80 feet deep with headings at bottom of shafts, and boreholes in addition 12 inches and 14 inches in diameter respectively, and from these 150,000 gallons of water are pumped daily to 1,400 houses within about 600 acres. The supply is intermittent, and is generally direct from the mains, but some of the houses have cisterns.

Wakefield (*Yorkshire*), a borough of 28,079 inhabitants, is supplied, on the constant system, direct from the mains, with water for domestic purposes; one-fourth from springs and three-fourths by water abstracted from the polluted river *Calder*. The waterworks were established in the year 1837 by a joint stock company called the Wakefield Waterworks Company. The reservoirs are situated at Stanley Fall, two miles from Wakefield, and a volume of 1,000,000 gallons is daily pumped from the river. The water is stated by the Corporation of Wakefield to be "polluted before entering the reservoirs by town "sewage and liquid refuse from manufactories, chemical works, gasworks, dye and "bleach works, tanyards, and also by mines; not only from the towns and district situate "in the basin higher up, but from the borough of Wakefield itself, as the water is "abstracted from the river about a mile below the main sewer outlet." Our own analyses (*see* page 53) and observations entirely confirm this statement, incredible as it may appear; and although the water is filtered by "a patent process," it is difficult to conceive anything more disgusting and dangerous to health, than a populous community thus systematically, and by an elaborate and costly arrangement of reservoirs, pumps, filters, and distributory apparatus, drinking its own filtered sewage, taken from a stream in a black and putrescent condition. We have analysed two samples of this water supply, taken at an interval of a year. Although the water, owing in part to putrescent fermentation and subsidence, and in part to filtration, was chemically less contaminated than might be expected, yet on both occasions it contained a large proportion of nitrogenous organic matter. It was of a greenish yellow colour, and, on one occasion, very turbid. We are glad to learn that it is intended to abandon the present water supply and to obtain water for the use of the town from a purer source. The area of the store reservoir is about four acres; and its contents 30,000,000 gallons. The area of the service reservoir is three-quarters of an acre, and contains 3,000,000 gallons. The high service reservoir is built partially above the surrounding ground, and is not covered; 5,650 houses, 42 manufactories, and 60 maltkilns within the borough are supplied with water. The rate of charge for water to dwelling houses is 1*s.* in the pound; hotels, spirit vaults, public houses where there is no brewing, 2*s.* in the pound; and where occupiers brew, 8*s.* 6*d.* in the pound on the rental. Waterclosets, 6*s.*, and 3*s.* each. No steps are taken to prevent waste. The waterworks cost 66,729*l.* 8*s.* 2*d.* The Company, aided by the Corporation, are now seeking for Parliamentary powers to impound excellent upland surface water in the valley of the upper *Don* for the supply of Wakefield. If they are successful they will abandon the present disgusting source.

Walker (*Northumberland*).—This urban sanitary district of 8,888 inhabitants obtains its supply of water from wells and from Newcastle Waterworks Company. (*See* p. 378.)

Wallasey (*Cheshire*), an urban sanitary district of 14,334 inhabitants, is supplied with water from the waterworks of the Board of Health. The service reservoir is situated in Liscard, and the pumping station at Poulton-cum-Seacombe, both in the parish and urban sanitary district of Wallasey. The well 7 feet in diameter is sunk in the New Red Sandstone (reached by boring through boulder clay, marl, running sand, and white rock), to a depth of 93 feet, with a bore-hole in addition 12 inches diameter for a depth of 25 feet, then 8 inches, for a further depth of 118 feet. The service reservoir contains 146,000 gallons, and it is built on the top of a water tower 200 feet high and covered, and 500,000 gallons of water are pumped into it daily. The area supplied—2,600 acres—contains 2,498 dwelling houses, 59 hotels and public-houses, 7 manufactories, and 3 breweries. The supply is constant and adequate, and 500,000 gallons are delivered to the district daily. Sewers are flushed once a month. It is not compulsory for the houses to be supplied through cisterns so long as the fittings are approved; the majority of the houses are supplied direct from the mains. The rate of charge for domestic use is 6 per cent. on the annual value of the premises, and for trade purposes by meter 14*d.* per 1,000 gallons. Waste preventers for closets and screw down taps are now insisted on. The waterworks cost 45,877*l.* This water is of most excellent quality for all dietetic purposes. It is clear, palatable, and wholesome, and, being of moderate hardness, can also be used for washing. (For analysis, *see* page 94.)

Wallingfen (*Yorkshire*), an urban sanitary district of 400 inhabitants, obtains its supply of potable water from the *Care Beck* and shallow wells. The supply is said to be adequate.

Wallingford. Washingborough.

Wallingford (*Berkshire*), a borough of 2,972 inhabitants, has no waterworks. The supply is from private wells sunk generally to a depth below the level of the neighbouring *Thames*.

Walmer (*Kent*), an urban sanitary district of 3,816, is supplied with water for domestic purposes by a private company from three wells, 6 feet in diameter and 110 feet deep, sunk into the Chalk; it flows through pipes into a service reservoir, and thence 140,000 gallons are delivered daily intermittently, direct from the mains, to 1,527 houses and three manufactories for domestic and trade purposes. The supply is said to be not adequate.

Walsoken (*Norfolk*), an urban sanitary district of 2,911 inhabitants, is supplied with water for domestic purposes by the Wisbech Water Company, who obtain the supply from springs issuing from the Chalk. (*See Wisbech*, p. 410.)

Walton-on-the-Hill (*Lancashire*), an urban sanitary district of 4,391 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 368.)

Wanstead (*Essex*), an urban sanitary district of 5,113 inhabitants, is supplied with water by the East London Waterworks Company. The present supply is declared to be "very inadequate." (*See* page 280.)

Warkton (*Northamptonshire*), a township of 303 inhabitants, obtains water from shallow wells. We have analysed samples from some of these wells. All the samples were too hard for washing and cleansing purposes. Those from the Upper and Lower Town wells and Goode's well were turbid and contaminated with excrementitious matter in so high a degree as to render their use for domestic purposes very dangerous. They resembled, in composition, London sewage filtered through a gravelly soil five feet in thickness, and could not be rendered safe by any process of filtration or purification. The waters from the Rectory well, Melking's well, and Mutton's well, although decidedly better in quality than the foregoing, were not desirable for domestic use by reason of their previous contact with a large amount of animal or excrementitious matters. The water from Mutton's well belonged unequivocally to the dangerous class and ought to be rejected. Those from the Rectory well and Melking's well, if the wells are deep. belong to the class of suspicious or doubtful waters; if they are shallow, to that of dangerous waters. On the whole the water from Melking's well was the best, as it contained the smallest proportion of unoxidized organic matter and was also the softest. Moreover it had been less contaminated with urine than the other samples, as is seen from the smaller proportion of chlorine which it contained. The three remaining samples from Chaplin's well, Cornwell's spring, and Boughton spring were all greatly superior to the preceding, nevertheless they exhibited considerable previous contamination with animal matters. Although Chaplin's well exhibited less previous contamination than the other two, yet the pollution was more recent, as evidenced by the marked presence of ammonia and by the large proportion of organic nitrogen; we therefore regard this as the most suspicious water of the series. (For analyses, *see* page 81.) If carefully protected from surface drainage, the other two samples might be used without considerable risk; indeed, if previously softened by Clark's process they would form a very fair domestic supply. The hardness of Cornwell's spring would then be about 6°, and that of the Boughton spring about 8°. (For analyses, *see* page 119.)

Warley (*Yorkshire*), an urban sanitary district of 3,341 inhabitants, is supplied with water from private shallow wells.

Warrington (*Lancashire*), a borough of 32,000 inhabitants, is supplied with water by the Warrington Waterworks Company from a well sunk into the New Red Sandstone at Winwick. The quantity of water delivered by the company is about 400,000 gallons per day, of which nearly *one-half* is supplied to mills and factories, so that about 200,000 gallons are used for domestic purposes, being at the rate of less than seven gallons per head per day. Only about 4,500 houses are supplied with water. The water company has always discouraged waterclosets, in consequence of its inability to furnish the water, but when the new well at Winwick is completed it is expected there will be sufficient water for all purposes. The depth of the well will be 150 feet, and the bore-hole 200 feet; total, 350 feet. Our analysis of this well or spring water (*see* page 116) shows it to be of most excellent quality for all dietetic purposes. It is clear, palatable, and wholesome, but it is too hard for washing. By Clark's process of softening (*see* page 205) its hardness could be reduced to little more than half its present amount.

Washingborough (*Lincolnshire*), a township of 580 inhabitants, obtains its potable water from shallow wells. We have analysed samples from some of these. All the samples exhibited strong evidence of previous animal contamination. The animal matter with which that from Mr. Ruston's pump had been in contact was derived from sewage, but that which had fouled the remaining samples was chiefly solid manure.

Part IV. Descriptive.

Waterloo-with-Seaforth.

Whitby.

The animal organic matter had been so nearly destroyed in all, except the sample from Mr. Ruston's pump, as to render these waters usable without much risk to health, but that exceptional water ought to be rejected as dangerous. We cannot regard any one of these samples as a desirable water for domestic purposes. They were all too hard for use in washing. (For analyses, *see* page 88.)

Waterloo-with-Seaforth (*Lancashire*), an urban sanitary district of 6,582 inhabitants, is supplied with water from waterworks belonging to the Corporation of Liverpool. (*See Liverpool*, p. 368.) There are few houses in the district furnished with cisterns, the general supply is direct from the mains. The over-flow pipes from cisterns are connected with the soil pipes. The rate of charge is ninepence three farthings in the pound upon the poor-rate assessment.

Wath-upon-Dearne (*Yorkshire*), an urban sanitary district of 2,000 inhabitants, is supplied with water for domestic purposes by a private company. The water is obtained partly from springs and partly from a gathering ground impounded in reservoirs holding 4,250,000 gallons, from thence it is delivered direct from the mains to 250 houses in this district, and also to the village of West Melton. The supply is said to be inadequate.

Watlington (*Oxfordshire*), a parish of 1,943 inhabitants, obtains water for domestic purposes from shallow wells. The use of the waters from Burnham's well and Mr. Westear Peel's well must be attended with great risk to health, as, in addition to excessive anterior pollution, they contained unoxidized organic matter of a suspicious character. They were obviously nothing but dilute sewage filtered through a few feet of earth. The water from the Brewery well was the safest and in all respects the best; but neither this, nor the water from Munday's well, can be considered as desirable for domestic purposes, both by reason of their anterior pollution and on account of their excessive hardness; nevertheless if the brewery well be deep (say 100 feet), and the surface water carefully excluded, the use of it will involve but little danger to health. (For analysis of sample from Brewery well, *see* page 98; for that of the others, page 84.)

Wavertree (*Lancashire*), an urban sanitary district of 7,380 inhabitants, is supplied with water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 358.) The supply is principally from the mains. There are a good many cisterns, particularly where there are waterclosets. The charges are 11*d.* per 1,000 gallons for watering streets, and 9*d.* in the pound on rateable value for domestic purposes.

Welchpool (*Montgomeryshire*), an urban sanitary district of 7,318 inhabitants, is supplied with water for domestic purposes chiefly from a gathering ground; the water flows into a large pool, then on to two filter beds, and from thence from 150,000 to 200,000 gallons of water is delivered daily, chiefly direct from the mains, on the constant system in winter, but intermittently in winter. The supply is said to be adequate.

West Derby (*Lancashire*), an urban sanitary district of 22,282 inhabitants, obtains a supply of water from the waterworks of the Corporation of Liverpool. (*See Liverpool*, p. 368.) Some houses are furnished with cisterns; others are supplied direct from the mains. The present water rate is 9¾*d.* in the pound on the poor rate assessment. An extra charge is made for water supplied for other than domestic purposes.

Westhoughton (*Lancashire*), an urban sanitary district of 7,000 inhabitants, obtains its supply of water for domestic purposes from shallow wells in gravel beds by the roadside, cattle pond, and by storing rain; the inhabitants have to fetch the water to their houses. "A good water supply is greatly needed."

Westleigh (*Lancashire*), an urban sanitary district of 5,587 inhabitants, is supplied with water principally from private wells and surface water. The wells are sunk in the New Red Sandstone and stratum overlying the Coal Measures, and vary in depth from 4 yards to 20 yards. The northern portion of the district is insufficiently supplied with water. The water has not been analysed, but the wells "are situated in "the midst of privies and cesspools, which must contaminate the water. A public "supply is much needed."

Weston-super-Mare (*Somersetshire*), an urban sanitary district and popular watering place, with a resident population of 10,568, greatly augmented during the season, is supplied with water partly by a local company who obtain their supply from a spring out of the Mountain Limestone in the neighbourhood of the town, and partly from private wells near the shore, some of which are "situated in a densely populated "and some in a sparsely populated district, and against or close to privies and drains, "highly dangerous and objectionable." We have analysed the water from the spring and the results will be found in the table at page 112. It contains the merest traces of organic matter and is probably not unwholesome, but it has a slight saline taste owing to the presence of a large proportion of common salt. Its hardness is also excessive.

Whitby (*Yorkshire*), an urban sanitary district of 12,351 inhabitants, is supplied with water by the Whitby Waterworks Company. The water is obtained from the "Hazel

" Head Springs," and flows direct into a covered service reservoir holding 300,000 gallons, and from thence 200,000 gallons of unfiltered water is delivered daily, chiefly on the constant system, direct from the mains to 2,500 houses, and two works for domestic and trade purposes. The present supply is said to be adequate; the rate of charge is 5 per cent. on rental. The water has not been analysed.

Whitchurch (*Shropshire*), a rural sanitary district of 3,896 inhabitants, obtains its potable water jointly from shallow wells, and springs and waterworks.

Whitefield (*Lancashire*), an urban sanitary district of 8,956 inhabitants, receives its water from the Bury and District Waterworks Company, whose supply is gathered principally from the hills between Blackburn and Haslingden. The supply is constant. (*See Bury*, page 325.)

Whitley, Upper (*Yorkshire*).—This urban sanitary district of 1,000 inhabitants is supplied with water from shallow wells. The water has not been analysed.

Whittlesey (*Cambridgeshire*), an urban sanitary district of 4,297 inhabitants, obtains a supply of water for domestic purposes from wells. We have analysed several samples from these wells. The samples from the wells Nos. 2 and 4 in the town were exceedingly foul from the percolation of sewage. They were very dangerous waters, and their use for domestic purposes ought to be prohibited. The samples from the Abyssinian pumps were much better, but cannot be recommended for domestic use, as they exhibited considerable previous sewage or animal contamination, and were also polluted by a not inconsiderable proportion of animal organic matter. All the samples were much too hard to be used for washing purposes. (For analyses, *see* page 88.)

Whitwick (*Leicestershire*), an urban sanitary district of 4,277 inhabitants, is supplied with water from shallow wells and springs. We have analysed several samples. With the exception of No. 5, these waters did not exhibit any very remarkable degree of impurity; in fact No. 6 was a fairly good water. No. 5 should be condemned on account of its very high previous sewage or manure contamination. The rather large amount of ammonia which this sample contained also indicated that it had very recently been in contact with decaying animal matter. (For analyses, *see* page 73.)

Whitwood (*Yorkshire*), an urban sanitary district of 3,342 inhabitants, is supplied with water from a coal pit and from shallow wells. The water has not been analysed.

Widnes (*Lancashire*), an urban sanitary district of 19,000 inhabitants, is partly supplied with water by the different manufacturers in the district, from wells sunk on their own premises, and also from waterworks constructed by the Local Board of Health. The reservoir is at Pea Hill, Cronton, and the pumping station at Stocks Well Ditton. The supply is furnished by the waterworks from a well, 10 feet in diameter, and 60 feet deep, sunk into the New Red Sandstone, through the upper division of the Bunter beds. A volume of 50,000 gallons of water is pumped per hour for 23 hours daily, into the service reservoir, capable of holding 2,000,000 gallons, which is only partly covered. The supply is direct from the mains, constant, and 1,300,000 gallons of water are delivered daily to 3,440 houses, and 53 works.

Wigan (*Lancashire*).—A borough of 40,000 inhabitants obtains a supply of water by pumping from a stream four miles north of the town, and by gravitation. The works were established in 1853, and belong to the Corporation. The reservoirs are situated near Standish paper mills about three miles, and the pumping station about one mile and a half north of Wigan. The volume of water pumped is about 700,000 gallons daily. The gathering ground is 2,200 acres, and the reservoirs contain 117,000,000 and 120,000,000 gallons respectively. The capacity of the high service reservoir is about 1,000,000 gallons; it is built partially above ground, and is arched over. The supply is constant, and about 700,000 gallons of water is delivered to the district daily. The houses are supplied direct from mains. It is filtered through sand before delivery, and is kept in darkness after filtration. The quality of the water was in 1868 not quite equal to that of most other Lancashire towns. The proportion of organic elements was rather high, and there was marked evidence of previous animal contamination, which as the water is derived from a stream, should be traced to its source (*see* page 50). The source, indeed, is indicated by Mr. J. Law Hunter, C.E., as being manure amongst which is a " very " little " *privy stuff*. We must not omit to mention, however, that our sample was taken during the long drought of 1868, when the reservoir was nearly empty, and consequently the water may have been below its usual standard of purity. The rates of charge for water are 2*d*. a week for cottages, 8*s*. 8*d*. a year for houses under 8*l*. yearly rent, and 5 per cent. on rental of houses above 8*l*. and up to 50*l*. per annum, increasing less rapidly afterwards up to 3*l*. 12*s*. 6*d*. a year for houses of a rent of 100*l*. and upwards per annum. Another sample which we collected on May 10, 1874, was of slightly better quality, but still far too much polluted with organic matter to be a suitable water for dietetic purposes. It was harder than the previous sample.

PART IV. DESCRIPTIVE.

Wilsden. Witton-cum-Twambrooks.

Wilsden (*Yorkshire*), an urban sanitary district of 3,127 inhabitants, is supplied with water for domestic purposes from three springs, the flow from which is constant. These are the property of the sanitary authority. There are also small springs from which the public are supplied at a small annual charge, and there are also private wells. The supply of water to the houses in the higher parts of the town during dry weather is very inadequate.

Wilton (*Wiltshire*), an urban sanitary district of 1,871 inhabitants, obtains its supply of water for domestic purposes from a public and from private wells sunk into the Chalk. The public well is 7 feet in diameter and 12 feet deep, sunk in a sparsely populated district, and about 60,000 gallons of water are pumped daily and delivered direct from mains on the intermittent system to 385 houses for domestic purposes. The supply is said to be adequate. The works cost 2,592*l.* The water has not been analysed.

Wimbledon (*Surrey*), an urban sanitary district of 10,000 inhabitants, is supplied with potable water partly by the Southwark and Vauxhall Water Company, and partly by the Lambeth Water Company (*see* p. 271). Some of the inhabitants obtain a supply from shallow private wells; the results of analysis of a sample of this latter source will be found on p. 226.

Winchester (*Hampshire*), a city of 17,003 inhabitants, is supplied with water by a company with a capital of 22,000*l.* There are two wells sunk in the Chalk 6 feet 6 inches, and 7 feet 6 inches in diameter respectively and about 180 feet deep, from which water is pumped to the reservoir, brick built and lined with cement, at the rate of about 250,000 gallons daily to 2,250 houses or thereabouts, which are supplied between 6 a.m. and 7 p.m. direct from the mains. The water is of most excellent quality for all dietetic purposes. It is clear, palatable, and wholesome and contains only minute traces of organic matter. It is, however, too hard for washing, but might be rendered soft by the application to it of Clark's simple and inexpensive softening process described at page 205. (For analysis, *see* page 101.)

Windhill (*Yorkshire*), an urban sanitary district of 5,783 inhabitants, is supplied with water purchased in bulk from the Shipley urban sanitary authority. The supply is constant and direct from the mains, and 55,000 gallons of water are delivered daily to 1,360 houses and 10 manufactories, distributed over an area of 240 acres. The quantity of water used for flushing sewers or watering streets is not known. The present supply is said to be adequate for the requirements of the town and district. (*See Shipley*, p. 393.)

Windsor (*Berkshire*), with a population of 11,769, and *Eton* (*Buckinghamshire*), with a population of 4,000, urban sanitary districts, are supplied with water for domestic purposes by shallow wells, but chiefly by a private company who obtain the supply from a well sunk on an island in the *Thames*. The water is of fairly good quality for dietetic purposes, but it is too hard for washing. (For analysis of this water, *see* p. 88.)

Winterton (*Lincolnshire*), an urban sanitary district of 1,750 inhabitants, obtains its supply of water for domestic purposes from shallow private wells. There is a well to nearly every house. The water has not been analysed.

Wisbech (*Norfolk*), an urban sanitary district of 9,362 inhabitants, is supplied with potable water by a private company. The water is obtained from springs issuing out of the Chalk at Marham, and flows into a small reservoir, and from thence by pipes for about eight miles to the pumping station, whence it is pumped, at an annual cost of 224*l.*, into the mains and distributed direct therefrom, on the intermittent system, to about 1,300 houses and 29 works. The supply is stated to be adequate to the requirements of the district.

Witney (*Oxfordshire*), an urban sanitary district of 2,976 inhabitants, has no waterworks, but derives its supply for domestic purposes from wells varying in depth from 6 to 15 feet; the water of these wells is frightfully polluted and entirely unfit for human consumption; one of them which we have analytically examined (*see* page 81) is supplied chiefly from percolations from sewers and cesspools, and contains a large proportion of unoxidised sewage matter besides ammonia from urine. There is a well 65 feet deep near to Messrs. Clinch and Co.'s brewery, sunk in an orchard of about ¾ acre area, on which are grown carrots, parsnips, and potatoes. The ground has been broken up for two years and manured with stable dung; nevertheless, owing to the depth of this well, the water is of very much better quality. (For analysis, *see* page 105.) The *Windrush* at the time of our visit contained purer water than any of these wells, but the best supply for Witney would be obtained by sinking a well at least 100 feet deep into the Oolite outside the town.

Witton-cum-Twambrooks (*Cheshire*), an urban sanitary district of 4,229 inhabitants, is supplied with water by a private company, who obtain it from a stream. It is stated to be unpolluted, and it is filtered. The district includes 700 houses supplied during 12 hours daily. The supply is direct from the mains, and the rate of charge is 1*s.* per 1,000 gallons.

Wiveliscombe (*Somerset*), an urban sanitary district of 2,059 inhabitants, obtains its supply of water for domestic purposes from springs. The water flows into subsidence reservoir, holding 500,000 gallons, and then into a service reservoir holding about 18,000, and from thence 14,000 to 18,000 gallons of unfiltered water is daily delivered on the intermittent system, direct from the mains, to the consumers. The supply is said to be adequate. The water has not been filtered.

PART IV. DESCRIPTIVE.

Wiveliscombe. Worksop.

Wokingham (*Berkshire*).—This rural sanitary district of 2,868 inhabitants obtains its supply of potable water from shallow wells. We have analysed samples from several of these wells. All the waters were entirely unfit for human consumption, and in the interest of the health of Wokingham all the wells supplying them ought to be closed at once. The water from the wells in the court near Peach Street, at Allan's Cottages, and in Police Street might be used with advantage for the fertilization of land. The water from the well at Allan's Cottages was one of the worst we have ever met with; it had more than twice the manure value of average London sewage. (For analyses, *see* page 87.)

Wolverhampton (*Staffordshire*), a borough of 70,000 inhabitants, is supplied with water from works belonging to the Corporation which cost 212,000*l.* There are several sources of supply, a small portion from wells in the Red Sandstone at Cosford, Tettenhall, and Goldthorn Hill, the remainder from a stream whose sources lie from 3 to 9 miles above the intake of the Company. The water is not filtered. It is pumped first into a storage reservoir containing 11,000,000 gallons, thence into a service reservoir, containing 700,000 gallons, and is afterwards delivered to the town at the rate of 1,600,000 gallons daily to 13,729 houses and 150 works within the borough of Wolverhampton, and in the town of Bilston and Willenhall; 1,110,000 gallons are used daily for domestic purposes, 240,000 gallons for trade purposes, 30,000 gallons for sanitary purposes, and 220,000 gallons is sold in bulk to the Bilston Township Commissioners for their own population. The reservoirs are built partly above the surrounding ground and the service reservoir is covered. The supply is constant and direct from the mains, except in the case of waterclosets for which cisterns are required.

The waters of the *Worf* and of the *Albrighton Brook* were considerably polluted, partly by sewage, and partly by drainage from cultivated land. They contained more organic matter than is desirable in waters used for domestic purposes. They would be improved by sand filtration, but would still be unsuitable waters for a town supply. (For analyses, *see* page 52.)

All the samples of well water were of most excellent quality, and perfectly wholesome for domestic use. The sample from the Artesian well is the best, as it was softer than the others and contained the smallest proportion of organic elements. As these samples were all drawn from deep wells the evidence of previous animal contamination which they exhibit need not be regarded. The water from the drinking fountain was of intermediate quality, but it obviously contained much more river than well water. Even if it were filtered it would still be considerably inferior to the *Thames* water supplied to London. All the samples were rather hard for washing and for manufacturing purposes, but in no case was the hardness sufficient to interfere with their wholesomeness. If considered desirable it might be reduced to less than one-half by the use of Clark's softening process. (For analyses, *see* page 94.)

Wombwell (*Yorkshire*), an urban sanitary district of 5,800 inhabitants, obtains its supply of potable water from shallow wells. The supply is inadequate, and works are now in course of construction, but have not progressed far enough to enable any definite information of them to be given for obtaining a better supply.

Wooldale (*Yorkshire*), an urban sanitary district of 4,952 inhabitants, is supplied with water for domestic purposes by shallow private wells and springs. The supply is inadequate for the requirements of the district. The water has not been analysed.

Woolwich (*Kent*), an urban sanitary district of 35,548 inhabitants. Those living south of the *Thames* are supplied with water for domestic purposes by the Kent Water Company (*see Kent Water Company*, p. 274), whilst those living north of the *Thames* are supplied by the East London Water Company. (*See East London Waterworks*, p. 281.)

Worksop (*Nottinghamshire*).—This urban sanitary district of 10,409 inhabitants obtains its supply of potable water from shallow wells. We have analysed several samples from the wells, and of these the only waters which could be used for domestic purposes without great risk to health were those from Park Street well and Mr. Dobree's well; but even these were largely composed of sewage purified by percolation through a considerable thickness of porous strata, they were therefore very undesirable waters. The remaining shallow well waters were dangerous to the health of persons using them; they contained actual sewage matter, and no time ought to be lost in closing them. (For analyses, *see* page 78.)

Worthing. York.

The water from the deep bore of Prior Well Brewery Co. was excellent for drinking and all domestic purposes, except washing. It contained but mere traces of organic matter and was quite free from any evidence of previous sewage or animal contamination. (For analysis, *see* page 94.)

Worthing (*Sussex*), an urban sanitary district and watering place, with a resident population of 8,000, is supplied from waterworks which have cost the Local Board probably 15,000*l*. The water is derived from two wells sunk into the Chalk 6 feet in diameter and 110 feet deep, with a bore-hole in addition 12 inches in diameter and 365 feet deep, connected with each other by a syphon. A volume of 120,000 gallons of water is delivered during 15 hours daily to the population. The present quantity with continuous pumping is declared to be "adequate, but the Board propose to "supply better machinery so that such supply may be had in a shorter time than now." Our analysis given at page 99 shows this water to be of most excellent quality for all dietetic purposes. It is clear, palatable, and wholesome, and contains the merest trace of organic matter. It is too hard for washing, but might be easily softened by Clark's process. (*See* page 205.)

Wouldham (*Kent*).—This parish of 818 inhabitants obtains water for domestic purposes from wells. We have analysed several samples from these wells. All the samples contained a large proportion of organic nitrogen, and, with two exceptions, exhibited a very high previous sewage or manure contamination; the waters from Mrs. Pye's pump and Langford's pump having been thus polluted to an extent which would be produced if one third of their volume had been derived from average London sewage. All the waters were excessively hard, with the exception of the samples from the Wouldham Cement Co.'s Works, and the well in a chalk pit and even these were somewhat harder than *Thames* water.

All the samples are to be condemned as unsuitable for domestic use; but the parish pump, Mrs. Pye's pump, and Langford's pump ought to be at once closed, as the domestic use of water from these sources must be attended with great risk to health. The water of the new well in Providence Place was but little better, but that from the Wouldham Cement Co.'s Works and the new well in a chalk pit are of fairly good quality. (For analyses of Wouldham Cement Co.'s and chalk pit water, *see* page 101; for the others, page 84.)

Wrexham (*Denbighshire*,) an urban sanitary district of 8,537 inhabitants, is supplied with water for domestic purposes by a private company, whose works cost 21,856*l*. The water is obtained from a gathering ground on millstone grit formation, 1,500 acres in area, and flows into a subsidence reservoir, thence on to two filter beds, and through a filtering medium of sea sand washed, and fine and coarse gravel in layers to a depth of 7 feet 6 inches. The town and immediate neighbourhood of Wrexham is only supplied at present, but as new works are about to be constructed, the mains of the company will be extended some miles north-east and west. The supply is constant and direct from the mains to about 1,900 houses and 50 works, and, it is stated, at the rate of 15 gallons per head of a population of 10,000. The supply is said to be inadequate, and new reservoirs are being constructed to hold 80,000,000 to 100,000,000 of gallons.

Yeardsley-cum-Whaley (*Cheshire*), an urban sanitary district of 1,159 inhabitants, is supplied with water partly from the river *Goyt* and partly from springs. There are no waterworks. The supply is said to be adequate.

York (*Yorkshire*).—This city of 50,765 inhabitants is supplied with water pumped from the river *Ouse* at a point about a mile and a half above the city; the intake is 14 feet below the level of the summer flow in the river, which is here deep and slow. The *Ouse* at this point is constituted by the confluence of the *Swale* and the *Ure*, the sources of these streams being 40 miles distant in the Yorkshire moors. They flow through an agricultural district, the nearest source of pollution being Borobridge, a small market town on the *Ure*, 10 miles above York. The water is pumped into two subsidence reservoirs capable of holding 2,250,000 gallons each, and there is one service reservoir of the same capacity and high enough to supply all parts of the district. These reservoirs are built partially above the surrounding ground and are not covered. The water is filtered and the quantity pumped is 1,440,000 gallons daily, which is delivered to 10,500 houses containing 3,150 waterclosets, and 162 business establishments within an area of 6 square miles. The supply is constant and direct from the mains. Considering its source, this water is of fairly good quality, but it exhibits unmistakable evidence of the admixture of the sewage of Borobridge and of other places. When our sample was taken the water was efficiently filtered; it was also clear and palatable. It is very hard and quite unfit for washing. (For analysis, *see* page 53.)

PART IV. DESCRIPTIVE.

Rural water supply.

SECTION III.

Rural Water Supply.

The following table of analyses illustrates some of the difficulties of the water supply in country places. The first line in it exhibits the composition of a spring water rising in the parish of Standish, in the county of Gloucester, at the head of the *Arlebrook*, which joins the *Severn* at Epney, after a course of five miles through the tract of clay-land country, lying there between the escarpment of the Cotswold upland and the river. This water is perfectly wholesome and of most excellent quality for all dietetic purposes; but by the time it has reached the first hamlet on its course it is hopelessly fouled and quite unfit for drinking, and in this condition it continues, as seen from the subjoined analyses, until it joins the *Severn* at Epney. The Lias formation—occupying a width varying from two to five miles in Gloucestershire along the foot of the Lower Oolite, which there forms a continuous hill side four or five hundred feet in height,—throws out, along its junction with the rock above it, a series of springs, of which this in Standish parish is an example; and they run into the various rivulets there traversing the *Severn* valley.

THE WATER SUPPLY OF COUNTRY PLACES.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

No. of Sample.	Description.	Temperature, Centigrade.	Dissolved Matters.								Hardness.			Remarks.
			Total solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
1	Spring at head of *Arlebrook*, Gloucestershire, Oct. 31, 1873.	11°8	44·52	**·040**	**·010**	0	·026	·036	0	1·60	18·4	13·5	31·9	Clear.
2	*Arlebrook* at first hamlet, Oct. 31, 1873.	9·0	35·42	**·213**	**·061**	·001	·075	·137	**440**	2·26	16·6	7·3	23·9	Slightly turbid.
3	*Arlebrook* at Epney, Oct. 31, 1873 -	—	35·24	**·248**	**·060**	0	·092	·152	**600**	2·60	15·2	8·7	23·9	Very turbid.
4	Spring above Frocester, Gloucestershire, Sept. 9, 1873.	11·0	31·30	**·111**	**·035**	0	0	·035	0	2·40	18·7	7·3	26·0	Slightly turbid. Palatable.
5	Frocester water below the village, Sept. 9, 1873.	13·5	63·72	**·344**	**·086**	·040	·095	·214	**960**	2·40	16·9	6·4	23·3	Turbid. Palatable.
6	Coaley spring water, Sept. 8, 1873	13·5	31·42	**·024**	**·006**	0	·061	·067	290	2·00	22·6	5·3	27·9	Clear and palatable.
7	Coaley brook water, Sept. 8, 1873 -	13·8	48·32	**1·014**	**·259**	·098	·332	·672	**3,810**	5·70	20·8	7·7	28·5	Very turbid. Palatable.
8	Wroughton spring water, May 5, 1873.	10·5	43·84	**·123**	**·028**	0	·248	·276	2,160	1·90	25·0	9·4	34·4	Clear and palatable.
9	*Ray* water near junction with *Thames*, May 3, 1873.	14·5	35·04	**·554**	**·123**	·023	·225	·367	**2,120**	2·60	17·5	6·7	24·2	Slightly turbid. Palatable.
10	Headwater of *Cole*, May 5, 1873 -	10·4	38·91	**·057**	**·025**	0	·384	·409	3,520	1·35	25·1	5·7	30·8	Clear and palatable.
11	*Cole* water near Lechlade, May 3, 1873.	13·0	20·40	**·276**	**·064**	·009	·148	·219	**1,230**	1·80	17·1	4·4	21·5	Slightly turbid. Palatable.
12	Headwater of *Ock* above Wantage, May 5, 1873.	10·5	27·36	**·047**	**·013**	·001	·298	·312	2,670	1·05	15·2	5·1	20·3	Clear and palatable.
13	*Ock* water at Abingdon, May 29, 1873.	15·6	33·16	**·399**	**·085**	·024	·125	·230	**1,130**	2·05	19·9	4·9	24·8	Slightly turbid. Palatable.
14	Spring water, Wendover, head of *Tame*, Aug. 6, 1873.	10·8	28·10	**·034**	**·010**	0	·369	·379	3,370	1·30	19·4	5·7	25·1	Do.
15	*Tame water*, Dorchester, May 29, 1873.	16·1	31·74	**·402**	**·103**	·010	·098	·209	**740**	2·15	17·3	5·4	22·7	Very turbid. Palatable.
16	Adwell spring, Sept. 17, 1873 -	9·0	36·62	**·135**	**·028**	0	·167	·195	1,350	1·40	24·9	7·6	32·5	Clear and palatable.
17	The same one mile below the spring, Sept. 17, 1873.	13·0	37·42	**·279**	**·042**	·002	·081	·125	**510**	1·80	27·8	5·1	32·9	Slightly turbid. Palatable.
18	Well water by farmhouse, Chilton Grove, Sept. 17, 1873.	12·0	93·80	**1·386**	**·326**	·022	1·714	2·058	**17,000**	9·20	21·4	27·1	48·5	Very turbid. Palatable.
19	Do. Do. field in Chilton Grove farm, Sept. 17, 1873.	10·0	173·80	**·494**	**·075**	·125	0	·178	**709**	8·80	34·1	17·4	51·5	Clear. Saline taste.
20	Well at Honey Grove farm, Bledlow, Sept. 17, 1873.	11·0	53·08	**·495**	**·100**	·006	·520	·625	**4,930**	5·90	22·3	7·7	30·0	Slightly turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The Gault and Kimmeridge Clay formations, occupying similar places below the Chalk, give rise in like manner to a series of springs along the junction of each with the porous rock above it; and these lie at the head of the various rivulets traversing a corresponding tract of clay-land country in the valley of the *Thames*. The geological map shows how large an area these several formations occupy, and how considerable is the extent which may thus be regarded as being fairly represented by the examples we are about to quote. These rivulets are the principal water supply of these clay-land districts. Excepting butts and ponds for the collection of roof and other surface water, there is no other source of domestic supply for the inhabitants. Wells are very rarely serviceable in the Lias except in the few spots where beds of sand or gravel overlie the clay.

These rivulets do not, except in wet weather, much increase in volume as they run. They traverse a springless district, and in dry weather are little more than surface

PART IV. DESCRIPTIVE.

Rural water supply.

channels for the spring waters at their head. Their water, thus nearly invariable in quantity, all the more rapidly deteriorates in quality during its flow; and waterclosets, privies, sheepfolds, and farmyard drainage foul it almost from the first. The *Arlebrook*, for example, receives the drainage of a large mansion and of several farmyards within a mile of its source. The two runnels at its head unite at a hamlet of several cottages to which it gives its name; and its water there may be fouled at any time, and must be fouled during rains, by the privies close by the places where the cottagers fill their buckets for domestic use. The deterioration which it has thus already suffered will be seen on a comparison of the analyses Nos. 1 and 2. Four miles farther on, it joins the river *Severn;* and the sample No. 3 was taken about 300 yards from the *Severn* bank at Epney, a village of 10 or 12 cottages and two farmhouses, where its water is drawn for the daily supply of a considerable population. Dr. Douglas W. Eshelby of Stonehouse, who has lately been appointed the medical officer of health for the Haresfield district of the Wheatenhurst Union through which the *Arlebrook* runs, has promptly directed the diversion of the foul drainages which have hitherto polluted this stream from its source downwards; and waterclosets and privies are being provided with water-tight vaults and tanks; but the overflow from these must eventually reach the river channel, and the position of the Epney villagers as regards their water supply, representing as it does that of very considerable populations elsewhere, is not to be envied.

The circumstances of the neighbouring Frocester parish and village are not materially different from those of Epney. There are here several springs of admirable water at the foot of the same hill side out of which the *Arlebrook* rises. We have followed the course of the runnels by which these waters are conveyed past houses, village inn, farmyard, and slaughter-house, to the hamlets and villages which they supply with water. The sample No. 4 taken at the head of Frocester parish represents these spring waters at their origin, and the analytical results show them to be of unimpeachable wholesomeness. Sample No. 5 taken midway of Frocester parish, which stretches between the hill top and the *Severn*, at a spot where a cottager was just about to fill her kettle, represents the same waters after being fouled more or less directly by the drainage from the court house, the mansion house, and the village inn, all provided with waterclosets, also from a butcher's shop and slaughter-house, from farmyards, and the village generally. Our analysis proves the water to be of a most dangerous character, and that it contains abundance of fresh excrementitious matters. Below Frocester is a thickly populated district which might be easily supplied with pure water from these upland springs. The quantity is abundant, but it is hopelessly spoiled within a mile of the place where it rises pure, and long before it reaches the people wanting it. It is a monstrous outrage of which cottagers complain, when, perfectly aware of the filth which they are liable to drink, they inform us that they take their water for the day's supply early in the morning before the more disgusting of the day's pollutions have taken place.

Another pair of samples in the same table should be examined for their illustration of the easy remedy for the present unfortunate water supply to these clay land parishes, of which it is susceptible. Coaley parish adjoining Frocester has its copious spring of pure water at the foot of the upland Oolitic escarpment. The sample of this water which we collected and analysed (No. 6) is scarcely surpassed in the kingdom for purity, as regards organic matter. This spring feeds the brook from which, at short intervals all through the parish, the inhabitants of the several Coaley hamlets have till lately taken their water for their daily use, and sample No. 7 in the above table reveals the character which this water has already acquired at a distance of not much more than a mile below its source. It can only be properly described as sewage, suitable enough for producing heavy crops of grass, but, of course, utterly unfit for every domestic purpose. The common lands of this parish were lately inclosed under the superintendence of a Deputy Commissioner of the Inclosure Office. All the frontages to the highways being thus fenced in, the footpaths by which the marginal common lands between the road side and the brook were traversed every day in procuring the daily water supply were closed, and the several landowners who benefited by the enclosure undertook to provide the necessary water in another way. This it was extremely easy to do. A small reservoir was built at the spring head; and a two-inch iron pipe laid from it conducted the pure spring water through every hamlet in the parish, and stand pipes at each give the necessary supply more easily accessible than before, and entirely free from those impurities which it inevitably gathered in its natural channel.

Sample No. 6 is the present Coaley water supply; No. 7, with which it is contrasted, represents the character of the water which the people used to drink. The history of this example of a pure country water supply is given in Appendix No. 11. We quote along with it the evidence given by Mr. G. Ridley and James Caird, Esq., C.B., two of Your Majesty's Inclosure Commissioners, before the Select Committee of the House of Lords (8th July 1873), on the Improvement of Land, as to the desirableness of such on alteration of the law as would enable landowners to charge their property with the cost of such proceedings as may be necessary for the provision of pure water to villages and hamlets.

Rural water supply.

The rivulets across the Lias Clay from the Lower Oolite in the *Severn* basin, of which we have thus given instances, are exactly similar to those which cross the Gault and Kimmeridge Clay formations below the Chalk in the valley of the *Thames*. Samples 8 and 9 are respectively the spring water at Wroughton near Swindon, and the same water after finding its way into the *Ray*, taken before the junction of that stream with the *Thames*. Here, again, the analytical results show the spring water to be of excellent quality and quite wholesome, whilst the river water is dangerous from the presence of much actual sewage matter. Samples 10 and 11, and 12 and 13, in like manner contrast the head waters of the *Cole* and *Ock* with the waters of these streams before they join the *Thames*, above Lechlade and at Abingdon respectively, after they have traversed the clay land district between the chalk escarpment and the river. These samples illustrate, as before, the excellence of the springs and the irremediable excremental foulness of the rivers which they feed. The villages scattered along the edge of the Chalk originally clustered round the bountiful springs which rise at intervals all along that line. The lower clay level no doubt originally was forest land and uninhabited. The necessities of cultivation have, however, long since filled the vale of the White Horse with scattered cottages and hamlets; and their water supply is a problem of the same kind as that which exists along the course of the fouled *Arlebrook* in Gloucestershire—of the same kind as that which has received so satisfactory a solution at Coaley in the same county. These head springs of the *Thames* tributaries rise at points much above the general level of the vale, to any part of which they might easily be conducted whenever there is a sufficient population to justify the outlay.

Samples 14 and 15, representing respectively the head waters of the *Tame* above Aylesbury and the lower water of the same river where it joins the *Thames* at Dorchester, after traversing an almost exclusively clay land country, illustrate the same general truth as that which the *Arlebrook* teaches. Here also there are many abundant Chalk springs of beautifully pure water which, as the foregoing table proves, are rapidly polluted by surface contributions of foul drainage, and thus become sometimes injurious, and always dangerous, as a source of the water supply of the district which they traverse.

Sample 16 was taken at the head of one of the rivulets tributary to the *Tame*. Sample 17 with which it is coupled in the table was taken out a mile below the other. The former, a good spring water, supplies the farm house and hamlet of Adwell, just below its source, and from this it necessarily flows in the polluted condition revealed by the analysis. The second sample was taken where the brook crosses the road between Thame and Wallingford at a point to which the neighbouring farmers have hitherto sent carts every day to fetch water for domestic use. These particular samples are interesting as having been examined at the time of the outbreak of typhoid fever (August and September 1873) in Marylebone, which was believed to have originated in the milk supplied from farms in this neighbourhood. No typhoid fever existed in that immediate neighbourhood at the time, but the company which received the milk from two of these farms, which were supplied with water at this point, at once very properly insisted that the water carts should for the future be sent one mile further and be filled with the spring water before it had become polluted in the manner which these samples indicate.

This Marylebone fever outbreak is an illustration of the way in which the water supply to country places may affect the health of town populations. Its history has been given in a report (1873) by Mr. J. Netten Radcliffe, one of the inspectors of the Medical Department of the Local Government Board. Chilton Grove Farm, on which it is believed to have originated, was one of the farms whose milk had been sent to Marylebone: and here alone of all the farms which supplied the milk company whose customers had been attacked, had there been a case of typhoid fever. The farmer had fallen a victim to this disease shortly before the outbreak of fever in the Metropolitan parish; and the water supply to the homestead at Chilton Grove will illustrate the difficulties and dangers which surround the present way of providing water for domestic use in rural clay-land districts. The farmhouse well, 20 feet deep, was close to the kitchen door, and near to foul drainage from pigsties, and from scullery and yard. Chamber slops were thrown into the filthy ditch within a few yards of it; and foul water necessarily drained thence into the well close by. It is believed accordingly that matter containing the specific poison of the typhoid fever which had occurred at the farmhouse, and been prevalent in the neighbourhood, may have obtained access to the well water which was used in washing out the milk cans, and that in this way the milk itself had become infected.

PART IV. DESCRIPTIVE.

Rural water supply.

This well water had long been known to be unsatisfactory, and another well had been dug in the pasture field, several hundred yards away, and the two had been connected by a drain so that the pump had drawn from both alike. Immediately, however, that the Marylebone fever was traced to this source the pump handle was taken away, and the samples Nos. 18 and 19 were taken a fortnight afterwards from those two wells respectively. It will be seen that while the latter is far from pure water, the former, no longer supplied from the latter by the continual draught which used to bring the connecting pipe between the two into use, is fouled to an extent which rendered it obviously most dangerous and even offensive, owing to the large proportion of actual excrementitious matters which analysis proves it to contain. But this, diluted by the purer water from the other well, was what had shortly before supplied the household here with water for their daily use. Chilton Grove Farm therefore may be taken as an example in an intenser form than usual of the ordinary experience, as to water supply, of the inhabitants of houses, cottages, and hamlets, in the clay land districts of the country.

The last sample in the above table, taken at Honey Grove Farm, Bledlow, near Thame, is an example of the same kind. The well is at the edge of the farmyard, and when it dries in summer the water of a surface runnel, necessarily fouled by the neighbouring village, is turned into it, there allowed to settle till it clears, and then supplied to the house as drinking water. The sample analysed was taken when the well was productive by natural infiltration and it was nearly clear and not apparently polluted. Its composition, however, stated in the table shows that it was in reality polluted with a large proportion of organic matter, partly of animal origin. Its use for dietetic purposes, even in this its better condition, must be attended with considerable risk to health.

We have added to the samples thus enumerated others illustrative of the difficulties of the country water supply in the dry uplands of Oxfordshire and Berkshire and in the wet lowlands of Lincolnshire respectively. In the former case, where the general upland level of the Chalk, here covered with Diluvial Clays and Gravel, is three or four hundred feet above the neighbouring river channel, pure water is obtainable only by very deep wells. At Highmore, Nettlebed, Gallows Tree Common, and Kidmore End, on the Oxfordshire side of the *Thames*, and at Southridge and Aldworth on the Berkshire side of the river, such wells have been dug. The water is lifted sometimes by hand, sometimes by a donkey and wheel. The work is necessarily either very laborious or very slow, and in many cases the cottagers prefer taking their drinking water from the surface ponds in which road water collects during rainy weather, and whence they can dip it up with little labour. We have given in the annexed table analyses of four such waters, of which samples were taken in November, when the ponds were full and when no such concentration of their filthy contents existed as necessarily occurs after a long drought, when the bulk has been reduced by evaporation. They are, nevertheless, undesirable waters.

COMPOSITION OF POND, TANK, FEN, WELL, AND SPRING WATERS.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
WHITCHURCH, roadside pond, Whitchurch Gate, November 20, 1873.	16·18	**·462**	**·109**	·006	·011	·125	**0**	·80	2·0	8·1	10·1	Very turbid.
GORING, Craze pond near, November 20, 1873.	12·26	**·521**	**·096**	·006	0	·101	**0**	1·90	0	6·7	6·7	Turbid.
GORING, rainwater from tank of four cottages at Shurville Hill, November 20, 1873.	9·42	**·215**	**·061**	·032	·072	·159	**660**	·80	·4	7·5	7·9	Clear.
STREATLEY, pond at New Town, December 5, 1873.	47·40	**1·076**	**·202**	·011	·060	·271	**370**	5·20	10·0	20·6	30·6	Turbid.
STREATLEY, pond at Blackwood, Southridge, December 5, 1873.	19·56	**·687**	**·116**	·005	0	·120	**0**	4·30	1·8	7·9	9·7	Very turbid, slight yellow colour, contained many living organisms.
HEMSTEAD PARK, KENT, pond in Park, February 28, 1874.	17·38	**·480**	**·064**	·034	0	·092	**0**	3·50	1·1	7·3	8·4	Turbid.
STREATLEY, Bower's Farm well, November 19, 1870.	62·64	**·108**	**·064**	0	1·129	1·193	**10,970**	11·10	33·3	11·0	44·3	Clear and palatable.
STREATLEY, Hill Cottage well, November 19, 1870.	30·38	**·044**	**·030**	0	·490	·520	4,580	1·20	20·8	3·4	24·2	Very turbid. Palatable.

COMPOSITION OF POND, TANK, FEN, WELL, AND SPRING WATERS—*continued*.

PART IV. DESCRIPTIVE.

Rural water supply.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
SPALDING, the *Welland* at Podehole, near, November 24, 1873.	110·40	**1·327**	**·159**	·080	0	·225	**340**	12·75	25·2	42·1	67·3	Turbid.
SPALDING, water from Mr. Allen's rain-water tank at Podehole, near, November 24, 1873.	5·28	**·142**	**·029**	0	·031	·060	**0**	·90	0	3·8	3·8	Slightly turbid.
BOURNE, well head at, November 22, 1873.	42·92	**·104**	**·020**	0	0	·020	0	3·10	23·4	11·8	35·2	Clear and palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The first sample is from the roadside pond at Whitchurch Gate, on the upland level above the village of Whitchurch, Oxfordshire. This pond, about 10 yards by 6 yards in extent, and 4 feet deep, is stated to be never empty; it supplies a baker's shop and several cottages collected in a hamlet there. The water was opaque and of a light chalky yellow colour; but the cottagers preferred filling their buckets here to carrying them half a mile to the nearest well, which is 330 feet deep.

Craze pond, on the same level, about two miles from this spot in the neighbouring parish of Goring, is a large shallow pond by cross roads, whose surface water keeps it supplied. Many farmers send their water-carts to be filled here, and 30 or 40 cottages hereabouts are supplied from this source; there is no deep well within two miles of this pond. The water, though far from clear on the day of our inspection, was not so muddy as that of the former sample. At Shurville Hill in this neighbourhood is a block of four cottages, in which fever occurred two years ago, attributable, it was thought by the doctor in attendance, to the bad drinking water that was used, which was obtained from this pond. The owner of these cottages has since provided a circular tank 10 feet deep and 8 feet in diameter, which receives the roof water, and this, after settlement here, is now preferred by the cottagers to the pond water which they used to drink. There are 10 people living in these cottages, one of whom, a laundress, uses a large quantity of water, and another feeding a large number of pigs also takes far more than an average quantity from the tank; it has never yet failed to maintain a sufficient supply for their wants. The composition of the water thus provided is given in the table. Though much inferior to spring or deep-well water, this rain-tank water is decidedly superior to even the best of the pond waters for dietetic purposes. In Berkshire, on the same level, on the other side of the river *Thames*, in the parishes of Streatley and Aldworth, we have taken samples from similar roadside ponds, to which hamlets at Newtown and at Southridge are confined for their water supply. At Southridge the normal supply is from a pond in Blackwood, filled during rains by surface collection off roads. This source has been already condemned by the Local Sanitary Authority, but no substitute has been yet provided. Although there is a deep well in the neighbourhood no public use of it is possible. The other case at Newtown is of a similar kind, but still worse; the water of this pond being highly charged with organic matter of suspicious origin. Both are represented in the table of analyses contrasted with the deep well waters which are obtainable below them, and which are seen to contain much smaller proportions of organic matter. The pond in Hemsted Park contains water of a quality very similar to that of the Whitchurch and Goring ponds. Like these waters, it is not suitable for dietetic purposes, as it contains a very large proportion of organic matter. It is, however, of moderate hardness, and is, therefore, useful for washing. For the true interpretation of the column headed "Previous sewage or animal contamination" in this and the preceding table, *see* page 17.

The difficulties of those who live in the fens of Lincolnshire and Cambridgeshire are represented by another series of samples. The water of the *Welland* at Pode Hole near Spalding, is pumped for the use of the hamlet at that point, and may be taken as a very favourable representation of the water supply of Deeping Fen. The drainage water of the fen, peaty and ferruginous, to which the more remote cottages, if they have not roof water, are condemned, is mixed in the *Welland* at this point with the upland waters—those of Bourne and of other springs of excellent quality rising outside of the fen—and of course, therefore, is at that point a very dilute solution of the fen impurities, nevertheless it was turbid and so much polluted with organic matter, chiefly of vegetable

PART IV. DESCRIPTIVE.

Rural water supply.

origin, as to be utterly unfit for domestic use, at the time our sample was taken. It is contrasted in the table with a roof water taken from the underground tank attached to the house of Mr. Allen, the Engineer in charge of the Pode Hole Fen pump, very much purer, more palatable, and more wholesome. It thus fairly represents the water which is obtainable not only in fen districts, but anywhere, wherever a clean roof and a sufficiently capacious tank or reservoir for the collection of rain water can be provided and successfully protected from external pollution. Such tanks should, however, always be above ground; otherwise, as experience shows, there can be no guarantee against excremental pollution.

The urgent necessity, illustrated by the facts just enumerated, which is thus proved to exist over the clay lands, the dry uplands, and the fen districts of the country, gives, in our opinion, great weight to the recommendations of Mr. James Caird, C.B., and Mr. G. Ridley, two of Your Majesty's Inclosure Commissioners, in connexion with this subject. In their evidence before the Select Committee of the House of Lords (1873), on the improvement of land, both of those gentlemen point out the need which we have thus illustrated, and suggest that landowners should be permitted, under due limitations, to charge their estates with the cost of providing wholesome water to villages and hamlets, even in cases where the advantage conferred cannot, in strictness, be described as agriculturally profitable in the sense which the Lands' Improvement Act (1864),—27 and 28 Vict. cap. cxiv.,—requires in any outlay which, under it, is at present chargeable on the inheritance. The supply of such water can be very easily and safely accomplished wherever the subsoil drainage of pasture and meadow lands is capable of collection in storage reservoirs of the moderate capacity sufficient for the needs of a hamlet or small village. The drainage from manured arable land is, as we have stated on page 129, by no means a desirable source of potable water, and must be unreservedly condemned if human excrements are used as manure. But with that exception, the drainage water of even arable lands is preferable to that from polluted shallow wells, which are at present the usual source of the water supply in country places.

SECTION IV.

The Water Supply to the Royal Residences.

PART IV. DESCRIPTIVE.

Water supply to Royal residences. Osborne.

WE have visited Your Majesty's residences at Balmoral, Osborne, and Windsor, and inspected the wells, springs, and other sources of the water supplied to them; and we have collected samples of the various waters there used. We have also inspected the supply to Abergeldie, the residence of His Royal Highness the Prince of Wales, and have analytically examined the two descriptions of water there supplied. Lastly, numerous samples of water from His Royal Highness's residence at Sandringham have been forwarded to us for examination.

All these waters have been subjected to analysis in the laboratory of the Commission, and we now submit to Your Majesty the following results of our investigations:—

Osborne (*Isle of Wight*).—At the time of our inspection the water from four different wells was in use in Your Majesty's marine residence, besides that of another well which supplied Osborne Cottage. Of these wells that supplying the kitchen offices yielded water which was reasonably safe for drinking and cooking. The well supplying the cross passage pump, the pavilion well, and the well in the entrance yard all receive more or less percolation from drains, or other sources of animal matter. The chemical evidence of such pollution afforded by the presence of nitrates above a certain proportion had been obliterated in the water from the well in the entrance yard, but the discovery in it of such large proportions of organic carbon, organic nitrogen, and chlorine proves conclusively the access of drainage to the well. The water supplied to Osborne Cottage is good and wholesome if filtered before use.

More recently, and with the object of obtaining better water, several trial wells have been sunk upon the estate, and a sample from each has been sent to us. We have also examined, with a view to the possible supply of them to Osborne, the waters at present delivered to Newport and Ryde. The results of these analyses, together with those yielded by the five wells then in use, are contained in the following table:—

COMPOSITION OF WATER SUPPLIED TO OSBORNE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
OSBORNE, ISLE OF WIGHT.												
Well supplying kitchen offices, March 8, 1873.	14·72	**·142**	**·026**	0	0	·026	**0**	2·90	4·8	5·9	10·7	Turbid. Palatable.
Cross Passage pump, March 8, 1873.	18·30	**·228**	**·055**	·001	·046	·102	**150**	3·30	1·8	6·6	8·4	Very turbid. Brown. Palatable.
Pavilion well, March 8, 1873	17·24	**·267**	**·061**	·001	·228	·290	**1,970**	2·40	1·7	6·7	8·4	Turbid. Palatable.
Well in Entrance Yard, March 8, 1873.	30·00	**·361**	**·065**	·002	·026	·093	**0**	5·80	·8	12·3	13·1	Very turbid. Palatable.
Water supply to Osborne Cottage, September 19, 1873.	23·82	**·181**	**·019**	·001	0	·020	**0**	4·10	8·6	7·4	16·0	Very turbid Palatable.
Trial well, December 13, 1873	9·84	**·075**	**·022**	·007	0	·028	**0**	3·20	0	4·6	4·6	Palatable.
Trial well, No. 1, January 19, 1874.	26·76	**·319**	**·032**	·016	0	·045	**0**	4·90	2·3	8·0	10·3	Ditto.
Trial well, No. 2, January 19, 1874.	16·32	**·137**	**·019**	·001	0	·020	**0**	3·80	0	8·6	8·6	Ditto.
Trial well, No. 3, February 18, 1874.	54·84	**·233**	**·038**	·004	0	·041	**0**	4·45	12·1	22·7	34·8	Ditto.
Trial well, No. 4, January 19, 1874.	66·12	**·429**	**·093**	·001	3·640	3·734	**36,090**	7·20	7·1	29·3	36·4	Ditto.
Trial well, No. 5, January 19, 1874.	13·08	**·063**	**·010**	0	0	·010	**0**	3·00	0	7·7	7·7	Ditto.
Trial well, No. 6, January 19, 1874.	8·16	**·118**	**·023**	0	0	·023	**0**	3·80	0	7·4	7·4	Ditto.
Newport water supply, November 4, 1871.	28·50	**·008**	**·005**	·001	·369	·375	**3,380**	3·30	23·4	6·0	29·4	Clear and palatable.
Ryde water supply, March 7, 1873	27·62	**·053**	**·013**	0	·485	·498	**4,530**	2·70	13·5	7·1	20·6	Ditto.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

PART IV. DESCRIPTIVE.

Water supply to Royal residences. Windsor Castle, Frogmore.

These analytical results show that Newport and Ryde are supplied with water which, though hard, is otherwise perfectly wholesome and of most excellent quality for dietetic purposes. If such water could be conveyed to Osborne and then softened by lime as described at page 205, Your Majesty would have a supply nearly equal to that furnished by the Rabate Fountain at Balmoral, which is one of the purest natural waters in the world. The examination of the water from the trial wells, however, shows that it will probably not be found necessary to resort to any external source of supply.

The water from the trial well (dated Dec. 13, 1873) was of excellent quality and quite free from any evidence of sewage or animal contamination. It contained only a very small proportion of organic matter, and was palatable and suitable for drinking or cooking. It was also soft and therefore well adapted for washing. The six remaining samples were all taken from trial wells on the Osborne estate. No. 5 was the best. It was an excellent water for drinking and all domestic purposes, being palatable, wholesome, and soft, and free from all evidence of previous sewage or animal contamination. Nos. 2 and 6 stand next in respect of quality, but they were markedly inferior to No. 5. They were wholesome and soft and free from evidence of pollution, but not quite so palatable as No. 5, and contained, moreover, about twice as large a proportion of organic matter. No. 1 was very muddy, and even after filtration retained in solution so much organic matter as to render it unfit for domestic use. No. 3 was also so much contaminated with organic matter as to render it undesirable for drinking or cooking, and was so hard as to be quite unfit for washing. No. 4 was grossly polluted with sewage or refuse animal matters. It was a dangerous water.

It is thus evident that excellent water exists upon the Osborne estate, and it is probably sufficiently abundant to render the further use of the contaminated wells unnecessary.

Windsor Castle and Frogmore derive their water from three large shallow wells, which yield an abundant supply. Two of these which supply the castle are sunk upon a small island in the *Thames*, and the third close to the river at Old Windsor Lock. We collected and submitted to analysis samples taken from the table decker's room at Windsor Castle, the butler's pantry at Frogmore, the two wells on the island in the *Thames*, and the one at Old Windsor Lock, which supplies Windsor Great Park, but not the Castle. For comparison with these, we also collected samples of water from the *Thames* at points contiguous to the wells themselves. This comparison indicates either that the wells derive their water chiefly from the adjacent Alluvium, or that the river water becomes much purified during its infiltration. The well waters, especially those supplied to the Castle, are greatly superior to the water of the neighbouring river. The following table contains the results of these analyses:—

COMPOSITION OF WATER SUPPLIED TO WINDSOR CASTLE AND FROGMORE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
Water from table decker's room at Windsor Castle, September 29, 1873.	32·06	**·116**	**·032**	0	·282	·314	**2,500**	1·90	17·5	7·3	24·8	Clear and palatable.
Water from the butler's pantry at Frogmore, September 29, 1873.	28·74	**·090**	**·024**	0	·039	·063	**70**	1·85	16·7	6·9	23·6	Ditto.
Large pump well supplying Windsor Castle, September 29, 1873.	30·08	**·015**	**·010**	·001	·063	·074	**320**	2·00	18·0	5·9	23·9	Ditto.
Small pump well supplying Windsor Castle, September 29, 1873.	32·54	**·100**	**·022**	0	·274	·296	**2,420**	1·90	19·4	5·1	24·5	Ditto.
Well at Old Windsor Lock, September 29, 1873.	36·96	**·112**	**·040**	0	·330	·370	**2,980**	2·90	21·5	7·9	29·4	Ditto.
The *Thames* opposite the pump wells, September 29, 1873.	26·92	**·195**	**·064**	0	·169	·233	**1,370**	1·90	17·4	4·7	22·1	Ditto.
Ditto, at Old Windsor Lock, September 29, 1873.	27·12	**·186**	**·051**	0	·059	·110	**270**	1·90	16·2	5·9	22·1	Ditto.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

The large pump well supplying Windsor Castle yielded water which was rather hard, but otherwise of excellent quality. The water obtained from the smaller pump well, which is sunk upon the same island in the Thames, was considerably inferior, but it was still of fairly good quality. It was of the same hardness as the first named sample.

Part IV. Descriptive.

Water supply to Royal residences. Balmoral Castle, Abergeldie.

The well at the pumping station at Old Windsor Lock furnished water of rather indifferent quality. It contained more organic matter and was harder than the other samples. These remarks, of course, apply to the water at the wells themselves. On its way to the tap in the table decker's room at Windsor Castle and to the butler's pantry at Frogmore the water suffers a small but marked deterioration, which probably arises from its storage in tanks or cisterns. It contained a larger proportion of organic matter, but was still fairly good water. The analyses prove the water drawn at the Castle to have been for some days, and that taken at Frogmore for, probably, a week or two, in a cistern or tank. Probably when the Castle and Lodge are fully occupied, which was not the case when the samples were taken, the quality of the water drawn there would approximate more closely to that of the supply actually furnished by the wells. It is desirable, however, that the cisterns and tanks should be periodically inspected, in order to ascertain if they are in any way foul or exposed to contamination.

Balmoral Castle (*Aberdeenshire*).—The *Dee* at Balmoral is one of the purest rivers in the world. The total solid matter contained in one gallon of its water scarcely exceeds a single grain. Even the justly celebrated Loch Katrine water is not so pure as this. The *Dee* water as it passes Balmoral Castle is clear, and, when seen in a small volume, colourless; in the deeper pools of the river, however, it exhibits the faint yellow colour of slightly peaty water. It acts strongly upon bright lead, but is without action upon the tarnished metal. Of even still greater purity is the water of the Rabate fountain used in the castle for cooking, and sometimes for drinking. Our sample, drawn from a tap in the steward's room, contained a smaller proportion of total solid impurity than any other sample of river, spring, or well water that we have examined. There was not even one grain of foreign matter in a gallon of it. Bright lead is but slightly attacked by this water, and tarnished lead not at all. It may therefore be conveyed in leaden pipes with perfect safety. The water of the *Gelder Burn*, supplied to the castle for general purposes, also contained considerably less total solid impurity than that present in an equal volume of Loch Katrine water; it is, however, considerably more peaty than the *Dee* and Rabate waters, and exhibits in consequence a perceptible yellow tint. This water has no action either upon bright or tarnished lead. All these waters are very soft, and admirably adapted for washing and cleansing purposes.

The pump water is used exclusively for drinking. It is derived from a well, situated about midway between the castle and the stables. It is clear, colourless, and palatable, but it exhibits unmistakeable evidence of contamination from drainage, and this contamination is likely to increase as the surrounding soil becomes more tainted with the polluting matter. We, therefore, recommend that this well should be closed, and that the Rabate water alone should be used for drinking. If, however, a supply of well water be considered desirable, a new well ought to be sunk near the *Dee*, and not less than 200 yards above the castle.

The following table shows the results of our analyses of these waters.

Composition of Water supplied to Balmoral Castle.

Results of Analysis expressed in Parts per 100,000.

DESCRIPTION.	Dissolved Matters.								Hardness.			Remarks.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Temporary.	Permanent.	Total.	
The *Dee* above Balmoral, March 9, 1872.	1·52	**·132**	**·014**	0	0	·014	**0**	·50	0	1·5	1·5	Clear and colourless.
The *Gelder Burn*, at Balmoral, March 9, 1872.	1·98	**·196**	**·019**	0	0	·019	**0**	·35	0	·9	·9	Slightly turbid. Yellowish.
Well used for drinking at Balmoral Castle, March 11, 1872.	7·50	**·111**	**·018**	0	·247	·265	**2,150**	1·15	·6	4·4	5·0	Clear, colourless, and palatable.
Rabate fountain, March 9, 1872 -	1·40	**·119**	**·014**	0	0	·014	0	·55	0	1·2	1·2	Slightly turbid. Palatable.

Note.—For the translation of these numbers into grains per gallon, *see* note to table on page 29.

Abergeldie (*Aberdeenshire*).—The spring water used for drinking at Abergeldie is sparkling, clear, and of excellent quality. Being a strong and deep-seated spring, the evidence of a moderate amount of previous animal contamination which it exhibits need not be regarded. It contains a much smaller proportion of organic matter than that present in the running waters at Balmoral. The general water supply of Abergeldie is brought from Kentore Den. It is good, wholesome, and soft water, but rather peaty

PART IV. DESCRIPTIVE.

Water supply to Royal residences.

At the time of our visit it was turbid and would have been much improved by filtration It acts slightly upon bright lead, but not at all upon the tarnished metal.

The following analytical table shows the composition of these waters :—

COMPOSITION OF WATER SUPPLIED TO ABERGELDIE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Permanent.	Total.	
Spring at the Castle, March 9, 1872	5·92	**·049**	**·009**	0	·120	·129	880	1·25	·9	2·9	3·8	Clear and palatable.
Kentore Den water, March 9, 1872.	4·68	**·198**	**·036**	0	0	·036	**0**	1·40	·4	2·2	2·6	Turbid.

Note.—For the translation of these numbers into grains per imperial gallon, *see* note to table on page 29.

Sandringham (*Norfolk*).—At the close of the year 1871, we submitted to analysis four samples of water which were at that time in use in Sandringham House. One of these was from a pump at the stables and was used for drinking, a second was from a pump in the court yard, the well for which was sunk in the year 1870. The water from this well was used only as a supply for the closets. The third was taken from the original pump near the house, which supplied the cisterns and tanks in the kitchen, and was used for all purposes. The fourth was taken from a tap in the kitchen deriving its supply from the same source as the third sample. The water from this tap was used for culinary and drinking purposes.

We were informed that the well which still supplied the before mentioned original pump was sunk to a depth of about 20 feet below the surface, or 14 feet below the floor line of the buildings or offices. It is steined with 9-inch brickwork, and the water stands in it to the depth of about 6 feet, so that it is within about 6 feet of the floor line. The soil is sand resting upon Carr stone. The new well is nearly as deep with about the same quantity of water, and is steined with 9-inch brickwork in cement. The soil is of the same description. The following table contains the results of our analyses of these samples, and of others which were subsequently forwarded to us for investigation, but as to the source of which we have received no information, except that they are from the neighbourhood of Sandringham House :—

COMPOSITION OF WATER SUPPLIED TO SANDRINGHAM HOUSE.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											REMARKS.
	Total Solid Impurity.	**Organic Carbon.**	**Organic Nitrogen.**	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	**Previous Sewage or Animal Contamination.**	Chlorine.	Hardness. Temporary.	Permanent.	Total.	
Pump at Sandringham House stables, December 10, 1871.	29·60	**·043**	**·022**	·003	2·122	2·146	**20,920**	5·80	·6	14·3	14·9	Clear and palatable.
New pump in court yard, December 10, 1871.	46·60	**·234**	**·056**	·018	1·275	1·346	**12,580**	6·40	8·6	17·1	25·7	Very slightly turbid. Palatable.
Original pump near house, December 10, 1871.	37·96	**·223**	**·068**	·001	1·310	1·379	**12,790**	5·25	7·6	15·4	23·0	Slightly turbid. Palatable.
From tap in kitchen, December 10, 1871.	38·12	**·480**	**·196**	·002	1·320	1·518	**12,900**	5·25	8·4	13·7	22·1	Slightly turbid. Palatable.
No. 48 - - - - -	31·56	**·054**	**·007**	0	·961	·968	**9,290**	2·15	15·3	8·9	24·2	Clear and palatable.
No. 52 - - - - -	52·80	**·301**	**·048**	0	1·284	1·332	**12,520**	10·00	15·5	16·6	32·1	Slightly turbid. Palatable.
No. 62 - - - - -	10·52	**·044**	**·012**	0	0	·012	**0**	4·10	0	3·8	3·8	Slightly turbid. Palatable.
No. 68 - - - - -	21·36	**·143**	**·027**	·003	1·076	1·105	**10,460**	4·70	3·2	7·4	10·6	Turbid. Palatable.
No. 119 - - - - -	37·70	**·166**	**·041**	0	·532	·573	**5,000**	3·60	12·0	11·8	23·8	Very turbid. Palatable.
No. 127 - - - - -	11·60	**·044**	**·006**	·032	·512	·544	**5,060**	2·10	·2	4·9	5·1	Clear and palatable.
No. 128 - - - - -	44·64	**·025**	**·008**	·004	·044	·055	**150**	3·10	27·4	15·4	42·8	Turbid. Palatable.
No. 131 - - - - -	44·00	**·180**	**·041**	0	1·230	1·271	**11,980**	5·00	16·5	16·3	32·2	Slightly turbid. Palatable.
No. 134 - - - - -	74·12	**·227**	**·047**	·001	4·576	4·624	**45,450**	4·85	16·7	29·7	46·4	Slightly turbid. Palatable.
No. 68 bis - - -	45·40	**·333**	**·075**	·012	0	·085	**0**	3·40	19·0	12·0	31·0	Very turbid.
No. 119 bis - - -	45·16	**·485**	**·112**	·008	0	·119	**0**	3·40	16·6	13·4	30·0	Do.

Note.—For the translation of these numbers into grains per imperial gallon, *see* note to table on page 29.

The condition of the Sandringham water supply at the close of the year 1871, may be gathered chiefly from an inspection of the columns in the above table headed "organic carbon," "organic nitrogen," and "previous sewage or animal contamination." The actual condition of the waters at the time of analysis, being indicated by the two first named columns, whilst their past history is revealed in the last mentioned column. The pump water from the stables contains only a very small amount of organic elements; in other words, its actual contamination is small; but on the other hand the evidence of its past pollution is very strong. The following comparison exhibits the aggregate quantities of the organic elements (organic carbon and organic nitrogen) contained in 100,000 lbs. of each water:—

PART IV. DESCRIPTIVE.

Water supply to Royal residences. Sandringham House.

1. Pump at stables - - -	·065 lb.
2. New pump in court yard - -	·290 „
3. Original pump - - -	·291 „
4. Tap in kitchen - - -	·676 „

Taking into consideration the past history of these waters, the large proportion of organic elements in the second and third samples is very ominous, and proclaims these waters to be unsafe for human consumption. The fourth sample was said to come from the well whence the third was drawn, and the mineral constituents in the two waters were almost identical; but the third sample had suffered serious pollution from animal organic matter on its way from the well to the kitchen, and this water as delivered from the kitchen tap was entirely unfit for dietetic use.

Of the samples of water sent subsequently for analysis, Nos. 52 and 134 contained large proportions of organic impurity, and consisted chiefly of the soakage from sewers or cesspools. They are consequently dangerous waters and quite unfit for human consumption.

Nos. 68, 119, and 131 contained more moderate proportions of organic impurity, but they exhibited evidence of considerable admixture with water from foul sources. They are suspicious waters, and their use for domestic purposes is very undesirable.

Nos. 48 and 127 are good waters, they contained, at the time of analysis, only mere traces of organic impurity, but they exhibited evidence of some anterior pollution, which may, however, be disregarded, if they are derived from springs or deep wells. No. 127 is soft and well adapted for washing. Nos. 68 (bis) and 119 (bis) were much polluted by organic matter and therefore unfit for domestic use.

No. 128 is an excellent water. It is palatable and may be safely used for dietetic purposes, but it is too hard for use in the laundry.

Lastly, No. 62 is in all respects a water of most excellent quality; soft, palatable, nearly free from organic matter, and from all evidence of anterior pollution. It is perfectly wholesome and suitable for all domestic purposes.

Shortly summarised, the following are the conclusions to which the results of the analyses lead:—

1. All the waters in use at the close of the year 1871 were derived from impure sources, and, on this account alone, their employment for dietetic purposes was undesirable if not positively dangerous.

2. The water from the pump at the stables was clear, colourless, and palatable. It contained but a small proportion of organic elements, and, if its origin were unexceptionable, it might be considered a good water for domestic use. It was also much softer than the other three samples and therefore more suitable for washing and cleansing operations.

3. The waters from the new pump in the courtyard and from the original pump were slightly turbid but inodorous and palatable. Independently of their impure source, these waters were unfit for human consumption by reason of the large proportion of organic matter, chiefly of animal origin, which they contained when drawn from their respective wells. They were also too hard to be used with advantage in the laundry.

4. The water from the tap in the kitchen was slightly turbid, but inodorous and palatable. It had been much polluted with organic matter of animal origin after leaving the original well, and its use for drinking or cooking must have been attended with great risk to health. In other respects it resembled the original well water.

5. A satisfactory remedy for these grave defects in the water supply to Sandringham House can only be obtained by going to an entirely new source for all the water used for dietetic purposes. The sandy soil around the House and offices obviously receives large contributions from sewers, or cesspools, and general surface soakage; it is therefore impossible to obtain from it a good and wholesome water. If, however, at a distance from the House, a deep well were sunk into a lower water-bearing stratum it would

PART IV. DESCRIPTIVE.

doubtless yield excellent water like that obtained from the Carrow Works, Norwich (400 feet deep), and at the Times Paper Mill, Taverham (150 feet deep).

Water supply to Royal residences. Sandringham House.

6. The analyses of the later samples show that water of excellent quality exists around Sandringham.

7. Not only is the present water supply dangerous in respect of quality, but it is also so deficient in quantity, as to leave Sandringham House almost entirely unprotected from fire.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

We have given in the foregoing pages a detailed account of the chemical examination of more than two thousand samples of drinkable water. We have classified these waters in conformity, firstly, with their respective sources,—rain, rivers, lakes, shallow wells, deep wells, and springs; and, secondly, with the various geological formations over or through which they have passed; and we have described the comparative merits of the waters belonging to these divisions. We have fully discussed the considerations respecting the alleged self-purification of polluted streams, the propagation of epidemic disease by potable water, the alleged influence of the hardness of water upon the health of communities, the superiority of soft over hard water for washing and cooking, the various processes for softening hard water, the improvement of water by filtration, its deterioration by transmission through mains and service pipes, and the merits and defects of the constant and intermittent systems of supply. And, lastly, we have given the results of our inquiries into the condition of the water supplied to the metropolis, to the cities, towns, and villages which we have visited or from which we have received official information, to rural districts, and to the Royal residences both in England and Scotland. These investigations into the composition of potable water, into the changes which it undergoes under various circumstances, into the deterioration of water by pollution and its improvement by natural intermittent filtration, and into the different modes of storage and treatment previous to, and even after its delivery to, consumers, have led us to the following conclusions and recommendations:—

As to the Chemical Quality of Water from different Sources.

1. Of the various kinds of water used for dietetic and domestic purposes *rain water*, when collected at a distance from towns upon specially cleansed surfaces and kept in clean receptacles, contains the smallest proportion of total solid impurity; but the organic contamination, even of such specially collected water, somewhat exceeds that of water from springs and deep wells.

2. Rain water collected from the roofs of houses and stored in underground tanks is much more impure; it is often polluted to a dangerous extent by excrementitious matters, and is rarely of sufficiently good quality to be employed for dietetic purposes with safety.

3. Water collected from the surface of uncultivated land, and either allowed to subside in lakes or reservoirs, or filtered through sand, constitutes *upland surface water* of good quality for domestic, and of still better quality for manufacturing purposes. Numerous large towns both in England and Scotland are supplied with water of this description. If the gathering ground be non-calcareous, the water is soft and well adapted for washing and for almost all manufacturing operations. It is nearly always wholesome, but sometimes suffers in palatability by containing an excessive quantity of peaty matter in solution.

4. Water collected from the surface or the drains of cultivated land is always more or less polluted with the organic matter of manure, even after subsidence in lakes or reservoirs. Such *polluted surface or drainage water* is not of good quality for domestic purposes, but it may be used with less risk to health than polluted shallow-well water, if human excrementitious matters do not form part of the manure applied to the land.

5. Surface water, which drains wholly or partially from cultivated land, should always be efficiently filtered before it is supplied for domestic use.

6. *River water*, usually in England but less generally in Scotland, consists chiefly of the drainage from land which is more or less cultivated. When it is further polluted by the drainage of towns and inhabited places, or by the foul discharges from manufactories, its use for drinking and cooking becomes fraught with great risk to health. A very large proportion of the running waters of Great Britain are either at present thus dangerous or are rapidly becoming so.

CONCLUSIONS AND RECOMMENDATIONS.

7. Still more dangerous to health is *shallow-well water*, when the wells are situated, as is usually the case, near privies, drains, or cesspools. Such water often consists largely of the leakage and soakage from receptacles for human excrements; but, notwithstanding the presence of these disgusting and dangerous matters, it is generally bright, sparkling, and palatable.

8. Of the different varieties of potable water the best for dietetic purposes are *spring* and *deep-well waters*. They contain the smallest proportion of organic matter and are almost always bright, sparkling, palatable, and wholesome; whilst their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge.

9. The average composition of the four great classes of unpolluted water is given in the following table which is condensed from the results yielded by the analysis of 589 samples.

AVERAGE COMPOSITION OF UNPOLLUTED WATER.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	Dissolved Matters.											No. of Samples analysed.
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Class I.—Rain water - -	2·95	·070	·015	·029	·003	·042	42	·22	·4	·5	·3	39. *See* p. 30
Class II.—Upland surface water -	9·67	·322	·032	·002	·009	·042	10	1·13	1·5	4·3	5·4	195.
Class V.—Deep well water -	43·78	·061	·018	·012	·495	·522	4,748	5·11	15·8	9·2	25·0	157.
Class VI.—Spring water - -	28·20	·056	·013	·001	·383	·396	3,559	2·49	11·0	7·5	18·5	198.

Note.—For the conversion of these numbers into grains per imperial gallon see directions at foot of table on page 29.

This concrete result of our analyses proves:—Firstly, that in respect of freedom from that most objectionable of impurities,—organic matter (organic carbon and organic nitrogen) these waters range themselves in the following order:—

1. Spring water,
2. Deep-well water,
3. Rain water,
4. Upland surface water.

the last being very much inferior to the first three. Secondly, that the evidence of previous sewage or animal contamination is strongest in the case of spring and deep-well water; but, as explained at page 17, this evidence may, in the case of these waters, be safely disregarded. And, thirdly, that as to hardness, rain water and upland surface water are, on the average, very much softer than spring and deep-well water.

10. In respect of wholesomeness, palatability, and general fitness for drinking and cooking, our researches lead us to the following classification of waters in the order of their excellence, and founded upon their respective sources:—

Wholesome.	1. Spring water.	Very palatable.
	2. Deep-well water.	
	3. Upland surface water.	Moderately palatable.
Suspicious.	4. Stored rain water.	
	5. Surface water from cultivated land.	Palatable.
Dangerous.	6. River water to which sewage gains access.	
	7. Shallow-well water.	

11. A large proportion of the water supplied for domestic purposes is used for washing, and in many towns considerable volumes are used in manufactories. For these purposes, it is of the utmost importance that the water should be soft,—a quality which is not

CONCLUSIONS AND RECOMMENDATIONS.

always associated with wholesomeness and palatability. Classified according to softness, waters from the various sources fall into the following order:—

1. Rain water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river water.
5. Spring water.
6. Deep-well water.
7. Shallow-well water.

The interests of the manufacturer and the laundress are thus opposed to those of the householder, inasmuch as they lead to a preference for moderately palatable or even unwholesome water, over that which is very palatable and wholesome. Most of the waters from springs and deep wells can be easily and cheaply softened on the large scale by a process described at page 205, and thus the sanitary authorities of towns have at their disposal a method of rendering hard water from springs and deep wells available for washing and manufacturing purposes, without diminishing either its palatability or its wholesomeness.

12. The chemical qualities of water are profoundly influenced by the character of the geological formations from which it is derived. Rocks and soils which impart to water salts other than those of potash and soda, render it more or less hard; and as such hardening salts are almost invariably compounds of lime and magnesia with carbonic and sulphuric acids, it follows that Chalk, Limestone, Dolomite, and rocks containing the carbonates of lime and magnesia or sulphate of lime, are those which are almost exclusively instrumental in communicating hardness to water. The following formations yield, as a rule, soft water:—

Igneous.	Coal Measures (non-calcareous).
Metamorphic.	Lower Greensand.
Cambrian.	London and Oxford clay.
Silurian (non-calcareous).	Bagshot Beds.
Devonian (non-calcareous).	Non-Calcareous gravel.
Millstone grit.	

On the other hand the following geological formations almost invariably yield hard water:—

Silurian (calcareous).	Conglomerate Sandstone.
Devonian (calcareous).	Lias.
Mountain Limestone.	Oolites.
Coal Measures (calcareous).	Upper Greensand.
New Red Sandstone.	Chalk.

13. The influence of geological formation upon the palatability and wholesomeness of *surface water* is often inconsiderable, owing to the deposit of peaty matters upon the surfaces of the rocks or soils; unpolluted surface waters from the most widely different geological formations, differing but little in the proportions of organic matter which they contain; but, where the water percolates or soaks through great thicknesses of rock, its quality, when it subsequently appears as *spring* or *deep-well water*, depends greatly upon the chemical character of the material through which it has passed. When the formation contains much soluble saline matter, the water becomes loaded with mineral impurities, as is frequently the case when it percolates through certain of the Carboniferous rocks, the Lias and the Saliferous Marls. When the rock is much fissured or permeated by caverns or passages, like the Mountain Limestone for instance, the effluent water differs but little from surface drainage, and retains most of the organic impurities with which it was originally charged. But when it is uniformly porous like the Chalk, Oolite, Greensand, or New Red Sandstone, the organic matter, at first present in the water, is gradually oxidised and transformed into innocuous mineral compounds. In effecting this most desirable transformation, and thus rendering the water sparkling, colourless, palatable and wholesome, the following are the most efficient water-bearing strata:—Chalk, Oolite, Greensand, New Red and Conglomerate Sandstone.

14. Surface water or river water which contains in 100,000 parts more than 0·2 part of organic carbon, or ·03 part of organic nitrogen is not desirable for domestic supply, and ought, whenever practicable, to be rejected.

15. Spring and deep-well water ought not to contain, in 100,000 parts, more than 0·1 part of organic carbon or ·03 part of organic nitrogen. If the organic carbon reaches

0·15 part in 100,000 parts, the water ought to be used only when a better supply is unattainable. In all cases in which spring and deep-well water of good quality are available, we recommend that they should be employed, in preference to surface or river water, for domestic supply.

CONCLUSIONS AND RECOMMENDATIONS.

As to the Possibility of rendering Polluted Water again Wholesome.

1. When the sewage of towns or other polluting organic matter is discharged into running water the suspended matters may be more or less perfectly removed by subsidence and filtration, but the foul organic matters in solution are very persistent. They oxidise very slowly, and they are removed only to a slight extent by sand filtration. There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source.

2. Of all the processes which have been proposed for the purification of sewage, or of water polluted by excrementitious matters, there is not one which is sufficiently effective to warrant the use, for dietetic purposes, of water which has been so contaminated. In our opinion, therefore, rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable water.

As to the Propagation of Epidemic Diseases by Potable Water

1. The existence of specific poisons capable of producing cholera and typhoid fever is attested by evidence so abundant and strong as to be practically irresistible. These poisons are contained in the discharges from the bowels of persons suffering from these diseases.

2. The admixture of even a small quantity of these infected discharges with a large volume of drinking water is sufficient for the propagation of those diseases amongst persons using such water.

3. The most efficient artificial filtration leaves in water much invisible matter *in suspension*, and constitutes no effective safeguard against the propagation of these epidemics by polluted water. (*See* Appendix No. 4, page 463.) Boiling the infected water for half an hour is a probable means of destroying its power of communicating these diseases.

4. Other epidemics, such as dysentery and diarrhœa, are also probably propagated by drinking water, but the evidence is here neither so abundant nor conclusive as it is in the case of cholera and typhoid fever.

As to the alleged Influence of the Hardness of Potable Water upon Health.

1. Whilst waters of excessive hardness may be productive of calculus, and perhaps other diseases; soft and not excessively hard waters, if equally free from deleterious organic substances, are equally wholesome.

2. In towns where the chief sanitary conditions prevail with tolerable uniformity, the rate of mortality is uninfluenced by the softness or hardness of the water supplied to the inhabitants.

As to the Superiority of Soft over Hard Water for Washing, Cooking, and Manufacturing Operations.

1. The washing of linen can only be performed with soft water. If the available water be hard, it must be artificially softened—an operation which, on the domestic scale, must be performed at great expense by the aid of either fuel, soda, or soap. In personal ablution also, the use of soft water is much more pleasant and efficient. It is also more economical; but by the general use of a very small quantity of water, the waste of softening material is here much less than in the laundry.

2. In cooking, the extraction of the soluble parts of such materials as are submitted to boiling, or to digestion at a high temperature, is more completely and economically effected by soft than by hard water.

3. In manufacturing operations involving the use of water, soft water is, almost without exception, preferable to hard. Dangerous encrustations in steam boilers are prevented by the use of soft water.

CONCLUSIONS AND RECOMMENDATIONS.

As to the Softening of Hard Water.

1. All hard water can be softened either by distillation or by the addition of a sufficient quantity of soap or carbonate of soda. Water, the hardness of which is due to the carbonates of lime and magnesia (temporary hardness) may be softened, either by boiling for half an hour, or by the addition of a proper quantity of slaked lime. Except the last, all these processes are expensive and inapplicable on the large scale.

2. Water, the hardness of which is wholly or chiefly of the temporary kind may be easily, cheaply, and efficiently softened on the large scale by the proper use of lime, and the wholesomeness and palatability of such water are sometimes increased and never diminished by the process.

3. The lime method of softening may be applied with ease and great economy to the whole supply of even the largest towns, provided the hardness of the water be wholly or chiefly of the temporary kind.

As to the Improvement of Water by Filtration.

1. Sand filtration, as carried out in waterworks, not only clarifies the water by removing suspended impurities, but also diminishes the proportion of organic matter in solution, to an extent dependent upon the thickness of the filtering medium and the rate at which the water passes through that medium.

2. Domestic filtration, as usually practised, is of little or no use; but, properly performed, it is much more efficient than sand filtration on the large scale, in improving the quality of water polluted by organic matters. The best materials for domestic filters are spongy iron and animal charcoal.

3. Although the improvement of excrementally polluted water by filtration may reasonably be considered, on theoretical grounds, to afford some feeble protection against the propagation of epidemic diseases by water, no trustworthy evidence can be adduced in support of such a view.

As to the Deterioration of Water during its Transmission through Mains and Service Pipes.

1. Potable water can be transmitted through mains of even great length, if they be properly laid, without any appreciable deterioration of quality; but if the joints are calked with hemp, or other similar organic material, the water is often seriously polluted for months, or even years, after the laying of the mains.

2. The experience of Glasgow, Manchester, and other towns proves conclusively, that leaden service pipes can be safely used for the delivery even of water which acts violently upon lead, if the pipes be kept constantly charged with water.

As to the Constant and Intermittent Systems of Supply.

1. All storage of drinking water in houses is attended with the risk of pollution. Good water is spoiled and bad water rendered worse by the intermittent system of supply. All drinking water ought to be drawn direct from the main.

2. Under proper supervision, the waste of water is less on the constant than it is on the intermittent system of supply.

3. These and other advantages have led to the adoption of the constant system in a great majority of British towns.

As to the Quality of the London Water Supply which is derived from the Thames.

1. The *Thames* above the intake of the respective water companies receives the sewage from a large number of towns and other inhabited places, the washings of a large area of highly cultivated land, and the filthy discharges from many industrial processes and manufactures.

2. The river is used for bathing, for the washing of sheep and cattle, and of dirty linen; and the putrid carcases of animals float upon its surface. It is the common water way for a large amount of polluting matter, much of which is at times dangerous to the health of persons who use even the filtered water for dietetic purposes.

3. In time of flood, a large proportion, both of the suspended and dissolved filth, is conveyed down to the intake of the metropolitan water companies; and in ordinary weather a considerable proportion of the soluble organic matter of sewage, discharged

into the river and its tributaries, likewise makes its way down to the works of the water companies, and is still present in the water distributed by them in London. CONCLUSIONS AND RECOMMENDATIONS.

4. The water is, nevertheless, when efficiently filtered, free from any offensive taste or odour.

5. Notwithstanding the application of partial remedies for sewage pollution at Banbury, Eton, and Windsor, and the greater care exercised by most of the companies in the storage and filtration of the water, the organic pollution contained in the *Thames* water delivered in London, though subject to fluctuation from the greater or less prevalence of floods, does not diminish.

6. There is no hope of this disgusting state of the river being so far remedied, as to prevent the admixture of animal and other offensive matters with the filtered *Thames* water as delivered in the metropolis. (*See* Appendix No. 4, page 463.)

7. The temperature of the water drawn from the companies' mains, is liable to excessive fluctuations, being near the freezing point in winter, and so high in summer as to render the water vapid and unpalatable.

8. We therefore recommend that the *Thames* should, as early as possible, be abandoned as a source of water for domestic use, and that the sanction of Your Majesty's Government be, in future, withheld from all schemes involving the expenditure of more capital for the supply of *Thames* water to London.

As to the Quality of the Water supplied to London from the Lee.

1. The pollution of the *Lee* above the intake of the water companies is similar in character to that of the *Thames*, but considerably less intense.

2. Sewage and other disgusting matters reach the intake of the metropolitan water companies drawing from this river, and the soluble portions of such matters are not wholly eliminated by the efficient filtration to which the water is subjected before delivery.

3. The water of the *Lee* is slowly, though irregularly deteriorating from year to year, and there is no hope of purifying it to such an extent as to render it, at all times, safe for domestic use.

4. We, therefore, recommend that the *Lee* should also be abandoned as a source of potable water. This measure is less urgent than the relinquishment of *Thames* water, but the sanction of Your Majesty's Government ought not, in our opinion, to be accorded to any further expenditure of capital upon the supply of *Lee* water to the metropolis.

5. Nothing would be gained by the abstraction of the water at any higher points, short of the springs forming the sources of the tributaries of these rivers.

As to the Quality of the Water supplied to London from Deep Wells in the Chalk.

1. The water supplied to London by the Kent Company from wells at Deptford is free from sewage and other objectionable organic matter.

2. Without any artificial filtration, this water is always clear, sparkling, transparent, and palatable.

3. Though hard, it is uniformly a perfectly wholesome water.

4. It contains much less organic matter, and a more uniform proportion of it, than the supplies from the *Thames* and *Lee*.

5. Its temperature is nearly uniform throughout the year, the water being of refreshing coolness in summer, and far removed from the freezing point in winter.

6. It is harder than *Thames* and *Lee* water, and therefore not quite so useful for washing as the river waters.

7. The continued and extended supply of this and similar water to the metropolis is, in our opinion, very desirable.

As to the Quality of the Water derived from public Shallow Wells in the Metropolis.

1. With the exception of the well supplying the pump near the S.E. entrance to Kensington Gardens, and a well at Maritime Almshouses, Mile End Old Town, all the public shallow wells in the metropolis, which we have investigated, yield water most disgustingly polluted, and quite unfit for human consumption.

2. We recommend that, with the two exceptions just named, all these wells be, in the interests of the public health, forthwith closed.

CONCLUSIONS AND RECOMMENDATIONS.

As to the proposed Supply of Water to the Metropolis from North Wales, and from the Lakes of Cumberland.

1. We are of opinion that both these schemes are capable of furnishing the metropolis with abundance of excellent water. But they would both be very costly, and they are, in our opinion, unnecessary.

As to the Supply of the Metropolis with Spring and Deep-well Water.

1. Abundance of spring and deep-well water of excellent quality can be procured in the basin of the *Thames*, and within a moderate distance of London; and we are of opinion that the metropolis and its suburbs should be supplied, on the constant system, exclusively with this palatable and wholesome water.

2. We recommend that this water should, before delivery to consumers, be softened with lime.

3. The introduction of this new supply of wholesome, palatable, and soft water will render necessary, either the throwing open of the metropolitan water supply to the competition of new private companies, or the transference of the control of that supply to a responsible public body invested with the necessary powers for the purchase of the existing works, and the construction of such other works as may be required for the acquisition and supply of so much spring and deep-well water as may be necessary to replace the river water now delivered in London and its suburbs. Of these two alternative measures we give strong preference to the last.

As to the Water Supplies of other British Cities, Towns, and Inhabited Places.

1. A large majority of the cities and large towns, other than London, are abundantly supplied with palatable and wholesome water. In manufacturing towns the supply is generally also soft.

2. In other towns, and in villages and other inhabited places, the water available for domestic purposes is frequently neither abundant nor wholesome. In these cases, it is a widely spread custom to drink, either the water of rivers into which the excrements of man are discharged, or the water from shallow wells which are largely fed by soakage from middens, sewers, and cesspools.

3. Immense numbers of the population are thus daily exposed to the risk of infection from typhoidal discharges, and, periodically, to that from cholera dejections.

4. The supply of villages and hamlets with wholesome water is often a problem of great difficulty, since the number of inhabitants is too small to permit of the execution of expensive works for such an object. We, therefore, recommend that in any scheme for the utilization for town supply, of the pure water of a river basin, the wants of all neighbouring villages and hamlets should be provided for as far as practicable; and we further recommend that the owners of land should be permitted to include the cost of village water supply among those expenditures on land improvement which they are now enabled, with the sanction of Your Majesty's Inclosure Commissioners, to charge upon their estates.

5. Whenever the necessities of the case compel the supply of water to a town from a river or stream into which the excrements of man, whether purified or not, are discharged, we recommend that storage reservoirs should be provided of sufficient capacity to render unnecessary the abstraction of water from such rivers or streams during floods. These storage reservoirs ought to be so constructed and worked as to allow of the discharge of their contents into the river or stream, whenever the quality of the latter becomes superior to that of the previously impounded water.

As to the Water Supplies of the Royal Residences.

1. Of the shallow-well water supplied to Osborne a portion is of moderately good quality and the remainder unfit for dietetic purposes. Several trial wells sunk upon the estate have afforded palatable and wholesome water of moderate hardness.

2. The water supplied to Windsor Castle from shallow wells sunk near the Thames is wholesome, and, though hard, of fairly good quality.

CONCLUSIONS AND RECOMMENDATIONS.

3. Of the three kinds of water used at Balmoral, that from the Rabate Fountain is wholesome and of most excellent quality for dietetic and all domestic purposes. That from the *Gelder Burn* is wholesome and very soft, but it is not so palatable as the Rabate water, owing to the presence of peaty matter in solution. The pump water derived from a well situated about midway between the Castle and stables is clear, colourless and palatable, but it is contaminated by drainage, and we therefore recommend that this well should be closed, and that the Rabate water alone should be used for drinking. If, however, a supply of well water be considered desirable, a new well ought to be sunk near the *Dee*, and not less than 200 yards above the Castle.

4. The spring water used for drinking at Abergeldie is sparkling, clear, and wholesome. The general water supply of Abergeldie is brought from Kentore Den. It is good, wholesome, and soft, but peaty. It would be much improved by filtration through sand, spongy iron, or animal charcoal.

5. Sandringham is supplied with water from shallow wells sunk near the house. These wells are all much polluted by animal matters, and the water they yield is quite unfit for dietetic purposes. It is dangerous water. There appears to be abundance of excellent and wholesome water obtainable within a short distance of Sandringham House.

All which we humbly certify to Your Majesty under our hands and seals this thirtieth day of June One thousand eight hundred and seventy-four.

(Signed) E. FRANKLAND. (L.S.)
JOHN CHALMERS MORTON. (L.S.)

S. J. SMITH,
Secretary.

Rivers Commission Office,
1, Park Prospect, Great Queen Street,
Westminster.

APPENDICES.

APPENDIX No. 1.

PARTICULARS of SAMPLES of RAIN WATER, of DEW, and of HOAR FROST, collected at ROTHAMSTED by J. B. LAWES, Esq., F.R.S., and Dr. J. H. GILBERT, F.R.S.:—

RAIN WATER, DEW, and HOAR FROST, collected at Rothamsted from Leaden Gauge 87·12 × 72 inches area = $\frac{1}{1000}$ of an acre.

Particulars of Collection.			Quantity collected.		Particulars of Sample.		Notes.
Day.	Hour.	Approximate direction of Wind.	Weight.	Measure.	Collected from	Samples Analysed.	
1869.			lbs. oz.	Inches.			
April 14 -	9 a.m.	S.W.	3 7	0·0152			
,, 14 -	4.30 p.m.	S.E.	25 4	0·1116	Carboy	Sample	Thunder rain.
,, 16 -	9 a.m.	S.W.	15 15	0·0704	Do.	Do.	Hail storm.
,, 16 -	4.30 p.m.	,,	34 0	0·1503	Do.	Do.	Do.
,, 17 -	9 a.m.	,,	73 13	0·3263	Do.	Do.	
,, 17 -	4.30 p.m.	N.W.	14 3	0·0627	Do.	Do.	
,, 18 -	9 a.m.	,,	4 6	0·0194	}		
,, 18 -	4.30 p.m.	S.W.	3 12	0·0166	} Do.	Do.	
,, 20 -	,,	,,	4 6	0·0194	}		
,, 21 -	9 a.m.	,,	23 8	0·1039	Do.	Do.	
,, 22 -	,,	,,	1 0·5	0·0046			Dew or frost.
,, 23 -	,,	,,	0 13	0 0036			Do.
,, 23 -	4.30 p.m.	,,	25 5	0·1119	Do.	Do.	Distant thunder.
,, 24 -	9 a.m.	N.W.	172 13	0·7638	Do.	Do.	
,, 26 -	,,	N.E.	0 13	0·0036			Dew or frost.
,, 27 -	,,	,,	1 0	0·0044			Do.
,, 28 -	,,	,,	0 1	0·0003			Do.
,, 30 -	,,	,,	0 9	0·0025			Do.
May 1 -	,,	,,	0 0·5	0·0002			Do.
,, 2 -	,,	S.E.	1 2·5	0·0052			Do.
,, 4 -	,,	N.E.	145 2	0·6415	Do.	Do.	
,, 4 -	4.30 p.m.	,,	41 0	0·1812	Do.	Do.	
,, 6 -	9 a.m.	S.E.	22 5	0·0986	Do.	Do.	
,, 6 -	4.30 p.m.	,,	10 15	0·0483			
,, 7 -	9 a.m.	S.W.	10 15	0·0483			
,, 7 -	4.30 p.m.	,,	0 8	0·0022			
,, 8 -	9 a.m.	,,	26 2	0·1155			
,, 8 -	4.30 p.m.	,,	9 12	0·0431			
,, 9 -	9 a.m.	,,	3 10	0·0161			
,, 10 -	,,	,,	65 8	0·2895			
,, 10 -	4.30 p.m.	,,	4 0	0·0177			
,, 11 -	9 a.m.	N.W.	1 13	0·0080			White frost.
,, 12 -	,,	,,	0 0·5	0·0002			Do.
,, 13 -	,,	N.E.	0 12	0·0033			Dew or frost.
,, 14 -	,,	,,	0 3	0·0008			
,, 17 -	,,	S.E.	6 7·5	0·0286			
,, 17 -	4.30 p.m.	S.W.	4 2	0·0183			
,, 18 -	9 a.m.	,,	34 3·5	0·1513	Carboy Spout	Do. Do.	Collected from 8 to 9 a.m.
,, 18 -	4.30 p.m.	,,	47 8	0·2099	Carboy Spout	Do. Do.	Collected from 3 to 4 p.m.
,, 19 -	9 a.m.	,,	26 5	0·1163			
,, 19 -	4.30 p.m.	,,	86 6	0·3818	Carboy Spout	Do. Do.	Collected from 10 to 11 a.m. Thunderstorm.
,, 20 -	9 a.m.	N.W.	1 15	0·0085			
,, 20 -	4.30 p.m.	,,	1 5	0·0058			
,, 21 -	9 a.m.	N.E.	1 6	0·0061			
,, 22 -	,,	N.W.	0 1	0·0003			
,, 23 -	,,	S.W.	16 5	0·0721	Carboy	Do.	
,, 24 -	,,	,,	0 0·5	0·0002			Dew or frost.
,, 26 -	,,	S.E.	Lost.	0·1900*			*Small rain-gauge.
,, 27 -	,,	N.E.	0 5·5	0·0016			Dew or frost.
,, 27 -	4.30 p.m.	,,	5 15	0·0262			
,, 28 -	9 a.m.	,,	40 11	0·1798	Carboy Spout	Do. Do.	Collected from 9 to 10 a.m.
,, 28 -	4.30 p.m	,,	45 12	0·2022			
,, 29 -	9 a.m.	,,	7 12	0·0342			
,, 31 -	,,	,,	2 15	0·0129			
,, 31 -	4.30 p.m.	S.W.	13 10·5	0·0605			

Rain Water collected at Rothamsted from Leaden Gauge 87·12 × 72 inches, area = 1/1000 of an acre—*cont.*

Particulars of Collection.			Quantity collected.		Particulars of Sample.		Notes.
Day.	Hour.	Approximate direction of Wind.	Weight.	Measure.	Collected from	Samples Analysed.	
1869.			lbs. oz.	Inches.			
June 1 -	9 a.m.	S.W.	1 0·5	0·0046			Dew or frost.
„ 3 -	„	N.W.	15 12	0·0696			
„ 3 -	4.30 p.m.	S.W.	1 2	0·0050			
„ 4 -	9 a.m.	„	1 12·5	0·0079			
„ 5 -	„	„	1 1	0·0047			Do.
„ 7 -	„	„	1 13	0·0080			Do.
„ 11 -	„	N.W.	0 7·5	0·0021			
„ 14 -	„	„	124 6	0·5498	{ Carboy Spout	Sample. Do.	Collected at 6.30 a.m.
„ 15 -	„	S.W.	33 7	0·1478	Carboy	Do.	
„ 15 -	4.30 p.m.	N.W.	5 10	0·0249	Do.	Do.	
„ 16 -	9 a.m.	„	19 4	0·0851			
„ 17 -	„	S.W.	1 13	0·0080			
„ 17 -	4.30 p.m.	N.W.	4 7	0·0196			
„ 18 -	„	S.W.	8 0	0·0354			
„ 19 -	9 a.m.	N.E.	0 3	0·0008			Dew or frost.
„ 20 -	„	N.W.	8 0	0·0354			
„ 21 -	4.30 p.m.	„	11 8	0·0508			
„ 24 -	9 a.m.	„	0 9·5	0·0027			Do.
„ 25 -	„	N.E.	0 12	0·0033			Do.
„ 26 -	„	„	0 0·5	0·0002			Do.
„ 28 -	„	„	0 0·5	0·0002			Do.
July 6 -	4.30 p.m.	S.W.	8 6	0·0371			
„ 9 -	9 a.m.	„	8 8	0·0376			
„ 10 -	„	„	0 2	0·0006			Do.
„ 13 -	„	N.W.	38 12	0·1713			
„ 14 -	„	S.E.	0 1·5	0·0005			Do.
„ 15 -	„	N.W.	0 1	0·0003			Do.
„ 16 -	„	„	0 3	0·0008			Dew or frost; gauge washed afterwards.
„ 17 -	„	N.E.	1 4·5	0·0057			Dew or frost.
„ 22 -	„	S.W.	1 4·5	0·0057			Dew or frost; the gauge having been previously repaired and washed.
„ 28 -	„	S.E.	21 4	0·0939	{ Spout Carboy	Do. Do.	
„ 28 -	4.30 p.m.	N.E.	126 0	0·5569			
„ 29 -	9 a.m.	S.W.	0 13·5	0·0038			Dew or frost.
„ 30 -	„	„	7 7	0·0328			
„ 31 -	„	„	6 12	0·0298			
Aug. 1 -	„	„	9 1·5	0·0403			
„ 3 -	„	„	Lost.	0·0600*			*Small rain-gauge.
„ 3 -	4.30 p.m.	—	83 14	0·3708	Spout	Do.	
„ 4 -	9 a.m.	S.W.	15 14	0·0702			
„ 5 -	„	N.W.	9 5·5	0·0414			
„ 6 -	„	„	0 4	0·0011			Dew or frost.
„ 6 -	4.30 p.m.	S.E.	10 4·5	0·0455			
„ 7 -	9 a.m.	N.W.	0 8	0·0022			Do.
„ 8 -	„	S.W.	76 9·5	0·3386			
„ 8 -	4.30 p.m.	„	1 12	0·0077			
„ 9 -	9 a.m.	N.W.	11 8	0·0508			
„ 11 -	„	„	4 11	0·0207			
„ 11 -	4.30 p.m.	„	3 9	0·0158			
„ 13 -	9 a.m.	S.W.	37 11	0·1665	Spout	Do.	Collected from 7.30 to 8 a.m.
„ 13 -	4.30 p.m.	N.E.	13 1·5	0·0580			Gauge washed after collection.
„ 14 -	9 a.m.	N.W.	3 3	0·0141			
„ 17 -	„	„	9 10·5	0·0428			
„ 18 -	„	S.W.	0 5	0·0014			Dew or frost.
„ 22 -	„	N.W.	0 2	0·0006			Do.
„ 24 -	„	S.W.	0 10	0·0028			Do.
„ 26 -	„	„	0 1·5	0·0005			Do.
Sept. 1 -	„	N.E.	0 6·5	0·0019			Do.
„ 6 -	„	S.W.	25 0	0·1105	Carboy	Do.	
„ 6 -	4.30 p.m.	N.W.	10 4·5	0·0455			
„ 8 -	9 a.m.	„	17 12	0·0784			Gauge washed after collection.
„ 10 -	„	S.E.	114 4·5	0·5052	Spout	Do.	Thunder rain. Collected from 6 to 7 a.m.
„ 10 -	4.30 p.m.	S.W.	Lost.	0·0775*	Carboy	Do.	Thunder rain. *Small rain-gauge.
„ 12 -	9 a.m.	N.W.	132 2	0·5840	Spout	Do.	Collected from 6 to 7 a.m.
„ 13 -	„	S.W.	35 11	0·1577			
„ 13 -	4.30 p.m.	N.W.	18 7·5	0·0817			

Rain Water collected at Rothamsted from Leaden Guage 87·12 × 72 inches area = $\frac{1}{1000}$ of an acre—*cont.*

Particulars of Collection.			Quantity collected.		Particulars of Sample.		Notes.
Day.	Hour.	Approximate direction of Wind.	Weight.	Measure.	Collected from	Samples Analysed.	
1869.			lbs. oz.	Inches.			
Sept. 14 -	9 a.m.	S.W.	12 9	0·0555	Carboy	Sample.	
„ 14 -	4.30 p.m.	„	0 3	0·0008			
„ 15 -	9 a.m.	N.W.	64 8	0·2851			
„ 17 -	„	S.W.	8 11	0·0384			
„ 17 -	4.30 p.m.	„	5 2·5	0·0229			
„ 18 -	9 a.m.	„	2 6·5	0·0107			
„ 18 -	4.30 p.m.	„	2 12	0·0121			
„ 19 -	9 a.m.	„	143 12	0·6854	Do.	Do.	
„ 28 -	„	„	1 7·5	0·0065			Dew or frost.
„ 29 -	4.30 p.m.	„	11 9	0·0511			
„ 30 -	9 a.m.	S.E.	6 5	0·0279			
Oct. 1 -	„	S.W.	137 3	0·6063	Do.	Do.	
„ 2 -	„	S.E.	3 0	0·0133			
„ 2 -	4.30 p.m.	„	6 0	0·0265			
„ 3 -	9 a.m.	„	50 0	0·2210			
„ 4 -	„	S.W.	3 10	0·0161			
„ 5 -	„	S.E.	3 8	0·0155			Heavy dew (not saved; gauge washed afterwards).
„ 6 -	„	„	3 5·5	0·0149			Dew or frost (washed afterwards).
„ 7 -	„	„	3 6	0·0150			Do. do.
„ 9 -	„	S.W.	3 10	0·0161			Do. do.
„ 10 -	„	„	3 5	0·0147			Do. do.
„ 11 -	„	„	3 2·5	0·0141			Do. do.
„ 12 -	„	„	2 5·5	0·0104			Do. do.
„ 13 -	„	„	19 1·5	0·0845	Do.	Do.	After washing gauge, 12th.
„ 16 -	„	„	21 14·5	0·0969			Gauge washed, 13th, 14th, and 15th p.m.
„ 16 -	4.30 p.m.	„	10 1·5	0·0447			Gauge washed after collection.
„ 18 -	9 a.m.	„	21 14	0·0967			Do. 17th p.m.
„ 18 -	4.30 p.m.	—	84 14	0·3752			Do. after collection.
„ 19 -	9 a.m.	N.W.	20 8	0·0906	Do.	Do.	
„ 24 -	„	„	7 12	0·0342			
„ 26 -	„	„	10 4·5	0·0455	Do.	Do.	Gauge washed Oct. 25th.
„ 30 -	„	„	34 0	0·1503			
„ 30 -	4.30 p.m.	„	8 12	0·0387			
„ 31 -	9 a.m.	„	2 0	0·0088			
Nov. 3 -	„	„	1 14	0·0083			
„ 4 -	„	„	17 8	0·0773			
„ 4 -	4.30 p.m.	„	2 3	0·0096			
„ 5 -	9 a.m.	„	0 7·5	0·0021			Gauge washed after a.m. collection, that is before p.m. collection.
„ 5 -	4.30 p.m.	S.W.	47 10	0·2105			
„ 6 -	9 a.m.	„	15 0	0·0663			
„ 8 -	„	„	2 4	0·0099			
„ 9 -	„	„	6 5	0·0279			
„ 9 -	4.30 p.m.	„	12 11	0·0560			
„ 11 -	9 a.m.	N.W.	4 1	0·0180			Snow water.
„ 12 -	„	„	1 7	0·0063			
„ 15 -	„	S.W.	3 5	0·0147			
„ 15 -	4.30 p.m.	„	13 3	0·0583			
„ 16 -	9 a.m.	„	1 8	0·0066			Gauge washed p.m.
„ 17 -	„	„	2 14	0·0127			White frost.
„ 18 -	„	„	3 3	0·0141			Do.
„ 19 -	„	„	0 14	0·0039			
„ 22 -	„	N.W.	64 3	0·2837			
„ 22 -	4.30 p.m.	„	51 13	0·2290	Do.	Do.	
„ 23 -	9 a.m.	„	3 15	0·0174			
„ 26 -	„	„	6 8	0·0287			
„ 27 -	4.30 p.m.	S.W.	63 0	0·2785	Do.	Do.	Gauged washed a.m.
„ 28 -	9 a.m.	N.W.	128 6	0·5675			
„ 29 -	4.30 p.m	S.E.	} 81 15	0·3621			Rain and snow.
„ 30 -	9 a.m.	N.E.					
„ 30 -	4.30 p.m.	„	3 0	0·0133			
Dec. 4 -	9 a.m.	„	16 7·5	0·0728	Do.	Do.	Snow water.
„ 8 -	„	„	1 4	0·0055			
„ 9 -	„	„	3 14	0·0172			
„ 9 -	4.30 p.m.	„	3 10	0·0161			
„ 10 -	9 a.m.	S.W.	16 7	0·0726			
„ 11 -	4.30 p.m.	„	34 1	0·1506			
„ 12 -	9 a.m.	„	70 5·5	0·3110			

Rain Water collected at Rothamsted from Leaden Gauge 87·12 × 72 inches area = $\frac{1}{1000}$ of an acre—*cont.*

Particulars of Collection.			Quantity collected.		Particulars of Sample.		Notes.
Day.	Hour.	Approximate direction of Wind.	Weight.	Measure.	Collected from	Samples. Analysed.	
1869.			lbs. ozs.	Inches.			
Dec. 12 -	4.30 p.m.	S.W.	Lost.	0·1325*			*Small rain gauge.
„ 13 -	9 a.m.	„	3 8	0·0155			
„ 13 -	4.30 p.m.	„	3 1	0·0136			
„ 14 -	9 a.m.	„	45 13	0·2025			
„ 15 -	„	„	60 5	0·2666			
„ 15 -	4.30 p.m.	„	2 8	0·0110			
„ 16 -	9 a.m.	„	1 15	0·0085			
„ 16 -	4.30 p.m.	S.E.	52 10	0·2326			
„ 17 -	9 a.m.	S.W.	134 2	0·5929			
„ 18 -	„	„	31 10	0·1398			
„ 18 -	4.30 p.m.	„	3 14	0·0172			
„ 19 -	9 a.m.	N.E.	35 5	0·1561			
„ 20 -	„	„	6 7	0·0284			
„ 21 -	„	„	49 8	0·2188			
„ 21 -	4.30 p.m.	N.W.	34 5	0·1517			
„ 22 -	9 a.m.	„	33 5	0·1473			
„ 24 -	„	„	6 14	0·0304			Snow and frost after collection: 24th p.m.,—30th a.m., frozen.
„ 30 -	„	„	34 5·5	0·1519			
„ 31 -	4.30 p.m.	S.W.	7 14	0·0348			
1870.							
Jan. 1 -	9 a.m.	„	83 11	0·3699			
„ 2 -	„	„	10 2	0·0448			
„ 3 -	„	„	10 1	0·0445			
„ 3 -	4.30 p.m.	„	15 3	0·0671			
„ 4 -	9 a.m.	„	18 1	0·0799			
„ 5 -	„	„	30 5·5	0·1342			
„ 6 -	„	„	8 1·5	0·0359			
„ 7 -	„	„	27 15	0·1234			
„ 8 -	„	„	22 9	0·0997			
„ 8 -	4.30 p.m.	„	32 13	0·1450			
„ 9 -	9 a.m.	N.W.	8 7·5	0·0375			
„ 10 -	„	„	5 8	0·0243			
„ 11 -	4.30 p.m.	S.W.	8 8	0·0376			
„ 12 -	9 a.m.	N.W.	10 11	0·0472			
„ 14 -	„	S.W.	60 10	0·2680			
„ 14 -	4.30 p.m.	„	3 4	0·0144			
„ 17 -	9 a.m.	S.E.	14 1	0·0622			
„ 24 -	„	N.E.	4 12	0·0210			Gauge washed, p.m.
„ 31 -	„	S.E.	*13 2·5	0·0583	Carboy	Sample	* This was the collection from Jan. 25 to Jan. 31 inclusive which had become frozen in carboy; brought to laboratory and allowed to thaw in a cool room.
„ 31 -	4.30 p.m.	„	21 6	0·0945	Spout.	Do.	Gauge washed, 12 noon; sample collected from noon to 4 p.m.
Feb. 1 -	9 a.m.	„	2 10	0·0116			
„ 2 -	„	„	33 14	0·1498	Carboy	Do.	
„ 2 -	4.30 p.m.	„	23 5	0·1031	Do.	Do.	
„ 3 -	9 a.m.	„	39 3	0·1732	Do.	Do.	
„ 4 -	„	„	0 6	0·0017			
„ 5 -	„	„	41 9	0·1837	Do.	Do.	
„ 5 -	4.30 p.m.	„	1 9	0·0069			
„ 6 -	„	„	12 2	0·0536	Do.	Do.	
„ 7 -	9 a.m.	„	183 12	0·8122	Do.	Do.	
„ 7 -	4.30 p.m.	„	20 5	0·0898			
„ 8 -	9 a.m.	„	26 15·5	0·1192	Do.	Do.	
„ 8 -	4.30 p.m.	„	10 15	0·0483			Snow water, Feb. 8th, after 4.30, to 16th.
„ 16 -	9 a.m.	N.E.	24 12·5	0·1096	Do.	Do.	
„ 16 -	4.30 p.m.	„	7 15	0·0350			Snow water.
„ 19 -	„	„	7 15	0·0350	Do.	Do.	Gauge washed, Feb. 17th, p.m.
„ 21 -	9 a.m.	N.W.	10 15	0·0483	Do.	Do.	Gauge washed after collection.
„ 22 -	„	„	0 8	0·0022			Snow water.
„ 23 -	4.30 p.m.	S.W.	4 6	0·0194			
„ 24 -	9 a.m.	„	6 11	0·0295			
„ 24 -	4.30 p.m.	„	7 3·5	0·0319			
„ 26 -	9 a.m.	„	1 0	0·0044			Gauge washed.

Rain Water collected at Rothamsted from Leaden Gauge 87·12 × 72 inches area = 1/1000 of an acre—*cont.*

Particulars of Collection.			Quantity collected.		Particulars of Sample.		Notes.
Day.	Hour.	Approximate direction of Wind.	Weight.	Measure.	Collected from	Samples Analysed.	
1870.			lbs. oz.	Inches.			
Feb. 27 -	4.30 p.m.	S.W.	3 15	0·0174			
" 28 -	"	"	3 3	0.0141			
Mar. 1 -	9 a.m.	"	1 5	0·0058			
" 1 -	4.30 p.m.	"	13 5·5	0·0591	Spou	Sample.	
" 2 -	9 a.m.	"	144 11·5	0·6397	Carboy	Do.	
" 3 -	"	N.E.	3 0	0·0133			
" 3 -	4.30 p.m.	"	5 5·5	0·0237			
" 4 -	9 a.m.	"	62 7	0·2759	Do.	Do.	Snow, hail, and rain.
" 5 -	"	"	19 3	0·0848	Do.	Do.	Do.
" 7 -	"	"	2 7	0·0107			Gauge washed after collection.
" 8 -	"	"	8 2·5	0·0362			
" 9 -	"	"	2 15	0·0129			
" 9 -	4.30 p.m.	N.E.	0 10·5	0·0030			
" 10 -	9 a.m.	N.W.	0 13	0·0036			
" 11	"	"	5 2·5	0·0229			
" 11 -	4.30 p.m.	"	2 8	0·0110			Blackish water.
" 12 -	9 a.m.	"	0 14·5	0·0041			Gauge washed, 7 a.m.
" 13 -	"	"	14 14·5	0·0660	Do.	Do.	Snow water.
" 14 -	"	"	1 3	0·0052			Frost.
" 16 -	"	S.W.	46 4	0·2044	Do.	Do.	
" 17 -	"	"	19 15	0·0881	Do.	Do.	
" 21 -	"	N.W.	7 14	0·0348			
" 22 -	"	S.W.	11 8·5	0·0510			Gauge washed, p.m. Guano sown in an adjoining field.
" 22 -	4.30 p.m.	N.W.	15 1	0·0666			
" 25 -	9 a.m.	"	1 10	0·0072			
" 26 -	4.30 p.m.	N.E.	13 15	0·0616			
" 28 -	9 a.m.	"	0 2	0·0006			
" 31 -	"	"	0 12	0·0033			White frost; gauge washed 29th p.m.
April 2 -	"	S.E.	0 11	0·0030	Carboy*	—	Frost; gauge washed April 1st, p.m.
" 4 -	"	"	0 11	0·0030	" *	—	Frost.
" 5 -	"	"	0 14·5	0·0041	" *	—	Frost; gauge washed 4th p.m.
" 6 -	"	S.W.	0 2	0·0006	" *	—	Frost; ploughing in next field from April 8th to 11th.
" 9 -	4.30 p.m.	"	16 5	0·0721			Gauge washed, 8th a.m.
" 10 -	"	"	6 0	0·0265			Gauge washed, 10th a.m.
" 13 -	9 a.m.	"	1 6	0·0061			Gauge washed, 11th p.m., after ploughing completed.
" 13 -	4.30 p.m.	"	3 3	0·0141			
" 14 -	9 a.m.	N.W.	1 2·5	0·0052	Carboy*		
" 19 -	"	S.E.	1 7	0·0063			White frost.
" 23 -	"	S.W.	5 9	0·0246	Spout }	Sample, April 26, 7 to 8 p.m. }	Gauge washed p.m.
" 27 -	"	N.W.	24 6·5	0·1080			Gauge washed 26th p.m.
" 28 -	"	"	4 14·5	0·0218			Working the experimental turnip land adjoining. The gauge washed when job completed 29th p.m.
" 29 -	4.30 p.m.	S.W.	2 6·5	0·0107			
" 30 -	9 a.m.	N.W.	34 0	0·1503	Carboy	Sample.	
May 1 -	"	"	7 2	0·0315			
" 2 -	"	S.W.	24 10	0·1089	Do.	Do.	Thunder rain.
" 3 -	"	N.W.	3 10	0·0161			
" 4 -	"	"	0 6	0·0017			
" 7 -	"	N.E.	0 6	0·0017			Gauge washed 5th p.m.
" 8 -	"	"	0 15	0·0041			Frost.
" 9 -	"	S.E.	1 0	0·0044			Do.
" 10 -	"	"	0 6·5	0·0019			Do.
" 11 -	"	"	0 5	0·0014			Frost or rain.
" 11 -	3 p.m. }	"	25 3	0·1113	Spout	Do.	Gauge washed about 11.30 a.m., and glass funnel substituted for the ordinary zinc one.
" 11 -	4.30 p.m. }				Do.	Do.	
" 11, 12	4.30 to 9 a.m.	"	83 11·5	0·3701	Carboy	Do.	
" 12 -	4.30 p.m.	S.W.	24 11	0·1091	Do.	Do.	
" 13 -	9 a.m.	"	4 10	0·0205			
" 13 -	4.30 p.m.	"	15 5·5	0·0679	Do.	Do.	

* Mixed together and put into a Winchester quart bottle.

APPENDIX No. 2.

EXPERIMENTS AT ROTHAMSTED.

RAIN and DRAINAGE WATERS collected in BARN FIELD, October 1873.

Dates. 9—10 A.M.	Rain Gauges 1/1000th acre area.		Rain Gauges 1/1000th acre area.		
	Old.	New.	20 inches deep.	40 inches deep.	60 inches deep.
October	Inches.	Inches.	Inches.	Inches.	Inches.
1— 2	0·0135	0·0110	—	—	—*
2— 3	0·0300	0·0290	—	—	—*
3— 4	0·0030	0·0020	—	—	—*
4— 5	0·0180	0·0460	—	—	—*
5— 6	0·0100	0·0020	—	—	—*
6— 7	—	—	—	—	—
7— 8	0·3000	0·2980	—	—	—
8— 9	0·2060	0·1990	—	0·0030	—
9—10	0·1110	0·1120	—	—	—
10—11	0·0050	0·0055	—	—	—
11—12	0·1500	0·1580	—	—	—
12—13	0·7270	0·7290	0·5440	0·4010	—
13—14	0·0970	0·0970	0·0430	0·0465	0·0385
14—15	0·0080	0·0020	0·0140	0·0230	0·0170
15—16	0·0150	0·0125	0·0050	0·0105	0·0070
16—17	0·0115	0·0045	0·0035	0·0060	0·0035
17—18	—	—	0·0025	0·0050	0·0025
18—19	—	—	0·0040	0·0050	0·0030
19—20	0·0600	0·0590	0·0030	0·0045	0·0030
20—21	0·0020	—	0·0025	0·0030	—
21—22	0·3950	0·4120	0·0395	0·0110	0·0060
22—23	0·2240	0·2360	0·0890	0·0450	0·0320
23—24	0·1495	0·1420	0·1880	0·1780	0·1160
24—25	0·0375	0·0355	0·0210	0·0345	0·0285
25—26	0·0115	0·0070	0·0115	0·0185	0·0120†
26—27	0·0115	0·0055	0·0045	0·0100	0·0055†
27—28	0·0110	0·0065	0·0025	0·0080	0·0020†
28—29	0·0090	0·0060	0·0030	0·0065	0·0035†
29—30	0·0090	0·0045	0·0025	0·0055	0·0025
30—31	0·0165	0·0135	0·0020	0·0045	0·0030
31 October—November 1	0·1985	0·2065	0·0065	0·0060	0·0040
Totals - -	2·8400	2·8115	0·9915	0·8350	0·2895
Per cent. drainage to rain according to - - { Old large gauge -			33·9	29·4	10·2
New large „ -			35·3	29·7	10·3
Mean of old and new			35·1	29·6	10·2

* In great part dew. ‡ Chiefly frost, with fog and dew.

EXPERIMENTS AT ROTHAMSTED.

RAIN and DRAINAGE WATERS collected in BARN FIELD.

Monthly Summary for the Harvest Year, September 1st, 1870, to August 31st, 1871.

Months.	Rain Gauge area 1/1000 acre.	Drain Gauges area 1/1000 area.			Proportion of Drainage to Rain.		
		20 inches deep.	40 inches deep.	60 inches deep.	20 inches deep.	40 inches deep.	60 inches deep.
	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.
September - -	2·3047	0·2155	0·0627	0·0177	9·3	2·7	0·8
October(1) - -	4·1335	1·0700	0·4530	0·1829	25·9	10·9	4·4
November(1) - -	1·3978	1·8392	1·4213	0·7054	131·6	101·7	50·5
December - -	2·6489	2·0944	1·9500	1·0721	79·0	73·6	40·5
January - -	1·4541	0·2544	1·1240	0·7236	17·5	77·3	49·8
February - -	1·6302	0·9126	1·1360	3·7063	56·0	69·7	43·3
March - - -	1·5032	0·3370	0·4263	0·2311	22·4	27·7	15·4
April - - -	2·8904	0·8108	0·7974	0·6334	28·0	27 6	21·9
May - - -	0·9554	0·0017	0·0460	0·0350	0·2	4·8	3·7
June - - -	3·8664	1·2941	1·1463	0·8980	33·5	29·7	23·2
July - - -	3·9110	0·8088	0·8493	0·6000	20·7	21·7	15·3
August - - -	0·7699	0·0021	0·0094	0·0021	0·3	1·2	0·3
Total - -	27·4655	9·6406	9·4217	5·8076	35·1	34·3	21·1
(1) Summary of October and November 1870 (deducting rain of October 29–31 from that month, and adding to November).							
October(1) - -	3·1902	1·0700	0·4530	0·1829	33·6	14·2	5·8
November(1) - -	2·3411	1·8392	1·4213	0·7054	78·6	60·8	30·1

EXPERIMENTS AT ROTHAMSTED.

RAIN and DRAINAGE WATERS collected in BARN FIELD.

Monthly Summary for the Harvest Year, September 1st, 1871, to August 31st, 1872.

Months.	Rain Gauge, area $\frac{1}{1000}$ acre.	Drain Gauge area $\frac{1}{1000}$ acre.			Proportion of Drainage to Rain.		
		20 inches deep.	40 inches deep.	60 inches deep.	20 inches deep.	40 inches deep.	60 inches deep.
	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.
September - -	4·7417	1·8210	1·4248	1·0766	38·4	30·0	22·7
October - -	0·1177	0·1177	0·2403	0·2291	10·5	21·5	20·5
November - -	0·6005	0·0688	0·1442	0·3491	11·5	24·0	58·1
December - -	1·4265	0·8175	0·7591	0·4793	57·3	53·2	33·6
January - -	4·5786	3·6413	3·5528	3·1308	79·5	77·6	68·4
February - -	1·5216	0·6413	0·7707	0·5811	42·1	50·6	38·2
March - - -	2·1206	0·9200	0·8249	0·8286	43·4	38·9	39·0
April - - -	1·6089	0·0893	0·1629	0·1266	5·6	10·1	7·8
May - - -	2·9028	0·7776	0·7532	0·6293	26·8	25·9	21·7
June - - -	3·2469	0·7690	0·7405	0·7635	23·7	22·8	23·5
July - - -	2·7212	0·0058	0·0057	0·0157	0·2	0·2	0·6
August - - -	2·2849	0·0180	0·0170	0·0270	0·8	0·7	1·2
Total - -	28·8719	9·6873	9·3951	8·2367	33·6	32·6	28·5

EXPERIMENTS AT ROTHAMSTED.

RAIN and DRAINAGE WATERS collected in BARN FIELD.

Monthly Summary for the Harvest Year, September 1st, 1872, to August 31st, 1873.

Months.	Rain Gauge area $\frac{1}{1000}$ acre.	Drain Gauges area $\frac{1}{1000}$ acre.			Proportion of Drainage to Rain.		
		20 inches deep.	40 inches deep.	60 inches deep.	20 inches deep.	40 inches deep.	60 inches deep.
	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.
September - -	1·3683	0·0039	0·0166	0·0105	0·3	1·2	0·8
October - -	4·6722	3·1344	2·6765	2·0978	67·1	57·3	44·9
November - -	4·0262	2·8539	2·8058	2·4376	70·9	69·7	60·5
December - -	4·1600	3·3753	3·4023	3·0456	81·1	81·8	73·2
January - -	3·7355	2·7686	2·7293	2·7125	74·1	73·0	72·6
February - -	1·3421	0·7078	0·5440	0·5500	52·7	45·3	41·0
March - - -	2·0459	0·8835	1·0171	0·8015	43·2	49·7	39·2
April - - -	0·6392	—	0·0055	0·0047	—	0·9	0·7
May - - -	1·8738	—	—	—	—	—	—
June - - -	1·7579	—	—	—	—	—	—
July - - -	2·3936	0·6248	0·4759	0·3718	26·1	19·9	15·5
August - - -	2·6455	—	0·0018	0·0007	—	0·1	0·1
Total - -	30·6602	14·3522	13·6748	12·0327	46·8	44·6	39·2

APPENDIX No. 3.

ANNUAL REPORTS to the REGISTRAR-GENERAL on the quality of the METROPOLITAN WATER SUPPLY for the YEARS 1868 to 1872, inclusive, by PROFESSOR FRANKLAND, F.R.S

"REPORT on the ANALYSIS of the WATERS supplied by " the METROPOLITAN WATER COMPANIES during " the several MONTHS of the YEAR 1868, by PRO- " FESSOR FRANKLAND, F.R.S., &c.

"*Royal College of Chemistry,*
" SIR, *January 28th*, 1869.

"IN the accompanying tables I have the honour to " submit to you a summary of the results of my analytical " examinations of the waters supplied to the metropolis, " to Edinburgh, and to certain provincial towns during " the year 1868. The analytical methods which I began " to employ in the previous year have been continued, and " I have the satisfaction to find, that an experience extend- " ing to more than 700 different samples of water, from " the most widely different sources in Great Britain, has " only served to confirm my confidence in the new processes " of analysis to which the metropolitan waters have, for " the past two years, been submitted.

" Table A. shows the temperature of the different waters " as delivered from the companies' mains on the days " when the samples were taken.

" Table B. the amount of solid impurity left on the " evaporation of 100,000 parts by weight of each sample.

" Table C. the amount of carbon contained in the organic " matter constituting a portion of this solid impurity (or- " ganic carbon).

" Table D. the amount of nitrogen contained in the or- " ganic matter (organic nitrogen).

" Table E. the amount of ammonia.

" Table F. the amount of nitrogen in the form of nitrates " and nitrites.

" Table G. the total quantity of combined nitrogen.

" Table H. the amount of previous sewage or manure " contamination deduced from the amount of nitrogen in " the form of nitrates, nitrites, and ammonia in excess of " that contained in rain-water in these forms. Nitrogenous " organic matter *of animal origin* (such as that contained " in the liquid and solid excrements of animals), when " present in water or in the soil through which water per- " colates, undergoes gradual oxidation, its nitrogen be- " coming converted into ammonia, nitrous acid, and nitric " acid, which remain in the water and constitute a record " of previous sewage or manure contamination. In under- " going a similar decomposition, *vegetable* organic matter " has never been observed to yield these products. I have " sought for them in vain in scores of samples of water " heavily contaminated with vegetable organic matter and " taken from both springs, rivers, and surface drains. But " rain-water generally contains minute traces of them " amounting in the maximum to ·032 part of nitrogen in " all these forms in 100,000 parts of rain-water. It is " necessary therefore to deduct this amount from that " found in the analysis of a sample of potable water. If " there is any remainder the water stands convicted of " having been in contact with decaying animal matter. " For sanitary purposes all forms of decaying animal sub- " stances may be classed as either sewage or manure " matters, and all waters which have been in contact with " an appreciable quantity of substances belonging to either " category ought, if possible, to be rejected for domestic " supply. To express this kind of contamination in terms " of some known standard, I employ average filtered and " fresh London sewage, which contains 10 parts of nitrogen " in the form of animal organic nitrogen, in 100,000 parts. " Thus a water which yields on analysis 1·032 part of " nitrogen in 100,000, as nitrous acid, nitric acid, and " ammonia, contains, in 100,000 parts the nitrogenous " remains or skeleton of an amount of animal organic " matter equal to that contained in 10,000 parts of average " fresh filtered London sewage. Such a water is therefore " said to have a previous sewage or manure contamination " of 10,000 parts in every 100,000 parts.

" Table I. expresses the hardness of each sample of " water, that is, the number of parts of carbonate of lime " (or its equivalent of other soap-destroying salts) contained " in 100,000 parts of the water.

"Table K. exhibits a comparison of the potable waters " used in London with those supplied to Edinburgh, and " some provincial towns.

"The tables are to be read thus: According to Table A. " the water delivered by the Chelsea Company in January " had a temperature of 7·2° centigrade. Table B. states " that 100,000 lbs. of this water contained 29·2 lbs. of " solid impurity. Table C. informs us, that the organic " matter constituting a portion of this impurity contained " ·353 lb. of carbon; Table D. that this organic matter " also contained ·058 lb. of nitrogen; Table E. that " 100,000 lbs. of this water contained ·001 lb. of ammonia; " Table F. that ·339 lb. of nitrogen existed in the same " weight of water, as nitrates and nitrites; whilst Table G. " shows that it contained a total of ·398 lb. of combined " nitrogen in the different forms of organic matter, nitrates, " nitrites, and ammonia. Table H. states that 100,000 lbs. " of the water had been, after reaching the earth as rain, " contaminated with sewage or manure matter equivalent " to 3,080 lbs. of average filtered London sewage; and " Table I. informs us that every 100,000 lbs. of this water " contained 15·4 lbs. of carbonate of lime or its equivalent " of other hardening salts.

"The past year was distinguished by very heavy floods " in the Thames basin in the winter, followed by excessive " drought in summer. It was therefore to be expected " that the quality of the waters of the Thames and the " Lea would vary between limits unusually wide. An " inspection of the accompanying analytical results shows " this to have been the case. Thus the total solid impurity " in Thames water varied from 22·6 to 38·6 parts in " 100,000, whilst that in the Lea water ranged from 21·2 " to 36 parts in 100,000. In January, the Thames over- " flowed its banks above the point at which the metro- " politan water supply is drawn, and, washing the surfaces " of cultivated fields, mingling with the stagnant ditches " and ponds, and receiving the contents of the suddenly " flushed sewers of Oxford, Reading, and Windsor, be- " came contaminated to an intolerable degree, as evidenced " by the unusually large proportion of organic carbon, " organic nitrogen, and previous sewage contamination " in the waters of those companies which draw from that " river. It is remarkable that the quality of the water " supplied from the Lea by the New River and the East " London companies, was but slightly affected by this " flood.

"On the other hand in the summer months, the waters " of both rivers attained a degree of purity which I have " never before observed in them. The excessive drought " prevented much animal matter, both solid and liquid, " from reaching the streams. The refuse was absorbed " into the thirsty soil, whence it was afterwards partially " dislodged by the heavy rains of October and December.

"It has been frequently asserted, but without proof, " that the noxious organic matter of sewage, when dis- " charged into a river of considerable magnitude is entirely " destroyed by oxidation after a flow of a few miles. " This assertion is erroneous. In his evidence before the " Rivers Pollution Commission, Sir Benjamin Brodie says, " (First Report of Rivers Pollution Commission; Minutes " of Evidence, p. 49,) 'I should say that it was simply im- " ' possible, that the oxidizing power acting on sewage " ' running in mixture with water over a distance of any " ' length, is sufficient to remove its noxious quality. " ' Taking the case of Oxford, if the sewage of Oxford was, " ' in its entirety, discharged into the river Thames, I " ' should say, that we could certainly not trust to the oxi- " ' dizing power to take away the noxious quality of the " ' water before it reaches, say, Teddington. I presume that " ' the sewage could only come in contact with oxygen from " ' the oxygen contained in the water, and also from the " ' oxygen on the surface of the water, and we are aware " ' that ordinary oxygen does not exercise any rapidly " ' oxidizing power on organic matter. I believe that an " ' infinitesimally small quantity of decaying matter is " ' able to produce an injurious effect upon health. " ' Therefore, if a large proportion of organic matter " ' was removed by the process of oxidation, the quantity " ' left might be quite sufficient to be injurious to health. " ' With regard to the oxidation, we know that to destroy " ' organic matter, the most powerful oxidizing agents are " ' required, we must boil it with nitric acid and chloric " ' acid, and the most perfect chemical agents. To think

" 'to get rid of organic matter by exposure to the air for " 'a short time is absurd.'

"My analyses of Thames water delivered in London " during the past year, completely confirm Sir B. Brodie's " opinion. They leave no doubt that, although oxidation " does take place to some extent, a considerable proportion " of the animal organic matter contained in the sewage of " Oxford, Reading, Windsor, &c. reaches Teddington in " an unoxidized condition.

"When compared with the mean analytical results of " 1867, the numbers obtained in 1868, show that the " water delivered by the Chelsea, West Middlesex, Grand " Junction, Lambeth, and East London companies con- " tained slightly less solid impurity in 1868, that delivered " by the New River Company contained a slight excess in " 1868 (·42 part in 100,000), whilst the Southwark and " Kent companies' waters exhibited a considerable in- " crease, amounting to 2·55 and 6·03 parts respectively " in 100,000. With the exception of the Lambeth, all " the companies delivered water containing a greater " maximum amount of solid impurity in 1868 than in " 1867. The maximum amount of solid impurity in the " Lambeth Company's water was the same in both years.

"In every case except one, the mean amount of organic " carbon was much less in the past than in the previous " year, the Southwark Company's water constitutes the " exception: it contained only ·003 part in 100,000 less " in 1868 than in 1867.

"The following table exhibits a comparison of the " previous sewage or manure contamination of the different " waters in the two years:—

	1867.			1868.		
THAMES.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.
Chelsea - - - - -	3230	1570	2107	3451	350	1858
West Middlesex - -	3290	1050	2069	3360	110	1590
Southwark - - -	3290	1130	1953	3130	150	1742
Grand Junction - -	3160	1050	2036	3340	330	1811
Lambeth - - - -	3150	1260	2144	4050	520	1992
OTHER SOURCES.						
New River - - -	3200	1290	2192	3300	140	1754
East London - - -	3280	230	1610	3400	0	1148
Kent - - - -	4820	2890	3619	5330	3540	3842

"The higher numbers in this table occurred in the " winter, the lower in the summer months, the summer " numbers being exceptionally low during the past year, " owing partly to the activity of aquatic vegetation in " purifying the water, and partly to the long drought " which prevented much filth from being washed into the " Thames and Lea for many months.

"The mean hardness of all the waters delivered in London " during 1868 was greater than during 1867, with the " exception of that of the Lambeth Company's water, " which was ·17° less in 1868. On the average the water " delivered to consumers during the past year, was nearly " 1° harder than that supplied during the previous year.

"I have again to call your attention to the very inefficient " filtration of a considerable proportion of the water " supplied to the metropolis. On several occasions the " water of the Lambeth, Southwark, and Chelsea com- " panies was in such a muddy condition as to render it " totally unfit for domestic use. In February last the " Lambeth Company's water was so turbid, that brightly " illuminated objects could not be seen through a stratum " of it 12 inches deep. On account of the great amount " of sewage which commingles with the river waters " supplied to London, their efficient filtration before " delivery is of the utmost importance.

"How far this is actually accomplished by the different " companies, may be seen from the following table, showing " the conditi on of the various samples when drawn from " the companies' mains

—	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
THAMES.				
Chelsea - - - -	7	2	1	2
West Middlesex - -	12	0	0	0
Southwark - - -	1	5	4	2
Grand Junction - -	9	2	1	0
Lambeth - - -	6	1	2	3
OTHER SOURCES.				
New River - - -	10	2	0	0
East London - - -	3	8	1	0
Kent - - - -	8	3	1	0

"Of all the companies supplying London with water, " the West Middlesex stands pre-eminent as regards care- " ful filtration; not even during the early part of the year, " when the Thames was excessively muddy from floods, " did this company on any occasion send out water which " was not perfectly clear and transparent. An inspection " of Table K. shows that in other respects also the West " Middlesex Company's water was superior to that of " every other company drawing from the Thames. It is " thus evident, that with efficient filtration Thames water " can be delivered to consumers clear and transparent, even " in the most unfavourable seasons.

"The New River and Grand Junction companies stand " next in regard to efficient filtration, whilst the Southwark " Company's water is almost invariably sent out in an im- " perfectly filtered condition. Only on one occasion in " the entire year, did I obtain a sample of clear water from " this company's mains, and the same was the case in " 1867.

"During the year, the water delivered by two of the " metropolitan companies exhibited for a time an excep- " tionally high degree of contamination. The first case " was that of the Kent Company's water, which, in Feb- " ruary and March, presented remarkable peculiarities. " In February it contained no less than 59·2 parts of solid " impurity in the 100,000 parts, 42 parts being the maximum " and 39·3 the mean amount observed during the year " 1867. Of the above 59·2 parts 14·7 were common salt, " the occurrence of which in such quantity is difficult to " account for, without assuming contamination from a " tidal river. In March the condition of things was much " worse, for the solid impurity had increased to 70·2 parts, " and the common salt to 23·7 parts. The attention of " the company's engineer was strongly drawn to this ab- " normal state of the water, and in the following month " the excess of impurity disappeared.

"The company's works are situated close to, and on " both sides of the river Ravensbourne, from which a con- " siderable portion of the supply was formerly derived. " The old reservoirs and filter beds, occupying a large area " of land, sunk below the level of the Ravensbourne, are " still retained, and one of them at least is used for the " temporary storage of a portion of the water raised from " the company's wells. The position of these reservoirs " must render it very difficult to exclude percolation from " the foul river, which runs within a few yards of them for " a considerable distance. The remark which you made " in 1866, in reference to a very similar state of things " then existing at the Old Ford station of the East London " Water Company, is applicable with equal force to the " Kent Company's works at Deptford.

"In the interests of the public health, the country has a " right to demand the security which could be afforded by " the filling up, and conversion into valuable land, of these " old reservoirs, which the company admits are of little or " no use.

"The second case of exceptional contamination occurred " to the Southwark Company's water during the months " of August, September, and October. Drawing its supply " from the same source as the other Thames companies, " the Southwark Company delivered during these months " water of a strikingly different composition. A reference " to the accompanying tables, B., C., and D., shows that " the total solid impurity, and (in September and October " the organic constituents, were in very marked excess in

" this as compared with the remaining Thames waters. " The proportion of common salt in Thames water delivered " by the other companies during the three months above mentioned, never exceeded 3·6 lbs. in 100,000 lbs. of " water; whilst in the Southwark Company's water it was " as follows: in August 7·5 lbs., in September 13·6 lbs., " and in October 7·2 lbs. I directed the attention of the " company's engineer to this abnormal condition of the " water, pointing out that the admission of a certain pro- " portion of tidal water of the Thames at Battersea, where " the company's reservoirs are situated close to the river, " would cause the excess of the impurities which I had " observed. The exceptional contamination had been " prevented when the November sample was taken, and it " has not since recurred. These instances show the great " importance of the analytical determination of common " salt, or of chlorine in the London waters. Many of the " companies' reservoirs are placed below high-water mark, " on the banks of tidal rivers, and are, therefore, liable " to percolations from the neighbouring streams, whence " they formerly received their supply of water. I have, " therefore, since October last added determinations of " chlorine to the other analytical results, and propose to " continue them in my future monthly reports.

" I have, &c.

" The Registrar General, &c. &c. &c. E. FRANKLAND."

"TABLE A.—TEMPERATURE (in Centigrade degrees) of the METROPOLITAN WATERS, as delivered from the Companies' Mains.

NAMES OF COMPANIES.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	7·2	7·2	8·3	9·1	13·3	19·1	18·8	19·4	18·9	12·7	7·8	9·4	12·6
West Middlesex - - -	8·0	7·2	7·7	9·4	13·9	18·9	21·1	20·5	18·9	13·3	7·8	10·5	13·1
Southwark - - - -	7·7	7·7	10·0	10·5	14·5	15·8	21·6	20·2	19·4	13·0	8·3	10·8	13·3
Grand Junction - - -	6·6	5·8	7·2	8·3	12·2	18·9	20·0	18·9	17·8	12·1	7·2	10·0	12·1
Lambeth - - - -	7·2	7·2	8·6	9·4	13·6	17·5	19·4	19·4	18·6	12·7	7·2	9·7	12·5
OTHER SOURCES.													
New River - - - -	8·0	6·6	7·5	9·4	14·1	18·2	19·5	20·5	19·1	13·3	7·2	10·3	12·8
East London - - -	6·4	7·2	7·2	9·7	16·1	17·5	19·4	18·9	18·3	12·7	8·3	11·1	12·7
Kent - - - - -	7·2	11·6	10·2	11·6	13·9	13·6	16·0	13·9	13·3	12·2	10·5	11·7	12·1

"TABLE B.—WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	29·2	30·8	29·0	29·4	26·4	29·4	23·0	24·8	25·4	29·2	31·2	33·0	28·40
West Middlesex - - -	31·4	30·0	30·2	30·8	26·4	23·4	22·6	24·0	24·4	25·6	30·2	32·5	27·62
Southwark - - - -	32·2	32·2	32·6	29·4	26·8	30·4	23·8	30·2	38·6	33·6	30·7	32·0	31·04
Grand Junction - - -	31·5	32·6	28·8	29·8	25·6	24·6	23·0	24·2	24·2	29·6	31·2	33·6	28·22
Lambeth - - - -	30·4	31·2	29·4	28·8	26·8	24·8	24·2	25·2	25·4	30·8	31·7	31·8	28·37
OTHER SOURCES.													
New River - - - -	30·2	30·8	27·4	26·4	23·6	24·2	23·6	24·0	24·8	25·8	29·7	31·9	26·86
East London - - -	36·0	34·4	30·0	27·4	24·8	24·4	21·2	21·2	24·2	24·4	31·7	32·2	27·66
Kent - - - - -	44·8	59·2	70·2	41·0	41·2	41·8	40·2	40·2	41·0	40·2	42·0	42·3	45·34

"TABLE C.—ORGANIC CARBON in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	·353	·326	·187	·197	·190	·148	·129	·154	·142	·213	·164	·240	·204
West Middlesex - - -	·271	·357	·136	·178	·178	·152	·129	·133	·108	·205	·144	·239	·186
Southwark - - - -	·485	·324	·264	·216	·195	·192	·128	·111	·194	·273	·157	·269	·234
Grand Junction - - -	·345	·329	·202	·170	·176	·170	·136	·137	·129	·236	·151	·257	·203
Lambeth - - - -	·542	·360	·289	·177	·182	·186	·108	·168	·133	·225	·168	·257	·233
OTHER SOURCES.													
New River - - -	·115	·217	·059	·111	·072	·063	·059	·068	·045	·050	·044	·092	·083
East London - - - -	·147	·272	·118	·099	·115	·113	·092	·115	·041	·061	·094	·096	·114
Kent - - - - -	·064	·081	·093	·049	·053	·053	·022	·046	·014	·034	·042	·042	·049

"TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	·058	·052	·029	·021	·018	·018	·035	·021	·025	·040	·022	·034	·031
West Middlesex - - -	·027	·031	·012	·021	·024	·023	·025	·029	·017	·019	·017	·044	·024
Southwark - - - -	·061	·032	·032	·027	·031	·046	·026	·023	·028	·042	·025	·036	·034
Grand Junction - - -	·031	·055	·027	·014	·020	·020	·024	·020	·016	·039	·024	·045	·028
Lambeth - - - -	·062	·045	·040	·020	·024	·022	·027	·030	·020	·035	·027	·034	·032
OTHER SOURCES.													
New River - - - -	·014	·026	·010	·013	·013	·015	·020	·017	·012	·013	·009	·016	·015
East London - - -	·024	·037	·022	·014	·018	·019	·023	·022	·016	·019	·021	·029	·022
Kent - - - - -	·013	·013	·029	·008	·006	·007	·008	·006	·007	·006	·026	·012	·012

"TABLE E.—AMMONIA in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	·001	·002	·003	·001	·001	·002	·002	·001	·001	·002	·000	·002	·0015
West Middlesex - - -	·001	·002	·001	·001	·001	·001	·002	·000	·001	·001	·000	·001	·0010
Southwark - - - -	·001	·001	·001	·002	·001	·001	·001	·001	·001	·002	·001	·001	·0012
Grand Junction - - -	·000	·001	·001	·001	·002	·001	·001	·001	·001	·002	·000	·001	·0011
Lambeth - - - -	·002	·001	·001	·001	·001	·002	·001	·000	·001	·002	·001	·001	·0012
OTHER SOURCES.													
New River - - - -	·001	·001	·000	·000	·000	·000	·001	·001	·000	·000	·000	·001	·0004
East London - - -	·001	·003	·001	·001	·002	·000	·001	·001	·001	·000	·001	·002	·0012
Kent - - - - -	·001	·001	·001	·001	·000	·000	·001	·000	·000	·000	·000	·000	·0004

"TABLE F.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	·339	·340	·262	·247	·166	·113	·067	·069	·066	·337	·216	·375	·216
West Middlesex - - -	·367	·321	·314	·237	·167	·096	·041	·044	·075	·159	·177	·282	·190
Southwark - - - -	·328	·344	·246	·222	·150	·107	·046	·089	·122	·227	·260	·326	·205
Grand Junction - - -	·366	·343	·278	·230	·161	·068	·066	·064	·088	·267	·297	·317	·212
Lambeth - - - -	·336	·310	·248	·236	·149	·101	·109	·084	·106	·435	·277	·372	·230
OTHER SOURCES.													
New River - - - -	·361	·355	·256	·253	·172	·096	·045	·087	·152	·190	·184	·334	·207
East London - - -	·307	·370	·231	·156	·016	·055	·000	·004	·033	·075	·213	·214	·139
Kent - - - - -	·408	·564	·399	·416	·386	·434	·398	·398	·387	·396	·396	·402	·415

"TABLE G.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

Names of Companies.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	·398	·394	·293	·269	·185	·133	·104	·091	·092	·379	·238	·411	·249
West Middlesex - - -	·395	·354	·327	·259	·192	·120	·068	·073	·093	·179	·194	·327	·215
Southwark - - - -	·385	·377	·279	·251	·182	·154	·073	·113	·151	·271	·286	·363	·240
Grand Junction - - -	·397	·399	·306	·245	·183	·089	·091	·085	·105	·308	·321	·363	·241
Lambeth - - - -	·400	·356	·289	·257	·174	·125	·137	·114	·127	·472	·305	·407	·264
OTHER SOURCES.													
New River - - - -	·376	·382	·266	·266	·185	·111	·066	·105	·164	·203	·193	·351	·222
East London - - -	·332	·410	·254	·171	·036	·074	·024	·027	·050	·094	·235	·245	·163
Kent - - - - -	·422	·578	·429	·425	·392	·441	·407	·404	·394	·402	·422	·414	·427

"TABLE H.—PREVIOUS SEWAGE OR MANURE CONTAMINATION in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - - - -	3080	3100	2320	2160	1350	820	370	380	350	3070	1840	3451	1858
West Middlesex - - -	3360	2910	2830	2060	1360	650	110	120	440	1280	1450	2513	1590
Southwark - - - -	2920	3130	2150	1910	1190	760	150	580	910	1970	2290	2945	1742
Grand Junction - - -	3840	3120	2470	1990	1310	370	350	330	570	2370	2650	2863	1811
Lambeth - - - -	3050	2790	2170	2050	1180	700	780	520	750	4050	2458	3404	1992
OTHER SOURCES.													
New River - - - -	3300	3240	2240	2210	1400	640	140	560	1200	1580	1520	3025	1754
East London - - -	2760	3400	1990	1250	0	230	0	0	20	430	1820	1879	1148
Kent - - - - - -	3770	5330	3680	3850	3540	4020	3670	3660	3550	3700	3640	3700	3842

"TABLE I.—DEGREES of HARDNESS (1 deg. = 1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1868.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	15·4	18·8	18·5	21·1	19·7	19·7	17·4	19·4	18·3	21·6	23·9	23·2	19·75
West Middlesex - -	17·3	18·4	21·4	21·1	18·8	18·4	16·4	19·2	17·4	19·4	24·5	23·7	19·58
Southwark - - -	17·5	19·7	19·7	21·4	18·3	18·2	18·2	18·2	21·4	19·5	24·3	23·2	19·97
Grand Junction - -	19·7	21·1	18·5	21·1	18·0	19·4	17·5	19·2	16·5	20·8	24·8	23·7	20·02
Lambeth - - -	16·5	18·5	18·3	20·8	18·3	18·9	17·5	19·4	18·6	20·6	24·5	22·1	19·50
OTHER SOURCES.													
New River - - -	20·5	20·5	18·5	20·0	17·4	18·2	18·2	19·2	18·0	21·1	28·0	25·4	20·00
East London - -	22·8	20·5	20·5	18·9	16·6	18·2	16·2	15·1	17·9	19·3	23·8	24·8	19·55
Kent - - -	26·2	30·0	32·3	28·5	27·1	27·8	26·2	27·1	27·1	27·0	31·3	30·3	28·41

"TABLE K.—COMPARISON of the LONDON with some NON-METROPOLITAN WATERS.
"The numbers in this Table relate to 100,000 parts of each Water.

NAME OF WATER.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Nitrogen, as Nitrates and Nitrites.	Ammonia.	Total combined Nitrogen.	Previous Sewage or Manure Contamination.	Hardness.	Soap destroyed.
THAMES.									
Chelsea - - -	28·40	·204	·031	·216	·001	·249	1858	19·75	237·00
West Middlesex - -	27·62	·186	·024	·190	·001	·215	1590	19·58	234·96
Southwark - - -	31·04	·234	·034	·205	·001	·240	1742	19·97	239·64
Grand Junction - -	28·22	·203	·028	·212	·001	·241	1811	20·02	240·24
Lambeth - - -	28·37	·233	·032	·230	·001	·264	1992	19·50	234·00
OTHER SOURCES.									
New River - - -	26·86	·083	·015	·207	·000	·222	1754	20·00	240·00
East London - - -	27·66	·114	·022	·139	·001	·163	1148	19·55	234·60
Kent - - - -	45·34	·049	·012	·415	·000	·427	3842	28·41	340·92
NON-METROPOLITAN.									
Glasgow, from Loch Katrine -	3·00	·161	·011	·000	·001	·012	0	0·30	3·60
Lancaster, from Bleasdale Fells	4·58	·129	·022	·000	·001	·023	0	0·87	10·44
Manchester, from Derbyshire hills.	6·20	·183	·009	·025	·006	·039	0	3·70	44·40
Edinburgh { Crawley Burn -	11·28	·187	·031	·000	·001	·032	0	6·08	72·96
Edinburgh { Comiston Water -	22·58	·085	·017	·744	·001	·762	7124	10·36	124·32
Edinburgh { Swanston -	12·70	·378	·059	·000	·001	·060	0	6·22	74·64
Edinburgh { Colinton -	14·10	·203	·042	·000	·000	·042	0	9·17	110·04
Preston, from Longridge Fells	12·44	·236	·031	·000	·006	·036	0	8·94	107·28
Worthing, from Chalk Wells -	32·44	·007	·000	·4204	·002	·4222	3902	24·69	296·28
Carlisle, from River Eden -	13·1	·233	·037	·000	·001	·038	0	8·73	104·76
Norwich - - - -	28·18	·227	·055	·000	·000	·055	0	23·68	284·16
Cockermouth, from River Cocker.	4·62	·069	·022	·000	·001	·023	0	2·16	25·92
Maryport, from River Derwent	6·00	·210	·041	·000	·004	·044	0	3·37	40·44
Keswick, from Skiddaw -	4·34	·132	·024	·000	·001	·025	0	3·37	40·44
Banbury, from River Cherwell	36·60	·382	·054	·2304	·003	·2874	2009	24·15	289·80
Whitehaven, from Ennerdale Lake.	2·16	·042	·017	·000	·000	·017	0	1·45	17·40

"REPORT on the ANALYSIS of the WATERS supplied by the METROPOLITAN WATER COMPANIES during the several MONTHS of the YEAR 1869. By Professor FRANKLAND, F.R.S., &c.

"*Royal College of Chemistry,*
February 10th, 1870.

"SIR,

"IT is now my duty to submit to you a summary of the results of my examinations of the waters supplied to the Metropolis during the year 1869. The analytical methods employed are those which I used in the analysis of these waters during the previous two years, but during the past year I have added a microscopical examination of the sediment deposited from those waters which were delivered to consumers in a turbid condition. In these microscopical examinations my object has not been to enumerate the different species of living organisms found in these sediments, but rather to ascertain how far the processes of filtration adopted by the different companies can be trusted as means for the removal of such organisms from the waters of the Thames and Lea. The zymotic or germ theory of epidemic disease has gained so much ground amongst physiologists as to render it desirable that the character, organised or otherwise, of the suspended matter in all waters which have been exposed to excremental pollution, should be ascertained. As the result of these examinations, it has been found that, with rare exceptions, this suspended matter contains living organisms.

"Table A. shows the temperatures possessed by the different waters as they issued from the companies' mains on the days when the samples were taken. It must be remembered, however, that owing to the intermittent system of supply, which is now nearly peculiar to the Metropolis, the temperatures given in this table are often very different from those at which the waters reach consumers when drawn from cisterns or water butts; thus, in the month of July last, the water delivered by the New River Company had a temperature of 16·4° C. (61·5° Fahr.); but at 11 P.M. of the 27th of July, the water drawn from a cistern supplied by this company marked 21·1° C. (70° Fahr.) on the thermometer. At this temperature even the best water is vapid and unpalatable.

"Table B. exhibits the weight of solid impurity left on the evaporation of 100,000 parts by weight of each sample.

"Table C. the weight of carbon contained in the organic matter constituting a portion of this solid impurity (organic carbon).

"Table D. the weight of nitrogen contained in the same organic matter (organic nitrogen).

"Table E. the weight of ammonia contained in 100,000 parts of the water.

"Table F. the weight of nitrogen in the form of nitrates and nitrites.

"Table G. the total weight of combined nitrogen.

"Table H. the amount of previous sewage or animal contamination deduced from the amount of nitrogen in the form of nitrates, nitrites, and ammonia, in excess of that contained in rain water in these forms.

"Sewage and animal excrementitious matters are believed sometimes to contain organic poisons, which when taken into the stomach are capable of producing in the human subject, such diseases as cholera and typhoid fever.

"These poisons cannot be discovered by chemical analysis. Like the infecting matter of small-pox, cow-pox, and glanders, and the venom of serpents, they can only be detected by their effects upon animals, and more especially upon man.

"Outbreaks of cholera and enteric fever have been frequently traced to the use of drinking water which has been contaminated with sewage or animal excrements containing the peculiar infecting matters of these diseases.

"Water which is subject to excremental pollution may thus at any time become dangerously infected.

"From Table I. showing the proportion of chlorine in each sample of water, we learn that the Mole contains more of this element than the Thames, since the Chelsea and Lambeth companies, whose intake is below the junction of these rivers, exhibit a higher average proportion of chlorine that that present in the water abstracted by the other Thames companies above the junction. Other things being equal, an increase of chlorine in a river water indicates a larger admixture of urine, and we accordingly find in Table H. that the Thames below its junction with the Mole exhibits, on the average, markedly more evidence of previous sewage contamination than does the water abstracted from the Thames above the junction.

"Table K. shows the hardness of each sample of water, that is the number of parts by weight of carbonate of lime (or its equivalent of other soap-destroying compounds) contained in 100,000 parts of the water.

"Finally Table L. contains the annual average of each determination, and thus exhibits the mean results yielded by the water supplied by each company throughout the year.

"Comparing the mean results of the past year with those of 1868, it is seen that the mean temperatures of each company's water were in some cases absolutely identical, and in all the others nearly so.

"All the companies drawing from the Thames delivered water containing a considerably smaller proportion of solid impurity in 1869 than in 1868. On the other hand the water of the New River and East London companies drawn from the Lea exhibit a marked augmentation of solid impurity in 1869 as compared with 1868. The water of the Thames has therefore improved in this respect, whilst that of the Lea has deteriorated. 100,000 parts of the water of the Kent Company contained on the average 4·1 parts of solid impurity less in 1869 than in 1868. Of Thames water, that delivered by the West Middlesex and Lambeth Companies contained on the average less organic carbon, whilst that supplied by the Chelsea, Southwark, and Grand Junction Companies contained more in 1869 than in 1868. Organic nitrogen was present in smaller quantity in the Chelsea and Lambeth Companies' waters in 1869 than in 1868, whilst the West Middlesex, Southwark, and Grand Junction waters contained last year slightly augmented proportions of this element. The water abstracted from the Lea by the New River and East London Companies, and that pumped from deep wells in the chalk by the Kent Company, contained both organic carbon and organic nitrogen in larger proportions in 1869 than in the previous year, nevertheless they still contain markedly smaller proportions of these organic elements than the waters abstracted from the Thames.

"All the river water delivered in London exhibited on the average a higher previous sewage or animal contamination during the past year than in 1868. On the other hand the Kent Company's deep well water afforded less evidence of such previous pollution.

"The mean hardness of every water delivered in London during the year 1869 was greater than during 1868. On the average the water delivered to consumers during the year 1868 was nearly 1° harder than that supplied during the previous year; but in 1869 the average hardness has again increased by nearly 2°.

"The filtration of much of the water supplied to London still continues imperfect, as is seen from the following table showing the condition of the various samples on the twelve occasions when they were drawn from the companies' mains.

—	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
THAMES.				
Chelsea - - - -	7	3	2	0
West Middlesex - -	12	0	0	0
Southwark - - -	4	5	1	2
Grand Junction - -	8	3	1	0
Lambeth - - -	5	3	1	3
OTHER SOURCES.				
New River - - -	12	0	0	0
East London - - -	6	3	2	1
Kent - - - -	12	0	0	0

"The West Middlesex, New River, and Kent Companies did not deliver a single turbid sample during the entire year. In my last annual report to you, the West Middlesex Company alone exhibited this evidence of unvarying efficiency of filtration. It is therefore gratifying to find that this most important feature of water supply is receiving more attention from the water companies.

"In consequence of the frequent instances of turbidity in the water supplied by the Southwark and Vauxhall, and Lambeth Water Companies, the Medical Officer of the Privy Council directed an inquiry to be made into the causes of this turbidity. The investigation was entrusted to Mr. J. Netten Radcliffe, who, in July last, made a valuable and elaborate report on the subject.

" He found the turbidity of the Southwark and Vauxhall " Company's water to be due: 1st, to deficiency of pro- " vision for subsidence; 2nd, insufficiency of area of fil- " tering surface; 3rd, in certain instances, to the admis- " sion of tidal water from the Thames into the reservoirs " at Battersea, either by direct inflow, by soakage, or by " leakage; and 4th, to the admission of unfiltered water " from the subsidence reservoirs into the pump wells. " Mr. Radcliffe adds that, 'it should be required abso- " 'lutely of the company that the communication of the " 'reservoirs at Battersea with the tidal portion of the " 'Thames by means of the old conduit leading to Batter- " 'sea Reach, and the direct communication of the subsi- " 'dence reservoirs with the pumping wells, should be " 'entirely cut off.'

" This company has since improved and extended its " filtering apparatus, and during the four last months of " the year it has supplied perfectly clear and transparent " water.

" As regards the turbidity of the Lambeth Company's " water, Mr. Radcliffe reports that it is due, 1st, to the " objectionable source of supply (the intake being, like " that of the Chelsea Company, below the junction of the " turbid Mole with the Thames); 2nd, to insufficient " provision for subsidence; and 3rd, to insufficient appa- " ratus for filtration.

" No substantial improvement seems to have yet been " made in this company's arrangements, as the water de- " livered in December last was very turbid, and contained " numerous living organisms.

" The following table shows the number of samples (out " of a total of 12) of each company's water in which living " organisms were found during the past year:—

	Number of occasions when living organisms were seen.
" Chelsea - - - -	3
" West Middlesex - - -	0
" Southwark - - -	8
" Grand Junction - - -	4
" Lambeth - - - -	5
" New River - - - -	0
" East London - - -	4
" Kent - - - -	0

" The intermittent system of distribution still prevails " in London, although the Royal Commission on Water " Supply have reported 'that the constant service system " 'ought to be promptly introduced to the farthest extent " 'possible in the supply of the Metropolis.'

" Out of 22 towns in Lancashire and Cheshire, the " water supply of which was recently investigated by the " Rivers Pollution Commission, it appears that there is " only one which is not supplied on the constant system, " and even this exceptional town has a constant supply " for from 12 to 15 hours out of the 24. It is singular " that a system of supply which is elsewhere almost uni- " versal, and which all unite in regarding as an urgent " sanitary necessity in all large towns, should be found so " difficult to introduce into the Metropolis.

" I have, &c.,

" The Registrar General, &c. &c. &c. E. FRANKLAND."

" TABLE A.—TEMPERATURE (in Centigrade degrees) of the METROPOLITAN WATERS, as delivered from the Companies' Mains.

NAMES OF COMPANIES.	1869. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	9·4	9·4	8·0	12·2	13·9	16·7	16·1	18·9	16·1	15·0	10·0	7·5	12·8
West Middlesex - -	7·8	9·7	7·2	12·8	14·2	17·5	16·7	19·7	16·4	15·5	9·6	6·7	12·8
Southwark - - -	8·8	10·6	8·0	18·9	15·0	17·7	17·2	19·7	16·1	16·1	10·4	6·7	13·3
Grand Junction - -	8·3	9·2	6·6	12·5	13·3	16·1	16·1	18·9	15·0	14·7	9·7	6·1	12·4
Lambeth - - -	7·8	9·4	8·0	12·8	13·6	16·7	16·1	19·2	15·8	15·0	9·4	7·2	12·6
OTHER SOURCES.													
New River - - -	7·2	8·6	7·2	11·9	13·9	16·7	16·4	19·4	16·4	15·3	9·4	7·2	12·5
East London - -	9·4	10·0	8·3	13·8	13·6	13·9	15·8	17·8	16·7	15·5	11·0	6·7	12·7
Kent - - -	11·7	11·7	11·1	13·6	13·3	12·8	13·3	15·0	13·3	13·6	11·1	6·7	12·8

" TABLE B.—WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	28·02	26·64	30·14	29·50	27·0	26·8	24·7	25·2	25·24	25·52	27·34	27·6	26·97
West Middlesex - -	29·02	28·78	30·18	28·50	26·5	26·8	25·5	23·9	24·58	23·52	26·94	27·4	26·80
Southwark - - -	30·84	27·86	30·04	28·98	27·1	26·6	25·2	23·9	25·80	25·00	26·20	27·9	27·12
Grand Junction - -	29·46	28·44	30·18	29·20	26·8	28·5	25·8	25·0	25·62	25·44	27·10	27·6	27·43
Lambeth - - -	28·02	27·60	29·56	28·50	27·6	27·7	25·1	25·2	25·00	25·80	28·70	28·6	27·28
OTHER SOURCES.													
New River - - -	30·70	32·00	29·80	28·40	26·6	28·1	27·1	24·0	24·20	25·01	25·90	28·9	27·56
East London - -	35·00	35·92	32·72	30·00	28·9	25·24	22·2	22·5	26·80	27·20	27·60	29·4	28·62
Kent - - -	41·00	42·64	40·80	42·00	41·3	41·26	40·2	41·0	42·30	42·20	40·10	40·1	41·24

" TABLE C.—ORGANIC CARBON in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·458	·475	·181	·132	·266	·140	·116	·125	·087	·178	·147	·289	·216
West Middlesex - -	·377	·336	·185	·118	·165	·196	·116	·088	·089	·116	·145	·139	·172
Southwark - - -	·515	·686	·206	·209	·273	·133	·138	·111	·078	·192	·147	·180	·239
Grand Junction - -	·384	·607	·150	·126	·269	·197	·161	·098	·086	·157	·158	·233	·219
Lambeth - - -	·414	·526	·171	·121	·279	·190	·126	·126	·101	·191	·169	·362	·231
OTHER SOURCES.													
New River - - -	·263	·291	·127	·068	·117	·091	·058	·070	·052	·060	·063	·075	·111
East London - -	·310	·298	·236	·100	·120	·128	·046	·068	·069	·119	·118	·117	·144
Kent - - -	·077	·185	·061	·030	·052	·034	·042	·018	·052	·071	·079	·076	·061

"TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·044	·067	·026	·026	·024	·020	·016	·021	·015	·019	·018	·045	·028
West Middlesex - -	·046	·042	·021	·025	·016	·034	·024	·017	·021	·017	·016	·018	·025
Southwark - - -	·080	·079	·035	·037	·035	·029	·024	·017	·022	·019	·021	·030	·036
Grand Junction - -	·058	·068	·027	·026	·029	·035	·026	·021	·030	·016	·020	·030	·032
Lambeth - - -	·043	·058	·016	·026	·024	·033	·025	·018	·026	·020	·021	·045	·030
OTHER SOURCES.													
New River - - -	·036	·042	·014	·020	·016	·017	·017	·018	·015	·019	·008	·014	·020
East London - -	·036	·029	·025	·030	·023	·022	·028	·016	·023	·016	·021	·016	·024
Kent - - -	·013	·010	·017	·012	·008	·019	·009	·008	·015	·025	·014	·016	·014

"TABLE E.—AMMONIA in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·001	·002	·001	·000	·001	·002	·001	·000	·000	·000	·001	·001	·001
West Middlesex - -	·002	·001	·000	·000	·001	·000	·000	·001	·000	·001	·000	·000	·001
Southwark - - -	·006	·003	·002	·001	·001	·000	·001	·001	·000	·001	·000	·000	·001
Grand Junction - -	·002	·004	·001	·001	·002	·002	·002	·000	·000	·000	·000	·000	·001
Lambeth - - -	·002	·003	·001	·000	·001	·000	·002	·000	·001	·000	·000	·002	·001
OTHER SOURCES.													
New River - - -	·001	·001	·000	·000	·001	·000	·000	·000	·001	·000	·000	·000	·000
East London - -	·002	·001	·001	·001	·001	·000	·000	·000	·000	·000	·000	·000	·001
Kent - - -	·001	·000	·000	·000	·001	·000	·000	·000	·000	·000	·000	·000	·000

"TABLE F.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·364	·230	·387	·280	·216	·164	·177	·157	·163	·113	·240	·351	·237
West Middlesex - -	·362	·286	·186	·250	·176	·169	·172	·121	·108	·155	·224	·260	·206
Southwark - - -	·337	·220	·338	·229	·207	·186	·112	·121	·095	·161	·228	·265	·208
Grand Junction - -	·340	·274	·302	·275	·208	·120	·122	·129	·115	·178	·230	·277	·214
Lambeth - - -	·352	·279	·288	·287	·252	·215	·186	·160	·148	·143	·268	·406	·249
OTHER SOURCES.													
New River - - -	·464	·387	·348	·286	·204	·126	·220	·169	·156	·175	·264	·274	·256
East London - -	·578	·450	·297	·274	·184	·006	·150	·085	·108	·129	·164	·208	·219
Kent - - -	·399	·391	·403	·373	·377	·400	·378	·421	·390	·439	·395	·377	·395

"TABLE G.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·409	·299	·414	·306	·241	·186	·194	·178	·178	·132	·259	·397	·266
West Middlesex - -	·410	·329	·207	·275	·198	·203	·196	·139	·129	·173	·240	·278	·231
Southwark - - -	·422	·302	·375	·267	·248	·215	·137	·139	·117	·181	·249	·295	·245
Grand Junction - -	·400	·345	·330	·302	·239	·157	·150	·150	·145	·194	·250	·307	·247
Lambeth - - -	·397	·340	·305	·313	·277	·248	·213	·178	·175	·163	·289	·453	·279
OTHER SOURCES.													
New River - -	·501	·430	·362	·306	·221	·143	·237	·187	·172	·194	·272	·288	·276
East London -	·616	·480	·323	·305	·208	·028	·178	·101	·131	·145	·185	·224	·244
Kent - - -	·413	·401	·420	·385	·385	·419	·387	·429	·405	·464	·409	·393	·409

"TABLE H.—PREVIOUS SEWAGE OR ANIMAL CONTAMINATION in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	3330	2000	3560	2480	1850	1340	1460	1250	1310	810	2090	3200	2057
West Middlesex - -	3320	2550	1540	2180	1450	1370	1400	900	760	1240	1920	2280	1742
Southwark - - -	3100	1910	3080	1980	1760	1540	810	900	630	1300	1960	2330	1775
Grand Junction - -	3100	2450	2710	2440	1780	900	920	970	830	1460	1980	2450	1832
Lambeth - - -	3220	2500	2570	2550	2210	1830	1560	1280	1170	1110	2360	3760	2177
OTHER SOURCES.													
New River - - -	4330	3560	3160	2540	1730	940	1880	1370	1250	1430	2320	2420	2244
East London - -	5480	4190	2660	2430	1530	0	1180	530	760	970	1320	1760	1901
Kent - -	3680	3590	3710	3410	3450	3680	3460	3890	3580	4070	3630	3450	3633

"TABLE I.—CHLORINE in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	1·886	1·75	1·90	2·00	1·73	1·73	1·60	1·52	1·70	1·65	1·75	1·70	1·74
West Middlesex - -	1·886	1·90	1·80	1·65	1·70	1·70	1·64	1·50	1·73	1·65	1·73	1·52	1·70
Southwark - - -	1·886	1·70	1·75	1·65	1·70	1·68	1·63	1·50	1·78	1·60	1·72	1·58	1·68
Grand Junction - -	1·986	1·65	1·63	1·60	1·71	1·72	1·62	1·57	1·70	1·70	1·80	1·60	1·69
Lambeth - - -	1·837	1·75	1·78	1·85	1·84	1·72	1·69	1·53	1·68	1·65	1·75	1·80	1·74
OTHER SOURCES.													
New River - - -	1·688	1·65	1·63	1·75	1·64	1·46	1·56	1·43	1·60	1·50	1·60	1·38	1·57
East London - -	2·085	2·10	2·10	1·84	1·77	1·72	1·77	1·72	1·74	1·70	1·88	1·70	1·84
Kent - - -	2·433	2·25	2·33	2·45	2·38	2·46	2·40	2·30	2·30	2·80	2·38	2·50	2·41

"TABLE K.—DEGREES OF HARDNESS (1 deg.=1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1869.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	19·81	18·34	23·2	23·21	22·5	21·5	20·3	20·6	21·52	19·19	22·0	19·47	20·97
West Middlesex - -	21·65	21·35	23·5	23·52	22·2	21·4	20·3	20·3	21·22	18·06	20·0	22·62	21·34
Southwark - - -	20·11	20·73	24·8	24·15	23·4	22·1	20·8	20·3	21·52	19·90	20·5	21·75	21·67
Grand Junction - -	21·35	20·61	24·8	24·15	22·9	21·8	20·6	20·3	20·93	18·91	20·8	22·62	21·65
Lambeth - - -	18·34	18·63	25·7	24·15	23·2	22·1	20·3	20·3	21·52	19·76	20·0	18·92	21·08
OTHER SOURCES.													
New River - - -	21·65	24·46	25·0	24·5	24·1	22·0	21·2	20·3	20·93	19·19	20·2	25·25	22·40
East London - -	23·05	26·96	25·7	24·5	24·5	20·0	18·8	20·2	23·01	21·81	20·8	25·25	22·88
Kent - - -	29·26	32·08	31·1	31·8	31·4	29·0	30·9	29·9	29·93	31·19	27·8	29·95	30·36

"TABLE L.—AVERAGES for 1869. The numbers in this Table relate to 100,000 parts of each WATER.

NAMES OF COMPANIES.	Temperature in Centigrade Degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.
THAMES.										
Chelsea - -	12·8	26·97	·216	·028	·001	·237	·266	2057	1·74	20·97
West Middlesex -	12·8	26·80	·172	·025	·001	·206	·231	1742	1·70	21·34
Southwark - -	13·3	27·12	·239	·036	·001	·208	·245	1775	1·68	21·67
Grand Junction -	12·4	27·43	·219	·032	·001	·214	·247	1832	1·69	21·65
Lambeth - -	12·6	27·28	·231	·030	·001	·249	·279	2177	1·74	21·08
OTHER SOURCES.										
New River - -	12·5	27·56	·111	·020	·000	·256	·276	2244	1·57	22·40
East London - -	12·7	28·62	·144	·024	·001	·219	·244	1901	1·84	22·88
Kent - - -	12·3	41·24	·061	·014	·000	·395	·409	3633	2·41	30·36

"REPORT on the ANALYSIS of the WATERS supplied by "the METROPOLITAN WATER COMPANIES during "the several MONTHS of the YEAR 1870. By Pro- "fessor FRANKLAND, D.C.L., F.R.S., &c.

"*Royal College of Chemistry,*
SIR, *January 20th*, 1871.

"I HAVE the honour to place before you, in the accompanying tables, the results of my analyses of the waters supplied to London by the eight metropolitan "companies during the year 1870. The methods of analy- "sis are the same as those employed during the previous "three years, and I have continued to supplement them "by observations on temperature and on clearness and "turbidity, and by microscopic examinations of the sus- "pended matter when the samples drawn from the com- "panies' mains are turbid.

"Table A. shows the temperatures of the different waters "as the latter flowed into the cisterns of consumers on the "days when the samples were taken. The lowest tempe- "rature observed was 3°·9 C. (39° Fahr.), which was "touched by the Grand Junction Company's water on the "1st of February. The highest temperature recorded was "21°·7 C. (71°·1 Fahr.), which was reached by the "East London Company's water on the 12th of August. "At this latter temperature water tastes mawkish and "vapid. It is worthy of remark that, whilst the rest of "the companies were delivering river water during the "months of July and August at a temperature of about "20° C. (68° Fahr.), the Kent Company's deep well "water was, in July 16°. 1 C. (61° Fahr.) and in August "only 15°·5 C. (59°·5 Fahr.).

"Table B. exhibits the weight of solid impurity left on "the evaporation of 100,000 parts of each sample. In my "last annual report I stated that all the companies draw- "ing from the Thames delivered water containing a con- "siderably smaller average proportion of solid impurity "in 1869 than in 1868, but on the other hand the water "of the New River and East London Companies, drawn "from the Lea, contained a larger average proportion in "1869 than in 1868. I have now to report, that without "exception, all the companies delivered during the past "year water containing a markedly smaller average pro- "portion of solid impurity than in 1869. The improvement "is greatest in the Kent Company's water (2·01 parts in "100,000) and least in the Lambeth Company's water (·61 "part in 100,000). This improvement is due partly to the "more careful treatment, storage, and filtration of the waters "and partly to the long continued drought in summer, "during which the Thames and Lea were chiefly supplied "by deep-seated springs. The latter appears to be the "most potent cause in the case of the river waters, since "the winter samples contained a larger proportion of "solid impurity in 1870 than in 1869.

"Table C. shows the weight of carbon contained in the "organic matters present in 100,000 parts of the different "waters. It may be assumed, without much error, that "the *actual weights* of the organic matters (which chemists "cannot yet determine) in the different waters are propor- "tional to the weights of carbon which they contain. The "organic carbon present in different samples of water thus "becomes an approximate expression for the relative "weights of organic matter which those waters contain. "The proportion of organic matter in the metropolitan "waters is more within the control of the seven companies "drawing from the Thames and the Lea than is commonly "supposed. On the one hand, large storage reservoirs "enable them to shut out the rivers when the latter are in "flood and carrying down the scourings of ditches and "sewers and the washings of cultivated fields; moreover "storage in reservoirs before filtration effects a certain "amount of purification by subsidence, which renders the "subsequent purification by filtration considerably greater. "The companies which possess the greatest storage capacity "are the East London, New River, and West Middlesex. "On the other hand the efficient filtration of the impounded "river water has a powerful influence in removing organic "matter, not only when the latter is in suspension but "even when it is actually dissolved in the water; the "degree of purification thus effected is directly proportional "to the thickness of the filtering medium and to the slow- "ness of the passage of the water. The filtering material "(Harwich sand) is expensive, costing, as Mr. Quick, the "Engineer to the Southwark Company, informs me, 10*s.* "per cubic yard, whilst land for filter beds in London is "sometimes unobtainable and always costly; the water "companies are therefore under strong temptation to use "the smallest quantity of filtering material, and to pass "the water at the most rapid rate possible through filter "beds of the smallest area. The necessary consequence "of their yielding to this temptation is the delivery of "turbid and impure water whenever the rivers happen to "be more than usually foul. The companies which possess "the most perfect filtering apparatus are the New River, "West Middlesex, and Southwark. Having up to August "1869 the worst filtering arrangements, the Southwark "and Vauxhall Company has since that date taken its "place amongst the best London companies in this respect; "it has also increased the capacity of its subsidence reser- "voirs, but is still susceptible of improvement in this "direction.

"The average proportion of organic matter (as measured "by organic carbon) in the metropolitan waters drawn "from the Thames and Lea was considerably less in 1870 "than in the previous year. Doubtless this, as well as "the improvement mentioned under table B, is to some "extent due to the long-continued drought; but in the "case of organic matter it is evident that the efforts of the "companies to deliver water of better quality have con- "tributed considerably to the total amelioration, since even "the winter samples of 1870 contrast, as a rule, favourably "with those of 1869. In February 1870 the Southwark "Company's water contained but little more than one "fourth of the proportion of organic matter which was "present in it in February 1869.

"Table D, exhibits the weight of nitrogen contained in "the organic matters found in 100,000 parts of each sam- "ple of water. Organic matters of animal origin, such as "those contained in solid and especially in liquid excre- "ments, are as a rule, more highly nitrogenous than or- "ganic substances of vegetable origin. The presence, "therefore, of any considerable proportion of organic "nitrogen in river waters, known, like those of the Thames "and Lea, to be polluted by sewage, is justly regarded "as throwing grave suspicion upon their quality. Here, "again, as in the case of organic carbon, slow filtration "through large volumes of sand is found to be very effica- "cious in diminishing the proportion of this objectionable "element. It is gratifying, therefore, to note that in this "respect the water of every metropolitan company has, "since my last annual report, undergone a more or less "marked improvement. This amelioration in the case "of the river waters has been greatest in those of the "Southwark and Grand Junction Companies, and it is "now most needed in the waters of the Lambeth and "Chelsea Companies. In regard to smallness of proportion "both of organic carbon and organic nitrogen the Kent "and New River Companies stand pre-eminent.

"Table E. shows the weight of ammonia contained in "100,000 parts of each water.

"Table F. the weight of nitrogen in the form of nitrates "and nitrites.

"Table G. the total weight of combined nitrogen. This "table sums up, as it were, the evidence of *past* and *present* "pollution of the water by nitrogenous organic matter. "This evidence is defective, especially in spring and sum- "mer, because combined nitrogen constitutes an important "portion of the food of both animal and vegetable organ- "isms, and hence the table shows that this item undergoes "great diminution during the months of May, June, July, "August, September, and October, when aquatic life is "most active. In the year 1869 the mean amount of "total combined nitrogen in 100,000 parts of Thames "water was ·254 part, whilst in 1870 it was ·245 part. In "the river Lea water it was in 1869, on the average, ·260 "part and last year ·242 part. There is thus a slight "diminution in both rivers; but if the comparison be "made between the years 1868 and 1870, both distinguished "by very dry and hot summers, it is found that the past "year exhibits a considerable increase in total combined "nitrogen, from which it may be inferred that more sewage "was poured into the Thames and Lea above the com- "panies' in-takes in the year 1870 than in the year 1868.

"Table H. shows, in terms of average London sewage, "the amount of *previous* sewage or animal contamination "deduced from the analytical results contained in tables "E. and F. So far as chemical analysis can show, the "whole of this animal matter had been oxidized and con- "verted into mineral and innocuous compounds at the "time the analyses were made; but there is always a risk "lest some portion (not detectable by chemical or micro- "scopical analysis) of the noxious constituents of the original "animal matters should have escaped that decomposition "which has resolved the remainder into innocuous mineral "compounds. But this evidence of previous contamina- "tion implies much more risk when it occurs in water from "rivers and shallow wells, than when it is met with in the "water of deep wells or of deep-seated springs. In the "case of river water there is a great probability that the "morbific matter sometimes present in animal excreta "will be carried rapidly down the stream, escape decom- "position, and produce disease in those persons who drink

" the water, as the organic matter of sewage undergoes " decomposition very slowly when it is present in running " water. In the case of shallow well water, the decom- " position and oxidation of the organic matter are also very " liable to be incomplete during the rapid passage of " polluted surface water into shallow wells. In the case " of deep well and spring water, however, if the proportion " of previous contamination be small, this risk is very in- " considerable, and may be regarded as *nil* if the direct " access of water from the upper strata be rigidly excluded, " because the excessive filtration to which such water has " been subjected in passing downwards through so great " a thickness of soil or rock, and the rapid oxidation of the " organic matters contained in water when the latter " percolates through a porous and aërated soil, afford a " considerable guarantee that all noxious constituents " have been removed. Thus, whilst the evidence of this " previous contamination in the Thames and Lea waters " exposes them to grave suspicion, I regard the same " evidence—although it is even greater in amount—in the " Kent Company's water as practically of no importance, " if access of drainage from the upper strata be rigidly " excluded from their deep chalk wells. Since the spring " of 1868 my analyses afford no indication of any such " soakage into these wells.

"The causes which I have already described as operating " to reduce the total amount of combined nitrogen must " obiously be active in obliterating from waters the evidence " of their previous contamination with animal matters. " The effect of these agencies is seen very strikingly in the " water delivered by the East London Company, which " being long stored in reservoirs before distribution. " frequently has the evidence of its previous sewage or " animal contamination entirely obliterated (see columns " July, August, and October in the table), although there " can be no doubt that this water is originally more " contaminated than that delivered by the New River " Company.

"Table I. shows the proportion of chlorine contained in " the different samples. This determination is of great " importance in connexion with the metropolitan water " supply, much of which is filtered and stored in reservoirs " on the banks of the tidal reaches of the Thames and " below high-water mark. Any considerable admixture of " the tidal waters of the river with the contents of these " reservoirs is indicated at once by an increase of the pro- " portion of chlorine. It was in this way that I was " enabled to detect and point out in 1868 the admission " of tidal water into the reservoirs of one of the London " companies. The culvert through which this water was " admitted is now about to be abolished. During the " past year no such admixture has been detected in any " of the companies' waters.

"Table K. shows the hardness of each sample of water, " that is the number of parts by weight of carbonate of " lime (or its equivalent of other soap-destroying com- " pounds) contained in 100,000 parts of the waters. The " mean hardness of all the river water delivered in London " during the past year was less than in the year 1869 but " greater than in 1868.

"Finally, Table L. exhibits the annual average of each " determination, and thus puts in juxta-position the mean " results yielded by the water supplied by each company " throughout the year.

"I have still to complain that some of the companies " continue occasionally to supply imperfectly filtered " water. The following table contains the results of my " observations, during the past year, upon the condition " of the different samples on the twelve occasions when " they were drawn from the companies' mains:—

—	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
THAMES.				
Chelsea - - -	8	2	0	2
West Middlesex - -	12	0	0	0
Southwark - - -	11	1	0	0
Grand Junction - -	10	2	0	0
Lambeth - - -	9	0	2	1
OTHER SOURCES.				
New River - - -	12	0	0	0
East London - - -	8	3	0	1
Kent - - - -	12	0	0	0

"The water of the Kent Company, being derived from " deep chalk wells, is not filtered before delivery. The " natural filtration which it receives through the pores of " the chalk is very greatly superior to the best artificial " operation of this kind. Of the remaining companies, " two only, the West Middlesex and the New River, " exhibit perfect filtration, these being the companies " which also (with the Kent Company) stood alone in the " previous year in delivering no imperfectly filtered water. " The Southwark Company, however, has made a near " approach to perfection, having only once delivered im- " perfectly filtered water since August 1869, and on this " single occasion the turbidity was but slight, whereas, " previous to that date, the water delivered by this com- " pany was almost uniformly muddy. With one exception " the remaining companies exhibit considerable improve- " ment; nevertheless the Grand Junction, and especially " the Lambeth Company require to make further con- " siderable improvements in their subsidence and filtration " plant. The Chelsea Company has rather retrograded " than advanced. On four out of twelve occasions during " the past year it was delivering an imperfectly filtered " supply, and on two of these occasions the water was so " muddy as to be entirely unfit for domestic use. The " continuance with perfect impunity of this state of things " would almost lead to the conclusion that the following " clause of the Metropolis Water Act of 1852 had been " repealed. (§ 4.) 'Every Company shall effectually filter " 'all water supplied by them within the Metropolis for " 'domestic use before the same shall pass into the pipes " 'for distribution.' From the nature of the suspended " matter in the East London Company's water, I am led " to the conclusion that the occasional turbidity of this " water is due more to foulness in the mains than to im- " perfect filtration. There is a vicious system of making " the joints of water mains which cannot be too strongly " condemned. A quantity of tow is first forced into the " space between the socket and pipe before the space is " filled up with molten lead. The tow is thus exposed to " the water which afterwards flows through the pipe, " forming a receptacle for dirt and a nidus for the develop- " ment of animal and vegetable organisms, the germs of " which are present even in filtered water. In this way it " is no uncommon thing for the water to pass on its way " to the consumer over several hundreds of square feet of " tow. I am informed by a competent authority that there " is not the least necessity for the use of tow, as the joints " can be readily made with lead alone.

"In the microscopical examinations, living organisms " were found in the Chelsea, Southwark, Grand Junction, " and East London Companies' waters; nevertheless in " this respect also there has been a marked improvement " since the year 1869, as seen from the following table:—

	Number of occasions when living organisms were present. 1870.	1869.
" Chelsea - - - -	2	3
" Southwark - - - -	1	8
" Grand Junction - -	1	4
" Lambeth - - - -	0	5
" East London - - -	3	4

"In neither year were any organisms found in the water " delivered by the West Middlesex, New River, and Kent " Companies.

"During the past year I have investigated Clark's pro- " cess for softening water by the addition of lime, and have " inquired into the application of this process to the waters " supplied to London. By an inspection of the beautiful " waterworks established by Mr. Homersham, C.E., at " Tring and Canterbury, I have convinced myself of the " perfect feasibility of applying this method of purification " to such vast volumes of water as those supplied to the " Metropolis, and by the use of the process for several " months past in softening the Grand Junction Company's " water supplied to my own house, I have demonstrated that " this admirable method (which is now free from all patent " rights) is even more valuable when applied to Thames " water than when used for the softening of chalk spring " waters,—a fact which had previously been doubted and " even denied. Chalk spring water is merely softened by " this process; it contains usually such an infinitesimal " proportion of organic matter as to render it almost in- " capable of improvement in this respect. On the other " hand, Thames water contains a large proportion of " nitrogenous organic matters derived partly from the " drainage of 800,000 people into the river above the in- " take of the water companies; and by the application to " it of Clark's process, not only is it rendered as soft, or " nearly so, as the chalk water similarly treated, but a " considerable proportion of the objectionable organic " matters which it contains in solution are removed by " becoming attached to the precipitate of chalk which is " produced by the addition of slaked lime to the water.

"The great purification from useless and sometimes "noxious matters effected by this process, and the com-"parative efficiency of the method in purifying chalk "spring water on the one hand and Thames water on the "other, are seen from the analytical results contained in "the following table:—

———	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
CHALK SPRING WATERS.				
Caterham water supply before softening	31·08	·020	·006	23·4
Ditto after Clark's process and passage through mains to Redhill	12·60	·064	·007	7·0
Tring water supply from Chiltern Water Company before softening	28·60	·036	·010	26·3
Ditto after Clark's process	8·18	·041	·008	3·2
Canterbury water supply before softening	33·60	·012	·012	26·3
Ditto after Clark's process	11·94	·000	·000	4·9
THAMES WATER.				
Grand Junction Company's water, 1st June 1870	23·98	·144	·018	18·8
Ditto after Clark's process, 19th June 1870	9·26	—	—	3·8
Grand Junction Company's water, 13th July 1870	23·02	·123	·023	17·6
Ditto after Clark's process, 11th July 1870	10·00	·080	·022	3·6
Grand Junction Company's Water, 10th October 1870	24·72	·102	·014	21·8
Ditto after Clark's process, 12th October 1870	9·26	·066	·019	3·4
Grand Junction Company's water, 7th November 1870	28·10	·134	·024	20·3
Ditto after Clark's process, 14th November 1870	11·64	·127	·027	5·0
Grand Junction Company's water, 8th December 1870	28·84	·166	·024	20·6
Ditto after Clark's process, 8th December 1870	14·10	·118	·021	4·9

"It will be seen from the above table that Clark's method "is equally efficacious in softening both kinds of water,— "indeed Thames water is chiefly chalk spring water soiled "by filthy organic impurities,—but besides softening "Thames water, the treatment also removes from it a not "inconsiderable proportion of organic elements, especially "organic carbon. The results in this respect would doubt-"less have been still better had not the conditions of the "experiments necessitated the exposure of the softened "water in a cistern on the roof of a house to all the im-"purities of a London atmosphere for 24 hours.

"In thus recommending the application of Clark's "process to Thames water, I wish it to be distinctly under-"stood that I by no means thereby imply that this water, "even when so treated, is safe and suitable for the supply "of this Metropolis.

"The chalk, oolite, and green-sand formations around "London contain, as I have already pointed out to you, "abundance of water which is of unsurpassed purity after "being submitted to this simple process. From these "sources of cool, colourless, refreshing, and perfectly safe "water it is to be hoped that one day this vast city will "be entirely supplied; for there is enough of the beverage "for London, even when its present population shall have "doubled itself. It is obvious, however, that the majority "of us are doomed to drink Thames water for many years "to come. The East London Company has just laid a "main to bring a further daily supply of 10,000,000 "gallons of this water into the Metropolis, and hence the "importance of improving its quality to the greatest "possible extent.

"The cost of applying this process to the London Water "Supply would be 14*s.* 7*d.* per 1,000,000 gallons. This "includes labour, cost of lime, and interest on capital "required for reservoirs and apparatus.

"The lowest charge to consumers of water in London is "25*l.* per million gallons (the domestic rate is in many "cases much higher), consequently, if the whole of the "additional cost were borne by consumers, it would be "met by an additional charge of 2*l.* 18*s.* 4*d.* per cent., "at the maximum, upon the present water rates. Thus "a consumer whose annual water-rate is at present 5*l.* "per annum, would have to pay for the purified water "5*l.* 2*s.* 11*d.* The vast improvement in the quality of the "water, as shown in the foregoing table, would be cheaply "purchased by this small addition to the usual rate; it is "not, however, impossible that the London Water Com-"panies would themselves be willing to bear a portion of "the expense.

"Finally, in regard to the system of supply, I can only "repeat the remark with which I closed my last annual "report, viz., that, amongst the towns of the United "Kingdom, London stands nearly alone in its continued "adherence to the antiquated and most objectionable "system of intermittent supply. It is to be hoped that "the efforts which are to be made in the coming session "of Parliament to procure a constant service will be suc-"cessful.

"I have, &c.
"The Registrar General, E. FRANKLAND.
"&c. &c. &c.

"TABLE A.—TEMPERATURE (in Centigrade degrees) of the METROPOLITAN WATERS, as delivered from the Companies' Mains.

NAMES OF COMPANIES.	1870.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea	7·8	5·0	7·9	12·2	13·2	16·1	19·4	19·4	16·1	14·4	9·4	5·5	12·2
West Middlesex	7·5	4·4	8·1	12·8	17·2	20·8	20·6	20·5	16·1	15·0	10·0	6·4	13·8
Southwark	8·3	4·7	9·4	13·3	14·7	16·4	21·1	20·4	17·2	15·3	10·6	5·8	13·1
Grand Junction	6·9	3·9	8·3	11·4	12·8	16·1	19·4	19·4	16·4	11·7	10·0	6·7	11·9
Lambeth	7·5	4·2	7·8	12·7	13·6	15·8	19·7	19·4	16·4	14·8	9·4	5·5	12·2
OTHER SOURCES.													
New River	7·2	4·7	6·1	12·5	12·8	17·2	20·3	20·1	16·4	15·3	10·3	6·7	12·5
East London	8·9	5·3	9·4	12·5	13·4	17·2	19·4	21·7	17·2	16·4	10·8	6·1	13·2
Kent	8·1	5·4	8·3	11·7	13·3	13·6	16·1		14·7	13·9	10·8	11·1	11·9

"TABLE B.—WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	29·20	31·62	27·82	25·40	23·96	23·76	22·98	23·80	22·44	23·80	27·96	27·70	25·87
West Middlesex - -	30·00	32·68	30·14	26·18	23·64	23·00	23·22	23·76	22·30	22·86	27·20	27·48	26·04
Southwark - - -	31·26	31·88	30·74	25·00	23·40	23·68	23·00	21·96	22·40	24·00	27·86	29·08	26·19
Grand Junction - -	31·20	32·36	30·66	26·00	24·70	23·98	23·02	23·82	22·96	24·72	28·10	28·84	26·70
Lambeth - - -	28·94	31·30	30·26	26·02	24·50	25·20	23·00	25·98	23·40	24·38	28·18	28·92	26·67
OTHER SOURCES.													
New River - - -	30·58	31·70	32·40	24·90	22·74	21·98	23·18	24·00	22·90	24·60	27·70	30·44	26·43
East London - -	34·52	36·00	34·32	26·26	23·54	22·38	23·46	21·84	21·76	23·72	27·26	32·75	27·28
Kent - - -	38·86	39·74	38·00	40·46	39·76	38·96	39·72	39·10	40·46	38·12	38·24	39·32	39·23

"TABLE C.—ORGANIC CARBON in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·407	·184	·268	·119	·115	·156	·121	·118	·127	·112	·188	·196	·176
West Middlesex - -	·317	·249	·209	·111	·128	·128	·112	·134	·118	·113	·119	·188	·160
Southwark - - -	·384	·180	·191	·121	·117	·164	·127	·121	·109	·137	·136	·139	·160
Grand Junction - -	·385	·180	·200	·123	·135	·144	·123	·133	·110	·102	·134	·166	·161
Lambeth - - -	·390	·184	·197	·135	·137	·163	·142	·149	·114	·133	·224	·218	·182
OTHER SOURCES.													
New River - - -	·215	·173	·126	·055	·063	·083	·119	·056	·048	·044	·040	·023	·087
East London - -	·331	·246	·157	·103	·135	·113	·091	·100	·119	·079	·112	·112	·141
Kent - - -	·065	·073	·063	·043	·069	·027	·044	·027	·043	·044	·021	·035	·046

"TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·039	·019	·029	·021	·020	·021	·025	·024	·030	·022	·030	·023	·025
West Middlesex - -	·030	·024	·024	·017	·019	·025	·024	·029	·024	·015	·017	·030	·023
Southwark - - -	·036	·018	·018	·013	·014	·021	·028	·031	·030	·025	·021	·038	·024
Grand Junction - -	·036	·022	·024	·015	·020	·018	·028	·025	·023	·014	·024	·024	·022
Lambeth - - -	·049	·023	·018	·019	·018	·024	·032	·028	·025	·020	·044	·036	·028
OTHER SOURCES.													
New River - - -	·020	·017	·013	·008	·017	·028	·016	·021	·013	·011	·012	·009	·015
East London - -	·039	·024	·017	·013	·027	·026	·022	·027	·032	·017	·018	·020	·023
Kent - - -	·018	·010	·008	·008	·018	·017	·009	·019	·017	·012	·005	·019	·013

"TABLE E.—AMMONIA in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·001	·000	·001	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
West Middlesex - -	·001	·001	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
Southwark - - -	·001	·001	·000	·000	·000	·000	·000	·000	·000	·000	·002	·000	·000
Grand Junction - -	·000	·001	·000	·000	·000	·000	·000	·000	·000	·001	·000	·000	·000
Lambeth - - -	·001	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
OTHER SOURCES.													
New River - - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
East London - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
Kent - - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000

TABLE F.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·355	·383	·348	·220	·186	·123	·094	·110	·105	·095	·262	·293	·214
West Middlesex - -	·385	·384	·600	·252	·125	·107	·097	·087	·094	·127	·188	·226	·223
Southwark - - -	·354	·379	·379	·213	·183	·109	·105	·077	·086	·110	·218	·259	·206
Grand Junction - -	·372	·385	·560	·220	·184	·123	·091	·078	·082	·128	·235	·271	·227
Lambeth - - -	·364	·380	·498	·216	·185	·132	·106	·118	·105	·141	·228	·278	·229
OTHER SOURCES.													
New River - - -	·388	·350	·629	·247	·189	·108	·140	·146	·145	·154	·181	·286	·247
East London - -	·479	·394	·524	·196	·097	·047	·014	·027	·042	·000	·140	·208	·181
Kent - - -	·426	·380	·750	·445	·394	·410	·466	·482	·478	·359	·446	·336	·447

"TABLE G.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·395	·402	·378	·241	·194	·144	·119	·184	·185	·117	·292	·316	·239
West Middlesex - -	·416	·409	·624	·269	·144	·132	·121	·116	·118	·142	·205	·256	·246
Southwark - - -	·391	·398	·397	·226	·204	·130	·133	·108	·116	·135	·241	·297	·201
Grand Junction - -	·408	·408	·584	·235	·203	·141	·114	·103	·105	·143	·259	·295	·250
Lambeth - - -	·414	·403	·516	·235	·206	·156	·138	·146	·130	·161	·272	·314	·258
OTHER SOURCES.													
New River - - -	·408	·367	·642	·255	·124	·131	·156	·167	·158	·165	·193	·295	·255
East London - -	·518	·418	·541	·209	·412	·073	·036	·054	·074	·017	·158	·228	·228
Kent - - -	·439	·390	·758	·453	·212	·427	·475	·501	·490	·371	·451	·355	·448

"TABLE H.—PREVIOUS SEWAGE or ANIMAL CONTAMINATION in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	3240	3510	3170	1880	1540	910	620	780	730	630	2300	2610	1827
West Middlesex - -	3540	3530	5680	2200	930	750	650	550	620	950	1560	1940	1908
Southwark - - -	3230	3480	3470	1810	1510	770	730	450	540	780	1880	2270	1748
Grand Junction - -	3400	3540	5280	1880	1520	910	590	460	500	970	2030	2390	1956
Lambeth - - -	3330	3380	4660	1840	1530	1000	740	860	730	1090	1960	2460	1973
OTHER SOURCES.													
New River - - -	3560	3180	5970	2150	1570	760	1080	1140	1180	1220	1490	2540	2149
East London - -	4470	3620	4920	1640	650	150	0	0	100	0	1080	1760	1532
Kent - - -	3940	3480	7180	4130	3620	3780	4340	4500	4410	3270	4140	3040	4152

"TABLE I.—CHLORINE in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	1·75	1·60	1·79	1·61	1·73	1·68	1·75	1·55	1·65	1·75	1·80	2·00	1·72
West Middlesex - -	1·80	1·61	1·63	1·63	1·65	1·62	1·70	1·55	1·65	1·70	1·78	1·85	1·68
Southwark - - -	1·82	1·55	1·65	1·62	1·62	1·65	1·70	1·58	1·65	1·65	1·78	1·95	1·68
Grand Junction - -	1·70	1·54	1·65	1·62	1·62	1·65	1·70	1·57	1·55	1·60	1·70	1·92	1·65
Lambeth - - -	1·78	1·50	1·73	1·63	1·60	1·65	1·67	1·62	1·55	1·65	1·85	2·00	1·69
OTHER SOURCES.													
New River - - -	1·50	1·52	1·55	1·50	1·52	1·53	1·58	1·52	1·45	1·50	1·60	1·50	1·52
East London - -	1·90	1·90	1·90	1·71	1·70	1·75	1·80	1·65	1·90	1·80	1·90	1·96	1·82
Kent - - -	2·30	2·30	2·22	3·13	2·35	2·35	2·40	2·38	2·34	2·20	2·30	2·15	2·37

"TABLE K.—DEGREES of HARDNESS (1 deg. = 1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1870. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	20·02	24·08	23·12	20·96	19·36	18·34	18·08	18·34	17·04	21·62	20·60	20·60	20·18
West Middlesex - -	22·32	24·38	23·94	20·40	18·60	17·43	17·82	18·34	17·30	19·28	19·72	20·60	20·01
Southwark - - -	22·04	24·38	25·30	20·96	19·10	18·08	18·08	17·30	17·30	19·42	20·30	21·78	20·34
Grand Junction - -	22·04	24·38	24·21	20·14	19·36	18·84	17·56	18·08	17·82	21·78	20·30	20·60	20·43
Lambeth - - -	19·47	24·38	24·21	21·48	19·36	20·40	18·08	18·84	17·30	18·72	20·30	21·20	20·81
OTHER SOURCES.													
New River - - -	24·96	26·13	24·21	20·14	19·62	17·82	18·34	18·60	17·82	18·58	20·90	22·70	20·82
East London - -	25·84	26·13	26·12	21·48	18·84	16·52	17·04	15·50	16·26	18·14	20·00	24·22	20·51
Kent - - -	29·95	29·36	28·03	28·58	28·32	28·32	27·22	27·22	27·78	5·56	27·24	29·70	28·11

"TABLE L.—AVERAGES for 1870. The numbers in this Table relate to 100,000 parts of each Water.

NAMES OF COMPANIES.	Temperature in Centigrade Degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen, as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.
THAMES.										
Chelsea - - -	12·2	25·87	·176	·025	·000	·214	·239	1827	1·72	20·18
West Middlesex -	13·3	26·04	·160	·023	·000	·223	·246	1908	1·68	20·01
Southwark - -	13·1	26·19	·160	·024	·000	·206	·231	1743	1·68	20·34
Grand Junction -	11·9	26·70	·161	·022	·000	·227	·250	1956	1·65	20·43
Lambeth - -	12·2	26·67	·182	·028	·000	·229	·258	1973	1·69	20·81
OTHER SOURCES.										
New River - -	12·5	26·43	·087	·015	·000	·247	·255	2149	1·52	20·82
East London - -	13·2	27·28	·141	·023	·000	·181	·228	1532	1·82	20·51
Kent - - -	11·9	39·23	·046	·013	·000	·447	·443	4152	2·37	28·11

"REPORT on the ANALYSIS of the WATERS supplied by "the METROPOLITAN WATER COMPANIES during "the several MONTHS of the YEAR 1871. By Professor FRANKLAND, D.C.L., F.R.S., &c.

"*Royal College of Chemistry,*
"SIR, *3rd February* 1872.

"THE accompanying tables place before you in a "condensed form the results of the analytical examina- "tions of the waters supplied to London by the eight "metropolitan companies during the year 1871.

"The sources from which these waters are obtained "continue to be the same, viz.:—

"The Chelsea and Lambeth Companies abstract their "water from the Thames, after it has received the pol- "luted Mole and the sewage of about 600,000 people, in- "cluding the filthy discharges from Oxford, Reading, and "Windsor.

"The West Middlesex, Southwark, and Grand Junction "Companies take their water from the Thames before it "joins the Mole, but below the sewer outfalls of Oxford, "Reading, and Windsor. The sewage of these towns is "not submitted to any process of purification before it is "discharged into the river, and the organic matters which "it contains in solution reach the in-take of the water "companies in almost undiminished quantity, and with "qualities scarcely appreciably changed. The suspended "organic matters of the sewage are to some extent de- "posited for a time in the sluggish reaches of the river, to "be afterwards dislodged and carried down the stream by "the next flood.

"The East London Company receives its supply of "water from the river Lea below the sewer outfalls of "Luton, Hertford, and Ware. Some of this sewage is "treated with lime before it is discharged into the river; "this process, however, only mitigates but does not destroy "the polluting qualities of the offensive liquid. According "to evidence given before the Rivers Pollution Commis- "sion, many privies hang over the river and its affluents. "'Whitwell is a place where nearly all the privies hang "'over the water, and in Welwyn the whole of the sewage "'runs in.' Nevertheless the Lea is much less polluted "than the Thames, and it is therefore to be regretted that "the East London Company has just spent about 500,000*l.* "in conveying water from the Thames to their works in "the Lea Valley. This new conduit will probably be "brought into operation during the year 1872, when a "considerable deterioration in the quality of the water "supplied by this company may be looked for.

"The New River Company obtains its daily supply of "about 23,000,000 gallons from the following sources:—

"Chadwell Spring - -	4,500,000	galls.
"Chalk well at Amwell Hill, "160 feet deep - -	2,400,000	"
"Chalk well at Amwell End, "390 feet deep - -	2,500,000	"
"Chalk well at Hoddesdon -	2,000,000	"
"From the chalk well at Ches- "hunt, 172 feet deep, and "other deep chalk wells more "than - - - -	1,100,000	"
"From the river Lea above the "sewer outfalls of Hertford "and Ware, but below those "of Luton, Whitwell, and "Welwyn - - -	10,500,000	"
	23,000,000	"

"The spring and well water is of excellent quality for "drinking, but too hard for washing; and even the Lea "above the company's intake being largely supplied by "springs from the chalk is, notwithstanding some pollution, "of very much better quality than the Thames at any part of "its course from Lechlade downwards. The proportions "of spring, well, and river water given in the above table "doubtless vary from season to season, but the numbers "stated in the table are believed to show the maximum "proportion of spring and well water which the present "arrangements of the company allow to be supplied.

"The Kent Company obtains its daily supply of about "7,500,000 gallons entirely from deep wells sunk into the "chalk. It is the only metropolitan company which does "not distribute any water from polluted rivers. A few "years ago there were some defects in the arrangements of "this company for dealing with the water between the "pumps and delivery mains, but these appear to have been "remedied, and during the past two years this water has "been uniformly of most excellent quality for drinking "and all domestic purposes except washing, for which it is "too hard, averaging 8° of hardness above that of the "Thames and Lea.

"It thus appears that London is at present daily supplied "(or can be supplied with the existing plant of the com-

" panies) with about the following volumes and qualities " of water :—

" Good wholesome water from " wells and springs in the " chalk - - - -	20,000,000	galls.
" More or less impure water de-" rived from polluted rivers	87,000,000	"
	107,000,000	"

" Unfortunately 12,500,000 gallons of the good and " wholesome water are allowed to mix with 11,000,000 " gallons of polluted river water before distribution to " consumers.

" Table A. shows the temperatures of the different waters " as delivered into consumers' cisterns on the days when " the samples were taken. The following ranges of tem- " perature were observed in the three different kinds of " water supplied to London :—

" Thames water - -	21°·5 C. (70°·7 Fahr.) to 2°·8 C. (37° Fahr.)
" Lea water - - -	22° C. (71°·6 Fahr.) to 3° C. (37°·4 Fahr.)
" Spring and deep well water	15°·5 C. (59°·9 Fahr.) to 9°·4 C. (48°·9 Fahr.)

" It is thus evident that spring and deep well water " preserves a much more uniform temperature than river " water, even after circulation through underground mains. " It is so much cooler in summer that it never tastes " mawkish or vapid, and so much warmer in winter as to " render less frequent the freezing and consequent burst- " ing of water pipes. In August and September, when the " river waters were so warm as to be nauseous to the " palate, the deep well water of the Kent Company tasted " cool and refreshing, whilst in winter it was at least 9°·4 C. " or 17° Fahr. above the freezing point.

" Table B. exhibits the weight of solid impurities left on " the evaporation of 100,000 parts by weight of each sample. " During the years 1869 and 1870, the total solid impurity " present in the Thames water delivered in London under- " went a continuous diminution. I regret to say that this " improvement has not only not been maintained during " the past year, but a considerable augmentation of the " proportion of these impurities has manifested itself in the " water of every company drawing from that river. It was " greatest in the Southwark Company's water (2·16 parts " per 100,000 of water), and least in the Lambeth Com- " pany's water (·87 part in 100,000 parts of water.) In the " East London Company's water taken from the Lea it " amounted to 1·29 part in 100,000, in the New River " water to ·5 part, and in the Kent Company's water to " ·58 part in 100,000 parts of water.

" Tables C. and D. exhibit the proportions of the two " chief elements of the organic matter, or *present* pollution, " actually existing in the different samples at the time of " analysis (organic carbon and organic nitrogen). These " analytical determinations reveal the degree of actual con- " tamination with organic impurity, and as the organic " matters in the Thames and Lea are to a considerable " extent of animal origin these numbers furnish very im- " portant information. They show that all the water ab- " stracted from the Thames and that taken by the East " London Company from the Lea were markedly more " contaminated with organic matter in 1871 than in 1870, " whilst the contamination in the New River and Kent " Companies' waters was not only much smaller in both " years but also considerably less in 1871 than in 1870. " In other words the water derived from rivers has deterio- " rated whilst that derived either wholly or partly from " springs and wells in the chalk has improved in quality.

" As the water delivered by the Kent Company contains " invariably, in a given volume, less organic matter than " that present in any of the remaining metropolitan waters, " it becomes a convenient standard wherewith to compare " the others, and I have therefore drawn out Table E., " which exhibits this comparison for every month in the " year. Taking the proportion of organic elements in a " given volume of the Kent Company's water as unity, the " following are the maximum, minimum, and average " quantities present in each of the other metropolitan " waters :—

	Maximum.	Minimum.	Average.
" Kent - - -	1	1	1
" New River - -	4·5	1·3	2·4
" West Middlesex - -	9·7	2·8	5·8
" East London - -	8·9	4·1	6·1
" Chelsea - -	17·5	3·4	6·3
" Grand Junction -	17·4	3·6	6·5
" Lambeth - -	16·4	3·5	6·6
" Southwark and Vaux- hall - -	15·1	3·7	7·5

" When it is borne in mind that organic matter, especially " such as is of animal origin, is by far the worst form of " impurity occurring in potable water, the above compa- " rison strikingly exhibits the folly of allowing the bright " and sparkling water of the spongy chalk, which is nearly " free from organic matter, to mix with the sewage and " surface drainage of the Thames basin before it is supplied " for the domestic use of the most populous and wealthy " city in the world.

" The Tables F. and G. require no comment.

" Table H. shows the total weight of combined nitrogen. " With a certain unimportant deduction for a minute " amount of this element which is met with, in combination " in rain water, this table sums up the evidence of *past* " and *present* pollution of each water by nitrogenous or- " ganic matter. The evidence is defective, especially in " spring and summer, because combined nitrogen consti- " tutes an important part of the food of both animal and " vegetable organisms, and hence the table shows that " this item undergoes great diminution in the waters of " the Thames and Lea during the months of April, " May, June, July, August, and September, when " aquatic life is most active. In the year 1869 the mean " amount of total combined nitrogen in 100,000 parts of " Thames water was ·254 part, in 1870 it was ·245 part, " and in 1871 it amounted to ·233 part. In the river Lea " water it was in 1869 on the average ·260 part, ·242 part " in 1870, and ·236 part in 1871. There has thus been a " progressive diminution in the proportion of combined " nitrogen in both rivers since the year 1868.

" Table I. shows the *past*, as distinguished from the " *present* pollution of the water by sewage and animal " matters; it gives, in terms of average London sewage, " the amount of previous animal contamination deduced " from the analytical results contained in Tables F. and " G. So far as chemical analysis can show, the whole of " this particular portion of the animal matter had been " oxidized and converted into mineral and innocuous com- " pounds at the time the analyses were made; but there " is always a risk lest some portion (not detectable by " chemical or microscopical analysis) of the noxious con- " stituents of the original animal matters should have " escaped that decomposition which has resolved the re- " mainder into innocuous mineral compounds. But this " evidence of previous contamination implies much more " risk when it occurs in water from rivers and shallow " wells, than when it is met with in the water of deep " wells or of deep-seated springs. In the case of river " water, there is great probability that the morbific matter " sometimes present in animal excreta will be carried rapidly " down the stream, escape decomposition, and produce " disease in those persons who drink the water, as the " organic matter of sewage undergoes decomposition very " slowly when it is present in running water. In the case " of shallow well water, the decomposition and oxidation " of the organic matter are also very liable to be incom- " plete during the rapid passage of polluted surface water " into shallow wells. In the case of deep well and spring " water, however, if the proportion of previous contamina- " tion be small, this risk is very inconsiderable, and may " be regarded as *nil*, if the direct access of water from the " upper strata be rigidly excluded, because the excessive " filtration to which such water has been subjected in " passing downwards through so great a thickness of soil " or rock, and the rapid oxidation of the organic matters " contained in water when the latter percolates through a " porous and aërated soil, afford a considerable guarantee " that all noxious constituents have been removed. Thus, " whilst the evidence of this previous contamination in the " Thames and Lea waters exposes them to grave suspicion " I regard the same evidence—although it is even greater " in amount—in the Kent Company's water as practically " of no importance, if access of drainage from the upper " strata be rigidly excluded from the deep chalk wells. " Since the spring of 1868, my analyses afford no indication " of any such soakage into these wells.

" The causes which I have already described as operating " to reduce the total amount of combined nitrogen must " obviously be active in obliterating from waters the evidence " of their previous contamination with animal matters. " The effect of these agencies is seen very prominently " in the water delivered by the East London Company, " which being long stored in reservoirs before distribution, " sometimes has the evidence of its previous sewage or " animal contamination entirely obliterated (see column " for September in the table), although there can be no " doubt that this water is originally more contaminated " than that delivered by the New River Company. The " numbers in this table are therefore comparative as regards " *evidence* of anterior pollution only, but not as regards " the *absolute quantity* or proportion of that pollution.

"Table K. shows the proportion of chlorine contained "in the different samples. This analytical determination "serves to detect the afflux of water from the tidal reaches "of the Thames into the filter beds and storage reservoirs "of the companies, many of which are situated on the "banks of the tidal reaches of the Thames and Lea below "high-water level. During the past year no such admix- "ture has been detected in any of the companies' waters.

"Table L. exhibits the hardness of each sample of water; "that is, the number of parts by weight of carbonate of "lime (or its equivalent of other soap-destroying com- "pounds) contained in 100,000 parts of the waters. The "mean hardness of all the river water delivered in London "during the past year was about 1½° greater than it was "in 1870. The hardness of the Kent Company's well "water is about 8 degrees greater than that of the river "water. This water is, however, readily softened down "to one third of the hardness of Thames water by the "application to it of Clark's simple and inexpensive "process, which has been long applied to the water supplied "to Caterham, Redhill, Tring, and Canterbury, indeed, "a portion of the supply was successfully so softened "before it was purchased by the Kent Water Company. "During the past year, I continued my experiments upon "the applicability of this process to the three kinds of "water supplied to London. The results of these experi- "ments are embodied in the following table:—

—		Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Hardness.
Thames Water.					
Grand Junction Company's water	16th January 1871	30·24	·177	·042	21·8
Ditto after Clark's process	16th " "	13·84	·153	·019	5·4
Grand Junction Company's water	8th February "	31·70	·241	·040	21·2
Ditto after Clark's process	9th " "	16·58	·178	·021	7·0
Grand Junction Company's water	10th March "	29·56	·145	·016	22·4
Ditto after Clark's process	10th " "	13·70	·114	·021	5·7
Grand Junction Company's water	15th April "	26·22	·109	·022	20·6
Ditto after Clark's process	15th " "	12·18	·080	·013	4·6
Grand Junction Company's water	9th May "	28·26	·248	·033	20·6
Ditto after Clark's process	9th " "	14·34	·181	·033	6·7
Mixture of River Lea Water with Spring and Deep Well Water.					
New River Company's water	14th February 1871	30·60	·135	·018	22·4
Ditto after Clark's process	14th " "	13·76	·100	·011	6·0
Water from Deep Wells in the Chalk.					
Kent Company's water	16th January 1871	40·42	·045	·014	29·1
Ditto after Clark's process	16th " "	19·00	·044	·016	7·0

"These results entirely confirm those upon which I "reported to you a year ago. They show how considerably "the polluted condition of Thames and Lea water can be "mitigated by this method of treatment, and how all the "hard water supplied to the Metropolis, can easily be "rendered soft and suitable for washing and cleansing "purposes.

"Lastly Table M. exhibits the annual average of each "determination, and thus puts in juxta-position the mean "results yielded by the water supplied by each company "throughout the year.

"The qualities of the metropolitan waters referred to in "the above tables are either only partially or not at all "under the control of the companies supplying the waters; "neither are the companies bound by any Act of Parliament "to pay the slightest attention to these qualities. No "matter how filthy the Thames, for instance, may be in "periods of flood, the companies drawing from that river "are free at all times to receive and distribute the water; "but there is one quality, not yet alluded to, which has "been the subject of legislation, viz.:—Clearness or freedom "from suspended impurity. The Metropolis Water Bill "of 1852 enacted (§ 4.) that 'Every Company shall effec- "'tually filter all water supplied by them within the Me- "'tropolis for domestic use before the same shall pass "'into the pipes for distribution.' This provision was "confirmed by the Metropolitan Water Supply Act of last "Session, and an inspector of filter beds has been appointed. "The new Act comes into operation during the present "month. The following table contains the results of my "observations, during the past year, upon the condition of "the different samples, as regards efficient filtration, on the "occasions when they were drawn from the companies' "mains:—

—	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
Thames.				
Chelsea	10	2	1	2
West Middlesex	15	0	0	0
Southwark	9	4	0	0
Grand Junction	11	1	3	0
Lambeth	7	2	3	2
Other Sources.				
New River	13	0	0	0
East London	10	3	0	0
Kent	12	0	0	0

"As the water of the Kent Company is derived from "deep chalk wells, it is not filtered before delivery. The "natural filtration which it receives through the pores of "the chalk is very greatly superior to the best artificial "operation of the kind, and this water has never, for "several years past, shown any signs of turbidity. Of the "remaining companies I have again to report as in the "two previous years, that two only the West Middlesex "and the New River, exhibit efficient filtration, whilst the "Chelsea and Lambeth Companies periodically deliver "water so muddy as to be entirely unfit, on this account "alone, for domestic use.

"The suspended matters in turbid water generally abound "with moving organisms, and my microscopical examina- "tions during the past year have shown the presence of "these organisms in most of the turbid samples delivered "by the Chelsea, Southwark, Grand Junction, Lambeth, "and East London Companies. The following table con- "trasts the condition of the waters in this respect in the "years 1869, 1870, and 1871:—

	Number of occasions when living organisms were found.		
	1869.	1870.	1871.
"West Middlesex	0	0	0
"New River	0	0	0
"Kent	0	0	0
"Southwark	8	1	4
"East London	4	3	3
"Grand Junction	4	1	1
"Lambeth	5	0	4
"Chelsea	3	2	2

"An inspection of the above table shows that the im- "provement regarding the exclusion of animalculæ from "the London waters, which I reported at the end of 1870 "has not been maintained in all cases.

"In conclusion, I trust, that this is the last occasion on "which I shall have to report that the Metropolis is still "supplied with water on the antiquated and universally "condemned intermittent system.

"I have, &c.

"The Registrar General. E. Frankland.

"&c &c. &c.

"TABLE A.—TEMPERATURE (in Centigrade degrees) of the METROPOLITAN WATERS, as delivered from the Companies' Mains.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	5·0	6·9	9·4	10·6	12·5	13·6	17·5	20·0	19·5	13·0	7·3	4·2	11·6
West Middlesex - -	4·7	6·9	9·4	11·9	13·8	14·7	18·5	21·5	20·5	13·3	7·0	4·3	12·2
Southwark - - -	2·8	6·5	10·0	11·7	14·3	13·9	18·5	21·5	21·0	13·3	7·0	3·8	12·0
Grand Junction - -	3·3	5·6	9·4	9·4	11·2	13·6	17·8	20·3	19·0	12·2	6·7	2·9	10·9
Lambeth - - -	4·2	6·4	9·4	10·8	13·0	13·6	17·8	20·5	20·5	13·0	7·0	3·7	11·7
OTHER SOURCES.													
New River - - -	4·4	6·4	9·2	10·6	13·0	15·4	17·7	20·8	20·3	13·8	8·0	4·2	12·0
East London - -	6·7	7·8	10·3	11·7	13·7	13·3	17·0	22·0	20·0	13·3	6·0	3·0	12·1
Kent - - -	9·4	11·1	11·7	12·2	13·3	12·5	15·5	15·0	15·0	13·0	9·7	12·0	12·5

"TABLE B.—WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	28·76	29·06	28·10	26·60	28·60	24·92	25·90	25·56	25·88	28·70	29·80	29·96	27·65
West Middlesex - -	29·42	31·08	29·24	27·84	27·40	24·22	25·26	24·86	25·48	26·80	29·10	29·80	27·54
Southwark - - -	33·72	32·00	29·32	27·74	28·80	26·06	25·20	25·60	23·84	28·30	29·16	30·50	28·35
Grand Junction - -	30·24	31·70	29·56	26·22	28·26	24·66	26·04	25·92	24·20	27·70	29·00	30·30	27·82
Lambeth - - -	27·48	28·94	28·34	26·04	28·60	25·86	26·50	26·40	24·80	27·50	30·00	30·00	27·54
OTHER SOURCES.													
New River - - -	31·04	30·60	27·56	25·74	26·76	23·16	24·76	23·14	24·34	28·60	29·10	28·36	26·93
East London - -	37·40	35·64	32·26	26·08	26·00	24·88	24·30	22·90	20·98	28·84	31·60	32·02	28·57
Kent - - -	40·42	40·36	39·40	40·94	39·38	40·04	39·14	40·00	38·96	38·60	39·94	40·52	39·81

"TABLE C.—ORGANIC CARBON in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·179	·232	·161	·135	·233	·123	·148	·207	·118	·538	·124	·092	·191
West Middlesex - -	·150	·198	·141	·128	·213	·118	·153	·171	·133	·283	·247	·142	·173
Southwark - - -	·193	·243	·161	·209	·264	·192	·182	·196	·128	·451	·317	·104	·220
Grand Junction - -	·177	·241	·145	·109	·248	·141	·185	·194	·130	·500	·116	·101	·191
Lambeth - - -	·203	·321	·140	·116	·244	·141	·158	·185	·142	·498	·125	·093	·197
OTHER SOURCES.													
New River - - -	·066	·135	·064	·057	·113	·043	·049	·065	·042	·123	·046	·033	·070
East London - -	·232	·257	·171	·136	·238	·131	·157	·196	·155	·208	·140	·104	·177
Kent - - -	·045	·026	·026	·018	·023	·019	·021	·038	·027	·022	·028	·015	·026

"TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·028	·031	·031	·022	·037	·016	·018	·031	·027	·058	·025	·027	·029
West Middlesex - -	·015	·035	·018	·018	·033	·010	·017	·017	·019	·048	·050	·028	·026
Southwark - - -	·027	·041	·027	·028	·045	·028	·023	·022	·029	·063	·039	·023	·033
Grand Junction - -	·042	·040	·016	·022	·033	·018	·030	·027	·018	·091	·030	·020	·032
Lambeth - - -	·033	·060	·031	·019	·033	·019	·023	·020	·024	·058	·017	·026	·030
OTHER SOURCES.													
New River - - -	·011	·018	·014	·006	·022	·007	·011	·011	·011	·023	·012	·014	·013
East London - -	·036	·045	·025	·029	·029	·015	·026	·038	·034	·047	·030	·034	·032
Kent - - -	·014	·008	·010	·005	·011	·007	·010	·017	·008	·012	·013	·008	·010

"TABLE E.—PROPORTIONAL AMOUNT of ORGANIC ELEMENTS, that in the Kent Company's Water being taken as 1.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	3·4	7·7	5·3	6·8	7·9	5·4	5·4	4·3	4·1	17·5	3·6	5·2	6·3
West Middlesex - -	2·8	6·9	4·4	6·3	7·2	4·9	5·5	3·4	4·3	9·7	7·2	7·4	5·8
Southwark - - -	3·7	8·4	5·2	10·3	9·1	8·5	6·6	3·9	4·5	15·1	8·7	5·5	7·5
Grand Junction - -	3·7	8·3	4·5	5·7	8·3	6·1	6·9	4·0	4·2	17·4	3·6	5·3	6·5
Lambeth - - -	4·0	11·2	4·7	5·9	8·1	6·2	5·8	3·7	4·7	16·4	3·5	5·2	6·6
OTHER SOURCES.													
New River - - -	1·3	4·5	2·2	2·7	4·0	1·9	1·9	1·4	1·5	4·3	1·4	2·0	2·4
East London - -	4·5	8·9	5·4	7·2	7·9	5·6	5·9	4·3	5·4	7·5	4·1	6·0	6·1
Kent - - -	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0

"TABLE F.—AMMONIA in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·000	·001	·000	·000	·000	·000	·000	·000	·000	·001	·000	·000	·000
West Middlesex - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·001	·000	·000	·000
Southwark - - -	·001	·001	·000	·000	·000	·000	·000	·000	·000	·001	·000	·000	·000
Grand Junction - -	·003	·002	·001	·000	·000	·000	·000	·000	·000	·000	·000	·000	·001
Lambeth - - -	·002	·001	·000	·000	·000	·000	·000	·000	·000	·001	·000	·000	·000
OTHER SOURCES.													
New River - - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000
East London - -	·015	·000	·001	·000	·002	·000	·000	·000	·000	·001	·000	·000	·002
Kent - - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000

"TABLE G.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·331	·355	·264	·179	·207	·141	·151	·089	·074	·220	·192	·259	·205
West Middlesex - -	·311	·391	·273	·183	·198	·129	·075	·062	·074	·180	·218	·257	·196
Southwark - - -	·385	·391	·247	·178	·213	·140	·104	·055	·073	·173	·211	·259	·202
Grand Junction - -	·324	·392	·285	·183	·200	·121	·095	·078	·078	·169	·230	·259	·201
Lambeth - - -	·340	·353	·260	·176	·231	·152	·146	·090	·093	·170	·236	·278	·210
OTHER SOURCES.													
New River - - -	·309	·377	·273	·199	·208	·137	·154	·138	·144	·270	·221	·264	·224
East London - -	·422	·460	·331	·179	·177	·093	·082	·034	·017	·260	·178	·180	·201
Kent - - -	·370	·468	·395	·510	·362	·358	·442	·361	·378	·338	·379	·479	·403

"TABLE H.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1871.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·354	·387	·295	·201	·244	·157	·169	·120	·101	·279	·217	·286	·234
West Middlesex - -	·326	·426	·291	·201	·231	·139	·092	·079	·093	·229	·268	·285	·222
Southwark - - -	·413	·433	·274	·206	·258	·168	·127	·077	·102	·237	·250	·282	·236
Grand Junction - -	·368	·434	·302	·205	·233	·139	·125	·105	·096	·260	·260	·279	·234
Lambeth - - -	·375	·414	·291	·195	·264	·171	·169	·110	·117	·229	·253	·304	·241
OTHER SOURCES.													
New River - - -	·320	·395	·287	·205	·230	·144	·165	·149	·155	·293	·233	·278	·238
East London - -	·470	·505	·357	·208	·208	·108	·108	·072	·051	·308	·208	·214	·235
Kent - - -	·384	·476	·405	·515	·373	·365	·452	·378	·386	·350	·392	·487	·414

"Table I.—Previous Sewage or Animal Contamination in 100,000 parts of the Waters.

Names of Companies.	1871. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - - -	2990	3240	2320	1470	1750	1090	1190	570	420	2490	1600	2270	1783
West Middlesex - -	2790	3590	2410	1510	1660	970	430	300	420	1490	1860	2250	1640
Southwark - - -	3540	3600	2150	1460	1810	1080	720	230	410	1420	1790	2270	1707
Grand Junction - -	2940	3620	2540	1510	1680	890	630	460	460	1370	1980	2270	1696
Lambeth - - -	3100	3220	2280	1440	1990	1200	1140	580	610	1390	2040	2460	1788
Other Sources.													
New River - - -	2770	3450	2410	1670	1760	1050	1220	1060	1120	2380	1890	2320	1925
East London - -	4020	4280	3000	1470	1470	610	500	20	0	2290	1460	1480	1717
Kent - - -	3380	4360	3630	4780	3300	3260	4100	3290	3460	3060	3470	4470	3713

"Table K.—Chlorine in 100,000 parts of the Waters.

Names of Companies.	1871. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - - -	1·95	2·15	2·00	1·73	2·00	1·70	1·70	1·80	1·80	1·85	1·85	1·85	1·86
West Middlesex - -	1·75	2·07	1·90	1·73	1·97	1·74	1·65	1·78	1·73	1·85	1·75	1·80	1·81
Southwark - - -	1·98	2·13	1·93	1·73	1·97	1·74	1·70	1·75	1·75	1·70	1·75	1·90	1·92
Grand Junction - -	1·85	2·10	2·00	1·73	1·97	1·70	1·70	1·75	1·75	1·80	1·75	1·70	1·82
Lambeth - - -	2·02	2·18	1·98	1·73	1·97	1·70	1·70	1·75	1·80	1.85	1·70	1·85	1·85
Other Sources.													
New River - - -	1·56	1·77	1·73	1·55	1·65	1·57	1·60	1·62	1·62	1·60	1·65	1·65	1·63
East London - -	2·20	2·30	2·20	2·10	2·16	1·90	2·00	2·10	2·12	2·15	2·00	2·15	2·12
Kent - - -	2·38	2·53	2·40	2·49	2·40	2·30	2·40	2·50	2·45	2·43	2·35	2·50	2·43

"Table L.—Degrees of Hardness (1 deg. = 1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the Waters.

Names of Companies.	1871. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - - -	20·00	19·42	20·90	20·00	20·60	20·00	21·48	21·48	20·90	22·40	23·30	24·80	21·27
West Middlesex - -	21·78	20·90	22·38	20·60	20·30	20·90	20·60	20·30	20·00	20·00	23·30	24·80	21·32
Southwark - - -	23·90	21·20	22·08	20·60	20·60	20·90	21·20	20·60	20·90	21·20	23·60	24·80	21·80
Grand Junction - -	21·78	21·20	22·38	20·60	20·60	20·00	21·78	22·08	20·00	20·60	23·60	24·80	21·62
Lambeth - - -	19·14	18·28	21·48	20·60	20·60	20·90	20·60	22·08	20·60	22·10	24·20	24·20	21·28
Other Sources.													
New River - - -	24·52	22·38	22·08	20·60	20·60	19·72	20·60	19·72	20·00	22·70	24·20	28·60	21·73
East London - -	26·64	24·22	22·38	19·14	18·58	20·30	19·72	18·28	18·28	22·70	26·00	25·70	21·83
Kent - - -	29·08	29·38	29·08	29·08	28·76	29·70	29·70	30·96	30·00	30·00	29·70	30·30	29·65

"Table M.—Averages for 1871. The numbers in this Table relate to 100,000 parts of each Water.

Names of Companies.	Temperature in Centigrade Degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.	Proportional Amount of organic Elements, that in the Kent Company's Water being taken as 1.
Thames.											
Chelsea - -	11·6	27·65	·191	·029	·000	·205	·234	1783	1·86	21·27	6·3
West Middlesex -	12·2	27·54	·173	·026	·000	·196	·222	1640	1·81	21·32	5·8
Southwark - -	12·0	28·35	·220	·033	·000	·202	·236	1707	1·92	21·80	7·5
Grand Junction -	10·9	27·82	·191	·032	·001	·201	·234	1696	1·82	21·62	6·5
Lambeth - -	11·7	27·54	·197	·030	·000	·210	·241	1788	1·85	21·23	6·6
Other Sources.											
New River - -	12·0	26·93	·070	·013	·000	·224	·238	1925	1·63	21·73	2·4
East London - -	12·1	28·57	·177	·032	·002	·201	·235	1717	2·12	21·83	6·1
Kent - -	12·5	39·81	·026	·010	·000	·414	·408	3713	2·43	29·65	1·0

"**Report** on the **Analysis** of the **Waters** supplied by "the **Metropolitan Water Companies** during the "several **Months** of the **Year** 1872. By Professor "**Frankland**, D.C.L., F.R.S., &c.

"*Royal College of Chemistry,*
"Sir, *10th February* 1873.

"I have now to submit to you in the accompanying Tables a condensed summary of the results of the analytical examinations of the waters supplied to London by the eight Metropolitan Companies during the year 1872. These chemical examinations have been, as heretofore, supplemented by observations of temperature and of clearness or turbidity, and in all cases where the turbid waters deposited any sediment, the latter has been subjected to microscopic examination.

"Table A. shows the temperatures of the different supplies delivered into the consumers' cisterns on the days when the samples were taken. The following ranges of temperature were observed in the three different kinds of water supplied to London:—

"The temperature of Thames water delivered by the Chelsea, West Middlesex, Grand Junction, Southwark, and Lambeth Companies varied from 5°·2 C. (41°·3 Fahr.) in January, to 21°·5 C. (70°·7 Fahr.) in August.

"The temperature of river Lea water delivered by the New River and East London Companies fluctuated from 6° C. (42°·8 Fahr.) in January, to 21° C. (69°·8 Fahr.) in August.

"The temperature of the deep well water supplied by the Kent Company ranged from 14°·5 C. (58°·1 Fahr.) in September, to 11°·5 C. (52°·7 Fahr.) in October.

"Thus whilst the temperature of the river waters varied by as much as 16°·3 C. (29°·3 Fahr.) being mawkish and vapid in summer and in danger of freezing in winter, the temperature of the deep well water of the Kent Company ranged only through 3° C. (5°·4 Fahr.). It was cool and refreshing in summer, and far removed from the freezing point in winter.

"Table B. gives the weight of solid impurities left on the evaporation of 100,000 parts by weight of each sample. These impurities consist of a great variety of substances, some of them very objectionable and occasionally dangerous, others comparatively harmless. The very objectionable impurities, which are organic and constitute but a small proportion of the substances present in any of the waters, are contained in much larger proportions in the water drawn from the Thames and Lea than in that supplied, from wells sunk in the chalk, by the Kent Company. In my last report (for 1871) I pointed out that these impurities had undergone in Thames water a considerable augmentation as compared with their amount in previous years, and I have now to add that this augmentation has been to a considerable extent, but not entirely, maintained. In the river Lea water the proportion of solid impurities has slightly increased, whilst in the deep well water it has very slightly diminished. In the Thames water these impurities were at their maximum in March and their minimum in September. In the Lea water the maximum was reached in January and the minimum in July. In the deep well water the maximum was attained in June and the minimum in April.

"Tables C. and D. give the proportions of polluting organic matters which actually existed in the waters at the time when they were submitted to analysis, these organic matters being here represented by their two chief elements, carbon and nitrogen. As the organic substances with which the Thames and Lea are polluted are to a large extent of animal origin, these tables convey very important information respecting the probable wholesomeness of the water taken from these rivers in different years and at different seasons of the same year. A comparison of these tables with those which I furnished to you a year ago shows that the waters of the Thames and Lea, which I described in my last annual report as markedly more contaminated with organic matter in 1871 than in 1870, have suffered a still more serious deterioration during the past year. The maximum of organic pollution during the past year was exhibited in the months of January, February, March, April, November, and December. During these months the Thames water as delivered in London was, even when well filtered, rarely in a condition fit for domestic supply. The removal of the in-take of the Lambeth Company from Thames Ditton to a position between Hampton and Sunbury has hitherto been attended with no amelioration of the quality of the water delivered by that company.

"The water delivered by the Kent Company from deep wells in the chalk has again been distinguished throughout the entire year for its comparative freedom from organic matters. I have, therefore, again used it as a standard of comparison in Table E. Taking the proportion of organic elements in a given volume of the Kent Company's water as unity, the following are the maximum, minimum, and average quantities present in each of the other metropolitan waters during the past year:—

	Maximum.	Minimum.	Average.
"Kent - - -	1	1	1
"New River - -	7·2	1·1	3·1
"East London - -	9·0	2·9	4·7
"West Middlesex -	11·1	2·5	5·2
"Southwark - -	14·0	3·0	5·9
"Chelsea - -	17·0	3·1	6·2
"Grand Junction -	16·1	2·9	6·4
"Lambeth - -	18·4	3·1	6·6

"The Thames and Lea start from their chief sources as free from organic matter as the deep well water supplied by the Kent Company, but, in the winter months especially, they become much polluted with sewage and the washings of manured fields before they reach the in-takes of the respective water companies.

"Tables F. and G. require no explanation.

"Table H. exhibits the total weight of combined nitrogen, and thus, after a certain small correction for the combined nitrogen which is contained in rain water, this table sums up the evidence of *past* and *present* pollution of each water by nitrogenous organic matter. This evidence is defective in the spring and summer months, because combined nitrogen forms an important part of the food of both animal and vegetable organisms which exist abundantly in the Thames and Lea during those months; any useful comparison therefore of this evidence of pollution must be confined to the autumn and winter months. Taking this basis of comparison, it appears that the mean amount of total combined nitrogen in 100,000 parts of Thames water in the six winter months of 1871 was ·31 part, whilst in the six winter months of 1872 it was ·30 part. In 100,000 parts of the water of the Lea it was ·322 part in 1871 and ·317 part in 1872. In 100,000 parts of the Kent Company's water it was ·414 part in 1871 and ·454 part in 1872, but in this case the comparison is made upon the whole year, because as the Kent Company's water is derived from deep wells, it is not subjected to the influence of aquatic animals and vegetables. These comparative numbers, taken in connexion with those contained in Tables C. and D., appear to indicate that there is a slight reduction in the total nitrogenous matters, but a very considerable increase in the polluting or organic matters contained in the waters of the Thames and Lea. The proportion of such actual polluting matters in the Kent Company's water is always an insignificant one.

"Table I. shows the *past* as distinguished from the *present* pollution of the water by sewage and animal matters; it gives in terms of average London sewage the amount of previous animal contamination deduced from the analytical results contained in Tables F. and G. The causes which I have already described as operating to reduce the total combined nitrogen in Table H. must obviously be equally active in obliterating from waters the evidence of their previous contamination with animal matters. The operation of these causes is seen with especial distinctness in the water delivered by the East London Company, which is known to receive more sewage than that abstracted from the same river (Lea) by the New River Company; nevertheless in September the East London Company's water retained evidence of only 60 parts of previous sewage or animal contamination in 100,000 parts, whilst the New River Company's water showed at the same date no less than 1,390 parts of previous contamination. The water of the first-named company had been stored before filtration in reservoirs during about eighteen days, whilst that of the latter company was transmitted at once from the river to the filters. It will be seen from an inspection of the table that in the months of January February, March, and December, when aquatic life is dormant, and when consequently the disturbing causes mentioned above are but slightly, if at all, in operation, the evidence of previous sewage or animal contamination exhibited by the East London Company's water is always in excess of that found in the New River Company's water.

"Table K. shows the proportion of chlorine contained in the water supplied by the different companies. The chief use of this analytical determination is the detection of the access of water from the tidal reaches of the Thames and Lea to the filters and storage reservoirs of the water companies, many of which are situated on the banks of polluted tidal streams. No such admixture has been detected in any of the companies' waters during the past year.

"Table L. exhibits the hardness of each sample of water; " that is, the number of parts by weight of carbonate of " lime (or its equivalent of other soap-destroying com- " pounds) contained in 100,000 parts of the waters. The " mean hardness of all the Thames water delivered in " London during the past year was 20°·7 or parts in " 100,000, whereas in 1871 it was 21°·4 or parts in " 100,000, of water. The mean hardness of the river Lea " was 21°·8 in 1871, and 21°·9 in 1872. The mean hard- " ness of the Kent Company's water was 29°·6 in 1871, and " 29°·2 in 1872. This Company's water is, therefore, " about 8° harder than Thames water, and 7° harder than " the Lea water. The use of any of these waters for wash- " ing entails in the metropolis a yearly loss of vast quantities " of soap or soda which are required to soften them before " they can be rendered available for washing. These " waters can be reduced to nearly the necessary degree of " softness by lime, which in some other towns is used to " soften similar waters before they are supplied to the " public. Lime costs about 8*d.* per cwt. when used on a " large scale; the public have to pay for soap 2*l.* 6*s.* 6*d.* " per cwt., and for soda 12*s.* 2*d.* per cwt. But the cost of " softening water by soap and soda is relatively much " higher than appears from this comparison, because to " obtain a softening effect equal to that produced by " 1 cwt. of lime it is necessary to use 17¾ cwts. of soap, " costing 41*l.* 5*s.*, or 5 cwts. of soda, costing 3*l.* Such a " wanton waste of the public money is nothing less than a " municipal scandal.

"Lastly, Table M. gives the annual average of each " determination, and thus brings into juxta-position the " mean results yielded by the water supplied by each " company throughout the year.

"The following table exhibits the degree of efficiency " with which each company drawing from the Thames and " Lea has filtered the water which it has distributed " during the past year:—

—	Number of Occasions when clear and transparent.	Number of Occasions when slightly turbid.	Number of Occasions when turbid.	Number of Occasions when very turbid.
Thames.				
Chelsea - - -	8	4	1	0
West Middlesex - -	12	0	0	0
Southwark - - -	6	7	0	0
Grand Junction - -	8	3	2	0
Lambeth - - -	6	3	3	1
Other Sources.				
New River - - -	12	1*	0	0
East London - - -	12	1†	0	0
Kent - - - -	12	0	0	0

* "White suspended particles." † "Floating particles."

"The water of the Kent Company is derived from deep " wells in the chalk, and is always clear and transparent " without any filtration. Of the remaining companies, " only three, the West Middlesex, New River, and East " London, exhibit satisfactory filtration; the subsidence " reservoirs and filter beds of all the others are quite in- " adequate to deal with Thames water when the river is " in flood. The filtration of the Chelsea Company has " improved since the year 1871, but that of the Lambeth " Company continues to be very inefficient, and this com- " pany still maintains its pre-eminence for the distribution " of muddy water.

"On being submitted to microscopical examination the " suspended matters in turbid water are almost invariably " found to contain large numbers of living and moving " organisms; thus during the past year the turbid samples " delivered by the Lambeth Company contained such " organisms on six occasions, those delivered by the " Chelsea and Grand Junction Companies on three and " two occasions respectively, and those drawn from " the mains of the Southwark and East London Com- " panies each on one occasion. These microscopic obser- " vations have now been continued for four years, and " during the whole of this time I have in no instance " observed living matter in the water distributed by the " West Middlesex, New River, and Kent Companies. " The following table contrasts the condition of the waters " in this respect in the years 1869, 1870, 1871, and 1872:—

	Number of occasions when living organisms were found.			
	1869.	1870.	1871.	1872.
" West Middlesex -	0	0	0	0
" New River - -	0	0	0	0
" Kent - -	0	0	0	0
" Chelsea - -	3	2	2	3
" Southwark - -	8	1	4	1
" Grand Junction -	4	1	1	2
" Lambeth - -	5	0	4	6
" East London -	4	3	3	1

"In conclusion, I have to report that, notwithstanding " the Act of Parliament passed in the session of 1871 for " the purpose of securing a constant supply of water to the " Metropolis, the delivery still continues on the old and " vicious intermittent plan. This system places great " obstacles in the way of our Fire Brigade, and renders the " water actually drawn from the butts of consumers much " more impure than the samples submitted by me to " analysis, which are drawn directly from the mains of the " respective companies,

" I have, &c.

" The Registrar General, E. Frankland.
" &c. &c. &c.

"Table A.—Temperature (in Centigrade degrees) of the Metropolitan Waters, as delivered from the Companies' Mains.

Names of Companies.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Thames.													
Chelsea - - -	6·0	8·5	10·0	10·0	13·4	14·7	18·3	21·0	17·9	10·0	11·0	8·3	12·4
West Middlesex - -	6·3	8·0	10·8	10·3	13·9	15·5	20·6	21·5	19·3	10·8	11·3	9·0	13·1
Southwark - - -	5·8	8·7	11·7	11·0	14·6	15·8	20·6	21·0	19·5	10·5	11·7	8·7	13·3
Grand Junction - -	5·2	7·8	10·0	10·0	13·3	14·4	18·9	20·0	18·3	8·9	10·3	8·0	12·1
Lambeth - - -	5·3	8·0	10·3	10·5	13·4	15·2	19·4	20·5	18·0	10·3	11·0	8·2	12·5
Other Sources.													
New River - - -	6·0	8·0	9·7	10·0	13·5	15·0	18·9	21·0	18·5	10·8	10·8	8·7	12·6
East London - -	6·0	7·0	10·3	9·7	14·7	14·4	18·9	20·5	18·8	9·0	8·0	8·0	12·1
Kent - - -	13·0	13·0	13·3	12·2	13·3	14·2	14·4	14·3	14·5	11·5	12·0	12·2	13·2

"TABLE B.—WEIGHT of SOLID IMPURITY in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	26·70	27·82	30·60	25·42	25·14	25·28	27·20	24·74	25·52	24·86	27·50	26·66	26·45
West Middlesex - -	29·70	28·72	30·54	26·24	27·64	26·08	27·00	23·68	25·34	25·94	26·84	23·74	27·20
Southwark - - -	29·04	30·02	31·44	26·14	26·62	24·92	25·92	23·82	22·86	24·78	27·88	29·52	26·91
Grand Junction - -	29·90	29·44	30·62	26·56	25·80	25·40	27·48	25·70	25·64	25·06	28·44	28·52	27·38
Lambeth - - -	28·20	30·76	30·68	26·92	26·38	26·22	27·70	25·82	24·16	24·90	29·56	29·12	27·53
OTHER SOURCES.													
New River - - -	32·30	30·90	29·22	25·98	24·78	24·28	25·30	25·34	24·96	26·30	30·26	30·74	27·53
East London - -	36·32	34·62	34·32	26·98	25·50	27·76	23·60	25·10	24·14	25·44	28·80	35·16	28·98
Kent - - -	39·88	41·24	40·20	36·64	39·10	42·44	38·90	39·30	38·10	39·14	38·38	42·16	39·62

"TABLE C.—ORGANIC CARBON in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·433	·358	·230	·401	·149	·150	·184	·193	·134	·163	·365	·411	·264
West Middlesex - -	·280	·338	·214	·257	·154	·147	·191	·179	·159	·126	·343	·366	·229
Southwark - - -	·359	·324	·208	·385	·164	·166	·183	·189	·144	·149	·401	·434	·259
Grand Junction - -	·408	·376	·318	·385	·158	·184	·179	·181	·139	·144	·388	·433	·274
Lambeth - - -	·486	·372	·198	·463	·156	·168	·177	·196	·129	·153	·414	·463	·281
OTHER SOURCES.													
New River - - -	·127	·239	·089	·167	·107	·093	·077	·093	·064	·059	·235	·275	·135
East London - -	·212	·289	·179	·165	·145	·144	·143	·157	·130	·145	·332	·402	·204
Kent - - -	·018	·018	·046	·051	·041	·050	·046	·044	·040	·052	·053	·058	·043

"TABLE D.—ORGANIC NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·084	·056	·027	·064	·021	·032	·042	·017	·013	·019	·067	·044	·040
West Middlesex - -	·063	·048	·030	·035	·022	·023	·027	·020	·013	·016	·041	·037	·031
Southwark - - -	·074	·061	·034	·061	·024	·029	·027	·026	·013	·018	·048	·052	·039
Grand Junction - -	·092	·060	·052	·066	·027	·033	·026	·017	·013	·020	·051	·063	·043
Lambeth - - -	·084	·068	·036	·062	·022	·028	·047	·025	·012	·025	·051	·061	·043
OTHER SOURCES.													
New River - - -	·039	·042	·010	·031	·010	·015	·015	·010	·006	·008	·029	·050	·022
East London - -	·046	·061	·334	·023	·027	·026	·032	·024	·011	·027	·046	·058	·035
Kent - - -	·013	·021	·008	·010	·008	·009	·013	·010	·005	·004	·008	·011	·010

"TABLE E.—PROPORTIONAL AMOUNT of ORGANIC ELEMENTS, that in the Kent Company's Water being taken as 1.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	17·0	10·6	4·8	7·6	3·5	3·1	3·8	3·9	3·2	3·2	7·1	6·6	6·2
West Middlesex - -	11·1	9·9	4·5	4·8	3·6	2·9	3·7	3·7	3·8	2·5	6·3	5·8	5·2
Southwark - - -	14·0	9·8	4·5	7·3	3·8	3·3	3·6	4·0	3·5	3·0	7·4	7·0	5·9
Grand Junction - -	16·1	11·2	6·8	7·4	3·8	3·7	3·5	3·7	3·4	2·9	7·2	7·2	6·4
Lambeth - - -	18·4	11·3	4·2	8·6	3·6	3·3	3·8	4·1	3·1	3·2	7·6	7·6	6·6
OTHER SOURCES.													
New River - - -	5·3	7·2	1·8	3·2	2·4	1·8	1·6	1·9	1·6	1·1	4·3	4·7	3·1
East London - -	8·3	9·0	3·9	3·1	3·5	2·9	3·0	3·4	3·1	3·1	6·2	6·7	4·7
Kent - - -	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0

"TABLE F.—AMMONIA in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·000	·001	·002	·001	·000	·000	·000	·000	·000	·001	·001	·005	·001
West Middlesex - -	·000	·001	·001	·001	·000	·001	·001	·000	·000	·000	·001	·005	·001
Southwark - - -	·001	·001	·000	·000	·000	·000	·000	·000	·001	·001	·001	·001	·001
Grand Junction - -	·001	·001	·001	·000	·000	·001	·001	·000	.000	·000	·001	·002	·001
Lambeth - - -	·001	·001	·001	·002	·000	·000	·001	·000	·001	·001	·001	·002	·001
OTHER SOURCES.													
New River - - -	·001	·001	·001	·000	·000	·000	·000	·000	·000	·000	·001	·003	·001
East London - -	·001	·003	·001	·001	·000	·000	·000	·000	·000	·001	·002	·002	·001
Kent - - -	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000	·000

"TABLE G.—NITROGEN as NITRATES and NITRITES in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·249	·296	·302	·216	·234	·187	·123	·153	·160	·199	·237	·221	·215
West Middlesex - -	·289	·286	·282	·232	·269	·158	·064	·090	·128	·178	·218	·211	·200
Southwark - - -	·320	·275	·289	·206	·230	·157	·067	·109	·108	·170	·212	·199	·195
Grand Junction - -	·308	·286	·289	·204	·227	·162	·155	·106	·081	·181	·216	·213	·202
Lambeth - - -	·301	·322	·306	·202	·235	·209	·150	·148	·117	·184	·234	·224	·219
OTHER SOURCES.													
New River - - -	·274	·358	·284	·279	·213	·182	·160	·149	·171	·187	·294	·290	·237
East London - -	·337	·392	·299	·187	·155	·187	·062	·063	·088	·105	·194	·321	·191
Kent - - -	·480	·494	·518	·366	·367	·510	·340	·532	·492	·394	·401	·439	·444

"TABLE H.—TOTAL combined NITROGEN in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872. Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	·383	·353	·331	·281	·255	·219	·165	·170	·178	·219	·305	·269	·256
West Middlesex - -	·352	·335	·318	·268	·291	·182	·092	·110	·141	·194	·255	·252	·232
Southwark - - -	·395	·337	·323	·267	·254	·186	·094	·135	·122	·189	·261	·252	·235
Grand Junction - -	·401	·347	·342	·270	·254	·196	·182	·128	·094	201	·268	·278	·247
Lambeth - - -	·386	·391	·343	·266	·257	·237	·198	·173	·130	·210	·286	·287	·264
OTHER SOURCES.													
New River - - -	·314	·401	·295	·310	·223	·197	·175	·159	·177	·195	·324	·343	·259
East London - -	·384	·455	·334	·211	·182	·163	·094	·087	·049	·133	·242	·381	·226
Kent - - -	·493	·515	·526	·376	·375	·519	·353	·542	·497	·398	·409	·450	·454

"TABLE I.—PREVIOUS SEWAGE OR ANIMAL CONTAMINATION in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872. Jan.	Feb.	March.	April.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	2170	2650	2720	1850	2020	1550	910	1210	1280	1680	2060	1930	1836
West Middlesex - -	2570	2550	2510	2010	2370	1270	330	580	960	1460	1820	1830	1689
Southwark - - -	2890	2440	2570	1740	1980	1250	350	770	770	1390	1810	1680	1637
Grand Junction - -	2770	2550	2580	1720	1950	1310	1240	740	490	1490	1850	1830	1710
Lambeth - - -	2700	2910	2750	1720	2030	1770	1190	1160	860	1530	2030	1940	1882
OTHER SOURCES.													
New River - - -	2480	3270	2530	2470	1810	1500	1280	1170	1390	1550	2630	2600	2052
East London - -	3060	3620	2680	1560	1230	1050	300	310	60	740	1640	2910	1597
Kent - - -	4480	4620	4860	3340	3350	4780	3080	5000	4600	3620	3690	4070	4124

"TABLE K.—CHLORINE in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	2·10	2·15	1·90	2·10	1·90	2·10	1·95	1·75	1·70	1·75	2·00	2·00	1·95
West Middlesex - -	1·95	2·05	1·75	1·70	1·85	1·70	1·90	1·75	1·65	1·70	1·90	1·95	1·82
Southwark - - -	2·00	2·05	1·85	1·70	1·80	1·80	1·85	1·75	1·70	1·70	1·90	1·90	1·83
Grand Junction - -	2·05	1·90	1·75	1·65	1·80	1·85	1·75	1·75	1·70	1·70	1·90	1·90	1·81
Lambeth - - -	1·85	2·05	1·92	1·70	1·90	1·95	1·70	1·70	1·70	1·75	1·90	1·80	1·83
OTHER SOURCES.													
New River - - -	1·65	1·95	1·75	1·75	1·90	1·70	1·85	1·60	1·60	1·60	1·55	1·65	1·71
East London - -	2·35	2·45	2·35	2·05	2·30	2·05	2·35	2·05	2·05	2·00	2·10	1·95	2·17
Kent - - -	2·50	2·95	2·55	2·60	2·60	2·60	2·70	2·45	2·50	2·30	2·45	2·40	2·55

"TABLE L.—DEGREES of HARDNESS (1 deg.=1 part of carbonate of lime, or its equivalent,) in 100,000 parts of the WATERS.

NAMES OF COMPANIES.	1872.												
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
THAMES.													
Chelsea - - -	19·1	21·5	28·3	20·3	21·2	21·2	22·4	18·9	20·0	19·7	18·0	19·7	20·4
West Middlesex - -	23·3	22·1	23·0	21·2	22·1	22·1	21·8	18·0	18·6	19·1	18·9	20·0	20·8
Southwark - - -	21·8	21·5	24·8	20·6	22·1	21·2	20·9	18·0	18·3	19·1	19·1	20·0	20·6
Grand Junction - -	20·3	21·5	24·2	20·6	22·1	21·2	22·1	20·3	19·7	19·4	19·1	20·0	20·9
Lambeth - - -	20·0	22·7	23·0	21·2	22·7	21·2	28·0	19·1	18·6	18·9	19·7	20·3	20·9
OTHER SOURCES.													
New River - - -	25·7	24·2	24·5	21·5	21·2	21·8	21·5	19·7	18·9	20·6	22·4	22·7	22·1
East London - -	27·2	26·0	26·6	21·8	21·2	22·1	19·4	17·7	17·7	19·4	20·0	23·0	21·8
Kent - - -	30·3	30·0	30·3	29·1	29·7	30·0	29·7	27·9	27·9	27·5	28·2	29·4	29·2

"TABLE M.—AVERAGES for 1872. The numbers in this Table relate to 100,000 parts of each WATER.

NAMES OF COMPANIES.	Temperature in Centigrade Degrees.	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen, as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination. (Estimated.)	Chlorine.	Total Hardness.	Proportional Amount of organic Elements, that in the Kent Company's Water being taken as 1.
THAMES.											
Chelsea - -	12·4	26·45	·264	·040	·001	·215	·256	1836	1·95	20·4	6·2
West Middlesex -	13·1	27·20	·229	·031	·001	·200	·232	1689	1·82	20·8	5·2
Southwark - -	13·3	26·91	·259	·039	·001	·195	·235	1637	1·83	20·6	5·9
Grand Junction -	12·1	27·38	·274	·043	·001	·202	·247	1710	1·81	20·9	6·4
Lambeth - -	12·5	27·53	·281	·043	·001	·219	·264	1882	1·83	20·9	6·6
OTHER SOURCES.											
New River - -	12·6	27·53	·135	·022	·001	·237	·259	2052	1·71	22·1	3·1
East London - -	12·1	28·98	·204	·035	·001	·191	·226	1597	2·17	21·8	4·7
Kent - - -	13·2	39·62	·043	·010	·000	·444	·454	4124	2·55	25·2	1·0

APPENDIX No. 4.

TYPHUS UND TRINKWASSER.

(From "Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege," Vol. VI., page 154.)

In Lausen,* einem Dorfe im Canton Basel, in dem seit Menschengedenken nie eine Typhusepidemie geherrscht hatte und seit vielen Jahren kein einziger Typhusfall vorgekommen war, brach plötzlich im August 1872 eine einen grossen Theil der Bevölkerung ergreifende und in den verschiedensten Theilen und Häusergruppen zugleich auftretende Typhusepidemie aus. Lausen ist ein ziemlich wohlhabender Ort von 90 Häusern mit 780 Einwohnern und hat sehr gute Gesundheitsverhältnisse; epidemische Krankheiten kommen hier nie vor; von Cholera war es vollkommen verschont, als alle umliegenden Orte sie hatten; mithin ein der Entwickelung einer Typhusepidemie sehr ungünstiges Gebiet. Nun liegt ½ Stunde südlich von Lausen ein kleines Nebenthal, das durch einen Berg, den Stockhalden, von Lausen getrennte Fürlerthal, und in ihm, auf einem ganz allein liegenden Gehöft erkrankte am 10. Juni ein Bauer, der in der letzten Zeit vielfach herumgereist war, an einem sehr schweren Abdominaltyphus, den er offenbar von der Reise mitgebracht hatte. In den nächsten zwei Monaten kamen noch drei weitere Fälle auf demselben Hofe vor, ein Mädchen, das über vier Wochen nach dem Bauer am 10. Juli erkrankte, und die Frau des Bauers und dessen siebenjähriges Söhnchen, die erst im August Typhus bekamen. In Lausen wusste man von den Erkrankungen auf diesem ausser allem Verkehr liegenden Gehöfte gar nichts, als plötzlich am 7. August zehn Einwohner an Typhus erkrankten und in weiteren neun Tagen die Zahl der Typhuskranken bereits 57 betrug. Die Zahl der Erkrankungen in den ersten vier Wochen betrug über 100 (über 12 Proc. der Bevölkerung) und im Ganzen bis zum Schlusse der Epidemie, Ende October, 130=17 Proc.

* Beiträge zur Entstehungsgeschichte des Typhus und zur Trinkwasserlehre. Von Dr. A. Hägler in Basel. Deutsches Archiv f. Klin. Med. XI., auch als Separatabdruck. Leipzig, Vogel, 1873, 31 S.

der Bevölkerung; und ausserdem erkrankten noch 14 Kinder anderwärts, besonders in Basel, die in Lausen ihre Sommerferien zugebracht und hier die Krankheit erworben hatten. Betrachtet man nun die Vertheilung der Typhusfälle auf die einzelnen Häuser, so ergiebt sich, dass diese von Aufang an ziemlich gleichmässig über das ganze Dorf vertheilt vorgekommen sind, nur mit gänzlicher Verschonung derjenigen Häuser, die ihr Wasser aus eigenen Brunnen und nicht aus der öffentlichen Brunnenleitung erhielten. Somit lag der Gedanke nahe, dass diese Brunnenleitung mit dem Ausbruche der Typhusepidemie in einem Zusammenhange stehe. Das Wasser dieser Leitung kommt aus einer Quelle am Fusse der dem Dorfe zugekehrten Seite des Stockhalden, wird hier in eine gemauerte, gut gedeckte und fest verschlossene Brunnenkammer gefasst und von hier in guten Teichen nach vier Brunnen des Ortes geleitet. Nur sechs Häuser haben und benutzen ihre eigenen Brunnen und in ihnen kam kein Typhusfall vor, wohl aber in fast allen anderen Häusern des Ortes, die auf die öffentlichen Brunnen angewiesen waren.

Man war deshalb gewiss berechtigt, die Wasserleitung als die Verbreiterin des Typhusgiftes anzusehen, um so mehr da sich eine andere Ursache nicht auffinden liess. Namentlich ist eine Verbreitung von dem Gehöft etwa durch die Luft undenkbarist, besonders da selbst einzelne noch im Fürlerthal gelegene Häuser, obschon sie mit dem inficirten auf demselben kleinen Plateau und mehr thalwärts liegen, frei von der Krankheit blieben, ein Beweis dafür, das das inficirte Fürlerhaus weder durch das Bodenwasser, noch viel weinger durch die Luft nach dem ungleich entfernter gelegenen und durch einen langen Hügel getrennten Dorfe die Infection verbreitet haben konnte.

Um nun aber einen ganz sicheren Beweis zu liefern, dass die Quelle die Ursache der Typhusverbreitung war, kam es darauf an, den Nachweis zu liefern, wo und wie die Quelle inficirt worden ist. Und dieser Nachweis ist gelungen, wenn auch nicht durch die Darstellung des noch unbekannten Typhuskeims, so doch durch den Weg und die Art, wie die Infection stattgefunden hat. Schon von früher bestand die Ansicht, dass die Quelle unterirdisch vom Fürlerbach gespeist werde, und da dieser Bach um Fürlerhof, in dem der erste Typhusfall vorkam, vorbeifloss und es nachgewiesen werden konnte, dass der Bach hier wiederholt mit den Entleerungen der Kranken verunreinigt worden war, sowohl durch den mit dem Bache in directer Verbindung stehenden Abtritt und Düngerhaufen, als auch durch Ausgiessen von Nachttöpfen in den Bach, Auswaschen beschmutzter Wäsche in ihm, &c., so musste ein sicherer Nachweis der Verbindung zwischen Quelle und Fürlerbach allerdings für die Verbreitung des Typhusgiftes durch die Quelle sehr beweisend sein. Dieser Nachweis nun wurde in folgender Weise mit absoluter Sicherheit geliefert. Schon vor zehn Jahren hatte man eine Beobachtung gemacht, die den Zusammenhang der Lausener Quellen mit dem Fürlerbach zeigte. Damals hatte sich ohne bekannten Grund, etwas unterhalb des Fürlerhofs dicht neben dem Bache, durch Einfallen der oberflächlichen Erdschicht ein Loch von circa 8 Fuss Tiefe und 3 Fuss Durchmesser gebildet, in dessen Tiefe eine mässige Menge klaren Wassers floss. In dieses Loch leitete man zum Versuch den ganzen kleinen Bach, der in dessen Tiefe lustig weiter floss und nirgends mehr zum Vorschein kam. Nach ein oder zwei Stunden aber strömten die bei dem trockenen Wetter sehr wasserarmen Brunnen in Lausen über von reichlichem anfangs trübem, später wieder hellem Wasser, und dies hielt an bis der Fürlerbach wieder in sein Bett eingedämmt und das Loch zugeworfen war. Aber noch jetzt, wenn die unterhalb dieser Stelle gelegenen Wiesen mit dem Fürlerwasser berieselt werden, fangen nach wenigen Stunden die Lausener Brunnen an stärker zu laufen. Wie alle Jahre mehrmals so wurde auch in diesem Sommer von Mitte bis ende Juli die Bewässurung der Fürlerwiesen vorgenommen, und zwar dieses Jahr mit dem durch faulige Typhusdejectionen verunreinigten Fürlerwasser; das reichlichere Brunnenwasser in Lausen ward anfangs wieder trüb und geschmackwidrig und circa drei Wochen nach dem Beginne der Wiesenbewässerung traten plötzlich in Lausen massenhafte Typhusfälle auf. Um der Sache näher auf den Grund zu kommen, stellte man nun folgende Versuche an, leider erst ende August, zu einer Zeit, als das Wasser der Lausener Brunnen wieder klar war. Man grub das oben erwähnte, vor zehn Jahren zugeschüttete Loch wieder auf und leitete das Bächlein wieder hinein: drei Stunden später gaben die Lausener Brunnen in derselben Zeit die doppelte Menge Wassers wie vor der Einleitung. Nun goss man zu dem Bächlein in das Loch circa 2,000 Maass Soole (=circa 18 Centner Kochsalz) und sehr bald konnte man in den Lausener Brunnen eine anfangs geringe, später bedeutend zunehmende und schliesslich sehr starke Chlorreaction nachweisen, und die Menge der festen Bestandtheile im Wasser vermehrte sich auf das Dreifache vie vor Einbringung der Soole. Einen weiteren Versuch machte man mit 50 Centner Mehl, die fein aufgerührt ebenfalls zu dem Bächlein in das Loch geschüttet wurden; aber weder nahm hierduf die Menge der festen Bestandtheile in den Lausener Brunnen zu, noch liess sich die geringste Spur von Stärkekörnern in ihnen nachwiesen. Hiermit ist also der sichere Nachweis geliefert, dass zwischen dem Ueberlaufe des Fürlerbächleins und den Lausener Brunnen ein Zusammenhang existirt, welcher durch den Versuch mit der Soole auf das Schlagendste constatirt ist, und dass das Wasser durch Spalten durchsickert, die fein genug sind, um grössere feste Stoffe, wie Stärkemehlkörner, nicht durchzulassen. Hiermit ist aber immer nicht gesagt, dass die Filtration eine so vollkommene ist, dass nicht "kleine organisirte " mikroskopische oder nicht einmal unter dem Mikroskope " sichtbare Körperchen (Typhuskeime?) ihren Durchgang " finden könnten." Es war somit festgestellt: (1.) dass das Fürlerbächlein in Fürlen durch Typhusdejectionen verunreinigt worden war; (2.) dass dasselbe, während der Zeit dieser Verunreinigung zur Wässerung der Fürlenwiesen benutzt, durch die Schutthalden des Stockhaldenhügels hindurch die Lausener Quelle vermehrt hatte; und (3.) dass die nachher bald auftretende Lausener Epidemie nur durch den Genuss dieses Quellwassers entstanden sein konnte.

Als Schlusssätze stellt Verfasser die folgenden auf: (1.) " Die Epidemie von Abdominaltyphus in Lausen war die " Folge von Infection des Trinkwassers durch Typhus" dejectionen, welche, gemischt mit Dünger und Abtritt" jauche und anderen faulenden organischen Stoffen, in " Fürlen dem Thalbache beigemengt worden waren." Da durch Dünger- und Abtrittjauche verunreinigte Wasser des Fürlerbachs in ähnlicher Weise schon wiederholt von den Bewohnern Lausens getrunken worden war, ohne dass Typhus entstand und eine Typhusepidemie erst auftrat, nachdem jener Jauche Typhusdejectionen beigemengt waren, so lehrt dies; (2.) "Zur Erzeugung des " Abdominaltyphus bedarf es also eines specifischen, von " Typhuskranken entstammenden Giftes; andere putride " Stoffe und faulende organische Substanzen, so wenig" stens Abtritt, und Düngerjauche denen Typhusdejec" tionen nicht beigemischt sind, vermögen nicht Typhus " zu erzeugen." (3.) " Das Typhusgift verliert seine " Wirkungsfähigkeit auch dann nicht, oder wenigstens " nicht immer, wenn es mit Wasser vermengt und mit " diesem unterirdisch durch Schutthalden und Geröllschich" ten geschwemmt wird; es ist also die gewöhnliche " Bodenfiltration keine Garantie für Desinfection des " Wassers."

Bei letzterem Satze verweilt Verfasser noch etwas länger, um auf einen bisher noch zu wenig beachteten Punkt aufmerksam zu machen, nämlich auf den ziemlich allgemein verbreiteten Glauben, dass eine aus dem Berge entspringende, also durch die Bodenschichten filtrirte Quelle rein von organischen und organisirten Infectionsstoffen sein müsse. Die Quelle am Fusse des bewaldeten Stockhalden hat das Gegentheil bewiesen, und das Erdfilter, das fein genug ist, Stärkemehlkörnchen zurückzuhalten, hat die Typhuskeime durchgelassen. Aehnlich wie die Lausener, mögen sich aber noch viele Quellen verhalten. Aus dem Jura z. B. sind eine grosse Menge solcher Quellen bekannt, die ein Wasser liefern, das weiter oben schon zu Tage war, verwendet worden war und das Abwasser höher gelegener Wohnungen in sich aufgenommen hatte. Auch von einer der Quellen der Baseler Wasserleitung, welche direct ans dem Berge entspringt, ist nachgewiesen, dass sie zum weitaus grössten Theil ein weiter oben verschwundener Bach ist, der an zwei Dörfern vorbeigeflossen und die Mühlen dieser Dörfer getrieben hat. Dieser Bach könnte für Basel einmal gerade so verhängnissvoll werden, wie der Fürlerbach für Lausen, und jedenfalls fordert uns die Lausener Epidemie dringend auf, die rückwärts gelegenen Quellengebiete unserer Trinkwasser genau zu überwachen.

Wie wichtig dieser Punkt ist, das lehrt uns eine ebenfalls in neuester Zeit beobachtete Typhusepidemie in der der Zusammenhang der Erkrankungen mit dem Trinkwasser, wenn auch nicht so schlagend wie in Lausen, doch ebenfalls mit einer an Gewissheit grenzenden Wahrscheinlichkeit festgestellt ist, die im vorigen Jahre beobachtete. Typhusepidemie in Stuttgart,* die Prof. Dr. O. Köstlin im Württemberger medicinischen Correspondenzblatt beschrieben hat. Im Februar 1872 kamen auffallend viele Typhusfälle in das Katharinenhospital zu Stuttgart, nämlich 49, während im Januar und ebenso wieder im März die Zahl der Typhusfälle die normale Menge nicht überschritt. Sobald man hieranf aufmerksam wurde und es sich herausstellte, dass auch die Zahl der in der Stadt

* Die Typhusepidemie des Februar 1872 und die Trinkwasserversorgung Stuttgarts von Professor Dr. O. Köstlin (Württemb. Med. Corr.-Bl. XLIII. 3).

krank liegenden eine ungewöhnlich grosse war, forschte man den möglichen Ursachen nach und hier stellte sich nun zunächst heraus, dass bei weitem der grösste Theil in einem bestimmten Stadttheile erkrankt war. Die Gesammtzahl der Erkrankungen im Februar betrug 180 und kamen von diesen die meisten und zwar vorzugsweise schwere Fälle auf den westlichen Stadttheil (sagen wir Bezirk I.), weniger auf den nordöstlich und südöstlich angrenzenden Stadttheil (Bezirk II.) und nur eine verhältnissmässig geringe Zahl auf die ganze übrige Stadt (Bezirk III.). Es kamen nämlich vor in—

Bezirk I. mit 193 Häusern, 94 Erkrankungen = 1 Erkrankung auf 2·05 Häuser. Bezirk II. mit 361 Häusern, 37 Erkrankungen = 1 Erkrankung auf 9·7 Häuser. Bezirk III. mit 7,046 Häusern, 49 Erkrankungen = 1 Erkrankung auf 143·8 Häuser.

Diese Zahlen können unmöglich bloss Zufall sein, "sie weisen darauf hin, dass die ätiologischen Momente "der typhösen Krankheiten in den verschiedenen Theilen "der Stadt mit sehr verschiedener Intensität eingewirkt "haben, am intensesten in dem I., westlichen Bezirk, "weniger intens, aber noch immer bedeutend in dem II., "angrenzenden Bezirk, viel schwächer in der übrigen "Stadt."

Bei Erforschung der verschiedenen möglichen Ursachen der Erkrankungen kommt Verfasser schliesslich dazu, nur das Trinkwasser als Veranlassung ansehen zu können und sucht dies aus der Art der Wasservertheilung in Stuttgart zu beweisen. Stuttgart ist sehr arm an Quellen, es erhält sein Wasser meist durch Zuleitung; der grösste Theil der Trinkwasserbrunnen wird von der vor circa 40 Jahren angelegten Wasserleitung, der sogenannten Kandellage, gespeist, die ihr Wasser aus einer grossen Reihe von Quellen und Zuflüssen benachbarter Thäler sammelt und neben der noch einige kleinere Leitungen existiren; die ihr Wasser durch verschiedene "Zuflüsse aus Sicker-"dohlen" erhalten, welche ohne Ausnahme wenigstens 6 Fuss unter Tage liegen, einer dieser Zuflüsse ist z. B. die "Vogelsangleitung." Von dieser Leitung erhält der westliche Stadttheil (Bezirk I.) ausschliesslich sein Wasser, und hier war schon Anfang Januar der "widrige jauchen-"artige Geruch und die gelbliche trübe Farbe des Wassers" aufgefallen und verschiedene chemische Analysen ergaben sehr bedeutende Verunreinigung mit organischen Stoffen, die so bedeutend war, dass "das Wasser, wenn die Ver-"unreinigung von Harn hergerührt hätte, mehr als ½ "Proc. Harn enthalten haben würde." Diese Verunreinigung erstreckte sich nach sicheren Angaben auf alle Brunnen des westlichen Bezirks, die sämmtlich ihr Wasser durch die Vogelsangleitung erhalten. Der Ursprung dieser Verunreinigung war nicht schwer zu finden. Die Sickerdohle, welche der Vogelsangleitung ihr Wasser zuführt, liegt im Vogelsangthal unter Wiesen, und diese Wiesen wurden zu Anfang des Winters 1871–72 stark mit den Abfuhrstoffen aus Stuttgarter Cloaken gedüngt. Als nun auf den sehr strengen und schneelosen December ein sehr warmer und regnerischer Januar folgte, so wurden die angehäuften Düngermassen durch den aufgethauten Boden in die Tiefe bis zur Sickerdohle geschwemmt und die Wasseranalysen ergaben, "dass mit dem Eintritt des "Thauwetters, von der ersten Woche des Januars an, "flüssige Excremente sich in reichlicher Menge dem "Wasser der Vogelsangleitung beimischten." Einige Wochen darauf zeigten sich in dem von diesem Wasser versehenen I. Bezirk die zahlreichen Typhusfälle. Im angrenzenden II. Bezirk verhalten sich die Thatsachen etwas anders. Wie man im I. Bezirk wegen des plötzlichen Auftretens zahlreicher Typhusfälle nicht an eine Ausbreitung von einzelnen Heerden aus durch Ansteckung oder Verschleppung denken konnte, ebenso wenig wäre eine solche Annahme für den II. Bezirk gerechtfertigt gewesen, da auch hier die Fälle gleichzeitig mit denen des I. Bezirks auftraten. Aber auch das Trinkwasser schien hier nicht die Ursache sein zu können, da die Brunnen dieses Bezirks nicht ihr Wasser aus der Vogelsangleitung, sondern aus der Kandellage erhalten. Und doch war auch hier im Januar und Februar öfters ein widerlicher fauliger Geschmack bemerkt worden. Die Ursache davon war folgende. An dem Kreuzungspunkte zweier Strassen, zwischen dem westlichen und dem angrenzenden Bezirke besteht eine Verbindung (mit Absperrschieber) zwischen Vogelsangleitung und Kandellage, die je nach dem Wasserbedürfniss und dem Wasserverhältniss der einzelnen Leitung auf- und zugemacht wird. Hier ist nun unzweifelhaft auch im Januar wohl zu wiederholten Malen das Wasser der Kandellage durch zufliessendes Wasser der Vogelsangleitung verunreinigt worden; aber die Verunreinigung des Kandellagewassers war auf diese Weise natürlich eine sehr viel geringere, und dem entsprechend war auch in diesem II. Bezirk die Häufigkeit und Heftigkeit der Typhusfälle eine sehr viel geringere. Die Fälle des III. Bezirks, die kaum das Normale überschreiten, bedürfen bei einer in einzelnen Stadttheilen herrschenden Epidemie selbstverständlich keiner besonderen Erklärung.

Sobald die Ursache der Erkrankung als höchst wahrscheinlich erkannt war, wurden Brunnenstube und Röhren der Vogelsangleitung gereinigt und mit Anfang März konnte die Epidemie als erloschen angesehen werden. Ein sicherer Nachweis für den direct krankmachenden Einfluss des Trinkwassers ist hier allerdings nicht geliefert; aber die örtlich mit der Vertheilung der verschiedenen Wasserleitungen genau zusammenfallende Vertheilung der Typhusfälle, das gleichzeitige, plötzliche Auftreten zahlreicher Typhuserkrankungen in verschiedenen Stadttheilen, die chemisch nachgewiesene Verunreinigung des Trinkwassers mit menschlichen Excrementen, unter denen, wenn es Verfasser auch nicht bestimmt erwähnt, in einer 90,000 Einwohner zählenden Stadt wohl auch Typhusexcremente gewesen sein mögen, das rasche Aufhören der Epidemie nach Beseitigung des verunreinigten Trinkwassers machen immerhin einen Zusammenhang dieses Wassers mit der Typhusepidemie höchst wahrscheinlich.

Die Typhusepidemie in Winterthur im Winter 1872, die Bansen* beschreibt, ist der vorstehenden so ähnlich, dass eine genauere Wiedergabe derselben füglich unterbleiben kann. Auch hier trat plötzlich im Februar und März eine für Winterthur sehr heftige Epidemie auf, in der 303 Personen erkrankten, von denen 249 in den bei weitem kleineren Theile der Stadt, welcher gerade nur von einer bestimmten Wasserleitung versorgt wird, die nach zahlreichen übereinstimmenden Berichten Ende Februar einen Jauchegeschmack und Geruch gehabt haben soll, vorkamen, während die anderen 54 Fälle in dem ungleich grösseren übrigen Theile der Stadt vorkamen und bei den meisten von ihnen eine contagiöse Entstehung: Pflege, Wäsche, etc. nachgewiesen werden konnte. Auch hier ergab sich gerade wie in Stuttgart Verunreinigung der Leitung durch auf die über ihr liegenden Felder gebrachten Dünger, der bei dem Thau- und Regenwetter des Februars in die Erde und durch sie in die Leitung gespült wurde.

* Bansen, Dr. Max, Ueber Entstehung des Typhus abdominalis. Schaffhausen, Baader in Comm. 8. 61 S. mit einem Plan von Winterthur.

APPENDIX No. 5.

The Watershed of the Upper Thames.

The Thames, according to the ordnance map, commences at a place called Waterhay Bridge, about a mile below Ashton Keynes Village, and about three miles west of Cricklade, in the county of Wilts. The stream above this point is called "Swillbrook." A brook running from "Thames Head," past Kemble through Somerford Keynes joins the "Swillbrook," about a mile below Somerford Keynes Village. Another brook from Braydon also joins the Swillbrook, a little above Waterhay Bridge. The length of "Swillbrook and Thames Head," streams is about 16 miles.

The following rivers are on the north side of the Thames and fall into it by taking generally a southward or south-eastward course. The lengths given, together with that given above of Swillbrook and Thames Head, are exclusive of sinuosities and also of minor tributaries,—

The Churn, in length - -	about 20 miles.
Ampney and Marston Brooks	„ 19 „
The Coln - - - - -	„ 27 „
The Leach - - - - -	„ 18 „
Small streams in Bampton District.	
The Windrush - - -	34 „
The Evenlode - - -	32 „
The Glyme - - -	7 „
The Dorne - - -	8 „

Beyond the watershed of the Evenlode is that of the Cherwell, but as this river falls into the Thames *below*

Oxford, it has not been considered to form part of the Upper Thames area.

The following are on the South side of the Thames and fall into it by taking a northward or north-eastward course:—

The Ray, in length about 10 miles.
Small streams in the Highworth District.
The Cole, in length about 12 miles.

Beyond Faringdon the Ock has its rise, and falls into the Thames at Abingdon below Oxford, and therefore is omitted here for the same reason as the Cherwell. The watershed of the Ock contains 100 square miles.

The springs discharged from the watershed of these three rivers on the south side of the Thames (containing 123 square miles) are not so abundant as from the same quantity of square miles on the north side of the river. The dip of the strata is south-eastward, and descends from the Thames on the south side, but *towards* the Thames on the north side. The surface slopes from the chalk hills towards the Thames, and the water which immediately runs off reaches that river, but at a slower rate than that from the north. Part of the water which is absorbed by the soil, and part which is lost in the streams in the passage over open and porous beds, sinks through those porous beds to the upper surface of the tenacious beds of the Oxford clay, Kimmeridge clay, and the Gault, and descending the plane of stratification in a contrary direction to that of the river is lost to the Thames. The same remarks apply to the watershed of the Ock.

I have separated the district called "Bampton" from that of the Windrush and of the Evenlode, because the brooks and rivulets in it, do not finally form a river of much larger size, and then pass on and into the Thames; but several small brooks take their course into the Thames without uniting, and this renders it incapable of being designated the watershed of any particular brook or river.

The same will refer to the district called "Highworth."

The area of the watershed of the Upper Thames, thus described is 875 square miles, and is made up as follows:—

		Square Miles.
West of the Thames:		
Swillbrook and Thames Head		74
North of the Thames:		
The Churn		73
Ampney and Marston Brooks		32½
The Coln		87
The Leach		36½
The Bampton and Thames District		119
The Windrush		141
The Evenlode		189
South of the Thames:		
The Ray	65½	
Highworth district	9½	
The Cole	48	
		123
Total		875

The average annual rainfall in this district may be taken to be 30 inches. It will be seen by the following results of rain gauge operations that an average for five years gives 31·25 inches but I take 30 inches to be a fair average for practical purposes:—

Year.	Cirencester.	Cowley, near Cheltenham.	Kempsford, near Fairford.
	inches.	inches.	inches.
1869	33·75	38·24	29·85
1870	23·06	26·96	17·61
1871	29·31	34·43	24.66
1872	40·40	49·03	34·22
1873	28·95	33·97	24·41
Average	$\frac{1}{5}$) 155·47	$\frac{1}{5}$) 182·63	$\frac{1}{5}$) 130·75
	31·09	36·52	26·15

Averages.
31·09
36·52
26·15

places 3=$\frac{1}{3}$) 93·76

31·25 Net average.

This paper being written at the commencement of the last month of 1873, and being desirous of including the rainfall of that year, I have taken the average of the December fall for the four previous years as the prospective rainfall for this month.

This fall of 30 inches annually, converted into gallons per acre would probably astonish some of our agricultural friends, amounting as it does to 678,720 gallons.

In estimating the portion of this rainfall available for the use of the inhabitants of the area, or elsewhere, two-thirds should be deducted for evaporation, the discharge into the rivers direct, and for percolation into porous strata which may not afterwards be thrown out by springs and in consequence may not reach the Thames, but pass under it. Some of this water we know must be brought to the surface by faults, as at Boxwell spring, near the Churn, below South Cerney; but this can only be part of that which percolates through the beds of the Upper Oolite to the surface of the Fuller's earth. The quantity of water which is absorbed by the extremely porous beds of the Under Oolite, is very large.

The Churn, Coln, Windrush, and Evenlode, descend through valleys of denudation, the Under Oolite being cut through to some depth below its junction with the Lias. The rainfall finds its way into these rivers by first sinking into the soil, and then issuing in the form of springs on the sides of the streams, and particularly by springs on the north-western sides of the narrow valleys through which they pass; but some of this is liable to be absorbed again in its passage over the Under Oolite which occupies a portion of the beds of those rivers below the junction with the Lias.

The loss by percolation through the Upper Oolite, including the Forest marble and Cornbrash, is to a considerable extent compensated by the immense discharge from the Fuller's earth by Boxwell, Ewen, Ampney, and Bibury Springs, which water, if not so discharged would pass down the plane of stratification and would not appear again in the Vale of the Thames; added to which must be reckoned half of the water pumped up from the Fullers earth by the engine, at "Thames Head" for the supply of the Thames and Severn Canal. The summit level of this canal extends from Daneway at the western end of Sapperton tunnel to Siddington near Cirencester, being about eight miles in length. From those two extremities the canal descends westward towards the vale of the Severn and eastward to the vale of the Thames at Lechlade. The water being retained on the summit by means of locks it descends in either direction about half to the Thames and the remainder towards the Severn.

The principal loss to the watershed of the Thames occurs in the Under Oolite, the area of which is about 106 square miles.

Taking the average rainfall to be thirty inches and deducting two thirds as above stated, leaves ten inches available for the supply of water to the inhabitants of the districts through which the rivers pass, which can be easily seen is much more than is required, there being only about 50,000 inhabitants, and an annual depth of ten inches on the amount of area, 875 square miles, gives 2,062,709 cubic yards of water per day or 240,954 gallons per minute, whereas at 30 gallons each per day, taking the population at 50,000, the quantity required would be only 1,041 gallons per minute.

The supply from the area of the watershed of each river is as follows:—

	Cubic yards per day.
Swillbrook and Thames Head	174,460
Churn	172,100
Ampney and Marston	76,620
Coln	205,110
Leach	86,054
Bampton district	280,489
Windrush	332,357
Evenlode	445,529
Ray	154,426
Highworth	22,392
Cole	113,172
	2,062,709

The following towns are included in the Upper Thames area, which unquestionably cause pollution of the rivers on the banks of which they are situate, from sewage and other causes; many, if not all, of these towns being destitute of a thorough system of drainage:—

Faringdon.
Lechlade.
Fairford.
Cricklade.
Cirencester.
Burford.
Stow-on-the-Wold.
Northleach.
Witney.
Highworth.
Swindon.

Besides these there are minor causes of pollution by villages, farmyards, &c., &c.

There are not many large manufactories on these rivers, with the exception of one or two paper mills and some breweries, there being no clothmills, dyer's establishments, or chemical works.

Nearly all the rivers have had their streams interrupted by the partial diversion of their original courses for the purposes of irrigation, and for driving corn mills, &c. This is particularly the case at Cirencester, where the Churn has been completely diverted for the purpose of driving several mills, and the old course entirely obliterated. This diversion has a serious effect upon the drainage of the town.

The town of Cirencester is situated in the valley, partly on a bed of gravel deposited on a clayey or tenacious subsoil. Nearly all the wells which supply the town are sunk into this bed of gravel, from whence plenty of water is obtained; but it is seriously and injuriously affected by the passage of sewage from the cesspools into the wells which are near, and also many of the privies have their contents discharged into the mill stream. I believe many of the other towns injure the water supply in a similar manner.

Cirencester, JOHN BRAVENDER.
11th December 1873.

APPENDIX No. 6.

REMARKS on the GEOLOGICAL STRATA of the UPPER THAMES, with NOTES on the YIELD of SPRINGS in the Basin of that River.

In the upper Thames Watershed, we have the Lias, Under Oolite, Fuller's earth, Upper Oolite, Forest Marble, Cornbrash, Kelloway, and Oxford Clay, on the north of the river. The Oxford Clay, Coral-rag, Coralline Oolite, Kimmeridge Clay, Portland Oolite, Lower Greensand, Gault, Upper Greensand, and the Chalk to the summit of the chalk hills on the south of the river.

The following are porous, and absorb a large quantity of the rain as it falls:—

Under Oolite.	Coralline Oolite.
Great Oolite.	Portland Rock and Sands.
Cornbrash.	Greensand.

Sandy beds of Forest Marble and the Chalk.

A great portion of the rains runs off the following strata as it falls:—

Lias.	A great portion runs off, except where covered with diluvium.
Fuller's earth.	Nearly all runs off. Area very small.
Forest Marble.	Part absorbed by Sandbeds, and about one fourth of the remainder runs off.
Oxford Clay, and Kelloway.	Part runs off and part is absorbed by the surface gravel; but the whole, or nearly the whole of the water of the Oxford Clay reaches the Thames.
Kimmeridge Clay.	A considerable portion runs off.
Gault.	Greater portion runs off, but, partly absorbed again by the lower Greensand.

At the head of the Churn, Coln, Windrush, and Evenlode, the Under Oolite has been cut through on the south and south-east side by denudation, which is the means of bringing to the surface a large quantity of the water which falls on the Under Oolite above, and descends through this rock to the Lias. Without this denudation the vale of the Thames could not receive any of the rainfall on the upper portions of the Under Oolite, nor could any of the water from the Fuller's earth reach that river except that which may be thrown out by means of faults. Like the water on the Lias, it would all quietly descend the slope of stratification and pass many feet under the Thames. The Fuller's earth is a thick bed of very retentive clay and but little water passes through it, it retains an enormous quantity on its surface beneath the Upper Oolite.

The whole of the rainfall of the Oxford clay and Kelloway would find its way into the Thames between the Western summit and Oxford. There are few, if any, springs properly so called in the Oxford Clay. A great portion of it is covered with gravel and alluvial soil some feet thick, and the rain rapidly sinks through the soil and gravel down to the impervious clay, and escapes into the ditches and brooks, and thence into the Thames, without appearing on the surface in large springs. The body of gravel is not sufficient to retain it for any length of time, which is a necessity for a spring. A spring thus produced, ceases soon after the commencement of dry weather.

A very large portion of the rainfall of the Great Oolite and Forest Marble, particularly that which falls on the sandy beds, descends through those formations to the Fuller's earth below, and thus accumulates the enormous quantity there found, part of which, fortunately for the country at the head of the vale of the Thames is brought to the surface by means of geological faults which form large and never-ceasing springs. The principal are:—

Boxwell Spring.
Ewen Spring.
Ampney Spring.
Bibury Spring.
Ablington Spring.
Winson Spring.

and others. Also three intermittent springs called "Winterwell," "Thames Head," and one opposite Tewsbury Quarry, also called "Thames Head."

The Boxwell Spring is situated in the parish of South Cerney, 4¾ miles S.E. of the engine at "Thames Head," at which point there is a considerable geological fault which throws up an immense quantity of water from the Fuller's earth. Some few years ago the inhabitants of Cheltenham brought a bill into Parliament in order to obtain water for the supply of that town from this spring I measured the spring on three or four occasions, it does not vary like some others; it runs not altogether alike in summer and winter but varies about 500,000 gallons between those periods. It gave out on the 6th of March 1864, 1,500,000 gallons in round numbers per diem, and when I measured it on the 8th of October in the same year it was discharging 1,100,000 gallons, and that was the only water which at that period ran down the Thames. The whole of the water in the Thames besides this, had become completely exhausted.

In the summer of 1864 the Earl of St. Germans decided on deepening and improving the Thames below and adjoining his property, with the view of obtaining a better outfall for the drainage works which had been executed under my superintendence on the Down Ampney estate. This estate is situated near Cricklade, at the top of the Upper Thames, and is bounded by the Thames from the town of Cricklade to near Castle Eaton, a distance of more than three miles. In August 1864 we found the water sufficiently low to enable us to commence the works, and on the 24th of that month we succeeded in confining nearly all the water descending the river into a definite space of 12 feet in width. I carefully ascertained the velocity and depth, and found that 13,000,000 gallons were passing in 24 hours. This observation was made towards the upper part of Marston meadow, about half to three quarters of a mile above Castle Eaton bridge. On the 13th of September the water passing down the river was confined to a width of 4½ feet, in another part of the river further up. The depth and velocity were carefully taken, and I found that about 7,000,000 gallons were descending in the 24 hours, the river having decreased nearly half in volume in 20 days. On the 8th of October the water passing down the river was confined to a width of 3 feet a little below the bridge at Water Eaton. I again carefully ascertained the depth and velocity and found that rather more than 1,000,000 gallons were descending in the 24 hours. In the morning of this day I had ascertained that no water was passing down the Thames at the bridge at Cricklade (that was about a mile above); there was no water in the river there, except in the hollow in its bed. I examined the Churn which flows into the Thames near Cricklade, and found it completely dry at South Cerney; and on descending the stream to where the water from Boxwell Spring joins the Churn, I observed a considerable quantity of water flowing into the Churn from Boxwell Spring. On visiting Boxwell Spring, about a quarter of a mile up the brook from this junction, I found it discharging about the usual quantity. I had some time before ascertained the flow of this spring, and did so at this time, and found the discharge about 1,100,000 gallons in 24 hours. The fact is, that the water passing Water Eaton was from the Boxwell Spring, and in passing over about three miles of porous gravel and somewhat peaty soil, there was a loss of 100,000 gallons per day at that time. This loss would eventually find its way into the Thames lower down the vale. It may be observed that from the middle of August to the middle of October scarcely any rain fell, and that which did fall was absorbed immediately, and made not the least difference to the water in the Thames. Our observations extended over 45 days from the 24th of August to the 8th of October, and during this period the entire supply of the Thames above Water Eaton ceased, except that which was supplied by Boxwell Spring. I ascertained the temperature of Boxwell Spring and I found that the water discharged from it is about two degrees warmer than the water in the canal not 10 yards from it. In winter the frost does not freeze over the spring nor the brook for 200 yards below its source, so soon as it freezes over in other places, and in the winter time when it has issued from the spring I have seen steam rise from the water. The difference in temperature may thus be accounted for:— The water in the summer time when the weather is warm falls upon a large area of the upper oolite in a very warm state; it descends through the porous rock and comes on to the surface of the Fuller's earth, and descending gradually for several months, it issues from this spring at a higher temperature than the water on the surface, because the effect of winter is apparent on the surface, but does not operate below.

Having alluded to the great loss in the Churn by passing over the porous rock of the Under Oolite, I may be excused for quoting a table of the results obtained in 1859, and I do so with the greater confidence because those results were obtained from a series of observations made by myself under the direction of Mr. Simpson, extending over a period of six weeks. At that time the millers on the stream complained very seriously of the loss of water from the Churn. I was concerned for two or three landowners and informed them what I thought was the cause, they hesitated in believing what I had to say. They thought that Mr. Hutchinson and Mr. Elevers whose properties are intersected by the Churn were the parties who caused the loss of water, because the one had made a fishpond and some ornamental water on the lias, and the other was driving a saw-mill and diverting the water. The miller thought by those works they were deprived of the water. I believed that they were not, and in consequence of our difference of opinion I recommended them to call in some practical engineer, and Mr. Simpson was called in. When he sent down his assistant I went over the river with him and pointed out what I thought was the cause, and after a minute inspection we decided on placing on the river some gauges, and he left me and my assistants to measure the water for six weeks We took it very accurately and made a return at the end of six weeks. He then made his calculations with the following results:— The Seven Springs is a place about four miles from Cheltenham upon the road to Cirencester, and is the head of the river Churn. There the water is thrown out by the lias and it is the furthest tributary of the Thames. At the Seven Springs the flow was 11 cubic feet per minute. At a quarter of a mile below the springs the flow was 31 cubic feet per minute; at three-quarters of a mile below it was 61 feet, at one mile below it was 73 feet, at two miles below it was 105 feet, at 2½ miles below it was 165 feet, at 4¾ miles below it was 312 feet, and at 5½ miles below, estimated at the maximum, it was 320 feet. Then we got off the lias on to the rubble beds of the under oolites which were absorbing a large quantity of water which I had pointed out before the observations had commenced, but at this point the volume of the river instead of increasing began to diminish, for at 6½ miles below the spring the flow had decreased to 290 cubic feet per minute, at 7 miles below it had decreased to 235 feet, at 7⅝ miles to 179 feet, at 8⅛ miles to 113 feet, at 8⅞ miles to 45 feet, at 9¾ miles to 35 feet, and at 12½ miles below it had decreased to 30 cubic feet per minute, the bed of the river absorbing almost the whole of the springs above. The loss of water in descending the Coln is much greater than the loss of the Churn, and I have no hesitation in stating that if this river (the Coln) were thoroughly puddled, as Mr. Simpson recommended in 1859 in the case of the Churn, the Lyreford Spring, a spring which discharges 3,000,000 gallons in the course of 24 hours and sometimes more, might be sent down to Cheltenham, and the abstraction of the water would not be felt at Toss bridge, which is about four miles from Withington where the lias terminates. Between Toss Bridge and Withington there is Oolite in the bed of the brook which absorbs an enormous quantity of water. The inhabitants of Cheltenham tried to get this Lyreford Spring diverted into Cheltenham, but Lord Eldon and some others who had some mills on the river opposed it, and the inhabitants did not succeed. Mr. Simpson was engaged then for Lord Eldon, but it did not suggest itself to him, that if this river were puddled they might safely take the whole 3,000,000 gallons to Cheltenham, it would have gone down to Cheltenham by the mere force of gravity and might have been carried to the top of the highest building in the place.

The yield of the Ewen Spring is about the same as Boxwell Spring, or a little more than 1,000,000 gallons. The Ampney Spring is at Ampney Cracis two miles east of Cirencester, and is thrown out from the Fuller's earth by a fault, and yields an enormous quantity. It is difficult to measure it, because it issues at more places than one. One of them was measured and found to discharge 4,000,000 gallons in 24 hours. Subsequently the entire flow was taken at some distance below the point of issue and found to amount to more than double this discharge. Late in the autumn of the same year after some wet weather when Winterwell was pouring into the head of those springs at least 3,000,000 of gallons daily, the flow of the last mentioned place below the springs was not less than 12,000,000. In summer Winterwell ceases and the discharge of the other spring is considerably less.

I also visited Bibury Spring and found it discharging rather more than the one at Ampney Crucis. It is derived from the same source. There is a spring about a mile above, at Ablington which I have also gauged and the discharge is more than 2,000,000 gallons. The spring above Winson from the same source gives out about a million and a half. The Bibury, Ablington, and Winson Springs are on the Coln, the Ampney Spring is between the Churn and the Coln, the Ewen Spring falls into the Thames at Ashton Keynes and does not get into the Churn. These springs are all from 300 to 380 feet above the sea.

The spring called "Winterwell" is an intermittent spring, that is, it only discharges at certain seasons when there is a large body of water descending the plane of the stratification of the Fuller's earth, when it rises higher in the bed of the Oolite than the surface it discharges, but whenever the water falls below that point the spring ceases to flow. So that it only sends out water in wet seasons, and in dry ones ceases to flow altogether. Some years ago I had occasion to deepen a well in Winterwell bottom not far below the spring just mentioned, this well was only 10 feet deep and had become dry, we sunk it six feet deeper and obtained an abundance of water and have had plenty ever since. The summer was a dry one, all the materials which were brought to the surface I recognised as the shale and rough ragstone from the top of the Fuller's earth. I was acquainted with the material, having previously sunk several wells into it, and always obtained an abundance of water. One well at the Whiteway near Cirencester is 65 feet deep, another at the Bowling Green Farm 30 feet deep, and my own well at Thomas Street, Cirencester, 27 feet deep, and this I succeeded one dry summer afterwards in sinking three feet deeper into the Fuller's earth. The well in the market place in Cirencester is about 20 feet deep, and has never been known to be entirely dry. In the autumn of 1867 we had some wet weather, and being desirous of fixing the source of these intermittent springs I invited Professor Morris, who was then lecturing at the Royal Agricultural College to go with me to see them. We visited Winterwell first and found it discharging an enormous quantity of water. This was on a Friday and the occupier of the land informed me that "Winterwell broke out middleday on the "previous Sunday." We left Winterwell and drove directly to the Thames Head Spring, which is situated on the south side of the canal close to Trewsbury Quarry (about half-a-mile west of the engine) where a quarryman resides. We enquired of him when Thames Head broke out and were informed that it was on the previous Sunday, showing, as I think, that the two springs have the same source, and continue to flow only while the rock above the Fuller's earth is saturated up to a line above the surface. The surface at Winterwell spring is 20 feet above the Fuller's earth and that of the Thames Head a little more, I think Mr. Taunton says 29 feet, but I have been unable to ascertain this myself. Both are situated in a minor valley of denudation.

The Fuller's earth is the source from which the Thames Head engine supplies the Thames and Severn canal on its summit level with most of the water. There is a conduit which conveys a portion from the Forest Marble into the well at the engine, but this forms but a small portion of the supply. In the dryest summer the engine has never been able to exhaust the water there. The well is 64 feet deep, and for months together the engine throws up more than 3,000,000 gallons into the summit level of the Thames and Severn canal every day. I visited this engine on the 6th of March 1864, it had been going for two years and had not been suspended for any greater length of time than a few hours during the whole of that period. There were then 26 feet of water in the well, and the engine was making no impression on it. I visited it subsequently in a very dry season indeed and I found that there were nine feet of water in the well, and the engine was making no kind of impression upon it, although the country was dry and scarcely any water in any of the rivers or brooks.

As the water on the surface of the Fuller's earth in the neighbourhood of "Thames Head" could never reach the surface of the ground in summer time, no one could complain of the loss by pumping, even if several more engines were acting at the same rate, on the contrary, an abundance of water would be brought to the surface which would not reach it in that neighbourhood, and probably not in England without pumping. Complaint might be made in consequence of taking the water from the Forest Marble, but this might be entirely avoided.

Cirencester,
8th January 1874.

JOHN BRAVENDER.

APPENDIX No. 7.

STATISTICS OF WATER SUPPLY AND MORTALITY.

EXPLANATION OF ABBREVIATIONS, &c.

In column C., U. = upland surface water, S. = polluted surface water, S.W. = shallow wells, D. W. = unpolluted deep wells, P. D. W. = polluted deep wells, Sp. = unpolluted springs, P. S. P. = polluted springs. In column F., the initials M., P., L. B. D. and S. D. signify that the population stated is comprised within Municipal, Parliamentary, Local Board, or Registration District, or sub-district limits respectively in England, and in Scotland the letters T. and V. indicate that the population is that of a town or village. In column L. the numbers are calculated for England and Wales on the average of ten years, from 1862 to 1871, and the mean population according to the censuses of 1861 and 1871, and in Scotland on the average of ten years, from 1860 to 1869, with the same mean population. The numbers in column M. to which * is attached are calculated from the Registrar General's Annual Reports, and are corrected by him for increase of population; those to which † is attached are also calculated from his reports, on the average of ten years, from 1862 to 1871, and the mean population of 1861 and 1871, all others are from returns supplied to the Rivers Pollution Commission by the various town authorities.

The very numerous blanks in the mortality columns of the following table, many of them opposite to very important towns, could not be filled up, owing to the non-existence of the necessary data for the towns as distinguished from the large registration districts in which they are situated.

Name of Town.	Mode of Supply.	Nature of Supply.	Organic Elements in 100,000 parts of Water.	Total Hardness in 100,000 parts of Water.	Population, 1871.	Mortality per Annum. Cholera per 10,000. 1832.	1848–49.	1853–54.	1865–66.	Diarrhœa, per 10,000.	All Causes, per 1,000.
A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.
ENGLAND AND WALES.											
Aberystwith	—	S., Sp.	·087 to 1·382 (?)	6·7 to 11·1 ?	6,898						
Accrington	Constant	D.W.	·062	9·9	21,788 L.B.						
Aldershot Camp	—	U.	·465	4·1							
Ashton-under-Lyne	Constant	„	·231	14·2	1,984 M.						
Askern	—	S.W., Sp.	·010 to ·509	29·7 to 152·4							
Banbury	—	S.	·436	24·1	4,106						
Barnstaple	Constant	„	·144	5·9	11,636						
Basingstoke	„	D.W.	·057	25·1	5,574						
Bath	Intermittent	P.Sp.	·161 to ·350	16·3 to 31·3	52,557 M.	—	12·89	0	·15	8·22	22·2†
Batley	Constant	U., S.	·153 to ·407	2·3 to 3·3	20,871 M.						
Bedford	„	Sp.	·154	40·8	16,849						
Bedlington	—	—	·054 to ·109	37·1 to 43·5	22,539						
Belvidere	—	D.W.	·137	22·4							
Berwick-on-Tweed	Partly constant.	Sp., S.	·038 to ·172	11·4 to 19·6	13,282 M.						
Birkenhead	Constant	D.W.	·062 to ·079	5·7 to 9·9	65,971 P.	—	24·32	7·52	12·70	12·42	24·0†
Birmingham	„	S., S.W., D.W.	·124 to ·667	12·6 to 127·1	343,787 M.	—	1·67	·98	·47	20·03	24·4*
Bishop Auckland	—	U.	·407	10·4	46,622 S.D.						
Bitteswell	—	S.W.	·147 to ·556	44·3 to 88·6							
Blackburn	Constant	U.	·270	5·9	76,339 M.						
Bodmin	„	S.	·179	6·3	4,672						
Bolton (Lanc.)	„	U., S.	·315 to ·380	·8 to 2·1	82,853 M.						
Bookham, Great	—	S.W., D.W., P.D.W.	·031 to ·952	26·3 to 49·3							
Boston	—	S.	·185	14·4	15,576						
Bournemouth and Christchurch.	Intermittent	U.	·265 to ·647	1·8 to 42·1	15,415						
Brackley	—	S.W.	·288 to ·390	40·7 to 62·8	7,859						
Bradford	Constant	„	·204 to ·661	6·4 to 7·1	145,830 M.	—	23·41	1·86	1·73	13·24	26·0*
Braintree	—	D.W.	·076	14·0	6,892						
Bridgwater	—	S.W.	·190	69·6	12,101						
Bridlington	—	Sp.	·064	23·9	9,684 S.D.						
Brighton	—	D.W.	·057 to ·066	21·2 to 21·5	90,011 M.	—	29·59	5·80	1·80	12·26	22·6†
Bristol	Constant	S.	·177	24·5	182,552 M.	52·44	80·33	11·69	1·68	9·96	23·9*
Bromyard	—	P.D.W., Sp.	·076 to ·225	29·9 to 41·3	3,700						
Burslem	—	D.W.	·056 to ·064	13·4 to 16·9	27,107						
Bury (Lanc.)	Constant	S.	·229	1·1	41,344 P.						
Bury St. Edmund's	—	D.W.	·109	30·0	14,928 M.	—	2·16	0	1·50	9·70	24·5†
Buxton	—	U.	·514 to ·679	2·2 to 5·7	6,229						
Camborne	—	Sp.	·039	2·7	14,928						
Cambridge	Constant	Sp., S.	·064 to ·151	25·1 to 27·9	30,078 M.	—	1·80	1·09	0	9·53	22·1†
Canterbury	„	D.W.	0 to ·299	4·9 to 54·3	20,962 M.	—	26·24	29·08	1·20	8·33	24·5†
Cardiff	—	U.	·243	20·0	39,536 M.	—	85·18	48·40	13·04	7·63	21·3†
Carlisle	—	„	·270	8·7	31,049 M.	132·46	12·27	5·05	·45	9·91	24·1†
Castleford	—	D.W.	·204	29·3	13,765						

Statistics of Water Supply and Mortality—*continued.*

Name of Town.	Mode of Supply.	Nature of Supply.	Organic Elements in 100,000 parts of Water.	Total Hardness in 100,000 parts of Water.	Population, 1871.	Mortality per Annum. Cholera, per 10,000. 1832.	1848–49.	1853–54.	1865–66.	Diarrhœa, per 10,000.	All Causes, per 1,000.
A.	B.	C.	D.	E.	F.	G	H.	I.	K.	L.	M.
ENGLAND AND WALES—*cont.*											
Caterham	—	D.W.	·018	4·4							
Cheltenham	—	S.	·159	15·1	44,519 P.	—	1·36	1·13	0	7·75	19·2†
Chepstow	—	Sp.	·067	6·0	6,770						
Chester	Partly constant.	U.	·262	10·7	35,701						
Chesterfield	Nearly all constant.	S.	·270	10·3	11,426						
Chorley	Constant	U.	·420	5·4	16,864 L.B.						
Christchurch	*See* Bournemouth.										
Chulmleigh	—	S., S.W.	·324 to 1·025	5·8 to 37·8	4,583						
Cirencester	—	Sp., S.W.	·049 to ·406	23·0 to 45·7	7,681						
Cockermouth	—	—	·091	2·2	7,057						
Colchester	—	P.D.W.	·204	25·7	26,343 M.	—	2·06	·51	0	10·70	21·3†
Congleton	—	S.W.	·076 to ·719	17·1 to 51·5	11,344						
Coventry	Intermittent	Sp.	·038	21·8							
Cowes, West	—	S.	·774	8·7	} 11,126						
„ East	—	„	·607	12·4							
Crathorne	—	S.W.	·494 to ·543	41·9 to 42·6							
Crayford	—	D.W.	·036	25·7							
Crewe	—	U.	·252	6·0							
Croydon	—	D.W.	·047	22·0	71,319 S.D.	—	29·48	28·22	3·28	9·45	19·9†
Darlington	Constant	S	·269	10·5	27,729 M.	—	1·85	1·39	1·53	8·46	22·3†
Dartmouth	—	Sp.	·069 to ·076	10·4 to 11·6	4,978						
Darwen, Over	Constant	U.	·340	6·2	26,553						
Deal	—	D.W., S.W.	·057 to ·632	23·6 to 71·1	8,004						
Devizes	—	S.W.	·319	80·5	6,840						
Devonport	—	U.	·128	·8	50,094						
Dewsbury	Constant	U., S.	·153 to ·407	2·3 to 3·3	24,773						
Dorchester	—	D.W.	·050	23·6	6,915						
Dover	—	D.W.	·042	23·6	28,506 M.	—	33·19	8·83	3·48	7·39	19·7†
Durham	Constant	U.	·102	25·0	14,406 M.						
Eastbourne	—	D.W.	·068	20·9	12,977 S.D.						
Epping	—	„	·093	·9	5,566						
Eton	—	„	·152	25·4	11,861						
Etruria											
Exeter	—	S.	·243	7·7	34,652 M.	123·05	13·40	3·05	38·49	10·12	25·5
Falmouth	Constant	S.	·276	2·7	5,294						
Folkestone	Intermittent	D.W., Sp.	·089 to ·227	23·9 to 26·9	12,694						
Frome	—	Sp., S.W.	·049 to ·431	38·7 to 50·3	9,753 P.						
Gainford	—	S.W.	·073 to ·885	48·5 to 90·0							
Gloucester	—	U.	·417	19·6	18,330	103·08					
Gosport	—	D.W.	·086	14·9							
Grantham	Constant	Sp.	·066	23·6	5,028						
Greaseley	—	S.W.	·309 to ·311	62·9 to 98·6	22,616						
Grimsby, Great	—	Sp.	·031	20·6	20,238						
Guildford	—	S.W.	·077	21·5	9,106						
Hagglescote	—	S.W., Sp.	·131 to ·208	35·7 to 59·0							
Halifax	Constant	U.	·164	3·2	65,510 M.						
Harrow-on-the-Hill	—	D.W., S.W.	·089 to ·131	32·1 to 48·5	10,867						
Hastings	—	D.W., S., Sp.	·029 to ·166	6·0 to 11·6	29,291 M.	—	24·05	1·89	1·13	7·51	20·4†
Hawes, near Bedale	—	S.W., Sp., P. Sp.	·072 to ·207	18·6 to 31·3	2,561						
Haydon	—	Sp.	·034	45·7							
Hebden Bridge	—	S.W., Sp.	·024 to ·076	2·9 to 7·9	11,193						
Heckmondwike	Constant	U., S.	·153 to ·407	2·3 to 3·3							
Helstone	—	S.W., Sp.	·084 to ·090	10·1 to 15·6	3,777						
Hereford	—	S.	·506	3·6	18,355						
Hertford	—	S., D.W.	·034 to ·390	24·8 to 26·0	7,164						
Hexham	—	U., Sp.	·029 to ·371	14·6 to 26·4	9,665						
Hillmorton	—	S.W.	·220 to 1·360	11·3 to 116·9							
Horbury	—	„	·157 to ·851	36·4 to 85·7	3,977 L.B.						
Huddersfield	Partly constant.	Sp.	·067	6·5	70,253 M.						
Hull	—	D.W.	·061	25·4	121,892 M.	104·93	—	—	—	—	25·2*
Hurworth	—	S.W., Sp.	·086 to ·447	26·4 to 52·4							
Ilfracombe	—	U.	·279	6·9	6,403						
Ilminster	—	Sp.	·063	43·5	7,821						
Ipswich	—	D.W.	·069	28·2	12,947 M.	—	5·49	10·07	·53	9·94	22·3†
Ivybridge	—	S.W., D.W.	·026 to ·418	3·6 to 7·6							
Kendal	Constant	S.	·149	4·2	13,446 M.						
Keswick	—	U.	·156	3·4	6,414						
Kettering	—	S.W., Sp.	·086 to ·504	30·6 to 39·1	10,008						
Kidderminster	—	S.W.	·158 to ·322	28·6 to 41·3	19,473 M.	—	3·95	0	1·65	10·30	21·2†
Lancaster	—	U.	·151	·9	17,248						
Leamington	Constant	S.	·215	27·5	22,730						
Leeds	„	U.	·283	8·3	259,212 M.	56·89	122·25	4·26	1·32	19·78	28·5*
Leek	—	D.W.	·056 to ·064	13·4 to 16·9	13,518						
Leicester	—	U.	·526 to ·768	13·4 to 24·8	95,220 M.	—	·33	·49	·44	27·12	27·0*
Leigh (Essex)	—	S.W.	·136 to ·309	4·6 to 60·0							
Leyland	—	S.W., Sp.	·063 to ·602	19·4 to 35·4	8,080						
Lewes	—	Sp.	·070 to ·110	19·3 to 22·7	10,753						
Lichfield	—	S.	·248	21·8	7,380						
Lincoln	Constant	„	·324	8·0	26,762						
Liskeard	„	S.W., Sp.	·035 to ·137	2·2 to 11·4	4,700						

Statistics of Water Supply and Mortality—*continued.*

Name of Town.	Mode of Supply.	Nature of Supply.	Organic Elements in 100,000 parts of Water.	Total Hardness in 100,000 parts of Water.	Population, 1871.	Mortality per Annum. Cholera, per 10,000. 1832.	1848–49.	1853–54.	1865–66.	Diarrhœa, per 10,000.	All Causes, per 1,000.
A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.
ENGLAND AND WALES—*cont.*											
Liverpool	Constant	U., D.W.	·004 to ·109	6·2 to 14·9	493,405 M.	92·20	128·99	31·35	40·13	19·16	34·0*
Llanidloes	—	S.W.	·075	5·1	3,426						
London	Intermittent	S.,D.W.,Sp.	·021 to ·765	15·5 to 32·1	3,254,260‡	37·09	59·84	45·46	19·96	10·49	24·6*
Longton	—	D.W.	·056 to ·064	13·4 to 16·9	19,748						
Lostwithiel	—	Sp.	·035	7·3							
Lynmouth	—	U.	·197	2·5							
Lynn	—	S.	·218	16·9	16,562 M.	86·65	·98	4·38	·60	6·21	22·8
Lynton	—	U.	·197	2·5							
Macynlleth	—	S.W., Sp.	·068 to ·094	3·4 to 9·9	4,624						
Macclesfield	Constant	S.	·193	5·4	35,450 M.						
Maidenhead	—	S.W.	·414 to ·469	48·5 to 65·8	6,170						
Maidstone	—	P. Sp.	·182	27·9	26,196 M.	—	27·15	24·38	5·95	8·83	23·4
Malpas	—	S.W., Sp.	·045 to ·510	21·2 to 38·5	3,512						
Malvern	—	Sp.	·040 to ·046	3·5 to 5·6							
Manchester	Constant	U.	·078 to ·266	2·5 to 4·6	351,189 M.	48·68	31·72	1·43	2·20	25·02	32·0
Marlborough	—	S.W.	·064 to ·094	25·7 to 28·5	3,660						
Maryport	—	U.	·251	3·4	15,719						
Merthyr Tydfil	—	„	·173	8·4	97,020 P.	72·45	219·01	59·25	24·62	5·10	25·1†
Middlesborough	Constant	„	·193	12·3	39,563 M.						
Newark	„	S.W.	·173	31·9	12,218						
Newbiggin-on-Sea Northumberland.	—	„	·165 to ·453	52·9 to 140·8							
Newcastle-on-Tyne	Constant	U.	·299	13·9	128,443 M.	187·32	33·09	1·91	3·69	13·19	29·0*
Newent	—	S.W.	·166 to 1·804	18·6 to 56·4	6,615						
Newnham	—	„	·102 to ·868	48·6 to 94·8	17,115						
Newport (I. of W.)	—	Sp.	·013	29·4	7,976						
Newport (Monmouth)	—	U., S.W.	·040 to ·103	17·7 to 52·2	26,957						
New Quay	—	S.W.	·044 to ·252	27·8 to 44·3							
Newton Abbot	—	S.	·366	2·3	12,137						
Newtown (Montgomery).	—	S.W., Sp.	·014 to ·099	9·3 to 17·0	5,744 P.						
Northampton	—	D.W.	·192	10·3	41,168 M.	—	14·47	2·36	·24	17·13	25·5†
Northwich	Intermittent	S.	·682	14·0	1,244 L.B.						
Norwich	—	U.	·282	23·7	80,386 M.	21·11	5·57	28·30	·40	13·24	24·4*
Nottingham	—	D.W.	·034 to ·070	19·8 to 26·2	86,621 M.	58·41	3·08	2·70	·27	13·76	24·2*
Oakham	—	S.W., P.Sp.	·184 to ·405	40·7 to 95·7	11,142 D.						
Ogley Hay	—	S.W.	·033 to ·159	4·7 to 32·5							
Oldham	Constant	U.	·180	6·9	82,629 M.	—	4·72	·34	1·71	11·36	25·7†
Oxford	—	Sp.	·199	25·4	31,404 M.	—	20·87	3·72	0	10·41	21·
Oxton	Constant	P.D.W.	·283	14·1	2,670						
Padiham	—	U.	·410 to ·689	5·4 to 7·4	11,630						
Padstow	—	S.W.	·220	28·7	6,633						
Penryn	Constant	S.	·276	2·7	3,679						
Penzance	—	Sp.	·197	3·0	10,406						
Peterborough	—	S.W.	·434	91·6	17,429						
Plumstead	—	D.W.	·092	30·6	28,318						
Plymouth	—	Sp.	·069	2·1	68,758 M.	225·87	158·94	11·80	2·08	12·98	23·3†
Pontefract	Intermittent	D.W.	·075	67·3	5,372 M.						
Portsmouth	—	Sp.	·070	23·3	113,569 M.	18·58	78·75	2·77	15·08	10·91	21·5*
Preston	—	U.	·267	8·9	85,427	—	3·42	·83	1·72	23·17	28·0†
Radcliffe	Constant	S.	·229	1·1	11,138						
Ramsgate	—	D.W.	·065	26·3	23,778						
Reading	—	S.	·222	22·8	32,324 M.	—	7·67	3·16	·39	10·98	22·4†
Redhill	—	D.W.	·031	4·6							
Redruth	—	Sp.	·061 to ·132	4·4 to 6·0	10,685						
Retford	—	S.W.	·104 to 2·695	18·7 to 115·6	14,956 S.D.						
Rochdale	Constant	U.	·134	5·1	44,559 M.	—	3·17	2·07	1·20	9·60	24·3†
Romford	—	D.W.	·133	27·5							
Rugby	—	S.	·160	15·9							
Runcorn	—	Sp.	·129	25·3							
Ryde	—	„	·066	20·6	11,234						
St. Austell	—	„	·016	2·3							
St. Helens	—	D.W.	0	12·7	45,240						
St. Leonards-on-Sea	—	P.Sp.	·278	16·9							
Salisbury	—	S.	·159	23·6	12,908 M.	—	184·77	16·82	2·21	2·84§	20·0§
Sandown, Isle of Wight	—	„	·553	10·9							
Sandgate	—	Sp., P.Sp.	·064 to ·176	16·6 to 29·7							
Sevenoaks	—	Sp.	·017	19·4	10,952						
Sheerness	—	D.W.	·122 to ·189	15·5 to 16·6							
Sheffield	—	U.	·413	4·4	239,946 M.	68·12	10·60	9·96	1·25	18·22	27·5*
Shortlands	—	D.W.	·028	23·9							
Sittingborne	—	„	·141	27·5							
Skipton	—	U.	·399	10·6	9,505						
Somerby	—	S.W.	·088 to ·130	29·1 to 65·7	3,990						
Somerton	—	S.W., D.W.	·084 to 2·090	35·7 to 75·7	5,699						
Southam	—	S.W.	·192 to ·564	29·4 to 60·2	10,524 D.						
Southampton	Constant	S.	·136	24·5	53,741 M.	—	70·38	14·08	24·42	10·17	3·8
Stafford	—	S.W.	·346 to ·516	29·4 to 68·8	14,437						
Stockport	Constant	U.	·223	8·3	53,014 M.						
Stockton-on-Tees	„	„	·193	12·3	27,738 M.						

‡ Registration districts within the limits of the Metropolis as defined in the Registrar-General's Reports.
§ Average of seven years from 1862 to 1868 inclusive.

Statistics of Water Supply and Mortality—*continued.*

Name of Town.	Mode Supply.	Nature of Supply.	Organic Elements in 100,000 parts of Water.	Total Hardness in 100,000 parts of Water.	Population, 1871.	Mortality per Annum. Cholera, per 10,000. 1832.	1848–49.	1853–54.	1865–66.	Diarrhœa, per 10,000.	All Causes, per 1,000.
A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.
ENGLAND AND WALES—*cont.*											
Stoke Row	—	D.W.	·076	25·4							
Stoke-upon-Trent	—	D.W.	·056 to ·064	13·4 to 16·9	130,985 P.	—	17·78	1·21	·98	15·11	27·9†
Stone	—	D.W.	·056 to ·064	13·4 to 16·9	10,088						
Stonehouse, Devon.	—	S.	·135	19·4							
Stow-on-the-Wold	—	D.W.	·037	18·9	4,996						
Streatley	—	S.W., D.W.	·074 to ·100	24·2 to 29·3							
Stroud	—	S., D.W.	·025 to ·592	21·8 to 32·5	38,910 P	—	9·09	3·21	·27	5·22	20·9†
Sudbury (Suffolk)	—	S.W., D.W.	·021 to ·807	32·0 to 105·8	6,908						
Sunderland	—	D.W.	·065	14·7	98,242 M.	126·03	51·43	5·95	10·14	12·06	26·3*
Swanage	—	D.W.	·079	42·8	3,919						
Swansea	—	U.	·049 to ·230	2·3 to 3·5	51,702 M.	—	55·85	33·62	101·64	5·36	23·2†
Taunton	Intermittent	,,	·289	2·6	15,466						
Tavistock	—	Sp.	·107	2·5	7,720						
Tewkesbury	—	S.	·448	10·0	5,409						
Thame	—	S.W.	1·042	78·9	5,912						
Thetford	—	S.W.	·051 to ·435	23·9 to 49·3	4,167						
Torquay	—	S.	·366	2·3	28,311						
Tôtness	—	Sp.	·022	17·2	4,073						
Tranmere	—	D.W.	0	11·3	16,143 L.B.						
Tring	—	,,	·049	3·2	7,757						
Trowbridge	—	P.D.W.	·293	57·1	11,508 L.B.						
Truro	—	S.W.	·121	26·0	10,999						
Tunbridge	—	S., D.W.	·042 to ·309	8·0 to 22·1	13,710						
Tunbridge Wells	Intermittent	Sp.	·006	3·3	24,748						
Tunstall (Staffordshire)	—	D.W.	·056 to ·064	13·4 to 16·9	27,775						
Ventnor	—	D.W.	·035 to ·067	21·8 to 26·3							
Wadebridge	—	S.W.	·076	26·3							
Wakefield	—	S.	·486 to ·493	13·5 to 15·4	28,069 M.						
Wallasey	Constant	D.W.	·038	9·1	14,779						
Warkton, near Kettering.	—	S.W.	·157 to ·806	34·8 to 50·8							
Warrington	—	Sp.	·029 to ·517	16·8 to 18·1	32,083 M.						
Washingborough, Lincolnshire.	—	S.W.	·083 to ·189	28·2 to 35·7							
Watford	—	D.W.	·045 to ·053	28·2 to 28·8	12,074						
Watlington, Oxfordshire	—	S.W.	·078 to ·424	29·9 to 36·4	4,289						
Weston-super-Mare	Constant	—	·034	48·5							
Weymouth	—	Sp.	·049 to ·051	20·3 to 20·6	13,257						
Whitehaven	—	U.	·059	1·4	18,446						
Whitwick	—	S.W.	·095 to ·236	13·1 to 24·0	11,940						
Whittlesey	—	,,	1·123 to 1·871	90·1 to 102·8	7,002 D.	—	15·61	16·91	0	10 88	20·8†
Wigan	—	—	·398	12·1	89,110 M.	14·44					
Winchester	Intermittent	D.W.	·066	23·0	14,705						
Windsor	Constant	,,	·152	25·4	11,769						
Witham	—	,,	·086	28·2	6,860						
Witney	—	S.W.	·777	54·3	2,976 L.B.						
Wokingham	—	,,	·379 to 1·309	47·2 to 131·7	8,347						
Wolverhampton	Partly Constant.	S., D.W.	·043 to ·621	16·9 to 29·7	68,291 M.	—	—	—	—	—	25·9*
Worcester	—	S.	·289	14·0	7,477						
Worksop	—	S.W.	·163 to ·701	35·9 to 82·0	10,459						
Worthing, East	—	D.W.	·007	24·7	10,854						
Wouldham	—	S.W.	·130 to ·219	34·9 to 47·6							
Yeovil	—	Sp.	·051	20·9	8,476						
York	Constant	S.	·204	26·6	43,796 M.	24·6	32·03	2·76	·50	11·74	23·5†
SCOTLAND.											
Aberdeen	Constant	U.	·428	2·03	88,189 T.	—	—	—	8·93	5·93	24·3
Abergeldie	,,	U., Sp.	·058 to ·234	2·6 to 3·8							
Airdrie	,,	U.	·428	9·8	15,671 T.	—	—	—	0	9·44	23·8
Alford-on-the-Don	—	S.W., Sp.	·055	9·3	482 V.						
Alloa	Constant	U.	·334	9·0	9,362 T.	—	—	—	—	—	26·9
Arbroath	,,	Sp.	·057	16·9	20,169 T.	—	—	—	0	4·60	24·1
Ayr	,,	,,	·038	11·6	17,954 T.	—	—	—	·51	4·63	24·6
Balmoral	,,	U., S.W., Sp.	·129 to ·215	·9 to 5·0							
Blairgowrie	,,	U.	·337	2·1	5,252 T.						
Brechin	,,	Sp.	·078	10·6	7,959 T.	—	—	—	—	—	27·5
Bridge of Allan	—	U.	·697	4·9	3,055 T.	—	—	—	—	—	25·7
Cupar	—	S.W.	·045 to ·321	21·5 to 36·4	5,105 T.	—	—	—	—	—	22·5
Dumbarton	Constant	U.	·457	3·8	11,423 T.	—	—	—	—	—	26·5
Dundee	,,	S.	·477 to ·478	6·0 to 6·6	119,141 T.	—	—	—	12·22	7·35	29·0
Dunkeld	,, (?)	U.	·203	2·7	783 V.						
Edinburgh	Intermittent	U., Sp.	·039 to ·437	6·0 to 11·6	197,581 T.	—	—	—	8·68	6·08	26·0
Forfar	—	S.W.	·070 to ·111	9·1 to 29·3	11,131 T.	—	—	—	1·85	5·72	27·4
Galashiels	Intermittent	S.	·136	6·0	10,312 T.	—	—	—	1·58‡	—	23·4
Glasgow	Constant	U.	·207 to ·388	·9 to 4·4	547,538 T.	—	—	—	—	7·08	30·8
Granton	,, (?)	S.	·269	27·5	1,104 V.						
Greenock	,,	U.	·538	1·9	57,821 T.	—	—	—	3·19	9·36	33·6
Hamilton	,,	,,	·526	6·3	11,498 T.	—	—	—	1·42	7·55	24·4

‡ Corrected for increase of population in 1866.

Statistics of Water Supply and Mortality—*continued.*

Name of Town.	Mode of Supply.	Nature of Supply.	Organic Elements in 100,000 parts of Water.	Total Hardness in 100,000 parts of Water.	Population, 1871.	Mortality per Annum. Cholera per 10,000. 1862.	1848–49.	1853–54.	1865–66.	Diarrhœa, per 10,000.	All Classes per 1,000.
A.	B.	C.	D.	E.	F.	G.	H.	I.	K.	L.	M.
England and Wales—*cont.*											
Hawick - -	Constant	U.	·111	8·6	11,356 T.	—	—	—	—	-	25·0
Inverness - -	„	„	·393	2·7	14,510 T.	—	—	—	0	6 19	25·2
Jedburgh - -	„	Sp.	·024	19·6	3,321 T.	—	—	—	—	—	21·4
Johnstone - -	„	U.	·296 to ·589	4·2 to 5·9	7,538 T.	—	—	—	—	—	26·4
Kelso - -	Partly constant.	Sp.	·041	16·5	4,564 T.	—	—	—	—	—	26·3
Kilmarnock - -	Constant	U.	·540	8·6	23,709 T.	—	—	—	2·12	7·47	26·0
Kirkintillock - -	—	S.W.	·160 to ·446	11·9 to 28·4	6,139 T.	—	—	—	—	—	24·0
Lanark - -	Constant	S.	·174	3·9	5,099 T.	—	—	—	—	—	26·8
Leith - - -	Intermittent	„	·340	13·3	44,721 T.	—	—	—	27·20	5·33	24·9
Linlithgow - -	Constant	Sp.	·044	18·3	3,690 T.	—	—	—	—	—	24·9
Melrose - -	„	„	·015	10·7	1,405 V.						
Montrose - -	„	S., Sp.	·045 to ·119	13·1 to 15·4	14,608 T.	—	—	—	1·72	5·43	23·4
Musselburgh - -	—	S.W.	·045 to ·357	11·9 to 41·6	7,517 T.	—	—	—	—	—	28·2
Paisley - -	Constant	U.	·296 to ·589	4·2 to 5·9	48,257 T.	—	—	—	1·48	5·10	28·5
Peebles - -	„	„	·237	4·0	2,631 T.	—	—	—	—	—	24·6
Perth - -	„	U.S.	·137 to ·227	2·9 to 7·6	25,606 T.	—	—	—	6·51	7·36	25·4
Pollokshaws - -	„	U.	·388	4·4	8,921 T.	—	—	—	—	—	24·9
Port Glasgow -	„	„	·318	3·3	10,823 T.	—	—	—	—	—	28·1
Selkirk - -	„	S.W.	·056	3·4	4,640 T.	—	—	—	—	—	22·6
Stirling - -	„	U.	·526	2·7	14,279 T.	—	—	—	0	11·70	26·1

APPENDIX No. 8.

Table illustrating the Improvements of Public Health which result from proper Works of Drainage and Water Supply.

From the Ninth Report of the Medical Officer of the Privy Council, 1866, page 35.

Death-rates per Annum, Total and Particular, per 10,000 of general Population, for each of the compared Periods.

Population in 1861.	Towns in Order of their Population.	Periods for which the Death-rates are compared. Before the Works.	After the Works.	A. General Death-rates. Before the Works.	After the Works.	B. General Death-rates, after excluding Small-pox and other Infantine Epidemics. Before the Works.	After the Works.	C. Typhoid Fever. Before the Works.	After the Works.	D. Diarrhœa, excluding Cholera so-called. Before the Works.	After the Works.	E. Cholera in each of the three Epidemics. 1848–9.	1854.	1866.	F. Phthisis. Before the Works.	After the Works.	G. Phthisis and other Pulmonary Diseases of Women, aged 15–55. Before the Works.	After the Works.	H. Death-rates of Infants under one year of age. Before the Works.	After the Works.
160,714	Bristol - -	1847-51 (?)	1862-5 (?)	245½	242	215	205¾	10	6½	10½	9½	82	11	1½	31	25½	16	13⅓	54	52
68,056	Leicester -	1845-51	1862-4	264	252	236½	225⅓	14⅗	7¾	16	19⅓	1	10	—	43⅓	29¼	17¾	16	84¼	81
52,778	Merthyr -	1845-55	1862-5	332	262	292⅓	221¼	21⅓	8⅔	11½	6¼	267	84	20	38⅔	34⅓	15½	13¾	80¼	61
39,693	Cheltenham -	1845-57	1860-5	194	185	182	172	8	4¾	8⅓	7	—	—	—	28¾	21¼	15	11¾	40½	37
																	all ages and both sexes			
32,954	Cardiff - -	1847-57	1859-66	332	226	294	191⅓	17½	10½	17¼	4½	208	66	15½	34¾	28⅔	66	58⅔	?	?
30,229	Croydon -	1845-50	1857-64	237	190	207	178¼	15	5½	10	7	27	21	2	?	?	59½	49	?	?
29,417	Carlisle - -	1845-53	1858-64	284	261	244	225	10	9¾	11½	12⅓	22	6	—	32	35⅔	16½	16⅔	71	65½
27,475	Macclesfield -	1845-52	1857-64	298	237	263⅓	217½	14¼	8½	11⅓	11	9	1	—	51⅓	35⅗	28⅓	22	77½	59⅔
24,756	Newport -	1845-49	1860-65	318	216½	275	187½	16⅓	10⅓	11	6⅓	112	1½	12	37	25	14	12½	67¼	53¼
23,108	Dover - -	1843-53	1857-65	225½	209	203	187	14	9	9½	7	40	10	4⅔	26½	21¼	13⅓	11¼	47⅘	46½
10,570	Warwick -	1845-55	1859-64	227	210	209¾	191⅓	19	9	5¾	8	10½	—	—	40	32⅓	16⅔	14⅔	51¼	46⅚
10,238	Banbury -	1845-53	1857-64	235	205	214	184½	16	8½	11⅓	5½	2	1½	—	26⅔	15⅔	14⅔	9⅓	53	45
9,414	Penzance -	1843-50	1856-65	221	222	197½	200⅓	7½	8	5⅓	9⅓	—	—	—	30⅔	29	13¼	14	?	?
																	all over 20 both sexes			
9,030	Salisbury -	1844-52	1857-64	275	219	253[2]	198½	7½	1¾	6⅓	2⅓	180	14½	—	44⅓	22⅔	53⅓	38½	43	40
8,664	Chelmsford -	1843-52	1855-65	196½	215	180	187	12	12⅔	7	8	4	—	—	32⅓	32⅔	12⅔	14⅕	44	42
																	all ages; both sexes			
7,847	Ely - -	1845-52	1859-64	228	205½	210	186¼	10⅔	4½	3¾	4¼	—	22	—	31	16¾	48	36	50⅓	42⅓
7,818	Rugby - -	1845-51	1855-64	191	186	164	164½	10	9	2⅓	7½	—	—	—	28½	16¼	15	7	42½	45
7,189	Penrith - -	1845-52	1856-64	253½	250	235½	230½	10	4½	3⅗	4⅘	9½	2⅓	—	39⅓	37½	7	19⅓	55⅓	55⅓
6,823	Stratford -	1845-53	1860-64	217	202	212¼	178	12½	4	11¼	5¼	—	—	—	26⅔	26½	14	13	46	48
6,494	Alnwick -	1845-51	1856-64	262	247	240	221½	13½	8⅔	7	4⅔	205	—	—	28⅓	33	13⅓	17⅓	?	?
6,334	Brynmawr -	1843-52	1856-65	273½	232⅓	232	209	23⅓	10¼	5	4¾	100	—	—	28⅓	30	14¾	13¾	76½	69
5,805	Worthing -	1843-52	1857-65	155	153	139	136½	7½	9¼	4¾	5½	—	—	—	30½	19½	14¾	9¼	24¼	22⅓
4,490	Morpeth -	1845-52	1856-64	262	247	234	225	16⅓	10	8½	14½	14	11⅓	—	30⅓	28	14	14⅔	56	57½
3,840	Ashby - -	1845-51	1856-64	216	202½	213	184	13⅓	5¾	4	8⅓	—	—	—	25½	31⅓	16	13	48	31

RIVER THAMES.—Daily Volume of Water flowing down the Thames opposite

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
January 1	- - -	653,232,000	434,840,000	710,016,000	681,624,000	529,968,000	470,545,000	2,016,760,000	3,762,320,000	624,840,000
2	- - -	624,840,000	416,988,000	738,408,000	681,624,000	488,397,000	488,397,000	2,016,760,000	5,140,800,000	653,232,000
„ 3	- -	653,232,000	434,840,000	681,624,000	738,408,000	529,968,000	553,686,000	2,292,800,000	3,762,320,000	681,624,000
„ 4	- - -	681,624,000	452,693,000	738,408,000	898,560,000	529,968,000	553,686,000	2,292,800,000	3,543,720,000	653,232,000
„ 5	- - -	624,840,000	434,840,000	710,016,000	1,052,610,000	506,250,000	488,397,000	2,367,760,000	3,440,240,000	624,840,000
„ 6	- - -	601,122,000	434,840,000	931,500,000	1,052,610,000	506,250,000	529,968,000	2,367,760,000	2,442,720,000	624,840,000
„ 7	- - -	681,624,000	416,988,000	1,133,350,000	1,012,240,000	488,397,000	488,397,000	2,154,280,000	2,292,800,000	624,840,000
„ 8	- - -	1,634,700,000	416,988,000	1,527,140,000	898,560,000	488,397,000	470,545,000	1,822,068,000	2,442,720,000	624,840,000
„ 9	- - -	3,992,560,000	416,988,000	1,419,580,000	832,680,000	488,397,000	470,545,000	1,634,700,000	1,948,000,000	601,122,000
„ 10	- - -	4,477,680,000	410,572,000	1,365,800,000	1,092,980,000	529,968,000	452,693,000	1,527,140,000	1,634,700,000	832,680,000
„ 11	- - -	4,222,800,000	410,572,000	1,634,700,000	2,154,280,000	529,968,000	470,545,000	1,365,800,000	1,365,800,000	931,500,000
„ 12	- - -	3,992,560,000	434,840,000	1,365,800,000	3,543,720,000	553,686,000	434,840,000	1,226,330,000	1,133,350,000	971,870,000
„ 13	- - -	3,647,200,000	416,988,000	1,092,980,000	3,762,320,000	601,122,000	452,693,000	1,133,350,000	1,012,240,000	971,870,000
„ 14	- - -	3,543,720,000	416,988,000	898,560,000	2,944,920,000	577,404,000	434,840,000	1,052,610,000	1,012,240,000	799,740,000
„ 15	- - -	3,336,760,000	410,572,000	553,686,000	2,517,680,000	529,968,000	434,840,000	971,870,000	931,500,000	710,016,000
„ 16	- - -	2,852,580,000	410,572,000	553,686,000	2,442,720,000	529,968,000	452,693,000	1,092,980,000	898,560,000	710,016,000
„ 17	- - -	2,442,720,000	416,988,000	766,800,000	2,292,800,000	553,686,000	416,988,000	1,419,580,000	766,800,000	1,012,240,000
„ 18	- - -	2,016,760,000	416,988,000	766,800,000	1,760,020,000	529,968,000	438,840,000	1,419,580,000	766,800,000	971,870,000
„ 19	- - -	1,885,340,000	434,840,000	1,052,610,000	1,473,360,000	488,397,000	452,693,000	1,179,840,000	898,560,000	898,560,000
„ 20	- - -	1,760,020,000	434,840,000	1,419,580,000	1,272,820,000	529,968,000	529,968,000	1,272,820,000	931,500,000	766,800,000
„ 21	- - -	1,697,360,000	380,635,000	1,885,340,000	1,365,800,000	506,250,000	488,397,000	1,822,068,000	1,012,240,000	553,686,000
„ 22	- - -	1,580,920,000	368,388,000	2,085,520,000	1,634,700,000	488,397,000	488,397,000	2,760,040,000	1,226,330,000	624,840,000
„ 23	- - -	1,473,360,000	374,220,000	2,367,760,000	1,580,920,000	488,397,000	488,397,000	3,129,800,000	1,419,580,000	766,800,000
„ 24	- - -	1,329,410,000	391,327,000	2,154,280,000	1,527,140,000	488,397,000	553,686,000	2,517,680,000	1,365,800,000	766,800,000
„ 25	- - -	1,473,360,000	391,327,000	2,367,760,000	1,419,580,000	488,397,000	832,680,000	2,667,600,000	1,419,580,000	1,012,240,000
„ 26	- - -	1,580,920,000	391,327,000	2,442,720,000	1,580,920,000	470,545,000	601,122,000	2,592,640,000	1,580,920,000	1,329,410,000
„ 27	- - -	1,634,700,000	410,572,000	2,592,640,000	1,760,020,000	470,545,000	681,624,000	2,592,640,000	1,885,340,000	1,365,800,000
„ 28	- - -	1,527,140,000	410,572,000	2,367,760,000	1,634,700,000	470,545,000	601,122,000	2,760,040,000	1,948,000,000	1,133,350,000
„ 29	- - -	1,419,580,000	404,757,000	2,223,040,000	1,329,410,000	470,545,000	601,122,000	2,592,640,000	1,885,340,000	1,133,350,000
„ 30	- - -	1,365,800,000	410,572,000	1,948,000,000	1,133,350,000	470,545,000	553,686,000	2,517,680,000	1,822,068,000	1,226,330,000
„ 31	- - -	1,329,410,000	404,757,000	1,634,700,000	832,680,000	553,686,000	601,122,000	2,667,600,000	1,634,700,000	1,527,140,000
February 1	1,885,340,000	1,329,410,000	382,773,000	1,419,580,000	1,052,610,000	799,740,000	529,968,000	2,667,600,000	1,580,920,000	2,016,760,000
„ 2	1,822,068,000	1,419,580,000	374,220,000	1,179,840,000	898,560,000	624,840,000	601,122,000	2,292,800,000	1,365,800,000	1,634,700,000
„ 3	1,760,020,000	1,527,140,000	376,358,000	1,133,350,000	931,500,000	653,232,000	601,122,000	2,016,760,000	1,133,350,000	1,272,820,000
„	1,634,700,000	1,473,360,000	376,358,000	971,870,000	931,500,000	710,016,000	529,968,000	1,822,068,000	1,012,240,000	1,179,840,000
„ 5	1,634,700,000	1,365,800,000	380,635,000	898,560,000	832,680,000	1,092,980,000	529,968,000	1,634,700,000	931,500,000	1,179,840,000
„ 6	1,634,700,000	1,329,410,000	470,545,000	931,500,000	738,408,000	1,527,140,000	529,968,000	1,634,700,000	931,500,000	1,052,610,000
„ 7	1,634,700,000	1,329,410,000	653,232,000	898,560,000	832,680,000	1,329,410,000	766,800,000	1,697,360,000	931,500,000	898,560,000
„ 8	1,580,920,000	1,272,820,000	506,250,000	971,870,000	1,092,980,000	1,052,610,000	865,620,000	1,580,920,000	931,500,000	766,800,000
„ 9	1,697,360,000	1,133,350,000	470,545,000	1,272,820,000	1,272,820,000	799,740,000	832,680,000	1,527,140,000	931,500,000	766,800,000
„ 10	1,885,340,000	1,052,610,000	397,142,000	1,365,800,000	1,272,820,000	577,404,000	1,012,240,000	1,419,580,000	1,179,840,000	799,740,000
„ 11	1,948,000,000	1,012,240,000	738,408,000	1,272,820,000	1,419,580,000	601,122,000	1,272,820,000	1,272,820,000	1,226,330,000	681,624,000
„ 12	1,885,340,000	931,500,000	710,016,000	1,272,820,000	1,329,410,000	601,122,000	1,133,350,000	1,179,840,000	1,226,330,000	624,840,000
„ 13	1,760,020,000	865,620,000	681,624,000	1,119,580,000	1,179,840,000	577,404,000	1,473,360,000	1,092,980,000	1,226,330,000	710,016,000
„ 14	1,697,360,000	865,620,000	865,620,000	1,697,360,000	1,012,240,000	624,840,000	1,329,410,000	971,870,000	1,179,840,000	710,016,000
„ 15	1,580,920,000	865,620,000	865,620,000	2,292,800,000	1,012,240,000	1,419,580,000	1,179,840,000	865,620,000	1,133,350,000	710,016,000
„ 16	1,335,800,000	865,620,000	931,500,000	2,292,800,000	1,012,240,000	2,154,280,000	1,012,240,000	931,500,000	1,133,350,000	681,624,000
„ 17	1,272,820,000	865,620,000	766,800,000	2,085,520,000	898,560,000	1,580,920,000	898,560,000	931,500,000	1,226,330,000	681,624,000
„ 18	1,226,330,000	865,620,000	766,800,000	2,085,520,000	898,560,000	1,226,330,000	506,250,000	1,012,240,000	1,272,820,000	681,624,000
„ 19	1,179,840,000	832,680,000	931,500,000	1,634,700,000	832,680,000	1,092,980,000	710,016,000	1,052,610,000	1,133,350,000	681,624,000
„ 20	1,052,610,000	766,800,000	738,408,000	1,329,410,000	832,680,000	738,408,000	601,122,000	1,092,980,000	1,012,240,000	710,016,000
„ 21	1,052,610,000	766,800,000	738,408,000	1,133,350,000	766,800,000	738,408,000	624,840,000	1,092,980,000	1,012,240,000	1,052,610,000
„ 22	1,012,240,000	766,800,000	865,620,000	1,092,980,000	766,800,000	653,232,000	506,250,000	971,870,000	1,419,580,000	766,800,000
„ 23	971,870,000	799,740,000	971,870,000	1,052,610,000	766,800,000	577,404,000	624,840,000	898,560,000	1,697,360,000	710,016,000
„ 24	1,272,820,000	865,620,000	971,870,000	1,092,980,000	738,408,000	601,122,000	624,840,000	799,740,000	2,085,520,000	710,016,000
„ 25	1,473,360,000	799,740,000	931,500,000	1,012,240,000	738,408,000	577,404,000	601,122,000	799,740,000	2,760,040,000	601,122,000
„ 26	1,634,700,000	738,408,000	601,122,000	865,620,000	681,624,000	553,686,000	553,686,000	799,740,000	3,129,800,000	577,404,000
„ 27	1,697,360,000	681,624,000	681,624,000	898,560,000	681,624,000	553,686,000	577,404,000	832,680,000	2,292,800,000	624,840,000
„ 28	1,697,360,000	710,016,000	653,232,000	865,620,000	681,624,000	577,404,000	577,404,000	1,052,610,000	1,885,340,000	624,840,000
„ 29	- - -	- - -	- - -	799,740,000	- - -	- - -	- - -	1,052,610,000	- - -	- -

the Lambeth Waterworks Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive).

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
624,840,000	470,545,000	488,397,000	1,948,000,000	738,408,000	553,686,000	4,107,680,000	865,620,000	404,757,000	710,016,000	1,885,340,000
681,624,000	470,545,000	488,397,000	2,367,760,000	738,408,000	488,397,000	3,129,800,000	1,365,800,000	382,773,000	601,122,000	2,292,800,000
865,620,000	470,545,000	470,545,000	2,592,640,000	681,624,000	452,693,000	3,037,460,000	1,365,800,000	391,327,000	601,122,000	2,760,040,000
1,012,240,000	506,250,000	470,545,000	2,367,760,000	553,686,000	470,545,000	3,233,280,000	1,272,820,000	391,327,000	738,408,000	3,233,280,000
1,329,410,000	391,327,000	488,397,000	2,154,280,000	364,500,000	452,693,000	3,129,800,000	1,272,820,000	382,773,000	1,012,240,000	3,140,240,000
1,760,020,000	391,327,000	488,397,000	2,154,280,000	506,250,000	410,572,000	3,129,800,000	1,473,360,000	382,773,000	1,697,360,000	3,877,440,000
3,129,800,000	416,988,000	470,545,000	2,016,760,000	766,800,000	384,912,000	3,440,240,000	1,473,360,000	382,773,000	2,367,760,000	4,222,800,000
3,647,200,000	416,988,000	488,397,000	2,016,760,000	2,852,580,000	488,397,000	3,647,200,000	1,365,800,000	553,686,000	2,442,720,000	4,107,680,000
3,233,280,000	378,496,000	488,397,000	2,292,800,000	4,222,800,000	506,250,000	3,762,320,000	1,527,140,000	488,397,000	2,517,680,000	3,762,320,000
2,667,600,000	366,444,000	470,545,000	2,154,280,000	4,107,680,000	506,250,000	3,877,440,000	1,473,360,000	434,840,000	2,223,040,000	3,762,320,000
2,292,800,000	366,444,000	506,250,000	1,885,340,000	4,107,680,000	506,250,000	3,877,440,000	1,473,360,000	488,397,000	2,085,520,000	4,107,680,000
1,918,000,000	416,988,000	488,397,000	2,223,040,000	3,336,760,000	577,404,000	3,543,720,000	1,365,800,000	391,327,000	1,948,000,050	4,732,560,000
1,760,020,000	506,250,000	529,968,000	2,442,720,000	2,667,600,000	865,620,000	2,944,920,000	1,419,580,000	397,142,000	1,822,068,000	3,647,200,000
2,292,800,000	529,968,000	799,740,000	3,647,200,000	2,292,800,000	1,473,360,000	2,367,760,000	1,419,580,000	384,912,000	1,697,360,000	2,994,920,000
2,292,800,000	601,122,000	1,272,820,000	6,500,200,000	1,885,340,000	1,419,580,000	2,016,760,000	1,473,360,000	434,810,000	1,948,000,000	2,442,720,000
2,016,760,000	577,404,000	1,226,330,000	5,870,000,000	1,419,580,000	1,179,840,000	1,822,068,000	1,473,360,000	577,404,000	1,760,020,000	2,223,040,000
1,527,160,000	553,686,000	865,620,000	5,716,000,000	1,052,610,000	1,052,610,000	1,634,700,000	1,329,410,000	898,560,000	1,473,360,000	2,016,760,000
1,419,580,000	553,686,000	799,740,000	5,716,000,000	931,500,000	1,052,610,000	1,634,700,000	1,179,840,000	1,473,360,000	1,527,140,000	1,822,068,000
1,419,580,000	553,686,000	710,016,000	4,860,000,000	898,560,000	1,133,350,000	1,634,700,000	1,133,350,000	1,760,020,000	2,016,760,000	1,822,068,000
1,329,410,000	553,686,000	681,624,000	4,350,240,000	898,560,000	2,292,800,000	1,580,920,000	1,052,610,000	1,580,920,000	2,016,760,000	2,517,680,000
1,052,610,000	653,232,000	577,404,000	3,992,560,000	766,800,000	2,223,040,000	1,473,360,000	931,500,000	1,272,820,000	1,822,068,000	3,233,280,000
898,560,000	766,800,000	601,122,000	3,037,460,000	710,016,000	2,085,520,000	1,419,580,000	898,560,000	1,133,350,000	1,527,140,000	3,037,460,000
832,680,000	832,680,000	553,686,000	2,852,580,000	710,016,000	3,233,280,000	1,365,800,000	865,620,000	971,870,000	1,634,700,000	2,944,920,000
799,740,000	931,500,000	470,545,000	2,667,600,000	971,870,000	3,877,440,000	1,272,820,000	799,740,000	1,092,980,000	2,292,800,000	2,667,600,000
865,620,000	931,500,000	506,250,000	2,367,760,000	1,634,700,000	3,336,760,000	1,133,350,000	766,800,000	1,092,980,000	4,107,680,000	2,760,040,000
832,680,000	766,800,000	470,545,000	2,154,280,000	1,697,360,000	3,233,280,000	971,870,000	738,408,000	898,560,000	4,222,800,000	2,760,040,000
971,870,000	832,680,000	470,545,000	1,948,000,000	1,580,920,000	2,513,680,000	898,560,000	738,408,000	710,016,000	3,992,560,000	2,592,640,000
898,560,000	710,016,000	1,133,350,000	1,822,068,000	1,822,068,000	2,592,640,000	898,560,000	710,016,000	553,686,000	3,877,440,000	2,442,720,000
898,560,000	710,016,000	971,870,000	1,697,360,000	1,760,020,000	2,760,040,000	1,012,240,000	653,232,000	553,686,000	3,992,560,000	2,154,280,000
832,680,000	681,624,000	553,686,000	1,473,360,000	1,580,920,000	2,442,720,000	1,885,340,000	653,232,000	577,404,000	3,877,440,000	1,948,000,000
832,680,000	624,840,000	553,686,000	1,365,800,000	1,948,000,000	2,016,760,000	2,760,040,000	653,232,000	470,545,000	3,440,240,000	1,697,360,000
1,133,350,000	601,122,000	1,133,350,000	1,365,800,000	2,292,800,000	577,404,000	3,336,760,000	653,232,000	506,250,000	2,852,580,000	1,580,920,000
1,226,330,000	553,686,000	2,154,280,000	1,473,360,000	2,292,800,000	1,527,140,000	3,992,560,000	681,624,000	488,397,000	2,292,800,000	1,527,140,000
1,226,330,000	506,250,000	2,085,520,000	2,016,760,000	2,154,280,000	1,473,360,000	4,222,800,000	865,620,900	506,250,000	1,948,000,000	1,419,580,000
1,473,360,000	601,122,000	1,885,340,000	2,517,680,000	2,016,760,000	1,527,140,000	4,350,240,000	1,179,840,000	553,686,000	1,697,360,000	1,329,410,000
1,365,800,000	577,404,000	1,634,700,000	2,517,680,000	2,154,280,000	1,365,800,000	4,605,120,000	1,133,350,000	624,840,000	1,527,140,000	1,329,410,000
1,092,980,000	577,404,000	1,580,920,000	2,760,040,000	2,223,040,000	1,272,820,000	3,992,560,000	1,272,820,000	577,404,000	1,527,140,000	1,527,140,000
898,560,000	624,840,000	1,885,340,000	2,592,640,000	2,292,800,000	1,179,840,000	3,440,240,000	1,419,580,000	653,232,000	1,419,580,000	1,697,360,000
832,680,000	553,686,000	2,016,760,000	2,442,720,000	2,016,760,000	1,133,350,000	2,760,040,000	2,154,280,000	710,016,000	1,473,360,000	1,760,020,000
799,740,000	553,686,000	1,697,360,000	2,367,760,000	2,223,040,000	1,052,610,000	2,292,800,000	3,543,720,000	766,800,000	1,634,700,000	1,760,020,000
738,408,000	506,250,000	1,419,580,000	2,367,760,000	2,442,720,000	1,012,240,000	2,367,760,000	3,233,280,000	710,016,000	1,580,920,000	1,634,700,000
710,016,000	488,397,000	1,226,330,000	2,944,920,000	2,367,760,000	865,620,000	2,154,280,000	2,442,720,000	931,500,000	1,527,140,000	1,634,700,000
681,624,000	470,545,000	1,012,240,000	4,350,240,000	2,517,680,000	898,560,000	2,016,760,000	2,085,520,000	898,560,000	1,419,580,000	1,527,140,000
681,624,000	653,232,000	971,870,000	5,716,000,000	2,223,040,000	799,740,000	2,944,920,000	1,822,068,000	738,408,000	1,473,360,000	1,365,800,000
681,624,000	898,560,000	799,740,000	4,860,000,000	2,016,760,000	766,800,000	3,992,560,000	1,580,920,000	799,740,000	1,419,580,000	1,272,820,000
681,624,000	738,408,000	738,408,000	4,477,680,000	1,822,068,000	738,408,000	4,107,680,000	1,179,840,000	681,624,000	1,329,410,000	1,226,330,000
653,232,000	681,624,000	624,840,000	4,732,560,000	1,697,360,000	710,016,000	4,350,240,000	1,052,610,000	653,232,000	1,226,330,000	1,179,840,000
653,232,000	624,840,000	710,016,000	5,000,400,000	1,948,000,000	681,624,000	4,222,800,000	1,052,610,000	601,122,000	1,179,840,000	1,092,980,000
624,840,000	624,840,000	766,800,000	5,000,400,000	2,154,280,000	624,840,000	4,222,800,000	1,012,240,000	553,686,000	1,092,980,000	1,133,350,000
653,232,000	601,122,000	865,620,000	3,877,440,000	2,085,520,000	601,122,000	3,877,440,000	931,500,000	529,968,000	1,133,350,000	1,012,240,000
653,232,000	624,840,000	1,133,350,000	3,336,760,000	1,697,360,000	529,968,000	3,233,280,000	931,500,000	488,397,000	1,226,330,000	1,012,240,000
738,408,000	624,840,000	1,052,610,000	2,667,600,000	1,419,580,000	653,232,000	2,667,600,000	1,012,240,000	470,545,000	1,272,820,000	971,870,000
766,800,000	529,968,000	971,870,000	2,154,280,000	1,272,820,000	624,840,000	2,223,040,000	1,012,240,000	506,250,000	1,179,840,000	931,500,000
710,016,000	470,545,000	1,133,350,000	1,885,340,000	1,179,840,000	681,624,000	2,085,520,000	971,870,000	488,397,000	1,226,330,000	1,012,240,000
653,232,000	529,968,000	1,179,840,000	1,697,360,000	1,052,610,000	624,840,000	1,885,340,000	931,500,000	488,397,000	1,365,800,000	931,500,000
577,404,000	470,545,000	1,760,020,000	1,527,140,000	1,012,240,000	577,404,000	1,697,360,000	931,500,000	470,545,000	1,365,800,000	1,012,240,000
577,404,000	488,397,000	2,085,520,000	1,527,140,000	898,560,000	553,686,000	1,760,020,000	898,560,000	488,397,000	1,365,800,000	1,527,140,000
601,122,000	577,404,000	1,948,000,000	1,634,700,000	865,620,000	577,404,000	1,473,360,000	865,620,000	434,840,000	1,419,580,000	3,037,460,000
601,122,000	506,250,000	1,885,340,000	1,760,020,000	898,560,000	553,686,000	1,329,410,000	832,680,000	452,693,000	1,272,820,000	3,336,760,000
- - -	624,840,000	- - -	- - -	- - -	553,686,000	- - -	- - -	- - -	1,092,980,000	—

Daily Volume of Water flowing down the Thames opposite the Lambeth Water-

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
March 1 -	1,634,700,000	710,016,000	832,680,000	832,680,000	653,232,000	506,250,000	506,250,000	1,092,980,000	1,822,068,000	553,686,000
„ 2 -	1,473,360,000	681,624,000	865,620,000	832,680,000	624,840,000	470,545,000	529,968,000	971,870,000	2,085,520,000	529,968,000
„ 3 -	1,365,800,000	681,624,000	1,012,240,000	799,740,000	624,840,000	553,686,000	470,545,000	898,560,000	2,085,520,000	529,968,000
„ 4 -	1,329,410,000	653,232,000	1,365,800,000	738,408,000	624,840,000	488,397,000	553,686,000	898,560,000	1,822,068,000	529,968,000
„ 5 -	1,329,410,000	681,624,000	971,870,000	738,408,000	653,232,000	488,397,000	553,686,000	1,272,820,000	1,419,580,000	506,250,000
„ 6 -	1,365,800,000	653,232,000	766,800,000	710,016,000	624,840,000	577,404,000	553,686,000	1,329,410,000	1,179,840,000	529,968,000
„ 7 -	1,697,360,000	577,404,000	577,404,000	710,016,000	624,840,000	601,122,000	553,686,000	1,133,350,000	1,133,350,000	766,800,000
„ 8 -	1,948,000,000	710,016,000.	410,572,000	681,624,000	601,122,000	577,404,000	488,397,000	1,179,840,000	1,052,610,000	1,012,240,000
„ 9 -	1,822,068,000	601,122,000	577,404,000	710,016,000	653,232,000	470,545,000	529,968,000	1,012,240,000	898,560,000	898,560,000
„ 10 -	1,419,580,000	653,232,000	529,968,000	653,232,000	601,122,000	553,686,000	529,968,000	931,500,000	898,560,000	971,870,000
, 11 -	1,272,820,000	653,232,000	506,250,000	653,232,000	601,122,000	529,968,000	470,545,000	931,500,000	865,620,000	971,870,000
„ 12 -	1,133,350,000	653,232,000	506,250,000	624,840,000	577,404,000	506,250,000	488,397,000	865,620,000	865,620,000	1,473,360,000
„ 13 -	1,092,980,000	710,016,000	624,840,000	653,232,000	601,122,000	529,968,000	488,397,000	766,800,000	898,560,000	1,329,410,000
„ 14 -	1,092,980,000	601,122,000	766,800,000	624,840,000	577,404,000	577,404,000	553,686,000	898,560,000	1,012,240,000	1,133,350,000
„ 15 -	1,473,360,000	577,404,000	898,560,000	553,686,000	710,016,000	738,408,000	553,686,000	931,500,000	931,500,000	1,012,240,000
„ 16 -	1,697,360,000	577 404,000	653,232,000	653,232,000	931,500,000	738,408,000	738,408,000	865,620,000	1,012,240,000	898,560,000
„ 17 -	1,527,140,000	601,122,000	653,232,000	738,408,000	738,408,000	653,232,000	710,016,000	832,680,000	832,680,000	710,016,000
„ 18 -	1,419,580,000	601,122,000	898,560,000	799,740,000	710,610,000	601,122,000	738,408,000	799,740,000	1,133,350,000	1,272,820,000
„ 19 -	1,329,410,000	681,624,000	971,870,000	832,680,000	653,232,000	553,686,000	738,408,000	865,620,000	1,329,410,000	1,948,000,000
„ 20 -	971,870,000	653,232,000	601,122,000	1,272,820,000	624,840,000	506,250,000	710,016,000	799,740,000	1,179,840,000	1,822,068,000
„ 21 -	931,500,000	624,840,000	738,408,000	766,800,000	624,840,000	577,404,000	681,624,000	766,800,000	1,365,800,000	2,154,280,000
„ 22 -	865,620,000	601,122,000	653,232,000	1,052,610,000	624,840,000	529,968,000	577,404,000	766,800,000	1,365,800,000	3,129,800,000
„ 23 -	865,620,000	577,404,000	553,686,000	898,560,000	681,624,000	470,545,000	601,122,000	799,740,000	1,272,820,000	3,440,240,000
„ 24 -	865,620,000	601,122,000	653,232,000	832,680,000	577,404,000	470,545,000	601,122,000	1,012,240,000	1,052,610,000	3,877,440,000
„ 25 -	865,620,000	577,404,000	653,232,000	766,800,000	577,404,000	470,545,000	577,404,000	1,179,840,000	1,012,240,000	4,107,680,000
„ 26 -	865,620,000	553,686,000	577,404,000	710,016,000	553,686,000	452,693,000	529,968,000	971,870,000	865,620,000	3,543,720,000
„ 27 -	832,680,000	577,404,000	577,404,000	653,232,000	577,404,000	529,968,000	553,686,000	971,870,000	931,500,000	3,233,280,000
„ 28 -	931,500,000	601,122,000	506,250,000	653,232,000	553,686,000	577,404,000	529,968,000	865,620,000	832,680,000	3,233,280,000
„ 29 -	681,624,000	577,404,000	624,840,000	653,232,000	553,686,000	488,397,000	506,250,000	766,800,000	898,560,000	3,543,720,000
„ 30 -	681,624,000	624,840,000	710,016,000	601,122,000	601,122,000	506,250,000	529,968,000	738,408,000	1,052,610,000	3,543,720,000
„ 31 -	832,680,000	601,122,000	681,624,000	601,122,000	601,122,000	529,968,000	488,397,000	710,016,000	1,133,350,000	4,222,800,000
April 1 -	898,560,000	577,404,000	738,408,000	553,686,000	766,800,000	[illegible]53,686,000	553,686,000	799,740,000	1,179,840,000	4,605,120,000
„ 2 -	971,870,000	553,686,000	710,016,000	577,404,000	766,800,000	470,545,000	553,686,000	1,133,350,000	1,092,980,000	3,762,320,000
„ 3 -	931,500,000	553,686,000	624,840,000	577,404,000	832,680,000	506,250,000	506,250,000	1,272,820,000	1,092,980,000	4,477,680,000
„ 4 -	898,560,000	470,545,000	577,404,000	577,404,000	832,680,000	577,404,000	624,840,000	1,365,800,000	1,473,360,000	4,350,240,000
„ 5 -	931,500,000	506,250,000	601,122,000	738,408,000	865,620,000	681,624,000	529,968,000	971,870,000	1,179,840,000	3,440,240,000
„ 6 -	971,870,000	553,686,000	681,624,000	681,624,000	1,272,820,000	553,686,000	529,968,000	971,870,000	1,052,610,000	3,037,460,000
„ 7 -	1,052,610,000	577,404,000	577,404,000	799,740,000	1,365,800,000	577,404,000	506,250,000	738,408,000	931,500,000	2,367,760,000
„ 8 -	832,680,000	577,404,000	577,404,000	681,624,000	1,329,410,000	681,624,000	488,397,000	681,624,000	832,680,000	2,154,280,000
„ 9 -	832,680,000	553,686,000	529,968,000	710,016,000	1,329,410,000	1,822,068,000	506,250,000	710,016,000	766,800,000	2,016,760,000
„ 10 -	832,680,000	553,686,000	624,840,000	931,500,000	1,226,330,000	2,760,040,000	488,397,000	624,840,000	710,016,000	2,667,600,000
„ 11 -	1,012,240,000	391,327,000	529,968,000	1,329,410,000	1,092,980,000	2,154,280,000	506,250,000	624,840,000	710,016,000	3,336,760,000
„ 13 -	681,624,000	391,327,000	506,250,000	1,272,820,000	1,012,240,000	1,580,920,000	506,250,000	624,840,000	710,016,000	3,129,800,000
„ 12 -	766,800,000	506,250,000	553,686,000	1,365,800,000	799,740,000	1,527,140,000	577,404,000	624,840,000	681,624,000	2,852,580,000
„ 14 -	681,624,000	529,968,000	506,250,000	1,329,410,000	832,680,000	1,419,580,000	653,232,000	624,840,000	681,624,000	2,517,680,000
„ 15 -	681,624,000	553,686,000	470,545,000	1,365,800,000	898,560,000	1,052,610,000	624,840,000	681,624,000	681,624,000	2,223,040,000
„ 16 -	681,624,000	601,122,000	452,693,000	971,870,000	931,500,000	681,624,000	832,680,000	681,624,000	653,232,000	1,948,000,000
„ 17 -	738,408,000	529,968,000	452,693,000	931,500,000	898,560,000	710,016,000	710,016,000	653,232,000	624,840,000	1,634,700,000
„ 18 -	738,408,000	506,250,000	434,840,000	766,800,000	865,620,000	738,408,000	738,408,000	653,232,000	624,840,000	1,527,140,000
„ 19 -	653,232,000	529,968,000	452,693,000	710,016,000	710,016,000	1,012,240,000	624,840,000	624,840,000	577,404,000	1,179,840,000
„ 20 -	653,232,000	529,968,000	434,840,000	681,624,000	681,624,000	1,012,240,000	577,404,000	601,122,000	577,404,000	1,179,840,000
„ 21 -	681,624,000	506,250,000	434,840,000	681,624,000	553,686,000	931,500,000	553,686,000	577,404,000	653,232,000	1,012,240,000
„ 22 -	799,740,000	529,968,000	452,693,000	653,232,000	577,404,000	766,800,000	506,250,000	577,404,000	624,840,000	931,500,000
„ 23 -	1,179,840,000	529,968,000	416,988,000	624,840,000	624,840,000	653,232,000	506,250,000	553,686,000	601,122,000	931,500,000
„ 24 -	1,365,800,000	506,250,000	434,840,000	624,840,000	624,840,000	624,840,000	529,968,000	553,686,000	553,686,000	898,560,000
„ 25 -	1,473,360,000	397,142,000	434,840,000	601,122,000	624,840,000	601,122,000	553,686,000	738,408,000	529,968,000	931,500,000
„ 26 -	2,154,280,000	506,250,000	434,840,000	577,404,000	624,840,000	577,404,000	710,016,000	624,840,000	529,968,000	971,870,000
„ 27 -	2,442,720,000	506,250,000	452,693,000	865,620,000	624,840,000	529,968,000	710,016,000	624,840,000	601,122,000	1,012,240,000
„ 28 -	1,634,700,000	506,250,000	452,693,000	1,179,840,000	553,686,000	577,404,000	710,016,000	577,404,000	624,840,000	1,012,240,000
„ 29 -	1,419,580,000	470,545,000	452,693,000	1,365,800,000	601,122,000	553,686,000	653,232,000	529,968,000	601,122,000	1,012,240,000
„ 30 -	1,329,410,000	506,250,000	434,840,000	1,473,360,000	506,250,000	601,122,000	624,840,000	506,250,000	601,122,000	1,052,610,000

works Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive)—*continued.*

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
624,840,000	931,500,000	1,580,920,000	1,822,068,000	865,620,000	624,840,000	1,329,410,000	766,800,000	470,545,000	1,092,980,000	2,592,640,000
577,404,000	1,052,610,000	1,473,360,000	1,365,800,000	832,680,000	1,226,330,000	1,179,840,000	832,680,000	434,840,000	971,870,000	2,292,800,000
577,404,000	1,133,350,000	1,329,410,000	1,272,820,000	832,680,000	1,365,800,000	1,329,410,000	1,272,820,000	470,545,000	1,092,980,000	2,223,040,000
577,404,000	1,133,350,000	1,133,350,000	1,226,330,000	799,740,000	1,133,350,000	1,226,330,000	1,473,360,000	416,988,000	1,052,610,000	2,085,520,000
553,686,000	1,419,580,000	1,133,350,000	1,179,840,000	766,800,000	1,012,240,000	1,179,840,000	1,885,340,000	416,988,000	931,500,000	1,760,020,000
553,686,000	1,473,360,000	1,092,980,000	1,092,980,000	710,016,000	931,500,000	1,133,350,000	2,016,760,000	416,988,000	931,500,000	1,527,140,000
553,686,000	1,760,020,000	1,226,330,000	1,092,980,000	710,016,000	799,740,000	1,012,240,000	1,634,700,000	416,988,000	898,560,000	1,419,580,000
624,840,000	2,085,520,000	1,226,330,000	1,179,840,000	738,408,000	434,840,000	931,500,000	1,365,860,000	416,988,000	799,740,000	1,527,140,000
653,232,000	2,592,640,000	971,870,000	1,092,980,000	738,408,000	738,408,000	898,560,000	1,226,330,000	434,840,000	971,870,000	1,634,760,000
624,840,000	3,129,800,000	898,150,000	971,870,000	799,740,000	624,840,000	898,560,000	799,740,000	452,693,000	898,560,000	1,634,700,000
624,840,000	3,647,200,000	832,680,000	898,560,000	1,092,980,000	931,500,000	931,500,000	898,560,000	601,122,000	865,620,000	1,822,068,000
553,686,000	3,647,200,000	766,800,000	898,560,000	1,052,610,000	971,870,000	931,500,000	898,560,000	653,232,000	766,800,000	1,822,068,000
601,122,000	3,543,720,000	710,016,000	832,680,000	1,052,610,000	971,870,000	832,680,000	832,680,000	529,968,000	766,800,000	1,634,700,000
624,840,000	2,944,920,000	653,232,000	832,680,000	1,133,350,000	1,179,840,000	865,620,000	832,680,000	452,693,000	766,800,000	1,580,920,000
624,840,000	2,292,800,000	681,624,000	832,680,000	1,272,820,000	1,133,350,000	766,800,000	766,800,000	470,545,000	766,800,000	1,580,920,000
681,624,000	1,885,340,000	624,840,000	766,800,000	1,179,840,000	1,052,610,000	738,408,000	832,680,000	529,968,000	738,408,000	1,634,700,000
601,122,000	1,580,920,000	601,122,000	865,620,000	1,365,800,000	931,500,000	766,800,000	971,870,000	681,624,000	738,408,000	1,760,020,000
601,122,000	1,226,330,000	577,404,000	971,870,000	1,133,350,000	865,620,000	766,800,000	1,133,350,000	766,800,000	710,016,000	2,085,520,000
601,122,000	1,133,350,000	601,122,000	1,052,610,000	1,092,980,000	766,800,000	766,800,000	971,870,000	710,016,000	766,800,000	2,085,520,000
601,122,000	1,012,240,000	577,404,000	1,052,610,000	1,092,980,000	710,016,000	898,560,000	865,620,000	624,840,000	738,408,000	1,948,000,000
553,686,000	931,500,000	553,686,000	931,500,000	1,226,330,000	681,624,000	1,365,800,000	799,740,000	529,968,000	738,408,000	1,822,068,000
601,122,000	799,740,000	529,968,000	1,052,610,000	1,272,820,000	653,232,000	1,885,340,000	738,408,000	506,250,000	738,408,000	1,760,020,000
506,250,000	799,740,000	452,693,000	971,870,000	1,473,360,000	710,016,000	1,419,580,000	738,408,000	470,545,000	710,016,000	1,760,020,000
488,397,000	738,408,000	488,397,000	1,226,330,000	1,822,068,000	681,624,000	1,329,410,000	710,016,000	470,545,000	738,408,000	1,580,920,000
506,250,000	710,016,000	529,968,000	1,226,330,000	1,885,340,000	710,016,000	1,052,610,000	653,232,000	452,693,000	799,740,000	1,365,800,000
483,397,000	738,408,000	553,686,000	2,154,280,000	2,367,760,000	624,840,000	832,680,000	624,840,000	416,988,000	681,624,000	1,226,330,000
488,397,000	738,408,000	553,686,000	1,419,580,000	3,037,460,000	601,122,000	865,620,000	681,624,000	434,840,000	681,624,000	1,179,840,000
506,250,000	738,408,000	553,686,000	1,052,610,000	3,440,240,000	738,408,000	832,680,000	653,232,000	434,840,000	738,408,000	1,052,610,000
529,968,000	653,232,000	577,404,000	865,620,000	4,222,800,000	738,408,000	832,680,000	601,122,000	410,572,000	1,226,330,000	1,012,240,000
470,545,000	681,624,000	506,250,000	898,560,000	3,877,440,000	710,016,000	799,740,000	624,840,000	404,757,000	2,016,760,000	1,012,240,000
452,693,000	738,408,000	506,250,000	898,560,000	3,129,800,000	681,624,000	832,680,000	653,232,000	410,572,000	2,367,760,000	971,870,000
529,968,000	681,624,000	577,404,000	865,620,000	2,154,280,000	553,686,000	766,800,000	653,232,000	410,572,000	1,885,340,000	1,052,610,000
681,624,000	681,624,000	601,122,000	898,560,000	1,634,700,000	553,686,000	738,408,000	653,232,000	410,572,000	1,760,020,000	971,870,000
577,404,000	653,232,000	577,404,000	865,620,000	1,365,800,000	553,686,000	738,408,000	624,840,000	404,757,000	1,634,700,000	971,870,000
601,122,000	653,232,000	529,968,000	898,560,000	1,179,840,000	529,968,000	738,408,000	601,122,000	404,757,000	1,760,020,000	931,500,000
653,232,000	653,232,000	529,968,000	832,680,000	1,092,980,000	506,250,000	738,408,000	624,840,000	434,840,000	1,634,700,000	865,620,000
553,686,000	832,680,000	506,250,000	971,870,000	1,012,240,000	488,397,000	710,016,000	577,404,000	410,572,000	1,473,360,000	832,680,000
553,686,000	1,272,820,000	506,250,000	898,560,000	1,012,240,000	506,250,000	766,800,000	577,404,000	404,757,000	1,272,820,000	865,620,000
553,866,000	1,092,980,000	506,250,000	898,560,000	971,870,000	577,404,000	799,740,000	577,404,000	434,840,000	1,092,980,000	832,680,000
577,404,000	1,012,240,000	506,250,000	865,620,000	898,560,000	624,840,000	799,740,000	577,404,000	410,572,000	1,012,240,000	832,680,000
577,404,000	898,560,000	506,250,000	832,680,000	898,560,000	624,840,000	766,800,000	601,122,000	391,327,000	832,680,000	832,680,000
577,404,000	832,680,000	506,250,000	865,620,000	865,620,000	624,840,000	710,016,000	577,404,000	404,757,000	898,560,000	865,620,000
553,686,000	681,624,000	506,250,000	931,500,000	799,740,000	577,404,000	710,016,000	601,122,000	397,142,000	865,620,000	832,680,000
577,404,000	681,624,000	506,250,000	1,133,350,000	766,800,000	553,686,000	681,624,000	577,404,000	404,757,000	766,800,000	766,800,000
601,122,000	624,840,000	506,250,000	1,092,980,000	766,800,000	601,122,000	624,840,000	553,686,000	404,757,000	898,560,000	832,680,000
577,404,000	624,840,000	529,968,000	1,133,350,000	865,620,000	601,122,000	624,840,000	553,686,000	434,840,000	865,620,000	832,680,000
553,686,000	577,404,000	529,968,000	1,092,980,000	931,500,000	601,122,000	601,122,000	553,686,000	404,757,000	799,740,000	799,740,000
624,840,000	766,800,000	553,686,000	865,620,000	865,620,000	601,122,000	452,693,000	553,686,000	452,693,000	738,408,000	799,740,000
624,840,000	1,092,980,000	506,250,000	2,592,640,000	865,620,000	601,122,000	529,968,000	553,686,000	488,397,000	710,016,000	799,740,000
601,122,000	1,272,820,000	529,968,000	738,408,000	865,620,000	577,404,000	506,250,000	553,686,000	601,122,000	653,232,000	766,800,000
553,686,000	865,620,000	506,250,000	681,624,000	766,800,000	681,624,000	452,693,000	553,686,000	898,560,000	624,840,000	832,680,000
506,250,000	681,624,000	553,686,000	653,232,000	766,800,000	898,560,000	488,397,000	529,968,000	1,179,840,000	653,232,000	738,408,000
488,397,000	624,840,000	624,840,000	681,624,000	1,012,240,000	1,052,610,000	470,545,000	488,397,000	1,133,350,000	681,624,000	653,232,000
506,250,000	553,686,000	553,686,000	653,232,000	898,560,000	971,870,000	452,693,000	529,968,000	971,870,000	832,680,000	681,624,000
553,686,000	577,404,000	470,545,000	577,404,000	898,560,000	971,870,000	506,250,000	488,397,000	766,800,000	710,016,000	738,408,000
553,686,000	529,968,000	434,840,000	624,840,000	931,500,000	766,800,000	601,122,000	452,693,000	529,968,000	971,870,000	710,016,000
553,686,000	470,545,000	506,250,000	553,686,000	1,012,240,000	766,800,000	529,968,000	488,397,000	506,250,000	653,232,000	738,408,000
506,260,000	506,250,000	434,840,000	681,624,000	1,133,350,000	653,232,000	506,250,000	488,397,000	506,250,000	624,840,000	710,016,000
470,545,000	506,250,000	434,840,000	681,624,000	1,133,350,000	653,232,000	488,397,000	488,397,000	488,397,000	931,500,000	710,016,000
470,545,000	529,968,000	416,988,000	799,740,000	1,133,350,000	553,686,000	470,545,000	488,307,000	470,545,000	898,560,000	738,408,000
529,968,000	506,250,000	434,840,000	865,620,000	1,052,610,000	601,122,000	470,545,000	488,397,000	529,968,000	681,624,000	653,232,000

Daily Volume of Water flowing down the Thames opposite the Lambeth Water-

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
May 1 -	898,560,000	506,250,000	434,840,000	799,740,000	577,404,000	601,122,000	653,232,000	506,250,000	624,840,000	865,620,000
„ 2 -	681,624,000	506,250,000	452,693,000	710,016,000	553,686,000	681,624,000	624,840,000	529,968,000	506,250,000	738,408,000
„ 3 -	865,620,000	506,250,000	470,545,000	710,016,000	506,250,000	681,624,000	601,122,000	488,397,000	553,686,000	710,016,000
„ 4 -	1,133,350,000	488,397,000	470,545,000	710,016,000	577,404,000	577,404,000	601,122,000	470,545,000	653,232,000	738,408,000
„ 5 -	2,367,760,000	506,250,000	452,693,000	653,232,000	488,397,000	553,686,000	577,404,000	488,397,000	553,686,000	738,408,000
„ 6 -	2,085,520,000	488,397,000	452,693,000	577,404,000	577,404,000	553,686,000	529,968,000	506,250,000	506,250,000	738,408,000
„ 7 -	1,697,360,000	529,968,000	452,693,000	577,404,000	506,250,000	506,250,000	506,250,000	470,545,000	506,250,000	529,968,000
„ 8 -	1,760,020,000	529,968,000	416,988,000	710,016,000	529,968,000	529,968,000	506,250,000	488,397,000	506,250,000	1,885,340,000
„ 9 -	2,016,760,000	488,397,000	452,693,000	766,800,000	506,250,000	488,397,000	553,686,000	488,397,000	506,250,000	2,944,920,000
„ 10 -	2,154,280,000	601,122,000	416,988,000	832,680,000	529,968,000	529,968,000	470,545,000	506,250,000	577,404,000	3,336,760,000
„ 11 -	1,580,920,000	553,686,000	452,693,000	738,408,000	529,968,000	452,693,000	488,397,000	470,545,000	553,686,000	3,440,240,000
„ 12 -	1,179,840,000	529,968,000	452,693,000	653,232,000	506,250,000	452,693,000	452,693,000	577,404,000	832,680,000	2,944,920,000
„ 13 -	1,052,610,000	506,250,000	470,545,000	601,122,000	529,968,000	470,545,000	470,545,000	577,404,000	931,500,000	2,667,600,000
„ 14 -	931,500,000	529,968,000	506,250,000	624,840,000	529,968,000	488,397,000	452,693,000	710,016,000	832,680,000	2,367,760,000
„ 15 -	832,680,000	506,250,000	434,840,000	624,840,000	506,250,000	488,397,000	470,545,000	601,122,000	971,870,000	2,292,800,000
„ 16 -	799,740,000	506,250,000	529,968,000	681,624,000	488,397,000	577,404,000	470,545,000	624,840,000	624,840,000	2,517,680,000
„ 17 -	766,800,000	488,397,000	506,250,000	710,016,000	553,686,000	529,968,000	452,693,000	601,122,000	553,686,000	2,085,520,000
„ 18 -	766,800,000	470,545,000	452,693,000	653,232,000	452,693,000	577,404,000	452,693,000	681,624,000	577,404,000	1,634,700,000
„ 19 -	1,092,980,000	488,397,000	488,397,000	766,800,000	488,397,000	653,232,000	488,397,000	681,624,000	553,686,000	1,365,800,000
„ 20 -	766,800,000	488,397,000	452,693,000	832,680,000	434,840,000	529,968,000	470,545,000	1,133,350,000	553,686,000	1,226,330,000
„ 21 -	738,408,000	488,397,000	434,840,000	653,232,000	452,693,000	529,968,000	681,624,000	1,012,240,000	553,686,000	766,800,000
„ 22 -	681,624,000	452,693,000	416,988,000	624,840,000	452,693,000	529,968,000	681,624,000	898,560,000	488,397,000	1,012,240,000
„ 23 -	653,232,000	506,250,000	416,988,000	681,624,000	470,545,000	488,397,000	488,397,000	799,740,000	488,397,000	931,500,000
„ 24 -	624,840,000	488,397,000	397,142,000	653,232,000	488,397,000	529,968,000	470,545,000	624,840,000	452,693,000	931,500,000
„ 25 -	653,232,000	488,397,000	416,988,000	653,232,000	470,545,000	553,686,000	506,250,000	601,122,000	529,968,000	898,560,000
„ 26 -	624,840,000	488,397,000	416,988,000	624,840,000	488,397,000	738,408,000	452,693,000	577,404,000	601,122,000	865,620,000
„ 27 -	653,232,000	452,693,000	416,988,000	506,250,000	488,397,000	624,840,000	434,840,000	601,122,000	506,250,000	766,800,000
„ 28 -	601,122,000	404,757,000	404,757,000	681,624,000	470,545,000	710,016,000	434,840,000	624,840,000	601,122,000	766,800,000
„ 29 -	624,840,000	434,840,000	416,988,000	1,760,020,000	470,545,000	624,840,000	434,840,000	577,404,000	529,968,000	832,680,000
„ 30 -	624,840,000	452,693,000	416,988,000	1,527,140,000	470,545,000	553,686,000	452,693,000	529,968,000	601,122,000	832,680,000
„ 31 -	601,122,000	416,988,000	434,840,000	1,365,800,000	470,545,000	553,686,000	452,693,000	506,250,000	553,686,000	898,560,000
June 1 -	624,840,000	506,250,000	416,988,000	1,272,820,000	452,693,000	470,545,000	470,515,000	506,250,000	553,686,000	931,500,000
„ 2 -	601,122,000	488,397,000	452,693,000	1,473,360,000	434,840,000	434,840,000	506,250,000	653,232,000	681,624,000	898,560,000
„ 3 -	601,122,000	470,545,000	452,693,000	1,179,840,000	452,693,000	434,840,000	553,686,000	1,133,350,000	529,968,000	832,680,000
„ 4 -	577,404,000	488,397,000	416,988,000	971,870,000	434,840,000	434,840,000	529,968,000	1,527,140,000	577,404,000	832,680,000
„ 5 -	601,122,000	506,250,000	416,988,000	766,800,000	434,840,000	470,545,000	601,122,000	1,948,000,000	577,404,000	766,800,000
„ 6 -	577,404,000	470,545,000	416,988,000	681,624,000	470,545,000	384,912,000	738,408,000	1,580,920,000	653,232,000	832,680,000
„ 7 -	553,686,000	506,250,000	434,840,000	577,404,000	488,397,000	488,397,000	681,624,000	1,473,360,000	601,122,000	832,680,000
„ 8 -	553,686,000	506,250,000	416,988,000	553,686,000	470,545,000	452,693,000	577,404,000	1,272,820,000	624,840,000	832,680,000
„ 9 -	601,122,000	506,250,000	404,757,000	577,404,000	488,397,000	470,545,000	601,122,000	1,179,840,000	624,840,000	931,500,000
„ 10 -	577,404,000	506,250,000	404,757,000	529,968,000	488,397,000	452,693,000	553,686,000	1,052,610,000	601,122,000	766,800,000
„ 11 -	601,122,000	470,545,000	434,840,000	553,686,000	529,968,000	434,840,000	506,250,000	1,092,980,000	601,122,000	766,800,000
„ 12 -	601,122,000	470,545,000	404,757,000	506,250,000	506,250,000	434,840,000	529,968,000	865,620,000	653,232,000	799,740,000
„ 13 -	601,122,000	470,545,000	397,142,000	553,686,000	506,250,000	434,840,000	470,545,000	1,365,800,000	624,840,000	971,870,000
„ 14 -	710,016,000	488,397,000	404,757,000	577,404,000	506,250,000	452,693,000	470,545,000	1,634,700,000	601,122,000	1,179,840,000
„ 15 -	681,624,000	470,545,000	416,988,000	653,232,000	470,545,000	416,988,000	452,693,000	1,365,800,000	506,250,000	1,133,350,000
„ 16 -	653,232,000	488,397,000	410,572,000	681,624,000	470,545,000	434,840,000	470,545,000	1,179,840,000	624,840,000	1,226,330,000
„ 17 -	624,840,000	506,250,000	416,988,000	653,232,000	470,545,000	434,840,000	452,693,000	1,052,610,000	506,250,000	1,133,350,000
„ 18 -	624,840,000	529,968,000	397,142,000	577,404,000	488,397,000	434,840,000	452,693,000	1,179,840,000	506,250,000	1,092,980,000
„ 19 -	624,840,000	553,686,000	470,545,000	577,404,000	470,545,000	410,572,000	434,840,000	1,133,350,000	506,250,000	1,092,980,000
„ 20 -	653,232,000	529,968,000	488,397,000	553,686,000	470,545,000	434,840,000	416,988,000	1,473,360,000	553,686,000	1,012,240,000
„ 21 -	653,232,000	529,968,000	416,988,000	577,404,000	506,250,000	452,693,000	410,572,000	1,634,700,000	506,250,000	971,870,000
„ 22 -	738,408,000	553,686,000	416,988,000	653,232,000	577,404,000	452,693,000	410,572,000	1,634,700,000	506,250,000	898,650,000
„ 23 -	865,620,000	529,968,000	416,988,000	624,840,000	601,122,000	452,693,000	410,572,000	1,697,360,000	577,404,000	898,560,000
„ 24 -	898,560,000	553,686,000	416,988,000	710,016,000	577,404,000	416,988,000	416,988,000	1,634,700,000	601,122,000	832,680,000
„ 25 -	898,560,000	529,968,000	404,757,000	553,686,000	529,968,000	416,988,000	397,142,000	1,634,700,000	470,545,000	799,740,000
„ 26 -	898,560,000	529,968,000	404,757,000	553,686,000	506,250,000	410,572,000	404,757,000	1,948,000,000	601,122,000	738,408,000
„ 27 -	931,500,000	553,686,000	404,757,000	577,404,000	506,250,000	404,757,000	391,327,000	2,223,040,000	624,840,000	710,016,000
„ 28 -	1,012,240,000	553,686,000	397,142,000	553,686,000	506,250,000	410,572,000	404,757,000	2,016,760,000	577,404,000	681,624,000
„ 29 -	931,500,000	553,686,000	404,757,000	553,686,000	434,840,000	404,757,000	416,988,000	1,948,000,000	506,250,000	681,624,000
„ 30 -	8,560,000	553,686,000	404,757,000	488,397,000	452,693,000	382,773,000	416,988,000	1,760,020,000	553,686,000	681,624,000

works Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive)—*continued.*

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
452,693,000	529,968,000	410,572,000	1,052,610,000	931,500,000	577,404,000	416,988,000	506,250,000	710,016,000	766,800,000	653,232,000
529,968,000	506,250,000	410,572,000	799,740,000	898,560,000	601,122,000	410,572,000	506,250,000	624,840,000	710,016,000	624,840,000
529,968,000	470,545,000	410,572,000	738,408,000	799,740,000	553,686,000	404,757,000	506,250,000	577,404,000	624,840,000	577,404,000
506,250,000	470,545,000	404,757,000	738,408,000	529,968,000	553,686,000	410,572,000	529,968,000	488,397,000	710,016,000	681,624,000
470,545,000	488,397,000	404,757,000	766,800,000	652,232,000	506,250,000	601,122,000	529,968,000	470,545,000	553,686,000	601,122,000
470,545,000	529,968,000	434,840,000	766,800,000	681,624,000	506,250,000	832,680,000	384,912,000	434,840,000	553,686,000	653,232,000
470,545,000	577,404,000	416,988,000	653,232,000	577,404,000	529,968,000	681,624,000	506,250,000	410,572,000	553,686,000	710,016,000
452,693,000	766,800,000	452,693,000	577,404,000	577,404,000	553,686,000	681,624,000	506,250,000	434,840,000	681,624,000	653,232,000
470,545,000	832,680,000	452,693,000	577,404,000	624,840,000	506,250,000	710,016,000	452,693,000	434,840,000	624,340,000	710,016,000
452,693,000	653,232,000	452,693,000	529,968,000	653,232,000	488,397,000	799,740,000	452,692,000	410,572,000	738,408,000	681,624,000
470,545,000	624,840,000	529,968,000	553,686,000	653,232,000	470,545,000	1,133,350,000	470,545,000	397,142,000	710,016,000	738,408,000
397,142,000	577,404,000	832,680,000	681,624,000	738,408,000	506,250,000	1,133,350,000	488,397,000	416,988,000	738,408,000	653,232,000
410,572,000	529,968,000	681,624,000	710,016,000	738,408,000	488,397,000	931,500,000	529,968,000	404,757,000	738,408,000	506,250,000
506,250,000	488,397,000	601,122,000	681,624,000	832,680,000	506,250,000	898,560,000	529,968,000	410,572,000	898,560,000	553,686,000
470,545,000	506,250,000	506,250,000	624,840,000	766,800,000	488,397,000	865,620,000	553,686,300	391,327,000	931,500,000	488,397,000
470,545,000	408,397,000	416,988,000	624,840,000	738,408,000	506,250,000	799,740,000	529,968,000	404,757,000	898,560,000	506,250,000
470,545,000	470,545,000	434,840,000	577,404,000	738,408,000	488,397,000	710,016,000	577,404,000	416,988,000	738,408,000	624,840,000
452,693,000	506,250,000	434,840,000	577,404,000	681,624,000	452,693,000	601,122,000	529,968,000	410,572,000	832,680,000	601,122,000
434,840,000	529,968,000	410,572,000	553,686,000	710,016,000	506,250,000	577,404,000	488,397,000	410,572,000	1,133,350,000	553,686,000
470,545,000	416,988,000	452,693,000	553,686,000	681,624,000	416,988,000	681,624,000	452,693,000	404,757,000	1,052,610,000	553,686,000
624,840,000	452,693,000	452,693,000	529,968,000	681,624,000	434,840,000	799,740,000	416,988,000	404,757,000	931,500,000	452,693,000
506,250,000	553,686,000	416,988,000	506,250,000	738,408,000	488,397,000	681,624,000	452,693,000	397,142,000	799,740,000	506,250,000
506,250,000	553,686,000	452,693,000	506,250,000	1,012,240,000	416,988,000	624,840,000	397,142,000	391,327,000	710,016,000	488,397,000
506,250,000	601,122,000	416,988,000	529,968,000	1,052,610,000	553,686,000	624,840,000	404,757,000	391,327,000	710,016,000	529,968,000
506,250,000	529,968,000	416,988,000	506,250,000	766,800,000	553,686,000	601,122,000	416,988,000	384,912,000	681,624,000	624,840,000
416,988,000	553,686,000	416,988,000	506,250,000	766,800,000	553,686,000	577,404,000	416,988,000	397,142,000	738,408,000	624,840,000
452,693,000	506,250,000	452,693,000	577,404,000	766,800,000	553,686,000	529,968,000	410,572,000	397,142,000	681,624,000	470,545,000
506,250,000	529,968,000	452,693,000	529,968,000	681,624,000	506,250,000	577,404,000	410,572,000	397,142,000	601,122,000	681,624,000
416,988,000	529,968,000	452,693,000	529,968,000	738,408,000	529,968,000	832,680,000	404,757,000	397,142,000	681,624,000	577,404,000
410,572,000	506,250,000	434,840,000	529,968,000	738,408,000	470,545,000	1,052,610,000	384,912,000	404,757,000	681,624,000	577,404,000
410,572,000	529,968,000	434,840,000	553,686,000	710,016,000	506,250,000	799,740,000	380,635,000	416,988,000	624,840,000	601,122,000
506,250,000	529,968,000	416,988,000	470,545,000	624,840,000	488,397,000	577,404,000	410,572,000	404,757,000	624,840,000	624,840,000
506,250,000	529,968,000	470,545,000	470,545,000	577,404,000	488,397,000	506,250,000	470,545,000	397,142,000	577,404,000	624,840,000
624,840,000	577,404,000	653,032,000	452,693,000	601,122,000	470,545,000	624,840,000	470,545,000	404,757,000	601,122,000	553,686,000
416,988,000	553,686,000	601,122,000	553,686,000	766,800,000	391,327,000	577,404,000	470,545,000	391,327,000	624,840,000	601,122,000
416,988,000	553,686,000	553,686,000	624,840,000	971,870,000	488,397,000	553,686,000	470,545,000	384,912,000	577,404,000	624,840,000
434,840,000	553,686,000	553,686,000	653,232,000	971,870,000	506,250,000	601,122,000	470,545,000	410,572,000	601,122,000	577,404,000
452,693,000	529,968,000	506,250,000	624,840,000	1,092,980,000	470,545,000	681,624,000	452,693,000	416,988,000	577,404,000	601,122,000
488,397,000	529,968,000	488,397,000	553,686,000	1,012,240,000	452,693,000	681,624,000	470,545,000	416,988,000	653,232,000	710,016,000
488,397,000	506,250,000	470,545,000	577,404,000	931,500,000	488,397,000	506,250,000	470,545,000	404,757,000	681,624,000	601,122,000
470,545,000	506,250,000	470,545,000	553,686,000	931,500,000	488,397,000	452,693,000	452,693,000	382,773,000	710,016,000	577,404,000
452,693,000	506,250,000	488,397,000	601,122,000	766,800,000	488,397,000	434,840,000	434,840,000	404,757,000	738,408,000	653,232,000
488,397,000	506,250,000	506,250,000	506,250,000	738,408,000	488,397,000	452,693,000	434,840,000	404,757,000	681,624,000	577,404,000
506,250,000	506,250,000	410,572,000	506,250,000	624,840,000	488,397,000	452,693,000	416,988,000	397,142,000	738,408,000	653,232,000
601,122,000	452,693,000	434,840,000	506,250,000	624,840,000	488,397,000	470,545,000	416,988,000	404,757,000	766,800,000	601,122,000
653,232,000	488,397,000	410,572,000	553,686,000	653,232,000	434,840,000	470,545,000	452,693,000	434,840,000	710,016,000	653,232,000
577,404,000	529,968,000	410,572,000	553,686,000	624,840,000	488,397,000	506,250,000	416,988,000	416,988,000	653,232,000	653,232,000
553,686,000	506,250,000	452,693,000	553,686,000	653,232,000	470,545,000	452,693,000	434,840,000	452,693,000	653,232,000	653,232,000
577,404,000	488,397,000	434,840,000	506,250,000	577,404,000	488,397,000	452,693,000	434,840,000	452,693,000	470,545,000	738,408,000
506,250,000	488,397,000	416,988,000	452,693,000	601,122,000	470,545,000	434,840,000	452,693,000	470,545,000	624,840,000	601,122,000
653,232,000	488,397,000	410,572,000	410,572,000	553,686,000	470,545,000	506,250,000	410,572,000	488,397,000	624,840,000	577,404,000
601,122,000	452,693,000	416,988,000	434,840,000	577,404,000	470,545,000	553,686,000	434,840,000	452,693,000	577,404,000	601,122,000
681,624,000	452,693,000	416,988,000	553,686,000	601,122,000	416,988,000	470,545,000	452,693,000	452,693,000	577,404,000	601,122,000
506,250,000	452,693,000	416,988,000	577,404,000	577,404,000	470,545,000	506,250,000	470,545,000	506,250,000	577,404,000	601,122,000
506,250,000	470,545,000	416,988,000	553,686,000	577,404,000	416,988,000	506,250,000	470,545,000	506,250,000	577,404,000	577,404,000
416,988,000	452,693,000	416,988,000	506,250,000	577,404,000	488,397,000	452,693,000	452,693,000	506,250,000	577,404,000	553,686,000
452,693,000	452,693,000	410,572,000	506,250,000	553,686,000	488,397,000	434,840,000	452,693,000	506,250,000	624,840,000	577,404,000
452,693,000	452,693,000	410,572,000	470,545,000	488,397,000	470,545,000	434,840,000	434,840,000	452,693,000	601,122,000	529,968,000
434,840,000	488,397,000	382,773,000	506,250,000	488,397,000	452,693,000	410,572,000	452,693,000	470,545,000	601,122,000	601,122,000
434,840,000	452,693,000	397,142,000	529,968,000	470,545,000	410,572,000	452,693,000	470,545,000	470,545,000	601,122,000	601,122,000
404,757,000	452,693,000	410,572,000	529,968,000	452,693,000	404,757,000	410,572,000	453,693,000	434,840,000	624,840,000	624,840,000

Daily Volume of Water flowing down the Thames opposite the Lambeth Water-

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & Day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
July 1 -	865,620,000	506,250,000	391,327,000	488,397,000	434,840,000	391,327,000	404,757,000	1,760,020,000	470,545,000	624,840,000
„ 2 -	832,680,000	470,545,000	391,327,000	488,397,000	470,545,000	404,757,000	404,757,000	1,580,920,000	488,397,000	601,122,000
„ 3 -	832,680,000	488,397,000	384,912,000	470,545,000	488,397,000	410,572,000	410,572,000	1,527,140,000	506,250,000	601,122,000
„ 4 -	799,740,000	470,545,000	384,912,000	488,397,000	488,397,000	404,757,000	488,397,000	1,419,580,000	452,693,000	577,404,000
„ 5 -	766,800,000	470,545,000	397,142,000	488,397,000	506,250,000	391,327,000	434,840,000	1,365,800,000	470,545,000	601,122,000
„ 6 -	766,800,000	452,693,000	391,327,000	488,397,000	488,397,000	366,444,000	434,840,000	1,226,330,000	470,545,000	653,232,000
„ 7 -	738,408,000	470,545,000	384,912,000	529,968,000	529,968,000	404,757,000	416,988,000	1,226,330,000	624,840,000	653,232,000
„ 8 -	624,840,000	488,397,000	384,912,000	506,250,000	529,968,000	404,757,000	410,572,000	1,133,350,000	624,840,000	653,232,000
„ 9 -	601,122,000	470,545,000	380,635,000	488,397,000	506,250,000	416,988,000	416,988,000	1,092,980,000	577,404,000	601,122,000
„ 10 -	624,840,000	452,693,000	397,142,000	488,397,000	506,250,000	416,988,000	397,142,000	971,870,000	506,250,000	681,624,000
„ 11 -	601,122,000	506,250,000	470,545,000	488,397,000	470,545,000	434,840,000	384,912,000	971,870,000	506,250,000	653,232,000
„ 12 -	577,404,000	577,404,000	452,693,000	506,250,000	488,397,000	416,988,000	397,142,000	971,870,000	470,545,000	738,408,000
„ 13 -	601,122,000	553,686,000	470,545,000	488,397,000	488,397,000	434,840,000	410,572,000	971,870,000	601,122,000	681,624,000
„ 14 -	601,122,000	529,968,000	452,693,000	529,968,000	452,693,000	410,572,000	397,142,000	971,870,000	553,686,000	681,624,000
„ 15 -	624,840,000	553,686,000	452,693,000	470,545,000	452,693,000	416,988,000	391,327,000	931,500,000	553,686,000	653,232,000
„ 16 -	1,179,840,000	529,968,000	416,988,000	470,545,000	434,840,000	410,572,000	391,327,000	931,500,000	553,686,000	710,016,000
„ 17 -	1,527,140,000	506,250,000	452,693,000	506,250,000	452,693,000	410,572,000	384,912,000	898,560,000	553,686,000	653,232,000
„ 18 -	1,697,360,000	488,397,000	452,693,000	470,545,000	434,840,000	416,988,000	374,220,000	898,560,000	577,404,000	653,232,000
„ 19 -	1,760,020,000	470,545,000	434,840,000	470,545,000	416,988,000	410,572,000	384,912,000	898,560,000	577,404,000	624,840,000
„ 20 -	1,580,920,000	470,545,000	470,545,000	470,545,000	434,840,000	410,572,000	397,142,000	898,560,000	506,250,000	601,122,000
„ 21 -	1,365,800,000	506,250,000	470,545,000	470,545,000	416,988,000	410,572,000	404,757,000	1,012,240,000	506,250,000	506,250,000
„ 22 -	1,272,820,000	506,250,000	452,693,000	470,545,000	452,693,000	410,572,000	404,757,000	931,500,000	506,250,000	506,250,000
„ 23 -	1,179,840,000	470,545,000	488,397,000	470,545,000	529,968,000	410,572,000	434,840,000	1,092,980,000	506,250,000	506,250,000
„ 24 -	1,092,980,000	452,693,000	434,840,000	488,397,000	452,693,000	410,572,000	452,693,000	1,092,980,000	553,686,000	601,122,000
„ 25 -	1,012,240,000	434,840,000	434,840,000	577,404,000	452,693,000	416,988,000	410,572,000	1,473,360,000	506,250,000	601,122,000
„ 26 -	898,560,000	434,840,000	506,250,000	416,988,000	470,545,000	404,757,000	397,142,000	1,092,980,000	488,397,000	601,122,000
„ 27 -	832,680,000	416,988,000	653,232,000	416,988,000	653,232,000	397,142,000	410,572,000	1,012,240,000	601,122,000	601,122,000
„ 28 -	799,740,000	434,840,000	601,122,000	434,840,000	529,968,000	416,988,000	404,757,000	931,500,000	799,740,000	624,840,000
„ 29 -	971,870,000	434,840,000	681,624,000	416,988,000	653,232,000	410,572,000	404,757,000	1,012,240,000	710,016,000	529,968,000
„ 30 -	832,680,000	416,988,000	681,624,000	416,988,000	624,840,000	410,572,000	404,757,000	1,226,330,000	577,404,000	577,404,000
„ 31 -	766,800,000	452,693,000	653,232,000	416,988,000	577,404,000	410,572,000	397,142,000	1,012,240,000	577,404,000	577,404,000
August 1 -	738,408,000	470,545,000	624,840,000	416,988,000	506,250,000	410,572,000	384,912,000	971,870,000	577,404,000	488,397,000
„ 2 -	710,016,000	488,397,000	653,232,000	416,988,000	470,545,000	410,572,000	397,142,000	971,870,000	452,693,000	506,250,000
„ 3 -	681,624,000	488,397,000	653,232,000	416,988,000	452,693,000	410,572,000	404,757,000	898,560,000	506,250,000	553,686,000
„ 4 -	601,122,000	506,250,000	577,404,000	434,840,000	434,840,000	410,572,000	397,142,000	799,740,000	577,404,000	529,968,000
„ 5 -	601,122,000	601,122,000	601,122,000	404,757,000	470,545,000	410,572,000	391,327,000	799,740,000	506,250,000	506,250,000
„ 6 -	601,122,000	529,968,000	529,968,000	416,988,000	470,545,000	410,572,000	397,142,000	766,800,000	470,545,000	506,250,000
„ 7 -	681,624,000	553,686,000	470,452,000	404,757,000	506,250,000	404,757,000	391,327,000	799,740,000	470,545,000	553,686,000
„ 8 -	710,016,000	470,545,000	506,250,000	416,988,000	488,397,000	404,757,000	384,912,000	738,408,000	506,250,000	553,686,000
„ 9 -	653,232,000	470,545,000	529,968,000	416,988,000	529,968,000	410,572,000	397,142,000	738,408,000	470,545,000	529,968,000
„ 10 -	601,122,000	506,250,000	553,686,000	416,988,000	506,250,000	410,572,000	397,142,000	766,800,000	452,693,000	577,404,000
„ 11 -	601,122,000	506,250,000	553,686,000	416,988,000	529,968,000	362,556,000	397,142,000	766,800,000	506,250,000	506,250,000
„ 12 -	553,686,000	452,693,000	506,250,000	410,572,000	577,404,000	380,635,000	410,572,000	931,500,000	452,693,000	506,250,000
„ 13 -	577,404,000	452,693,000	488,397,000	410,572,000	601,122,000	384,912,000	416,988,000	1,226,330,000	452,693,000	506,250,000
„ 14 -	577,404,000	434,840,000	452,693,000	452,693,000	553,686,000	384,912,000	404,757,000	931,500,000	470,545,000	577,404,000
„ 15 -	601,122,000	434,840,000	470,545,000	452,693,000	452,693,000	416,988,000	391,327,000	898,560,000	434,840,000	553,686,000
„ 16 -	601,122,000	434,840,000	434,840,000	416,988,000	470,545,000	434,840,000	410,572,000	898,560,000	470,545,000	653,232,000
„ 17 -	601,122,000	452,693,000	434,840,000	452,693,000	799,740,000	391,327,000	404,757,000	898,560,000	470,545,000	766,800,000
„ 18 -	624,840,000	452,693,000	452,693,000	470,545,000	681,624,000	391,327,000	404,757,000	971,870,000	470,545,000	766,800,000
„ 19 -	653,232,000	434,840,000	452,693,000	452,693,000	470,545,000	397,142,000	410,572,000	865,620,000	452,693,000	681,624,000
„ 20 -	624,840,000	416,988,000	410,572,000	506,250,000	601,122,000	404,757,000	404,757,000	1,092,980,000	470,545,000	653,232,000
„ 21 -	624,840,000	410,572,000	452,693,000	529,968,000	577,404,000	404,757,000	416,988,000	931,500,000	470,545,000	653,232,000
„ 22 -	624,840,000	404,757,000	452,693,000	577,404,000	601,122,000	404,757,000	404,757,000	898,560,000	434,840,000	601,122,000
„ 23 -	601,122,000	410,572,000	370,332,000	681,624,000	529,968,000	404,757,000	404,757,000	1,092,980,000	452,693,000	470,545,000
„ 24 -	601,122,000	416,988,000	434,840,000	577,404,000	553,686,000	397,142,000	404,757,000	1,272,820,000	452,693,000	553,686,000
„ 25 -	601,122,000	416,988,000	452,693,000	529,968,000	601,122,000	404,757,000	404,757,000	1,580,920,000	452,693,000	553,686,000
„ 6 -	653,232,000	434,840,000	506,250,000	553,686,000	529,968,000	391,327,000	404,757,000	2,154,280,000	416,988,000	506,250,000
„ 27 -	931,500,000	452,693,000	470,545,000	553,686,000	488,397,000	397,142,000	404,757,000	2,223,040,000	452,693,000	488,397,000
„ 28 -	898,560,000	416,988,000	416,988,000	488,397,000	506,250,000	404,757,000	404,757,000	1,948,000,000	434,840,000	470,545,000
„ 29 -	766,800,000	410,572,000	434,840,000	470,545,000	470,545,000	397,142,000	397,142,000	1,760,020,000	416,988,000	452,693,000
„ 30 -	766,800,000	416,988,000	470,545,000	488,397,000	452,693,000	391,327,000	404,757,000	1,760,020,000	416,988,000	452,693,000
„ 31 -	710,016,000	410,572,000	452,693,000	488,397,000	404,757,000	397,142,000	404,757,000	1,634,700,000	416,988,000	452,693,000

works Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive)—*continued.*

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
410,572,000	452,693,000	452,693,000	529,968,000	452,693,600	416,988,000	452,693,000	470,545,000	434,840,000	601,122,000	624,840,000
470,545,000	452,693,000	470,545,000	529,968,000	452,693,000	416,988,000	434,840,000	470,545,000	434,840,000	577,404,000	653,232,000
488,397,000	452,693,000	470,545,000	529,968,000	506,250,000	416,988,000	416,988,000	452,693,000	410,572,000	553,686,000	653,232,000
488,397,000	434,840,000	452,693,000	529,968,000	488,397,000	434,840,000	434,840,000	434,840,000	452,693,000	601,122,000	653,232,000
506,250,000	434,840,000	434,840,000	553,686,000	506,250,000	410,572,000	452,693,000	452,693,000	452,693,000	601,122,000	624,840,000
506,250,000	452,693,000	416,988,000	553,686,000	577,404,000	397,142,000	434,840,000	470,545,000	434,840,000	577,404,000	624,840,000
470,545,000	470,545,000	452,693,000	529,968,000	577,404,000	416,988,000	416,988,000	470,545,000	434,840,000	681.624,000	601,122,000
470,545,000	470,545,000	452,693,000	601,122,000	553,686,000	452,693,000	434,840,000	488,397,000	434,840,000	506,250,000	577,404,000
470,545,000	452,693,000	452,693,000	529,968,000	529,968,000	452,693,000	416,988,000	470,545,000	410,572,000	553,686,000	601,122,000
488,397,000	434,840,000	488,397,000	577,404,000	529,968,000	452,693,000	416,988,000	470,545,000	416,988,000	577,404,000	601,122,000
470,545,000	416,988,000	434,840,000	506,250,000	470,545,000	452,693,000	410,572,000	452,693,000	434,840,000	624,840,000	577,404,000
452,693,000	452,693,000	506,250,000	529,968,000	470,545,000	470,545,000	404,757,000	488,397,000	506,250,000	624,840,000	529,968,000
434,840,000	470,545,000	577,404,000	506,250,000	470,545,000	529,968,000	452,693,000	488,397,000	653,232,000	624,840,000	624,840,000
391,327,000	404,757,000	470,545,000	506,250,000	470,545,000	601,122,000	416,988,000	488,397,000	624,840,000	653,232,000	577,404,000
470,545,000	410,572,000	488,397,000	470,545,000	452,693,000	553,686,000	410,572,000	488,397,000	601,122,000	681,624,000	681,624,000
452,693,000	416,988,000	470,545,000	488,397,000	488,397,000	506,250,000	434,840,000	488,397,000	506,250,000	624,840,000	710,016,000
452,693,000	410,572,000	470,545,000	506,250,000	1,133,350,000	506,250,000	416,988,000	470,545,000	470,545,000	577,404,000	577,404,000
410,572,000	434,840,000	470,545,000	488,397,000	529,968,000	488,397,000	416,988,000	452,693,000	470,545,000	601,122,000	601,122,000
452,693,000	434,840,000	506,250,000	470,545,000	601,122,000	452,693,000	410,572,000	452,693,000	488,397,000	601,122,000	601,122,000
404,757,000	434,840,000	470,545,000	452,693,000	577,404,000	434,840,000	416,988,000	470,545,000	488,397,000	577,404,000	624,840,000
470,545,000	416,988,000	470,545,000	434,840,000	506,250,000	404,757,000	434,840,000	452,693,000	452,693,000	577,404,000	601,122,000
488,397,000	410,572,000	470,545,000	452,693,000	601,122,000	410,572,000	410,572,000	434,840,000	452,693,000	577,404,000	529,968,000
488,397,000	410,572,000	470,545,000	470,545,000	506,250,000	404,757,000	416,988,000	416,988,000	434,840,000	577,404,000	624,840,000
434,840,000	410,572,000	452,693,000	416,988,000	470,545,000	380,635,000	416,988,000	410,572,000	488,397,000	601,122,000	624,840,000
488,397,000	410,572,000	452,693,000	470,545,000	488,397,000	404,757,000	416,988,000	378,496,000	452,693,000	601,122,000	577,404,000
470,545,000	410,572,000	470,545,000	470,545,000	553,686,000	397,142,000	488,397,000	384,912,000	452,693,000	653,232,000	577,404,000
434,840,000	416,988,000	434,840,000	470,545,000	799,740,000	391,327,000	397,142,000	434,840,000	452,693,000	653,232,000	624,840,000
452,693,000	416,988,000	488,397,000	488,397,000	865,620,000	391,327,000	391,327,000	452,693,000	434,840,000	624,840,000	577,404,000
434,840,000	416,988,000	470,545,000	766,800,000	710,016,000	404,757,000	452,693,000	416,988,000	452,693,000	577,404,000	601,122,000
452,693,000	410,572,000	434,840,000	766,800,000	577,404,000	391,327,000	452,693,000	434,840,000	452,693,000	653,232,000	553,686,000
452,693,000	416,988,000	434,840,000	488,397,000	553,686,000	391,327,000	434,840,000	416,988,000	470,545,000	624,840,000	601,122,000
434,840,000	416,988,000	452,693,000	506,250,000	577,404,000	397,142,000	410,572,000	452,693,000	416,988,000	624,840,000	653,232,000
452,693,000	416,988,000	434,840,000	488,397,000	577,404,000	391,327,000	391,327,000	434,840,000	470,545,000	653,232,000	624,840,000
452,693,000	391,327,000	404,757,000	506,250,000	529,968,000	391,327,000	434,840,000	470,545,000	434,840,000	653,232,000	601,122,000
416,988,000	391,327,000	404,757,000	506,250,000	506,250,000	384,912,000	470,545,000	470,545,000	416,988,000	738,408,000	506,250,000
416,988,000	397,142,000	416,988,000	506,250,000	506,250,000	397,142,000	470,545,000	470,545,000	416,988,000	653.232,000	601,122,000
434,840,000	404,757,000	434,840,000	553,686,000	470,545,000	391,327,000	488,397,000	470,545,000	416,988,000	624,840,000	577,404,000
452,693,000	397,142,000	488,397,000	553,686,000	553,686,000	410,572,000	434,840,000	470,545,000	416,988,000	710,016,000	601,122,000
434,840,000	397,142,000	404,757,000	470,545,000	624,840,000	410,572,000	434,840,000	452,693,000	434,840,000	710,016,000	601,122,000
434,840,000	397,142,000	384,912,000	506,250,000	577,404,000	410,572,000	416,988,000	470,545,000	434,840,000	832,680,000	601,122,000
410,572,000	410,572,000	416,988,000	577,404,000	488,397,000	404,757,000	434,840,000	452,693,000	416,988,000	738,408,000	577,404,000
416,988,000	410,572,000	452,693,000	506,250,000	488,397,000	434,840,000	452,693,000	452,693,000	416,988,000	710,016,000	553,686,000
410,572,000	416,988,000	470,545,000	488,397,000	434,840,000	410,572,000	416,988,000	452,693,000	410,572,000	653,232,000	577,404,000
416,988,000	416,988,000	452,693,000	529,968,000	470,545,000	404,757,000	410,572,000	434,840,000	416,988,000	653,232,000	577,404,000
410,572,000	416,988,000	452,693,000	488,397,000	416,988,000	416,988,000	410,572,000	434,840,000	404,757,000	624,840,000	577,404,000
404,757,000	410,572,000	434,840,000	488,397,000	434,840,000	410,572,000	416,988,000	410,572,000	416,988,000	681,624,000	601,122,000
404,757,000	434,840,000	470,545,000	506,250,000	452,693,000	410,572,000	488,397,000	416,988,000	416,988,000	653,232,000	601,122,000
404,757,000	434,840,000	470,545,000	470,545,000	470,545,000	391,327,000	410,572,000	410,572,000	404,757,000	624,840,000	577,404,000
416,988,000	410,572,000	470,545,000	488,397,000	452,693,000	452,693,000	382,773,000	416,988,000	404,757,000	653,232,000	506,250,000
416,988,000	410,572,000	470,545,000	529,968,000	434,840,000	488,397,000	434,840,000	416,988,000	416,988,000	577,404,000	470,545,000
434,840,000	410,572,000	452,693,000	529,968,000	488,397,000	506,250,000	452,693,000	416,988,000	410,572,000	653,232,000	601,122,000
416,988,000	416,988,000	416,988,000	506,250,000	577,404,000	506,250,000	452,693,000	410,572,000	410,572,000	601,122,000	624,840,000
416,988,000	416,988,000	452,693,000	452,693,000	577,404,000	529,968,000	452,693,000	410,572,000	434,840,000	681,624,000	624,840,000
410,572,000	416,988,000	452,693,000	470,545,000	506,250,000	529,968,000	452,693,000	416,988,000	434,840,000	577,404,000	624,840,000
416,988,000	416,988,000	553,686,000	470,545,000	506,250,000	529,968,000	470,545,000	452,693,000	416,988,000	653,232,000	624,840,000
416,988,000	416,988,000	681,624,000	488,397,000	506,250,000	529,968,000	410,572,000	470,545,000	410,572,000	601,122,000	506,250,000
410,572,000	452,693,000	577,404,000	488,397,000	470,545,000	506,250,000	404,757,000	470,545,000	410,572,000	601,122,000	601,122,000
416,988,000	416,988,000	506,250,000	470,545,000	529,968,000	470,545,000	416,988,000	434,840,000	410,572,000	624,840,000	577,404,000
452,693,000	416,988,000	488,397,000	506,250,000	488,397,000	506,250,000	410,572,000	452,693,000	404,757,000	577,404,000	601,122,000
434,840,000	416,988,000	470,545,000	470,545,000	506,250,000	488,397,000	410,572,000	452,693,000	416,988,000	624,840,000	653,232,000
452,693,000	416,988,000	470,545,000	506,250,000	488,397,000	452,693,000	410,572,000	452,693,000	410,572,000	601,122,000	601,122,000
470,545,000	416,988,000	452,693,000	452,693,000	470,545,000	416,988,000	416,988,000	488,397,000	410,572,000	601,122,000	601,122,000

Daily Volume of Water flowing down the Thames opposite the Lambeth Water-

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
September 1	681,624,000	410,572,000	452,693,000	470,545,000	434,840,000	391,327,000	397,142,000	1,473,360,000	410,572,000	452,693,000
„ 2	898,560,000	416,988,000	434,840,000	488,397,000	452,693,000	380,635,000	397,142,000	1,226,330,000	410,572,000	452,693,000
„ 3	1,272,820,000	416,988,000	452,693,000	434,840,000	452,693,000	382,773,000	404,757,000	1,092,980,000	397,142,000	488,397,000
„ 4	1,272,820,000	434,840,000	434,840,000	470,545,000	553,686,000	382,773,000	404,757,000	971,870,000	397,142,000	553,686,000
„ 5	1,012,240,000	410,572,000	434,840,000	470,545,000	577,404,000	384,912,000	391,327,000	799,740,000	397,142,000	470,545,000
„ 6	832,680,000	416,988,000	452,693,000	470,545,000	553,686,000	416,988,000	397,142,000	865,620,000	416,988,000	470,545,000
„ 7	832,680,000	410,572,000	434,840,000	416,988,000	553,686,000	404,757,000	404,757,000	832,680,000	416,988,000	529,968,000
„ 8	766,800,000	416,988,000	434,840,000	506,250,000	553,686,000	384,912,000	391,327,000	832,680,000	434,840,000	506,250,000
„ 9	738,408,000	410,572,000	452,693,000	416,988,000	624,840,000	397,142,000	404,757,000	865,620,000	416,988,000	470,545,000
„ 10	653,232,000	410,572,000	434,840,000	410,572,000	653,232,000	404,757,000	404,757,000	766,800,000	434,840,000	488,397,000
„ 11	653,232,000	416,988,000	416,988,000	52,693,000	653,232,000	404,757,000	404,757,000	799,740,000	470,545,000	601,122,000
„ 12	577,404,000	416,988,000	434,840,000	470,545,000	624,840,000	404,757,000	391,327,000	766,800,000	416,988,000	470,545,000
„ 13	624,840,000	404,757,000	410,572,000	452,693,000	[illegible]4,840,000	404,757,000	404,757,000	766,800,000	434,840,000	506,250,000
„ 14	653,232,000	410,572,000	416,988,000	452,693,000	506,250,000	397,142,000	410,572,000	738,408,000	416,988,000	506,250,000
„ 15	710,016,000	416,988,000	434,840,000	470,545,000	553,686,000	397,142,000	410,572,000	766,800,000	470,545,000	506,250,000
„ 16	738,408,000	410,572,000	434,840,000	452,693,000	488,397,000	397,142,000	404,757,000	766,800,000	470,545,000	470,545,000
„ 17	653,232,000	410,572,000	452,693,000	434,840,000	529,968,000	397,142,000	416,988,000	766,800,000	364,500,000	434,840,000
„ 18	624,840,000	404,757,000	434,840,000	434,840,000	470,545,000	397,142,000	404,757,000	832,680,000	368,388,000	470,545,000
„ 19	577,404,000	397,142,000	434,840,000	452,693,000	506,250,000	397,142,000	391,327,000	832,680,000	506,250,000	470,545,000
„ 20	577,404,000	410,572,000	452,693,000	452,693,000	470,545,000	410,572,000	404,757,000	931,500,000	553,686,000	470,545,000
„ 21	601,122,000	410,572,000	452,693,000	452,693,000	452,693,000	416,988,000	416,988,000	931,500,000	470,545,000	470,545,000
„ 22	653,232,000	404,757,000	434,840,000	434,840,000	470,545,000	382,773,000	404,757,000	865,620,000	506,250,000	470,545,000
„ 23	653,232,000	404,757,000	416,988,000	434,840,000	452,693,000	397,142,000	416,988,000	1,012,240,000	506,250,000	452,693,000
„ 24	681,624,000	404,757,000	452,693,000	470,545,000	434,840,000	416,988,000	416,988,000	1,226,330,000	529,968,000	470,545,000
„ 25	624,840,000	410,572,000	434,840,000	470,545,000	434,840,000	416,988,000	410,572,000	1,580,920,000	506,250,000	452,693,000
„ 26	577,404,000	410,572,000	434,840,000	488,397,000	434,840,000	410,572,000	391,327,000	2,517,680,000	553,686,000	470,545,000
„ 27	577,404,000	404,757,000	434,840,000	488,397,000	452,693,000	410,572,000	488,397,000	3,543,720,000	553,686,000	470,545,000
„ 28	553,686,000	404,757,000	452,693,000	506,250,000	434,840,000	404,757,000	553,686,000	3,440,240,000	506,250,000	470,545,000
„ 29	553,686,000	410,572,000	434,840,000	710,016,000	434,840,000	416,988,000	577,404,000	3,336,760,000	553,686,000	506,250,000
„ 30	577,404,000	410,572,000	434,840,000	738,408,000	416,988,000	410,572,000	470,545,000	3,336,760,000	553,686,000	506,250,000
October 1	577,404,000	404,757,000	470,545,000	624,840,000	416,988,000	434,840,000	452,693,000	2,292,800,000	553,686,000	506,250,000
„ 2	577,404,000	404,757,000	470,545,000	577,404,000	434,840,000	410,572,000	452,693,000	1,948,000,000	506,250,000	529,968,000
„ 3	601,122,000	404,757,000	529,968,000	553,686,000	410,572,000	410,572,000	452,693,000	1,634,700,000	506,250,000	529,968,000
„ 4	832,680,000	404,757,000	553,686,000	553,686,000	434,840,000	410,572,000	434,840,000	1,419,580,000	506,250,000	553,686,000
„ 5	1,133,350,000	397,142,000	452,693,000	553,686,000	416,988,000	410,572,000	416,988,000	1,272,820,000	529,968,000	577,404,000
„ 6	1,092,980,000	434,840,000	601,122,000	832,680,000	410,572,000	410,572,000	416,988,000	799,740,000	506,250,000	577,404,000
„ 7	1,092,980,000	416,988,000	738,408,000	832,680,000	410,572,000	416,988,000	416,988,000	799,740,000	506,250,000	681,624,000
„ 8	1,052,610,000	416,988,000	865,620,000	766,800,000	470,545,000	416,988,000	416,988,000	766,800,000	553,686,000	506,250,000
„ 9	931,500,000	416,988,000	710,016,000	931,500,000	738,408,000	434,840,000	434,840,000	681,624,000	506,250,000	529,968,000
„ 10	971,870,000	410,572,000	710,016,000	1,092,980,000	931,500,000	397,142,000	416,988,000	653,232,000	506,250,000	470,545,000
„ 11	1,012,240,000	416,988,000	681,624,000	1,092,980,000	832,680,000	434,840,000	434,840,000	624,840,000	506,250,000	529,968,000
„ 12	971,870,000	416,988,000	681,624,000	1,052,610,000	710,016,000	416,988,000	434,840,000	738,408,000	506,250,000	681,624,000
„ 13	1,179,840,000	410,572,000	624,840,000	1,179,840,000	601,122,000	404,757,000	410,572,000	832,680,000	506,250,000	681,624,000
„ 14	1,365,800,000	404,757,000	577,404,000	1,012,240,000	601,122,000	416,988,000	452,693,000	832,680,000	506,250,000	681,624,000
„ 15	1,272,820,000	404,757,000	601,122,000	971,870,000	506,250,000	416,988,000	416,988,000	898,560,000	470,545,000	653,232,000
„ 16	931,500,000	384,912,000	577,404,000	1,092,980,000	529,968,000	410,572,000	416,988,000	865,620,000	506,250,000	601,122,000
„ 17	1,329,410,000	416,988,000	624,840,000	1,226,330,000	577,404,000	416,988,000	416,988,000	1,419,580,000	506,250,000	506,250,000
„ 18	2,154,280,000	404,757,000	931,500,000	1,052,610,000	529,968,000	410,572,000	553,686,000	1,634,700,000	506,250,000	601,122,000
„ 19	2,292,800,000	434,840,000	1,092,980,000	971,870,000	553,686,000	416,988,000	553,686,000	1,365,800,000	506,250,000	931,500,000
„ 20	2,442,720,000	434,840,000	865,620,000	865,620,000	601,122,000	416,988,000	488,397,000	1,580,920,000	488,397,000	1,365,800,000
„ 21	3,336,760,000	416,988,000	799,740,000	1,133,350,000	681,624,000	410,572,000	470,545,000	1,365,800,000	488,397,000	1,760,020,000
„ 22	2,944,920,000	416,988,000	710,016,000	766,800,000	710,016,000	434,840,000	452,693,000	1,179,840,000	488,397,000	1,419,580,000
„ 23	2,667,600,000	410,572,000	653,232,000	710,016,000	2,154,280,000	434,846,000	416,988,000	1,092,980,000	506,250,000	971,870,000
„ 24	2,367,760,000	404,757,000	577,404,000	681,624,000	4,605,120,000	410,572,000	416,988,000	971,870,000	506,250,000	766,800,000
„ 25	2,016,760,000	410,572,000	577,404,000	624,840,000	4,107,680,000	416,988,000	601,122,000	971,870,000	506,250,000	710,016,000
„ 26	1,580,920,000	452,693,000	553,686,000	624,840,000	3,037,460,000	416,988,000	577,404,000	898,560,000	506,250,000	681,624,000
„ 27	1,329,410,000	488,397,000	738,408,000	624,840,000	1,948,000,000	416,988,000	799,740,000	766,800,000	529,968,000	710,016,000
„ 28	1,365,800,000	452,693,000	1,226,330,000	577,404,000	1,226,330,000	434,840,000	710,016,000	865,620,000	529,968,000	766,800,000
„ 29	1,885,340,000	452,693,000	1,092,980,000	553,686,000	971,870,000	452,693,000	681,624,000	799,740,000	488,397,000	710,016,000
„ 30	2,154,280,000	416,988,000	931,500,000	601,122,000	832,680,000	434,840,000	681,624,000	738,408,000	488,397,000	653,232,000
„ 31	1,760,020,000	452,693,000	1,760,020,000	601,122,000	832,680,000	416,988,000	653,232,000	710,016,000	506,250,000	766,800,000

works Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive)—*continued.*

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
470,545,000	416,988,000	434,840,000	470,545,000	506,250,000	452,693,000	410,572,000	452,693,000	404,757,000	577,404,000	577,404,000
416,988,000	416,988,000	416,988,000	470,545,000	488,397,000	470,545,000	397,142,000	434,840,000	410,572,000	624,840,000	624,840,000
452,693,000	416,988,000	416,988,000	452,693,000	529,968,000	452,693,000	391,327,000	452,693,000	404,757,000	577 404,000	577,404,000
470,545,000	416,988,000	410,572,000	470,545,000	529,968,000	488,397,000	416,988,000	452,693,000	410,572,000	577,404,000	601,122,000
488,397,000	416,988,000	434,840,000	488,397 000	577,404,000	470,545,000	452,693,000	416,988,000	416,988,000	624,840,000	601,122,000
506,250,000	410,572,000	416,988,000	529,968,000	553,686,000	416,988,000	452,693,000	416,988,000	404,757,000	601,122,000	601,122,000
470,545,000	452,693,000	416,988,000	529,968,000	529,968,000	404,757,000	397,142,000	488,397,000	416,988,000	577,404,000	601,122,000
452,693,000	434,840,000	410,572,000	529,968,000	553,686,000	470,545,000	452,693,000	488,397,000	416,988,000	577,404,000	577,404,000
470,545,000	416,988,000	410,572,000	601,122,000	506,250,000	470,545,000	452,693,000	488,397,000	416,988,000	529,968,000	601,122,000
470,545,000	416,988,000	416,988,000	681,624,000	553,686,000	452,693,000	452,693,000	488,397,000	404,757,000	577,404,000	601,122,000
601,122,000	416,988,000	416,988,000	553,686,000	681,624,000	434,840,000	452,693,000	488,397,000	416,988,000	577,404,000	624,840,000
488,397,000	410,572 000	410,572,000	653,232,000	624,840,000	452,693,000	470,545,000	470,545,000	416,988,000	553,686,000	624,840,000
488,397,000	416,988,000	391,327,000	577,404,000	601,122,000	434,840,000	470,545,000	470,545,000	416,988,000	553,686,000	577,404,000
506,250,000	416,988,000	397,142,000	553,686,000	577,404,000	416,988,000	470,545,000	470,545,000	410,572,000	529,968,000	577,404,000
404,757,000	452,693,000	397,142,000	529,968,000	577,404,000	416,988,000	434,840,000	470,545,000	416,988,000	553,686,000	653,232,000
434,840,000	434,840,000	404,757,000	624,840,000	529,968,000	434,840,000	434,840,000	470,545,000	416,988,000	529,968,000	601,122,000
470,545,000	488,397,000	410,572,000	624,840,000	601,122,000	410,572,000	434,840,000	452,693,000	416,988,000	577,404,000	681,624,000
434,840,000	470,545,000	410,572,000	681,624,000	529,968,000	362,556,000	434,840,000	434,840,000	416,988,000	553,686,000	681,624,000
391,327,000	470,545,000	416,988,000	624,840,000	553,686,000	362,556,000	416,988,000	434,840,000	434,840,000	577,404,000	601,122,000
416,988,000	488,397,000	434,840,000	624,840,000	553,686,000	364,500,000	506,250,000	434,840,000	410,572,000	577,404,000	553,686,000
434,840,000	470,545,000	434,840,000	601,122,000	529,968,000	370,332,000	506,250,000	452,693,000	404,757,000	577,404,000	601,122,000
452,693,000	488,397,000	434,840,000	601,122,000	553,686,000	384,912,000	506,250,000	452,693,000	410,572,000	553,686,000	601,122,000
434,840,000	488,397,000	410,572,000	738,408,000	506,250,000	384,912,000	416,988,000	452,693,000	404,757,000	529,968,000	577,404,000
434,840,000	470,545,000	416,988,000	931,500,000	553,686,000	380,635,000	416,988,000	434,740,000	416,988,000	553,686,000	601,122 000
470,545,000	470,545,000	434,840,000	577,904,000	529,968,000	380,635,000	410,572,000	434,840,000	404,757,000	577,404,000	624,840,000
416,988,000	434,840,000	410,572,000	681,624,000	529,968,000	384,912,000	416,988,000	416,988,000	434,840,000	553,686,000	601,122,000
434,840,000	452,693,000	410,572,000	710,016,000	529,968,000	404,757,000	416,988,000	410,572,000	434,840,000	553,686,000	577,404,000
434,840,000	452,693,000	416,988,000	710,016,000	488,397,000	397,142,000	434,840,000	470,545,000	452,693,000	577,404,000	624,840,000
470,545,000	452,693,000	404,757,000	766,800,000	488,397,000	488,397,000	434,840,000	434,840,000	470,545,000	553,686,000	553,686,000
470,545,000	452,693,000	410,572,000	832,680,000	470,545,000	488,397,000	434,840,000	434,840,000	506,250,000	470,545,000	577,404,000
434,840,000	452,693,000	410,572,000	799,740,000	452,693,000	404,757,000	452,693,000	416,988,000	898,560,000	553,686,000	601,122,000
488,397,000	452,693,000	391,327,000	832,680,000	470,545,000	391,327,000	416,988,000	416,988,000	1,012,240,000	553,686,000	553,686,000
529,968,000	416,988,000	410,572,000	832,680,000	488,397,000	384,912,000	553,686,000	404,757,000	1,012,240,000	577,404,000	577,40,4000
506,250,000	434,840,000	404,757,000	799,740,000	488,397,000	384,912,000	529,968,000	410,572,000	931,500,000	601,122,000	601,122,000
470,545,000	416,988,000	410,572,000	799,740,000	470,545,000	416,988,000	553,686,000	410,572,000	971,870,000	624,840,000	529,968,000
434,840,000	416,988,000	410,572,000	832,680,000	452,693,000	382,773,000	506,250,000	434,840,000	971,870,000	553,686,000	553,686,000
452,693,000	416,988,000	410,572,000	832,680,000	410,572,000	382,773,000	488,397,000	452,693,000	931,500,000	553,686,000	577,404,000
470,545,000	434,840,000	410,572,000	799,740,000	588,397,000	397,142,000	470,545,000	452,693,000	865,620,000	577,404,000	601,122,000
391,327,000	434,840,000	391,327,000	681,624,000	488,397,050	410,572,000	452,693,000	452,693,000	738,408,000	577,404,000	601,122,000
710,016,000	434,840,000	416,918,000	624,840,000	506,250,000	410,572,000	488,397,000	452,693,000	624,840,000	577,404,000	601,122,000
681,624,000	434,840,000	434,840,000	624,840,000	353,686,000	416,988,000	470,545,000	452,693,000	577,404,000	506,250,000	577,404,000
653,232,000	416,988,000	470,545,000	601,122,000	553,686,000	391,327,000	470,545,000	470,545,000	601,122,000	553,686,000	601,122,000
653,232,000	434,840,000	452,693,000	624,840,000	553,686,000	397,142,000	452,693,000	470,545,000	553,686,000	529,968,000	681,624,000
601,122,000	416,988,000	452,693,000	624,840,000	529,968,000	382,773,000	470,545,000	488,397,000	529,968,000	506,250,000	832,680,000
681,624,000	404,757,000	452,693,000	601,122,000	577,404,000	384,912,000	470,545,000	488,397,000	553,686,000	553,686,000	766,800,000
529,968,000	410,572,000	452,693,000	553,686,000	577,404,000	384,912,000	470,545,000	470,545,000	601,122,000	553,686,000	506,250,000
577,404,000	397,142,000	434,840,000	553,686,000	738,408,000	384,912,000	452,693,000	470,545,000	553,686,000	529,968,000	681,624,000
577,404,000	416,988,000	470,545,000	577,404,000	624,840,000	391,327,000	434,840,000	506,250,000	553,686,000	577,404,000	601,122,000
506,250,000	416,988,000	529,968,000	577,404,000	577,404,000	382,773,000	529,968,000	529,968,000	488,397,000	529,968,000	624,840,000
452,693,000	416,988,000	653,232,000	601,122,000	577,404,000	382,773,000	601,122,000	529,968,000	506,250,000	577,404,000	553,686,000
416,988,000	416,988,000	710,016,000	624,840,000	577,404,000	382,773,000	529,968,000	553,686,000	506,250,000	577,404,000	553,686,000
434,840,000	434,840,000	470,545,000	624,840,000	529,968,000	391,327,000	506,250,000	529,968,000	470,545,000	681,624,000	624,840,000
434,840,000	452,693,000	766,800,000	681,624,000	506,250,000	384,912,000	488,397,000	553,686,000	488,397,000	710,016,000	624,840,000
434,840,000	470,545,000	832,680,000	832,680,000	553,686,000	384,912,000	488,397,000	577,404,000	470,545,000	624,840,000	577,404,000
434,840,000	488,397,000	681,624,000	865,620,000	529,968,000	391,327,000	488,397,000	601,122,000	506,250,000	577,404,000	653,232,000
434,840,000	452,693,000	601,122,000	1,052,610,000	506,250,000	416,988,000	488,397,000	553,686,000	488,397,000	971,870,000	653,232,000
452,693,000	470,545,000	971,870,000	971,870,000	506,250,000	397,142,000	470,545,000	553,686,000	452,693,000	971,870,000	710,016,000
397,142,000	488,397,000	1,133,350,000	898,560,000	529,968,000	434,840,000	470,545,000	529,968,000	488,397,000	1,133,350,000	601,122,000
470,545,000	488,397,000	1,052,610,000	898,560,000	624,840,000	410,572,000	488,397,000	506,250,000	470,545,000	865,620,000	681,624,000
529,968,000	488,397,000	898,560,000	832,680,000	577,404,000	397,142,000	470,545,000	529,968,000	434,840,000	738,408,000	506,250,000
577,404,000	488,397,000	1,179,840,000	832,680,000	553,686,000	452,693,000	488,397,000	577,404,000	470,545,000	710,016,000	577,404,000

Daily Volume of Water flowing down the Thames opposite the Lambeth Water-

For the Year	1853.	1854.	1855.	1856.	1857.	1858.	1859.	1860.	1861.	1862.
Month & day.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
November 1	1,365,800,000	416,988,000	3,233,280,000	653,232,000	766,800,000	416,988,000	601,122,000	710,016,000	506,250,000	653,232,000
„ 2	1,272,820,000	410,572,000	3,762,320,000	681,624,000	681,624,000	410,572,000	738,408,000	710,016,000	503,250,000	653,232,000
„ 3	1,226,330,000	434,840,000	3,037,460,000	577,404,000	553,686,000	410,572,000	799,740,000	710,016,000	506,250,000	601,122,000
„ 4	1,226,330,000	434,840,000	2,944,920,000	577,404,000	681,624,000	416,988,000	931,500,000	681,624,000	503,250,000	577,404,000
„ 5	1,092,980,000	416,988,000	3,233,280,000	624,840,000	1,329,410,000	434,840,000	1,052,610,000	681,624,000	506,250,000	506,250,000
„ 6	1,052,610,000	416,988,000	2,760,040,000	577,404,000	1,697,360,000	434,840,000	1,527,140,000	653,232,000	529,968,000	799,740,000
„ 7	1,052,610,000	410,572,000	2,292,800,000	577,404,000	2,223,040,000	452,693,000	1,822,068,000	624,840,000	624,840,000	865,620,000
„ 8	931,500,000	416,988,000	1,760,020,000	506,250,000	1,226,330,000	452,693,000	2,016,760,000	624,840,000	624,840,000	738,408,000
„ 9	898,560,000	416,988,000	1,822,068,000	553,686,000	1,052,610,000	404,757,000	1,419,580,000	624,840,000	577,404,000	653,232,000
„ 10	832,680,000	410,572,000	1,697,360,000	577,404,000	971,870,000	410,572,000	1,092,980,000	624,840,000	506,250,000	681,624,000
„ 11	799,740,000	410,572,000	1,365,800,000	553,686,000	799,740,000	410,572,000	832,680,000	601,122,000	766,800,000	738,408,000
„ 12	799,740,000	410,572,000	1,092,980,000	577,404,000	681,624,000	452,693,000	710,016,000	601,122,000	710,016,000	681,624,000
„ 13	799,740,000	434,840,000	898,560,000	577,404,000	653,232,000	416,988,000	624,840,000	681,624,000	710,016,000	653,232,000
„ 14	799,740,000	434,840,000	832,680,000	553,686,000	653,232,000	416,988,000	577,404,000	601,122,000	1,052,610,000	577,404,000
„ 15	624,840,000	416,988,000	799,740,000	529,968,000	624,840,000	410,572,000	529,968,000	624,840,000	1,822,068,000	624,840,000
„ 16	766,800,000	434,840,000	799,740,000	553,686,000	653,232,000	416,988,000	529,968,000	898,560,000	1,527,140,000	710,016,000
„ 17	710,016,000	506,250,000	766,800,000	488,397,000	529,968,000	416,988,000	529,968,000	832,680,000	1,052,610,000	506,250,000
„ 18	710,016,000	452,693,000	766,800,000	506,250,000	624,840,000	416,988,000	506,250,000	1,272,820,000	832,680,000	506,250,000
„ 19	681,624,000	452,693,000	738,408,000	553,686,000	601,122,000	416,988,000	488,397,000	2,085,520,000	681,624,000	506,250,000
„ 20	653,232,000	410,572,000	738,408,000	553,686,000	624,840,000	416,988,000	553,686,000	1,822,068,000	488,397,000	553,686,000
„ 21	624,840,000	434,840,000	710,016,000	553,686,000	624,840,000	410,572,000	577,404,000	1,473,360,000	529,968,000	553,686,000
„ 22	601,122,000	416,988,000	681,624,000	529,968,000	601,122,000	404,757,000	553,686,000	1,822,068,000	577,404,000	553,686,000
„ 23	653,232,000	416,988,000	681,624,000	529,968,000	601,122,000	416,988,000	529,968,000	2,367,760,000	931,500,000	553,686,000
„ 24	653,232,000	452,693,000	681,624,000	553,686,000	601,122,000	410,572,000	529,968,000	2,517,680,000	1,365,800,000	577,404,000
„ 25	799,740,000	470,545,000	681,624,000	553,686,000	971,870,000	404,757,000	488,397,000	2,154,280,000	931,500,000	553,686,000
26	1,329,410,000	434,840,000	653,232,000	577,404,000	1,052,610,000	410,572,000	553,686,000	1,822,068,000	710,016,000	506,250,000
„ 27	1,580,920,000	434,840,000	601,122,000	601,122,000	931,500,000	410,572,000	506,250,000	1,697,360,000	766,800,000	506,250,000
„ 28	1,948,000,000	416,988,000	624,840,000	529,968,000	799,740,000	416,988,000	710,016,000	1,885,340,000	766,800,000	506,250,000
„ 29	1,527,140,000	410,572,000	624,840,000	601,122,000	931,500,000	416,988,000	832,680,000	1,822,068,000	624,840,000	577,404,000
„ 30	1,329,410,000	452,693,000	577,404,000	601,122,000	738,408,000	434,840,000	1,052,610,000	1,760,020,000	653,232,000	553,686,000
December 1	1,760,020,000	470,545,000	601,122,000	553,686,000	681,624,000	434,840,000	1,473,360,000	1,948,000,000	865,620,000	553,686,000
„ 2	1,822,068,000	452,693,000	577,404,000	506,250,000	601,122,000	434,840,000	1,948,000,000	2,367,760,000	799,740,000	553,686,000
„ 3	1,634,700,000	452,693,000	601,122,000	470,545,000	624,840,000	452,693,000	1,365,800,000	2,517,680,000	553,686,000	506,250,000
„ 4	1,527,140,000	434,840,000	577,404,000	470,545,000	624,840,000	434,840,000	1,092,980,000	2,760,040,000	601,122,000	553,686,000
„ 5	1,365,800,000	434,840,000	601,122,000	553,686,000	681,624,000	434,840,000	971,870,000	2,667,600,000	601,122,000	529,968,000
„ 6	1,226,330,000	434,840,000	577,404,000	832,680,000	624,840,000	416,988,000	1,419,580,000	2,760,040,000	766,800,000	529,968,000
„ 7	1,092,980,000	434,840,000	577,404,000	1,092,980,000	653,232,000	434,840,000	1,527,140,000	3,037,430,000	681,624,000	710,016,000
„ 8	971,870,000	416,988,000	601,122,000	1,226,330,000	624,840,000	416,988,000	1,697,360,000	3,336,760,000	1,419,580,000	832,680,000
„ 9	971,870,000	416,988,000	577,404,000	1,133,350,000	653,232,000	434,840,000	1,365,800,000	3,877,440,000	1,365,800,000	898,560,000
„ 10	931,500,000	452,693,000	577,404,000	1,052,610,000	624,840,000	434,840,000	1,092,980,900	4,605,120,000	1,272,820,000	799,740,000
„ 11	931,500,000	416,988,000	529,968,000	1,272,820,000	577,404,000	434,840,000	832,680,000	4,477,680,000	1,226,330,000	931,500,000
„ 12	898,560,000	416,988,000	529,968,000	1,473,360,000	577,404,000	434,840,000	766,800,000	4,222,800,000	1,133,350,000	832,680,000
„ 13	865,620,000	410,572,000	553,686,000	1,948,000,000	577,404,000	416,988,000	653,232,000	3,762,320,000	1,133,350,000	931,500,000
„ 14	799,740,000	434,840,000	529,968,000	2,667,600,000	601,122,000	416,988,000	710,016,000	3,129,800,000	1,226,330,000	1,092,980,000
„ 15	766,800,000	416,988,000	529,968,000	2,760,040,000	553,686,000	434,840,000	624,840,000	2,517,680,000	1,226,330,000	1,052,610,000
„ 16	799,740,000	416,988,000	553,686,000	1,760,020,000	553,686,000	416,988,000	653,232,000	2,154,280,000	1,052,610,000	865,620,000
„ 17	799,740,000	434,840,000	506,250,000	1,419,580,000	577,404,000	434,840,000	506,250,000	1,760,020,000	1,052,610,000	832,680,000
„ 18	766,800,000	410,572,000	506,250,000	1,419,580,000	553,686,000	416,988,000	434,840,000	1,634,700,000	971,870,000	865,620,000
„ 19	799,740,000	452,693,000	529,968,000	1,052,610,000	577,404,000	452,693,000	404,757,000	1,527,140,000	931,500,000	832,680,000
„ 20	766,800,000	434,840,000	553,686,000	931,500,000	624,840,000	488,397,000	410,572,000	1,365,800,000	898,560,000	799,740,000
„ 21	738,408,000	601,122,000	374,220,000	865,620,000	577,404,000	601,122,000	410,572,000	1,272,820,000	832,680,000	738,408,000
„ 22	766,800,000	601,122,000	384,912,000	832,680,000	601,122,000	434,840,000	410,572,000	1,179,840,000	738,408,000	681,624,000
„ 23	799,740,000	488,397,000	470,545,000	1,052,610,000	624,840,000	488,397,000	653,232,000	1,133,350,000	710,016,000	577,404,000
„ 24	832,680,000	452,693,000	410,572,000	710,016,000	601,122,000	410,572,000	766,800,000	1,012,240,000	681,624,000	529,968,000
„ 25	799,740,000	470,545,000	506,250,000	766,800,000	529,968,000	553,686,000	799,740,000	1,012,240,000	653,232,000	529,968,000
„ 26	766,800,000	488,397,000	832,680,000	799,740,000	529,968,000	553,686,000	1,473,360,000	931,500,000	601,122,000	529,968,000
„ 27	738,408,000	470,545,000	1,527,140,000	710,016,000	529,968,000	653,232,000	2,442,720,000	832,680,000	553,686,000	529,968,000
„ 28	710,016,000	452,693,000	2,016,760,000	710,016,000	577,404,000	470,545,000	2,442,720,000	766,800,000	653,232,000	577,404,000
„ 29	681,624,000	470,545,000	1,760,020,000	710,016,000	529,968,000	553,686,000	2,223,040,000	766,800,000	624,840,000	506,250,000
„ 30	506,250,000	470,545,000	1,365,800,000	601,122,000	506,250,000	529,968,000	1,948,000,000	898,560,000	710,016,000	681,624,000
„ 31	710,016,000	470,545,000	1,052,610,000	529,968,000	553,686,000	529,968,000	2,016,760,000	1,760,020,000	624,840,000	653,232,000

works Seething Wells, near Thames Ditton, 1853 to 1873 (inclusive)—*continued.*

1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.
Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.	Gals. in 24 hrs.
681,624,000	488,397,000	1,329,410,000	799,740,000	416,988,000	416,988,000	452,693,000	553,686,000	488,397,000	971,870,000	601,122,000
799,740,000	488,397,000	1,365,800,000	738,408,000	416,988,000	410,572,000	488,397,000	553,686,000	506,250,000	971,870,000	553,686,000
898,560,000	452,693,000	931,500,000	681,624,000	577,404,000	382,773,000	470,545,000	529,968,000	434,840,000	1,419,580,000	710,016,000
1,226,330,000	470,545,000	799,740,000	653,232,000	553,686,000	410,572,000	372,276,000	506,250,000	416,988,000	1,179,840,000	529,968,000
1,012,240,000	434,840,000	766,800,000	710,016,000	577,404,000	397,142,000	470,545,000	488,397,000	416,988,000	865,620,000	738,408,000
865,620,000	452,693,000	738,408,000	624,840,000	529,968,000	391,327,000	470,545,000	506,250,000	410,572,000	1,092,980,000	799,740,000
766,800,000	470,545,000	529,968,000	624,840,000	529,968,000	397,142,000	488,397,000	488,397,000	470,545,000	832,680,000	931,500,000
506,250,000	434,840,000	529,968,000	577,404,000	529,968,000	416,988,000	404,757,000	506,250,000	434,840,000	865,620,000	1,012,240,000
971,870,000	452,693,000	506,250,000	624,840,000	529,968,000	416,988,000	404,757,000	506,250,000	410,572,000	710,016,000	799,740,000
971,870,000	452,693,000	506,250,000	738,408,000	506,250,000	434,840,000	410,572,000	506,250,000	434,840,000	710,016,000	738,408,000
865,620,000	452,693,000	506,250,000	738,408,000	488,397,000	434,840,000	397,142,000	488,397,000	452,693,000	738,408,000	738,408,000
865,620,000	434,840,000	506,250,000	898,560,000	506,250,000	434,840,000	416,988,000	488,397,000	434,840,000	738,408,000	681,624,000
799,740,000	434,840,000	470,545,000	865,620,000	529,968,000	410,572,000	470,545,000	470,545,000	416,988,000	529,968,000	681,624,000
766,800,000	452,693,000	470,545,000	1,052,610,000	529,968,000	410,572,000	488,397,000	470,545,000	452,693,000	653,232,000	577,404,000
506,250,000	506,250,000	452,693,000	1,226,330,000	553,686,000	410,572,000	434,840,000	488,397,000	434,840,000	710,016,000	624,840,000
681,624,000	434,840,000	470,545,000	1,012,240,000	577,404,000	410,572,000	488,397,000	488,397,000	488,397,000	710,016,000	577,404,000
653,232,000	410,572,000	452,693,000	931,500,000	601,122,000	434,840,000	470,545,000	488,397,000	452,693,000	865,620,000	601,122,000
601,122,000	434,840,000	506,250,000	971,870,000	529,968,000	416,988,000	470,545,000	488,397,000	434,840,000	766,800,000	653,232,000
577,404,000	506,250,000	681,624,000	1,052,610,000	529,968,000	410,572,000	470,545,000	488,397,000	434,840,000	898,560,000	577,404,000
577,404,000	488,397,000	766,800,000	1,092,980,000	506,250,000	410,572,000	488,397,000	488,397,000	488,397,000	1,092,980,000	577,404,000
577,404,000	434,840,000	1,272,820,000	971,870,000	553,686,000	404,757,000	470,545,000	488,397,000	391,327,000	1,012,240,000	577,404,000
577,404,000	434,840,000	1,885,340,000	865,620,000	553,686,000	404,757,000	452,693,000	553,686,000	434,840,000	1,092,980,000	577,404,000
601,122,000	416,988,000	2,016,760,000	865,620,000	452,693,000	506,250,000	529,968,000	404,757,000	488,397,000	971,870,000	553,686,000
577,404,000	506,250,000	1,948,000,000	799,740,000	488,397,000	766,800,000	577,404,000	384,912,000	506,250,000	1,419,580,000	653,232,000
799,740,000	681,624,000	1,527,140,000	865,620,000	434,840,000	681,624,000	529,968,000	380,635,000	416,988,000	1,365,800,000	577,404,000
738,408,000	766,800,000	1,419,580,000	766,800,000	488,397,000	624,840,000	506,250,000	416,988,000	452,693,000	1,580,920,000	553,686,000
653,232,000	601,122,000	1,419,580,000	681,624,000	470,545,000	601,122,000	488,397,000	452,693,000	470,545,000	1,948,000,000	577,404,000
653,232,000	488,397,000	1,365,800,000	653,232,000	488,397,000	577,404,000	624,840,000	380,635,000	506,250,000	2,085,520,000	710,016,000
624,840,000	410,572,000	1,272,820,000	577,404,000	506,250,000	577,404,000	931,500,000	370,332,000	470,545,000	2,085,520,000	624,840,000
624,840,000	488,397,000	1,634,700,000	624,840,000	488,397,000	577,404,000	931,500,000	378,496,000	470,545,000	2,016,760,000	553,686,000
577,404,000	488,397,000	1,365,800,000	577,404,000	529,968,000	452,693,000	865,620,000	364,500,000	470,545,000	2,292,800,000	577,404,000
577,404,000	434,840,000	1,133,350,000	577,404,000	766,800,000	488,397,000	832,680,000	360,612,000	434,840,000	2,592,640,000	624,840,000
1,012,240,000	488,397,000	971,870,000	653,232,000	1,133,350,000	470,545,000	624,840,000	366,444,000	434,840,000	2,667,600,000	577,404,000
1,634,700,000	470,545,000	931,500,000	624,840,000	799,740,000	553,686,000	681,624,000	362,556,000	488,397,000	2,517,680,000	529,968,000
1,885,340,000	553,686,000	898,560,000	865,620,000	653,232,000	601,122,000	601,122,000	356,600,000	488,397,000	2,367,760,000	577,404,000
1,226,330,000	624,840,000	832,680,000	1,133,350,000	624,840,000	738,408,000	506,250,000	372,276,000	506,250,000	2,223,040,000	553,686,000
1,092,980,000	624,840,000	799,740,000	1,580,920,000	681,624,000	832,680,000	470,545,000	374,220,000	488,397,000	2,667,600,000	577,404,000
738,408,000	601,122,000	1,012,240,000	1,697,360,000	506,250,000	1,179,840,000	488,397,000	404,757,000	470,545,000	3,037,460,000	577,404,000
738,408,000	577,404,000	1,179,840,000	1,473,360,000	488,397,000	1,226,330,000	738,408,000	382,773,000	434,840,000	3,440,240,000	577,404,000
601,122,000	553,686,000	1,092,980,000	1,179,840,000	529,968,000	1,329,410,000	416,988,000	380,635,000	404,757,000	3,233,280,000	601,122,000
653,232,000	506,250,000	971,870,000	1,179,840,000	529,968,000	1,527,140,000	529,968,000	380,635,000	404,757,000	2,760,040,000	577,404,000
653,232,000	624,840,000	832,680,000	1,179,840,000	488,397,000	971,870,000	601,122,000	366,444,000	470,545,000	2,517,680,000	601,122,000
624,840,000	488,397,000	832,680,000	1,179,840,000	601,122,000	931,500,000	738,408,000	380,635,000	416,988,000	2,085,520,000	577,404,000
601,122,000	452,693,000	738,408,000	1,179,840,000	506,250,000	832,680,000	832,680,000	391,327,000	416,988,000	1,885,340,000	577,404,000
553,686,000	488,397,000	681,624,000	1,329,410,000	601,122,000	799,740,000	832,680,000	653,232,000	434,840,000	1,948,000,000	529,968,000
553,686,000	488,397,000	681,624,000	1,419,580,000	681,624,000	1,052,610,000	1,012,240,000	1,092,980,000	434,840,000	1,948,000,000	553,686,000
553,686,000	470,545,000	653,232,000	1,365,800,000	553,686,000	1,473,360,000	1,365,800,000	1,092,980,000	434,840,000	2,016,760,000	577,404,000
553,686,000	470,545,000	624,840,000	1,226,330,000	553,686,000	1,697,360,000	1,885,340,000	1,133,350,000	416,988,000	2,852,580,000	601,122,000
553,686,000	452,693,000	577,404,000	1,226,330,000	506,250,000	1,822,068,000	2,223,040,000	766,800,000	452,693,000	3,543,720,000	601,122,000
529,968,000	452,693,000	577,404,000	1,052,610,000	506,250,000	2,016,760,000	1,948,000,000	577,404,000	404,757,000	3,543,720,000	577,404,000
529,968,000	506,250,000	577,404,000	1,012,240,000	488,397,000	1,822,068,000	1,885,340,000	452,693,000	506,250,000	4,222,800,000	577,404,000
506,250,000	553,686,000	601,122,000	898,560,000	506,250,000	1,822,068,000	2,367,760,000	416,988,000	553,686,000	5,716,000,000	577,404,000
506,250,000	653,232,000	601,122,000	799,740,000	624,840,000	2,085,520,000	3,233,280,000	434,840,000	624,840,000	6,024,000,000	577,404,000
506,250,000	601,122,000	577,404,000	799,740,000	529,968,000	2,367,760,000	2,367,760,000	434,840,000	624,840,000	5,140,800,000	601,122,000
506,250,000	601,122,000	577,404,000	738,408,000	681,624,000	2,760,040,000	1,948,000,000	410,572,000	653,232,000	4,350,240,000	601,122,000
506,250,000	506,250,000	506,250,000	653,232,000	624,840,000	2,760,040,000	1,634,700,000	410,572,000	553,686,000	3,877,440,000	577,404,000
506,250,000	488,397,000	506,250,000	653,232,000	488,397,000	2,142,720,000	1,365,800,000	384,912,000	653,232,000	3,336,760,000	601,122,000
488,397,000	452,693,000	553,686,000	709,740,000	529,968,000	2,517,680,000	1,092,980,000	391,327,000	710,016,000	2,129,800,000	624,840,000
470,545,000	506,250,000	506,250,000	832,680,000	529,968,000	2,667,600,000	971,870,000	380,635,000	553,686,000	2,667,600,000	577,404,000
452,693,000	470,545,000	799,740,000	799,740,000	553,686,000	3,129,800,000	766,800,000	384,912,000	710,016,000	2,223,040,000	624,840,000
506,25,0000	488,397,000	1,473,360,000	799,740,000	470,545,000	3,762,320,000	865,620,000	391,327,000	738,408,000	1,885,340,000	653,232,000

APPENDIX No. 10.

REPORT on the CHOLERA OUTBREAK in the Parish of ST. JAMES, WESTMINSTER, during the Autumn of 1854.

The parish of St. James, Westminster, occupies an area of 164 statute acres. At the census of 1831, it contained 37,053 inhabitants; in 1841, 37,457; and in 1851, 36,406. Its population may therefore be said to be nearly stationary; the small diminution since 1841 being probably owing to public improvements, especially to those made in connexion with the building of the Museum of Economic Geology in Jermyn Street.

For the purposes of registration, the parish is divided into three sub-districts, viz., St. James's Square sub-district occupying 85 acres, with a population of 11,469; Golden Square sub-district, extending over 54 acres, and numbering 14,139 inhabitants; and Berwick Street sub-district, having an extent of 25 acres, and a population of 10,798. Since 1841, the population of St. James's Square sub-district has decreased, whilst that of the other two districts shows a slight increase.

The parish is immediately surrounded by the following registration sub-districts: Mayfair and Hanover Square in St. George's parish, on the west; All Souls, Marylebone, on the north; St. Anne's, Soho, on the east; and Charing Cross in St. Martin's-in-the-Fields, on the east and south.

1832. In the first visitation of cholera in 1832, the parish of St. James, then numbering 600 more inhabitants than in 1851, suffered in only a moderate degree in comparison with many others, and on the whole, somewhat later in point of time. The earliest deaths in the parish took place in March, and then the epidemic, subsiding until July, reappeared and continued during August, September, and October. The total number of deaths occasioned by it cannot now be determined. About 90 cases fell under the observation of the parochial medical officers, of which number half proved fatal. To these would have to be added the deaths occurring in private practice. On the authority of Messrs. Braine and French, who at that time had medical charge of the cholera hospital, it may be stated that among the localities attacked, were Peter Street, Hopkins Street, Maidenhead Passage, Pulteney Court, Berwick Street, Wardour Street, Broad Street, and Carnaby Street, together with the courts and yards leading out of Great Windmill Street, the neighbourhood of St. James's Market, and also Angel Court and Crown Court, Pall Mall. At this period the general sanitary condition of the parish was doubtless defective, for attention was not then so strongly directed to questions concerning the public health. At the commencement of 1848 the Committee of Health and Sanitary Improvement detected, and exposed by their house-to-house visitation, numerous deficiencies in local cleanliness, especially in the public sewerage. In consequence of these inquiries a decided amelioration of such defects was accomplished; and it was a subject of congratulation amongst those who were interested in the health of the parish, that the epidemic of 1848–9 which so speedily followed was even less severely felt by the inhabitants than the visitation of 1832.

1848–9. During the autumn of 1848 only three deaths from cholera occurred in St. James's, viz., one each in Berwick Street, Poland Street, and Rupert Street. In the first four months of 1849 no fatal case occurred in the parish, although from the middle of January to the middle of February the effects of cholera were plainly manifested all over London. On the 26th of May one fatal case happened in Golden Square. In July five deaths were registered, and the disease, continuing through August and September, proved fatal altogether to 56 persons, viz., 19 belonging to Berwick Street district, 19 to Golden Square district, and 18 to St. James's Square district. Seventeen additonal deaths were registered from diarrhœa. Thus the mortality from cholera in the whole parish in 58 weeks of 1848–9 was 15 in 10,000 persons living, whilst the corresponding rate in all London was 75, and in the immediate surrounding districts about 46. In St. Anne's, Soho, the relative mortality was 30 to 10,000 persons living, and of 48 deaths which occurred in that parish, to a population of 16,480, only five took place in St. Anne's Court, then containing about 500 inhabitants. This visitation of 1848–9 commenced about the same period in St. James's as in the adjoining parishes, showing itself earliest in the Golden Square district, next in the Berwick Street, and last in that of St. James's Square, but reaching its height in all three about the same period, and causing its greatest mortality in the weeks ending the 1st and 8th of September, corresponding in this respect with the general result throughout the metropolis.

The streets which suffered most were the following:— In the Berwick Street district, Peter Street (four deaths), Archer Street (two), and Pulteney Place (two); in the Golden Square district, the workhouse (five inmates), Regent Street (two), South Row (two), and Little Windmill Street (two); in the St. James's Square district, Angel Court (six), Jermyn Street (three), Little St. James's Street (two), Great Windmill Street (two), and Queen's Head Court (two). The rest of the mortality consisted of single deaths in various streets. No fatal case occurred in Broad Street in 1848–9, although a man died of diarrhœa at No. 6.

1850. Four fatal cases of cholera are recorded during this year in the following localities; Silver Street, Carnaby Street, Marshall Street, and Oxford Street.

1851. In this year one case is registered in Rupert Street.

1852. A single death is returned at 5, Marshall Street.

1853. During the last four months of 1853, when cholera for the third time invaded the metropolis, ultimately to become epidemic, several fatal attacks occurred in St. James's parish as follows:—

In August, one case occurred in Great Windmill Street, and another in Bentinck Street. The next death, on October 2nd, was in Poland Street. After a short interval five cases followed in one week, viz., three in the workhouse on October 26th and 30th, and November 1st, two in Marlborough Court, October 30th, one in King Street on the 31st October, and one in Great Marlborough Street on the 1st November. On the 4th November another fatal attack happened in the workhouse, and the last death for the year 1853 was in Blenheim Street, on November 15th.

It is important to remember these successive visitations of cholera in St. James's parish, and especially the presence of the disease during the autumn of 1853, for they serve to establish its liability to the inroads of that epidemic, although they entirely fail to prepare its inhabitants for the impending calamity of 1854.

1854. At the commencement of this year, there were but five deaths from cholera registered throughout the whole of the metropolis during the month of January, in February only two, the last being on February 4th. For the eight succeeding weeks no fatal case was registered in London. During the month of April four deaths occurred. Three weeks passed without a death from cholera, and then four happened in the latter part of May. In the first three weeks of June three deaths occurred, in the fourth week no death. In the first week of July one death was registered, in the second week five deaths, in the third week 26, in the fourth 133, in the fifth 399, and so the numbers kept increasing weekly up to 2,050 in the week ending September 9th, and then diminished again, as shown in the subjoined table. The mortality from cholera in all London was reduced to 8, in the week terminating the 8th of November.

Now according the Registrar-General's returns, no death from cholera took place during last year in St. James's parish until the week ending the 5th August, when one fatal case was returned. From this date the cholera mortality in the parish rose and fell, as shown in the annexed table, in which the corresponding mortality in all London, and that in London exclusive of St. James's is also shown.

—	July 29.	Aug. 5.	Aug. 12.	Aug. 19.	Aug. 26.	Sept. 2.	Sept. 9.	Sept. 16.	Sept. 23.	Sept. 30.	Oct. 7.	Oct. 14.
London - - -	133	399	644	729	847	1,287	2,050	1,549	1,284	754	411	249
London, excluding St. James's.	133	398	639	717	841	1,209	1,763	1,482	1,265	747	410	249
St. James's - -	0	1	5	12	6	78	287	67	19	7	1	0

Adding to this list one more death, which was recorded in the St. James's Square district in the week ending October 21st, the total number of deaths from cholera registered in St. James's in the 17 weeks ending November 4th was 484. But this number gives a very inadequate idea of the entire loss inflicted by the epidemic. Thus the house list of deaths by cholera, furnished to the committee by Mr. Buzzard, the vestry clerk, from the local registers, gives a total of 501 deaths recorded between July 1st and September 30th. Besides these, it is estimated that about 150 of the inhabitants died during the same period in the Middlesex, University College, Royal Free, St. Georges's, and King's College Hospitals, out of the parish, whose deaths would therefore be registered elsewhere. It would appear, indeed, from the investigations of Messrs. Fraser, Hughes, Ludlow, and Whitehead, that some deaths must have escaped registration altogether, and that possibly more than 40 non-resident persons, who came to work or visit in the parish, also died. Hence the fatal attacks in St. James's parish were probably not less than 700.

So great a number would imply a relative mortality during the above defined 17 weeks of 220 to every 10,000 persons living in the parish, instead of 152, as estimated upon the data furnished to the registrar's office. The highest relative mortality in any metropolitan parish, not containing a hospital, during the same period, was, in Bermondsey, viz., 158. St. Olave's alone, which includes St. Thomas's Hospital, exceeded it, its ratio being 162. In the adjoining sub-district of Hanover Square the ratio was 9; in All Souls, Marylebone (including a hospital), 28; in St. Anne's, Soho, 37; and in the Charing Cross district of St. Martin's-in-the-Fields (including a hospital), 33. It should also be borne in mind that the mortality from cholera in St. James's parish in 1848–9, was as already stated, only 15 in 10,000 inhabitants.

It is well known, however, that the epidemic did not act equally within all parts of the parish, the St. James's Square sub-district experiencing, according to the registrar, a relative mortality of only 16 to every 10,000 persons living, whilst the ratio in the Berwick Street district was 212, and in the Golden Square district 217.

But, as before stated, the actual rate beyond the registration returns, in the two last-named districts, was considerably greater than this. Moreover, it must now be remembered that it was only in a certain singularly well-defined portion of them that the influence of the *great* outbreak was felt. The "*cholera area*," as it may be called, of St. James's parish, may be variously described. Reference to the map prefixed to this Report will render the description easily understood. Spreading out from the north-east angle of Golden Square, which is altogether excluded from it, it extends westward to King Street, north as far as Great Marlborough Street and Noel Street, east to the line of Wardour Street, and south to Little Pulteney Street, from the west end of which its limits are expressed by a line crossing over Great Pulteney Street and Bridle Lane, returning to the north-east angle of Golden Square. Beyond Wardour Street, to the east, lies St. Anne's Court, Soho, with its dependencies, which, though out of St. James's parish, must be included in the cholera area. It has been shown by Mr. Whitehead that the limits of the cholera district are also very accurately defined within an irregular four-sided figure, the north and south angles of which are placed respectively near the middle of Poland Street and at the south end of Little Windmill Street, whilst the west and east points are at the north-west corner of King Street and the east end of St. Anne's Court. The included space is rather longer from east to west than from north to south. The centre of this figure falls at the junction of Cambridge Street with Broad Street, and it has been remarked by Mr. Whitehead, as may be shown with compasses upon the map, that a circle having a radius of 210 yards struck from the north-west angle of Cambridge Street includes almost the entire area, except St. Anne's Court. Two notches vacant of mortality require, however, to be taken out of this circle, one corresponding with a part of Great Marlborough Street, the other, with one half Golden Square and the southern part of Bridle Lane. As thus defined, and henceforth in this Report intended to be understood, the "cholera area," including St. Anne's Court, and excluding the vacant spaces just mentioned, covers nearly 30 acres of ground, containing, besides streets, courts, and mews, 825 dwellings, St. Luke's Church, Craven Chapel, the workhouse, a block of model lodging houses (unfinished in 1854), a brewery, and various factories and workshops. In round numbers its population, in the autumn of 1854, as well as can be estimated, was nearly 14,000 inhabitants (inclusive of 500 in the workhouse). This would be about 460 persons to an acre. Now the ascertained deaths of residents within this "cholera area" are 618, being at the rate of 440 to 10,000 persons living. The deaths of non-residents, so far as these are known, viz., 45, are also indicated on the map.

The ascertained deaths and per-centage of mortality in the several streets within the cholera area are tabulated in the Appendix, whilst the distribution of the deaths is represented on the map. No street in the cholera area was without death, but the mortality was greatest towards the centre of the area, and diminished towards its borders. There are exceptions depending mostly on an extreme mortality in some one house in a small street, as in Cross Street on the west, Bentinck Street on the north, and Peter Street on the south-east. In Hopkins Street, then containing only three houses, the mortality was 18 per cent. In Broad Street, the very heart of the area, the deaths were rather more than 10 per cent., or 1,000 to every 10,000 persons living. In Cambridge Street, Pulteney Court, and Kemp's Court, the population was also decimated. In Marshall Street, South Row, Marlborough Row, Silver Street, Great Pulteney Street, Little Windmill Street, the southern portions of Wardour, Berwick, and Poland Streets, the mortality diminished, varying from 8 to 5 per cent., and taking a still wider sweep from the centre in the remoter parts of all these longer streets, as a rule, it gradually ceased. It will also be seen, on consulting the map, that in the centre of the cholera area but few houses escaped the invasion of the disease. Of 45 contiguous houses belonging to Pulteney Court, New Street, Husband Street, Hopkins Street, and the south side of Broad Street, only seven escaped without a death, and in three of these seven, one a factory, 18 non-residents were fatally seized. In Broad Street, containing 49 houses, only 12 houses escaped without a death.

So also the proportion of houses fatally attacked, just as we have seen with regard to the per-centage of deaths, became less in passing from the centre of the cholera area. In the whole area, including houses where non-residents were seized, this proportion was 38·8 per cent.

Of the 825 houses in this area fatal attacks of residents occurred in 313. There were 159 houses having single deaths; 85 with 2 deaths, 34 with 3, 15 with 4, 12 with 5, 3 with 6, 4 with 8, and 1 with 12. Five inmates also died in the workhouse. "There were," says Mr. Whitehead, speaking of only a part of the area, "no less than 21 instances of "husband and wife dying within a few days of each other. "In one case, besides both parents, four children also "died. In another both parents and three of their four "children. In another, a widow and three of her four "children. At an average distance of 15 yards from St. "Luke's Church stand four houses, which collectively lost "33 persons."

Such being the locality of this serious visitation and such its general results, we may in the next place attempt to trace within the limits of the parish its commencement, progress, and cessation from day to day and from place to place. For this purpose, it is obvious that owing to the variable duration of the illness the death statistics would lead to erroneous conclusions, and it is much to be regretted that no complete data can be obtained for fixing the hour of attack. By deducting the period assigned to the duration of the disease from the day of death, where such information is recorded, either in the registrar's or hospital documents, a rude approximation to the period of attack may be obtained. In regard especially to cholera, this method may give tolerably fair results; but when we remember the difficulty of obtaining correct information and the importance of a few hours more or less, too great reliance must not be placed upon such results, nor too great use be made of them as the foundation of particular views. In the table placed in the Appendix 576 fatal cases in St. James's and St. Anne's are arranged to show the streets in which they took place and the days on which the deceased are presumed to have been attacked. This tabular view of daily attacks is of course incomplete, and would differ widely from one of daily deaths. It is confessedly a partial view or an imperfect journal of the progress of the epidemic; but in its general aspect it may approach the truth. For convenience of reference, the streets are classified in four zones or belts, running east and west across the parish, beginning with the northern zone from west to east, and then proceeding with the next one to the south, and so on. Only the two middle zones pass through the cholera area.

The earlier deaths from cholera in the metropolis last summer were scattered very widely about in the extreme south, east, west, and north, the central districts escaping for a brief period. The first fatal attack in St. James's Parish occurred on July 26th in St. James's Market, Jermyn Street. It terminated fatally on the 29th, by which date 81 deaths had been registered in the south, 48 in the east, 11 in the west, 11 in the north, and 13 in the central metropolitan districts. It may therefore be said that the cholera in the summer of 1854 as well as of 1849 showed itself in this parish later than in most parts of the metropolis; and in reference to the immediately adjoining districts it must be added that St. Martin's-in-the-Fields, St. Anne's, Soho, and All Souls, Marylebone, were attacked before, and St. George's, Hanover Square, after St. James's.

Referring now to the table, it will be seen that shortly after the first case already spoken of as happening on July 26th in the south of the parish, viz., in St. James's Market, two fatal attacks occurred in the west and centre, viz., in South Row on the 3rd August and in Silver Street on the 5th. By the time these three attacks had occurred many more deaths had been recorded in the various districts of the metropolis, as follows: south districts 371, east 108, west 33, north 23, and central 27. The fourth fatal seizure in St. James's was on the 7th, in the south, in Great Windmill Street; the fifth and sixth, both on the 11th were in the west, viz., in King Street and Marlborough Row. On the following day, three persons were fatally attacked, two in the south and south-east of the parish, viz., in Piccadilly and Great Windmill Street, and one in the very centre of the district to be presently rendered as memorable, viz., in Broad Street at No. 31. On the 14th one seizure occurred in the west, in Heddon Court, and on the same day two near the centre, viz., in Silver Street and Marshall Street. On the 16th, two persons were attacked in Berwick Street and one in Swallow Street; on the 17th one in Marlborough Street, on the 18th and 19th two persons in Marshall Street, on the 18th a man in Piccadilly and on the 19th a man in Berwick Street. The deaths in Marshall Street were in one house (the first being introduced from the borough), and two of those in Berwick Street were also in one dwelling. During this week diarrhœa was very prevalent all through the Berwick Street district and the adjacent part of the Golden Square district, but in the eleven following days, until the 30th August, diarrhœa had disappeared, and very few fatal attacks of cholera occurred, these were in the south or west, but chiefly towards the centre of the yet future cholera area, viz., in Carnaby Street, Silver Street, Marshall Street, and Broad Street. It appears therefore that the disease manifested its fatal effects first in the south-east, west, and east quarters and afterwards towards the centre of the cholera area. Up to this date (August 30th) 38 cases only had occurred throughout the entire parish; but in the afternoon of the 31st August 31 fatal attacks can be traced. On the 1st September 131, and on the 2nd 125. On the 3rd, 4th, and 5th, the numbers are respectively 58, 52, and 26; and on the 6th, 7th, and 8th, 28, 22, and 14. After that attacks occurred as follows, 6, 2, 3, 1, 3, 0, 1, 3, 4, and subsequently throughout the rest of September either 1, 2 or 0 per diem. In Dr. Snow's report, the number of daily attacks is also fully and carefully reckoned, as his inquiry took place immediately after the eruption of the disease.

We have here a record of what has so forcibly struck the attention of those who have studied this memorable eruption of cholera, viz., the ordinary gradual approach of the disease, accompanied by no unusual manifestation of its effects, a lingering about certain localities, a lull in its operation, and then on a sudden a terrible outburst, overwhelming every one by surprise, outstripping the most prompt and energetic attempts to mitigate its effects, and then quickly declining by well-marked though not quite such speedy steps.

It is this startling suddenness of the outbreak that has given it a scientific interest, scarcely less momentous than its social importance, and as few of us will probably ever witness its like again, it is most desirable that no pains should be spared in its thorough investigation.

On consulting the table in the Appendix in which the distribution of a great majority of the attacks in the several streets is indicated day by day, it will be seen that the suddenness of the principal outburst, as also its rapid subsidence, is chiefly marked in those streets and courts which are nearest to the centre of the cholera area, whilst in the borders of this space and beyond its limits there is no such abrupt and extreme rise and fall in the number of the attacks. In Broad Street especially its commencement was sudden and its duration short; but the disease continued somewhat later to attack a few persons in other localities.

On the whole however the great explosion was almost simultaneous throughout the district, and even in the remotest streets it must be remarked that though the attacks were few the period of greatest activity corresponded with that of the principal outburst, and indeed with that of the highest cholera mortality throughout the rest of London (see table, p. 486.) There was moreover a small simultaneous outburst in Rotherhithe.

There yet remain several characteristics of this visitation, which may here be noticed as tending either to associate it with or distinguish it from other less severe and sudden outbreaks of the disease.

In the first place it may be remarked that in 1854, though the epidemic visited the same streets as in 1832 and 1848–9, it did not limit itself so precisely to its old localities as is often observed. A coincidence in the localities affected is perhaps more marked in regard to the straggling cases on the outskirts of and beyond the cholera area than in the heart of that district. We are informed by Dr. Fraser that in the whole parish identical houses were visited in only 11 instances, out of about a total, as we estimate, of 350 in which fatal attacks occurred. On the contrary, entire streets in the centre of the affected area, as Broad Street, Silver Street, Cambridge Street, Pulteney Court, and New Street, in which no deaths from cholera occurred in 1848–9, suffered the most in 1854.

Certain apparent eccentricities in preference of localization, such as are very common in cholera visitations, displayed themselves here also. For example, one side of a street would suffer more than the other. In streets running north and south, the dwelling-houses being about equal on the two sides, the east side sometimes suffered most; in streets running east and west, the south side was generally most affected. Cambridge Street and Little Windmill Street are exceptions to the former, and Silver Street to the latter statement. The order in which houses were attacked followed no definite rule.

Some narrow streets and courts suffered severely, others nearly or quite escaped, as Tylers, Great Crown, and Walkers Courts, whilst wide streets, as Broad Street itself, were heavily visited.

In St. Anne's Court the middle houses suffered most, in some *culs de sac*, as Bentinck Street and Peter Street, those near the dead end.

The south-eastern half of the cholera area is a few feet lower than the north-western half, but the mortality was not attached to any particular level.

A want of cleanliness in streets or houses was by no means a constant accompaniment of the disease. Some houses in the midst of others affected escaped, without any favourable sanitary condition. The map shows that of houses in the cholera area directly opposite untrapped sewer-grates 40·2 per cent. had fatal attacks in them, thus barely exceeding the general per-centage throughout the area, 38·8. Of two adjacent and equally well ordered factories one lost 7 workmen, the other none. Of nearly 200 workmen and women employed in another large factory, none living in the neighbourhood, the females numbering about 160, the males about 30, 16 of the former and two of the latter were fatally seized, whilst in the workhouse, not 150 yards away, which had at the same time about 500 residents, only five inmates died. Of 35 men working in the open air on the unfinished lodging-houses, seven died.

Corner houses sometimes escaped, the six, for instance, on the north side of Broad Street, in one of which, however, there were three severe though not fatal attacks. Of corner houses in the cholera area, about 30 per cent. had fatal attacks in them. Public houses, so often situated at the corners of streets, were singularly lightly visited.

As a general condition, remoteness from the centre of the cholera area seems most to have been associated with exceptional suffering, and proximity to it by exceptional immunity from the disease.

Towards the centre of the area in Broad Street the number of deaths appears to have been nearly equal on each floor, if we reckon the ground floors and kitchens together. In reference to the population, however, the ground floors suffered most, next in diminishing proportion, the first floors, third floors, and kitchens, and least of all the second floors. Yet throughout the neighbourhood generally, including Broad Street, the deaths on the second floors were the most numerous of all. In the streets furthest removed north and south from the centre the residents in the upper floors suffered somewhat more in proportion.

A calculation embracing the principal streets and courts shows that the number of deaths was rather greater in the front than in the back rooms of the house.

The attacks in any given house were seldom quite simultaneous, commonly in quick succession, and more rarely at long intervals.

Tolerably true on the whole was this singular malady to its ordinary characteristics in the selection of its victims, whether we regard their occupations, general condition in life, sex, or age.

Of 636 registered deaths belonging to the parish, 298 were of males and 338 of females, which is rather more females in proportion than usual. The ages of these deceased persons (with the exception of six unknown) were as follows:—

Ages.	0–10.	10–20.	20–30.	30–40.	40–50.	50–60.	60–70.	70–80.	80–90.	0–90.
Males - - - -	79	32	48	50	47	16	19	4	2	297
Females - - - -	36	33	40	51	61	51	30	10	1	333
Total - -	135	65	88	101	108	67	49	14	3	630

It appears therefore that as usual with cholera the smallest number of deaths happened in the second decade of life. The fewest deaths in any one year of age (viz.), two were between 14 and 15. The inmates dying in the workhouse were aged persons.

The occupations of 454 persons dying (247 male and 207 female) are indicated in the subjoined, constructed from the Registrar-General's return.

Occupations.	Males.		Females.		Total.
	Adults.	Sons.	Spinsters, Wives, Widows.	Daughters.	
Postmaster, retired - -	1	—	—	—	1
Government clerk - -	1	—	—	—	1
Police - - - -	2	—	—	1	3
Fireman - - -	—	—	—	1	1
Chelsea pensioner - -	1	—	—	—	1
Solicitor - - -	—	1	1	—	2
Surgeon - - -	1	—	—	—	1
Dentist - - -	1	—	—	—	1
Druggist - - -	—	1	—	—	1
Artist - - - -	1	—	1	—	2
Schoolmaster - - -	—	—	1	—	1
Governess - - -	—	—	1	—	1
Lodging house keeper - -	—	—	2	—	2
Eating and coffee house keeper	1	—	—	1	2
Domestic servants - -	2	—	28	2	32
Coachmen - - -	1	1	1	1	4
Charwomen - - -	—	1	4	—	5
Nurse - - - -	—	—	1	—	1
Laundress - - -	—	—	1	—	1
Hairdresser - - -	1	1	2	1	5
Hatter - - - -	1	—	—	—	1
Tailor - - - -	40	12	17	9	78
Shoemaker - - -	28	8	8	3	47
Undertaker - - -	1	1	1	—	3
Dressmakers, including staymakers and waistcoat makers.	—	—	15	—	15
Straw hat maker - -	—	—	1	—	1
Commercial traveller - -	—	—	1	—	1
Pawnbroker - - -	2	—	—	—	2
Marine store dealer - -	—	—	1	—	1
Livery stable keeper - -	2	—	—	—	2
Carman - - -	2	—	1	—	3
Warehouseman - -	—	1	—	—	1
Shopman and shopwoman -	1	—	1	—	2
Messengers and porters -	15	6	2	5	28
Errand boy - - -	—	1	—	—	1
Printer - - -	2	1	—	—	3
Compositor - - -	1	—	—	—	1
Bookbinder - - -	2	—	—	—	2
Stationer - - -	2	—	—	—	2
Pianoforte maker - -	3	1	—	1	5
Picture dealer - - -	—	—	1	—	1
Engravers and chasers - -	4	—	1	—	5
Artificial flower makers -	—	—	2	—	2
Feather manufacturers -	—	—	1	2	3
Dyer - - - -	—	—	—	1	1
Draper - - -	—	—	1	—	1
Mattrass maker - -	—	—	1	2	3
Brush maker - - -	—	—	1	—	1
Carpet planner - -	1	—	—	—	1
Coach trimmers - -	2	—	—	—	2
Engineers - - -	1	—	1	1	3
Carpenters - - -	4	2	5	2	13
Painter and plumber - -	8	1	2	—	11
French polisher - -	—	—	3	1	4
Timber seller - - -	—	1	—	—	1
Cabinet maker - -	4	—	3	2	9
Upholsterer - - -	2	—	—	1	3
Japanner - - -	—	—	2	—	2
Curiosity dealer - -	—	—	—	1	1
Toy maker - - -	1	—	—	—	1
Box and gun case maker -	3	—	1	—	4
Wine cooper - - -	—	—	1	—	1
Frame maker - - -	—	—	1	—	1
Basket maker - - -	1	—	—	—	1
Glass cutter - - -	—	—	—	1	1
Jeweller - - -	—	3	—	2	5
Gold beater - - -	1	—	—	—	1
Gilder - - - -	—	—	—	1	1
Smiths, copper, tin, iron, gun, brass.	3	5	2	3	13
Steel manufacturer - -	—	—	1	—	1
Ironmonger - - -	—	—	3	—	3
Coal vendor - - -	1	1	—	—	2
Scavenger - - -	1	—	—	—	1
Labourers, general, including bricklayers, paviors, and masons.	8	5	16	6	35
Milkwoman - - -	—	—	1	—	1
Cheesemonger - - -	3	1	-	-	4
Butcher - - -	6	1	1	-	8
Fishmonger - - -	—	—	—	1	1
Greengrocer - - -	3	—	—	.	3
Baker - - - -	5	1	2	2	10
Confectioner - - -	—	—	1	—	1
Publican - - -	1	—	1	—	2
Waiter at public house -	1	2	—	—	3
Wine merchant - -	1	—	—	—	1
Grocer - - -	—	—	2	—	2
Tobacconist - - -	—	—	1	—	1
Gentlemen - - -	6	—	1	—	7
Alms (workhouse) - -	2	—	3	—	5
Totals - -	188	59	153	54	454
Occupation not registered -	41	10	91	40	182
General totals -	229	69	244	94	636
	298 Males.		338 Females.		636 Total.

The total number of persons of any given occupation in the district is not known, so that the ratio of mortality in each must remain uncertain. A few general conclusions are evident. The families of tailors show the largest number of deaths, next to these shoemakers, then labourers, including bricklayers, masons, and paviors, then domestic, especially female servants, next messengers and porters, then dressmakers, next follow mechanics of various kinds, as carpenters, smiths, painters, cabinet makers, and so forth. Of persons dealing in articles of food, bakers suffered most, and then butchers, whilst the families of greengrocers, publicans, and fishmongers suffered less. General trades and the professions are also represented. It is necessary to observe that tailors and their families undeniably form a very large proportion of the working population of this district. On the whole it would appear that the disease did not limit its attack to any one class, nor yet to the very poor.

It is remarked by Mr. Sibley, the registrar of the Middlesex Hospital, that a large number of the persons brought there for treatment presented a very uncleanly appearance, more so, indeed, than patients admitted into hospitals for ordinary disease. This may doubtless be explained, partly by the circumstance that the patients so admitted were probably the most destitute of those who were attacked, and partly by the fact of their being suddenly seized by the disorder whilst engaged in the usual occupations of their trade.

Finally, in this extraordinary outbreak the symptoms of the disease quite corresponds with those of cholera generally. The common occurrence of the attack within the fore part of the twenty-four hours, the extremely short duration of the early cases, and the gradual amelioration observable in the later ones, were all plainly noticeable, and lastly, it is certainly true that in the cases occurring at the commencement of the great outburst, premonitory diarrhœa was of short duration or altogether absent.

It will have been noticed that the preceding estimate of the results of the cholera outbreak in St. James's parish is founded entirely on the death statistics. The number of attacks followed by recovery is unknown, nor can any certain information be collected as to the relative amount of diarrhœa prevailing.

Circumstances attending the Outbreak.

The sudden, severe, and concentrated character of the particular outburst of cholera which has been depicted, and which constitutes the most remarkable local visitation of that disease hitherto recorded in the metropolis, may at first create a hope that here at least the circumstances which principally determined the localisation of this singular epidemic would not escape a rigorous investigation. But the disadvantages attending a comparatively late inquiry, and the difficulties encountered in its prosecution were so great that very decided conclusions must not be expected.

From our ignorance of the real or specific cause of cholera, all inquiries like the present are practically limited to a consideration of those conditions which may determine the action of that cause upon and within certain localities. Further, it must be remembered that in this comparatively restricted field of investigation the want of knowledge just alluded to constitutes a grave difficulty. For if the cause of cholera were itself as well understood as electricity, arsenic, prussic acid, or morphia, means could be found by which to determine its presence, qualities, and quantity, and thus to lay bare on positive evidence the conditions which influenced its action or cessation of action in given places. But since we do not know the cause of cholera, the questions to be solved concerning its appearance and disappearance, its spreading and concentration, can only receive provisional answers approximating to the truth according as we have advanced, in the obscurity of our research, towards accuracy of observation, correctness of deduction, and freedom from fallacy and error.

In attempting to analyse the circumstances which may be supposed to have had more or less influence in directing the terrible energies of this unknown cause towards particular portion of the metropolis, we shall first examine the probable effect of those general conditions which must have operated in very much the same manner and degree in every part of it; such as the rainfall, the temperature, and dryness and movement of the air. This will facilitate the subsequent examination of *special* or *local* conditions.

General or Meteorological Conditions.

It has been pointed out by the Registrar-General, speaking of the metropolis generally, that "in the thirty-sixth week of 1854, when cholera raged, and the deaths from all causes rose to their maximum (3,413), the average daily range of temperature was 30° 9. Considerably the greatest in the fifty-two weeks; the highest temperature of the week was 81° 2, the lowest was 43° 1, therefore the entire range was 38° 1; the horizontal movement of the air was only 195 miles, far less than in any other week; there was no rain in that or the previous week, and the mean temperature of the previous week had risen to 65° 1, the highest mean weekly temperature in the year."—(Summary of Births, Deaths, &c. in London for 15 years, 1850–1854.)

This brief summary does not exhaust the interest attached to the general meteorological conditions prevailing in the metropolis during last summer and autumn, as especially applicable to our present inquiry.

Rain.—From the 6th August when cholera had fairly established itself in London, to the 11th September, when it had begun to decline, *i.e.*, for a period of 37 days, there were only seven days on which rain fell; the total quantity during that time being under three-tenths of an inch, one-third of which, *i.e.*, one-tenth of an inch, fell in one day, the 15th August. From the 25th August to the 11th September (18 days) there was no rain at all, and it was within that period that cholera manifested its greatest virulence.

Temperature of Air.—From the middle to the end of July the temperature was excessive, and from thence to the end of September it was also decidedly above the average for that season of the year. Its maximum and mean daily value and its daily range stood very high on the 27th, 28th, 29th, and 30th of August, and on the 3rd, 4th, and 12th of September; the maximum temperature fluctuating from 80° to 111° in the sun; the three hottest days being the 27th, 28th, and 30th August. On the 31st August, and on the 2nd, 5th, 6th, and 7th September, the temperature, though not so high, was from ½° to 4° above the average calculated for 38 previous years. On the 1st September the temperature fell slightly $\frac{6}{10}$ of a degree below the average for that day, still however reaching to 72° in the shade, and 94° in the sun. On the 27th, 28th, and 29th August there was more or less cloud and haze, but from the 30th August to the 6th September the sky was almost continually clouldless.

Temperature of Water in the Thames.—During the months of July and August the mean temperature of the water at Greenwich was 64°, in September 63°. In the two weeks ending September 2nd it ranged from 60° to 68°.

Hygrometric state of the Air.—As tested by the dew point the air was drier than usual in the months of August and September. Compared week by week its mean dryness increased and diminished somewhat like the mortality from cholera, but examined daily during the latter part of August and beginning of September extreme variations are recorded at Greenwich on any one day; and from the 30th August to the 6th September the lowest atmosphere was not far from complete saturation at some period of each 24 hours.

Wind.—On the 26th August the wind, which for four weeks had been from S.W., W., or S., changed to N.W. On the next three days there was only occasionally a very gentle movement from the N. On the 30th what wind there was, was N., and then S.W. and W.S.W. On the 31st, S.W. and then N.E. On the 1st September, N. On the 2nd, S.E. and E. From the 3rd to the 12th September, N.E.; and after that S.W. again.

Horizontal Movement of the Air.—The stillness of the air during the two weeks ending September 2nd and September 9th, in which the mortality from cholera rose to its height, was very remarkable, the total horizontal movement for those weeks being not more than 245 and 195 miles. Now, during the 10 years from 1845 to 1854 the average weekly movement was 783 miles, and the average for the year 1854 itself, 687. Instead, however, of 100 miles a day, the average daily rate in the two cholera weeks, as they might be called, was but little more than 30 miles. But even this is not an adequate account of the unusual stillness of the air, for during the 10 previous years not 10 single weeks can be found in which the movement was less than 195 miles, and further during the two weeks just indicated, even the slight movement which did occur was not continuous, but interrupted by long intervals of calm. Thus, out of 16 days from the 27th August to the 11th September, there were 11 days more or less calm; seven of these, viz., 27th, 28th, and 29th August, and 1st, 4th, 10th, and 11th of September, were calm throughout, and four, viz., 30th August, and 2nd, 7th, and 9th September were calm during one-half of the 24 hours.

Barometer.—Coinciding with this dry, hot, and quiet state of the atmosphere, the barometric range was continously high, as would be expected.

Electricity and Ozone.—The electricity when observed was positive and of moderate tension. The ozone action was defective or not manifested at all, a fact probably of serious import.

General conclusions.—From the preceding account it is plain that the period of greatest mortality from cholera in the metropolis last autumn was characterised by a previous long continued absence of rain, and by a high state of the temperature both of the air and of the Thames, conditions which would render the waters of that river more concentrated as to impurity, favour periodically evaporation from its surface, and explain the alternating (diurnal and nocturnal?) extremes of dryness and saturation of the air. There was also an unusual stagnation of the lower strata of the atmosphere, highly favourable to its acquisition of impurity to the operation of those partial currents which are caused by local variations of temperature, and to the more subtle movements dependent on the law of diffusion, Moreover, at the rise of the epidemic in London after the middle of July, it will also be found that somewhat similar conditions prevailed for many days, whilst at its decline they were all more or less changed, and although it is impossible to assert that the relations here pointed out were uniformly exact, or to fix the precise share which each of the conditions enumerated might separately have in favouring the spread of cholera, the whole history of that malady, as well as of the epidemic of 1854, and indeed of the plagues of past epochs, justifies the supposition that their combined operation, either by favouring a general impurity in the air, or in some other way concurred in a decided manner during last summer and autumn to give temporary activity to the special cause of that disease.

If this supposition be correct, it is obvious that the same general meteorological conditions would operate simultaneously in the limited locality to which the present inquiry is directed; and here too we have found that the cholera outbreak suddenly declared itself after the four hottest and calmest days of August, viz., 27th, 28th, 29th, and 30th. But, as previously shown in the history of this local outbreak, the resulting mortality was so disproportioned to that in the rest of the metropolis, and more particularly to that in the immediate surrounding districts, that we must seek more narrowly and locally for some peculiar conditions which may help to explain this serious visitation.

Special or Local Conditions.

The considerations involved in this part of the inquiry may be discussed under the following heads:—Elevation of site; soil and subsoil; surface and ground plan; streets and courts; density of the population; character of the population; internal economy of dwelling-houses, as regards light, ventilation, and general cleanliness, cesspools, closets, and house drains, sewerage, and water supply.

Elevation of Site.—As shown in the table at page 55, the mean elevation of St. James's parish above the Thames high-water mark is 58 feet, whilst that of the Berwick Street and Golden Square districts respectively is 65 and 68 feet. The highest point in the parish, about 75 feet, is near the junction of South Row with Marshall Street, situated in the last-named district. So far then from the unusual mortality from cholera in those districts in 1854 being thus explained, it stands as the most remarkable exception to that very interesting general relation which has been shown by Mr. Farr to prevail throughout the metropolis between lowness of level and a high mortality from cholera.

According to the prevalent rule the annual mortality from that disease in St. James's parish would not be above 40 in 10,000 persons living, whereas in 17 weeks of 1854 it reached a registered ratio of 152, or even by taking the mean of the low rate of 1849 and the higher rate of 1854, a proceeding which though it serves to equalise the mortality numerically, in no way diminishes or explains the exceptional character of that of 1854, the ratio is still 84 to the 10,000 living persons. Indeed, as is clearly shown in the table, the actual mortality was greatest in the highest quarter of the parish, largely exceeding that of immediately adjacent districts which have a nearly corresponding elevation, and reducing the cholera area of St. James's to a level with Bermondsey which has a mean elevation corresponding with the high-water mark (compare the table, p. 55).

In the epidemic of 1849 similar exceptions to the general rule were instanced in St. Giles's (Holborn) and in Bethnal Green, but none of so extraordinary a character as that now under consideration, and full allowance being made for the acknowledged irregularities in the local distribution of successive visitations of cholera, this fact alone would suggest the existence of some special localising condition.

Soil and Subsoil.—Beneath the artificial or made soil of from 8 to 12 feet thick, which as is usual in districts long covered with houses is composed principally of accumulated rubbish charged with various *débris*, the natural subsoil of the entire parish is gravel, forming part of the gravel bed which extends in a westward direction through Hyde Park. Towards and at the bottom of the gravel, which varies from 20 to 30 feet in depth, are veins or layers of sand resting upon the London clay and abundantly charged with water.

This gravelly substratum insures a good natural drainage of the surface soil, and of the basements of houses, and is of course favourable to the salubrity of the district.

It should here be mentioned that the ancient pest-field used by the neighbouring parishes in the time of the Great Plague had its locality east of Regent Street and north of Golden Square. As considerable doubt and error still prevail in regard to the site of this field, a slight digression may be permitted in order to settle a subject both of medical and topographical interest.*

The history of this pest-field is associated with the name of William the renowned Earl of Craven, the same who fought under Gustavus Adolphus, was married it is said to Elizabeth, daughter of James I. and Queen of Bohemia, and, having lived through troublous times reluctantly surrendered at the head of the Coldstream regiment, the protection of St. James's Palace to the Dutch guards of the Prince of Orange; this remarkable man, who died in 1697 at the great age of 88, continued to reside at Craven House, Drury Lane, throughout the whole of the time of the Plague in 1665–6. He first hired and then purchased a field on which pest-houses (said to be 36 in number) were built by him for persons afflicted with the disease, and in which a common burial ground was made for thousands who died of it. In 1687 the Earl gave this field and its houses in trust for the poor of St. Clement's Danes, St. Martin's-in-the-Fields, St. James's, Westminster, and St. Paul's Covent Garden, to be used only in case of the plague re-appearing, and the place came to be known as the Earl of Craven's pest-field, the pest-field, the pest-house field, or Craven field. In 1734 the surrounding district having become covered with houses and streets, a private Act, 7th George II. c. 11., discharged this pest-house field from its charitable trusts, transferring them without alteration to other land and messuages at and near Byard's watering place (Bayswater), Paddington, now called Craven Hill. This Act refers to the original conveyance for a description of the abutments and boundaries of the field, states that it contains three acres more or less, and mentions as belonging to it "one "way or passage of sixteen ffoot wide . . . . . to "and from the premises by the slaughter house there "leading into Eyre Street."

The original extent of the Craven estate, so far as it corresponded with the site of the pest-field, is correctly shown in the map prefixed to this report. Some additional property lying between West Street and Carnaby Street, purchased by Lord Craven in 1774, has nothing whatever to do with the ancient pest-field. Moreover, a small portion of the north-east field itself no longer belongs to the estate, having been first rented and subsequently purchased by St. James's parish, as a burial ground. The present public baths and wash-houses are built over the greater part of this portion. The width of the pest-field from the middle line of Marlborough Row and West Street to the west side of Dufour's Place is about four chains, its length from the top of Browns Court at the back of the premises in part of Great Marlborough Street to the set off against No. 4, Marshall Street, is rather less than eight chains, so that including the part sold to the parish it contains three acres and a fraction, forming a tolerably exact parallelogram twice as long as it is wide. The short narrow piece of Marshall Street next to Silver Street (although now 18 feet wide) undoubtedly corresponds with the way or passage mentioned in the Act, for in what appears to be the original trust deed, now existing in the Craven Office, this way is described as excepted out of the premises abutting the pest-field on the south, and the "Eyre Street" mentioned was probably an extension of Air Street running northwards to join Silver Street near the point in question before Golden Square was built. In an early and perhaps unique impression of Blome's map of St. James's parish (one of the series to illustrate Strype's edition of Stowe) which is now in the possession of Mr. Crace, the pest-field is shown with a passage leading to it on the south from Silver Street, Golden Square being also laid down. The date of this map is probably 1680–90. The field itself is represented as if covered with grass, excepting a roadway which extends from the entrance passage nearly to its northern boundary. On the east of this roadway, about two-thirds of the distance up, the pest-houses are shown probably in a conventional manner as a single block of buildings. In a later impression of this map printed in 1720, the houses, grass, and roadway are all scraped out.

From this description and the plan, it will be seen that at the present moment nearly the whole of Marshall Street, South Row, and part of Broad Street, traverse the old pest-field, whilst West Street and Marlborough Row occupy a strip of its western edge. Considerable doubt exists as to the precise parts of the field in which the burial pit or pits were dug. In quite recent times evidences have been met with in two spots, one the site of Craven Chapel, the other in the right-hand lower corner of the former field, which would seem to indicate at least two places of burial. The latter position corresponds with Maitland's statement that "at the lower end of Marshall Street contiguous to "Silver Street was a common cemetery in which thousands "of corpses were buried in the time of the plague;" whilst Craven Chapel stands on part of the open ground of the old Carnaby Market, a space which for some reason was long unoccupied by any building, though houses had been built on other portions of the field, and which open ground was styled the pest-field up to the time of Craven Chapel being built.

It has been often alleged that in some way or other the remains of decomposing animal matter, or indeed of the plague matter itself, laying in the soil of this district, are chargeable with the great mortality from cholera near it. Popular opinion has even gone so far as to maintain that the disease of last autumn was not cholera, but a direful kind of black fever. But it is scarcely conceivable that

* The acknowledgments of the Committee are due to Mr. Wickens, solicitor to the Craven estate, to Mr. Goodwyn, to Mr. Crace, and to Mr. Farrant, for their assistance in regard to this matter.

any specific poisonous agent should remain undecomposed in the ground for 200 years, and it is improbable that animal matters generally enclosed for so long a period in a gravelly soil should retain noxious qualities of any kind, yet the possibility of this latter contingency cannot be absolutely denied. Supposing it to be so, such substances could only act by tainting the air directly, in consequence of the disturbance of the soil, or indirectly through the leakage of gases or fluids into the sewers, or they might otherwise act by contaminating the well-waters of the neighbourhood.

Deep cuttings, made in laying down new sewers, were carried through one part of the old pest-field in 1851 (as shown by the blue colour), and through other parts (as indicated by pink colour) in the winter of 1853–4, the last-named works being completed in February 1854, but no evidence exists of either line having passed directly through an ancient plague pit. No serious nuisance occurred at the time the ground was opened, and no immediate ill consequences ensued to the health of the surrounding inhabitants. It is well known that the whole of the pest-field was not used as a burial place, and, as it happened, the cuttings for the new sewers passed through a fine gravelly soil. Moreover, an interval of at least seven months occurred between the period at which the earth was broken up and the outbreak of cholera which was imagined to have been thus produced; and, it may be added, the site of the pest-field comprises but a small part of the "cholera area," and was not more severely visited than other quite distant parts of it.

In reference to the opinion that the sewers themselves may have become channels of contamination by the passage into them of gases or fluids from the pest-field soil, it must be remarked that percolation of any kind would be very unlikely through sewers so newly constructed; at all events this would have taken place much more easily through the older and more decayed ones, and yet in 1832 and 1849, although cholera penetrated the district, no unusual outburst took place: moreover, as will be subsequently explained, the drainage from the pest-field flows in two definite directions, whilst the aggravated effects of cholera were equally felt along other lines of sewers.

As regards the possible contamination of the well-water by the fluids of the pest-field, it must be remembered that in the numerous excavations which have been made in its soil from time to time for the foundations of houses, in sinking wells, and in cuttings for sewers, drains, gas, and water pipes, not only must much of the actual plague deposit have been removed, but the soil has been so perforated and channelled that for many generations past, in addition to the natural drainage which is very perfect, it has been draining itself continually in these artificial ways, and so ridding itself of its noxious contents. Hence the chances of the contamination of the well-water by the pest-field fluids would become less and less every year, and would certainly be greater in 1832 and 1849 than in 1854. Even the older sewers have been known to rob the water supply from certain wells, and the new cuttings being of greater depth must act still more efficiently to relieve the soil of any impure fluids with which it may be charged.

On the whole the supposition of the injurious influence of the pest-field as a special cause of the cholera outbreak in St. James's is not supported by any important facts.

Surface and Ground Plan.—With the exception of St. James's and Golden Squares, Burlington Gardens, part of the churchyard, and the workhouse green, every spot in St. James's parish is either covered by buildings or more or less perfectly paved; and it is hardly necessary to add that there are no open ditches, ponds, or stagnant waters, and no pieces of habitually damp ground. The surface is least occupied by houses in St. James's Square district, more so in the Golden Square, most of all in Berwick Street district.

Streets and Courts.—In the St. James's Square and Golden Square districts there are many long, direct, and wide streets, but in the Berwick Street and contiguous parts of the Golden Square district most of the streets and courts are comparatively narrow, short, and exceedingly intricate in their arrangement. Some of the streets even have a dead wall across one end, whilst of the greater number of those which have a thoroughfare both ways the junctions with each other are at such irregular intervals that they appear to be obstructed, the view either way is exceedingly limited, and the neighbourhood is very perplexing to a stranger. Even so considerable a street as Broad Street presents no direct outlet at either end. Out-of-door ventilation along the streets is seriously impeded in such a neighbourhood. The heart of the district is much protected both on the east and on the west, the quarters from which the prevalent winds of this country blow. In calm weather the stagnation of the street atmosphere must be almost complete; indeed, during the hot, still days at the end of last August this was painfully felt and noted by many of the inhabitants. As a special instance it may be mentioned that the persons residing in Pulteney Court and New Street complained of feeling suffocated by the temporary closing of Cock Court during the erection of the model lodging-houses named Ingestre Buildings.

Lastly, it must be noted, as touching this question of out-of-door ventilation, the yards to the houses are generally very small, and all available spaces behind the dwellings are covered with factories, workshops, or small tenements or cottages, all offering further impediments to a proper circulation of air outside the houses.

Density of Population.—From the close covering up of the surface, which has just been described, it might be expected that this part of St. James's would be very densely populated: the fact is so to a startling degree. The entire parish in 1851 had a population of 222 persons to an acre, standing in this respect within three of the top of the list of the 36 registration districts in the metropolis. The sub-district of St. James's Square had a density of 134 per acre, that of Golden Square 262, whilst the Berwick Street sub-district had a population of 432 persons to an acre, being actually the most densely crowded of the 135 sub-districts into which London and its suburbs are divided.*

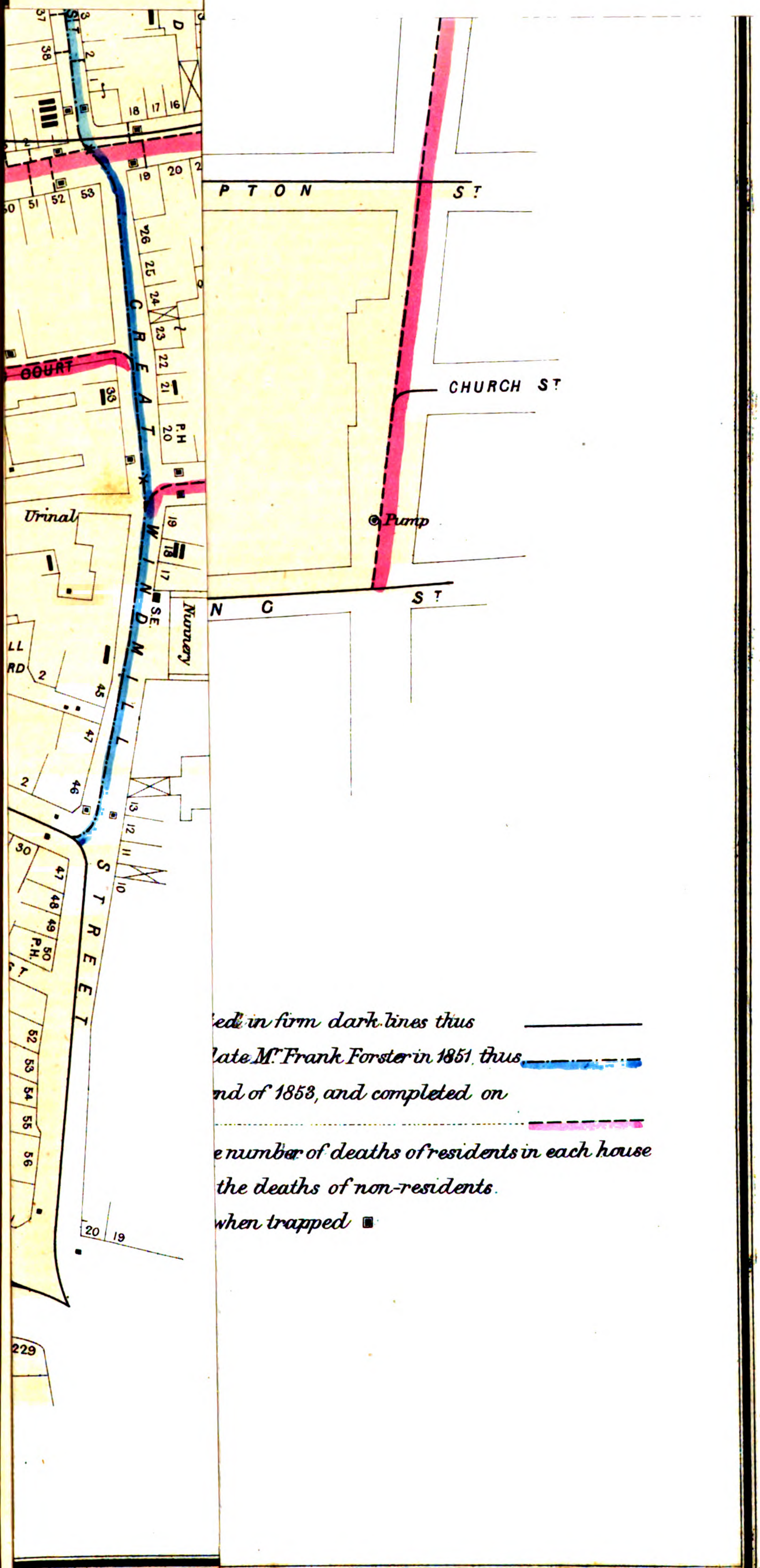
The removal of the block of houses between Hopkins Street and New Street for the erection of Ingestre Buildings, which were incomplete at the time of the cholera outbreak, would somewhat reduce the population in the Berwick Street sub-district in 1854. The relatively smaller population in the Golden Square district is accounted for by its including Golden Square, the whole width of Regent Street, Great Marlborough Street, the Earl of Aberdeen's, the Pantheon, and the workhouse yards; but there are parts of it contiguous to the Berwick Street sub-district, and comprised within the cholera area, which are quite as densely crowded as the latter; and since all parts are not equally overcrowded in either, the high rate of the population per acre implies a much greater concentration of the evil in special localities.

Character of the Population.—Confining our attention now to the district affected by the cholera, it may be stated in general terms that the great mass of the persons inhabiting the densely crowded parts is composed of the families of labourers, mechanics, and journeymen (many of them tailors), of persons in short employed at fair wages, and manifesting no peculiarity in moral characters, habits, or occupation beyond those usual to their class.† The number of those who live otherwise than by industry is certainly small. Besides the residents in this crowded district, there is a daily influx of probably 2,000 persons engaged within it in various workshops and factories, in none of which, however, are any specially injurious processes carried on. The larger and less crowded streets are occupied by tradespeople and the professional classes in every way corresponding with those of similar neighbourhoods.

Dwelling-houses.—Internal economy as to space, light, ventilation, and general cleanliness.—For the most part the houses in this district are old, having been built about the years 1700 to 1740. As already stated, the yards are very small, and much covered, but there are no houses built back to back. In some streets the houses are what are termed third-class houses, containing from 10 to 15 rooms. In the smaller streets they are fourth-class houses. The rooms, of course, vary in size and height, and, as usual in dwellings constructed 150 years back, are not objectionable unless overfilled with inhabitants. Cellars and vaults are common; the front areas are narrow and much covered in. Of light there is, generally speaking, an abundance, as the numerous windows constructed before the adoption of a window duty have been reopened since its abolition. The in-door ventilation is, on the whole, defective, the staircases and passages being narrow, and the sashes, with some ex-

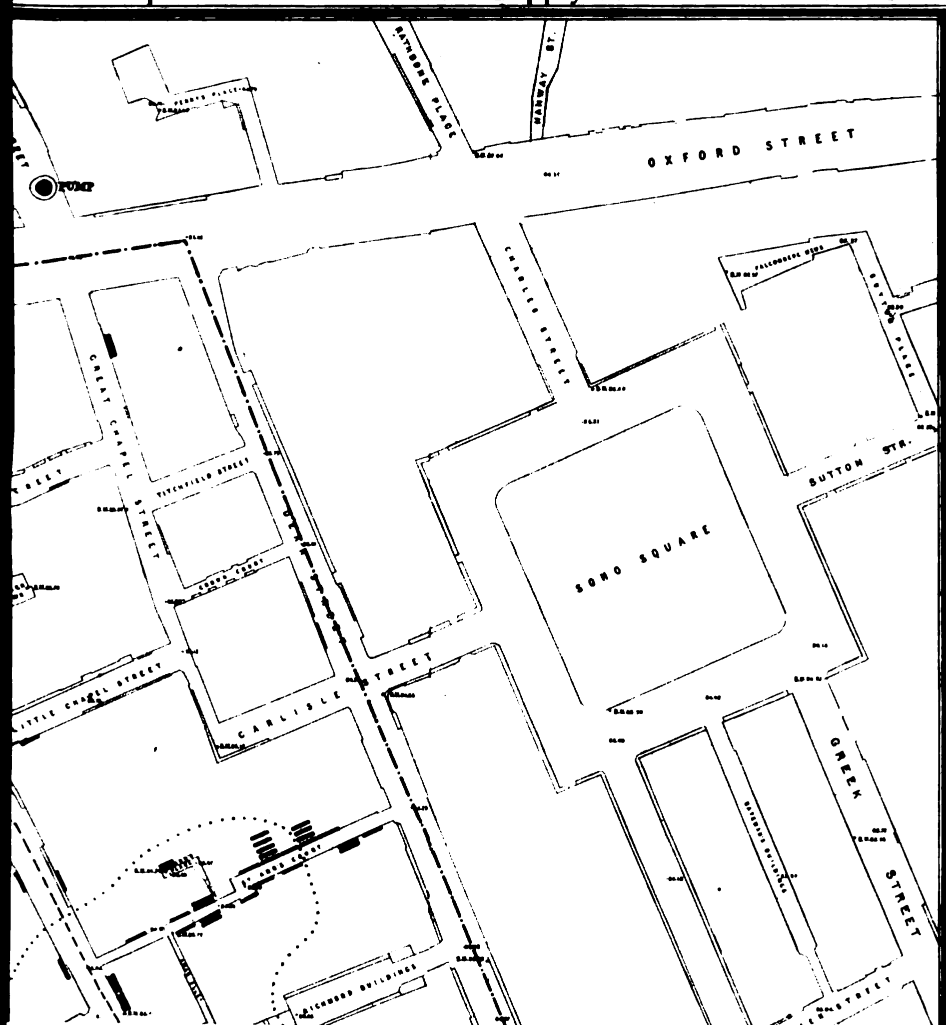
* See table, p. 493. We may here point out an accidental but important error in the Registrar-General's weekly returns, commencing September 30th, 1854, by which the respective areas of St. James's Square and Golden Square sub-districts—85 and 54 acres—are reversed. This has further vitiated the estimated population per acre in those sub-districts in the table given in the weekly return for December 30th, p. 517, where the population is said to be 212 in St. James's Square, and 166 in Golden Square, instead of 134 and 262 respectively.

† It was found in the epidemic of 1849 that through London generally there were fewer deaths from cholera on Wednesdays, Thursdays, and Fridays than on the other days of the week; the fewest of all being on Fridays. The highest mortality took place on Mondays and Tuesdays. This difference was attributed in part to the indulgences often practised at the beginning and end of each week. In St. James's, however, the greatest number of attacks was on Friday, and the daily range of mortality does not justify any general inference unfavourable to the habits of those who were seized—a conclusion entirely in accordance with their varied position in society, and also with the assertions of those who know the district.



Stanford's Geog¹ Estab^t 6 & 7, Charing Cross

Sixth Report - The Domestic Water Supply of Great Britain - 1874.



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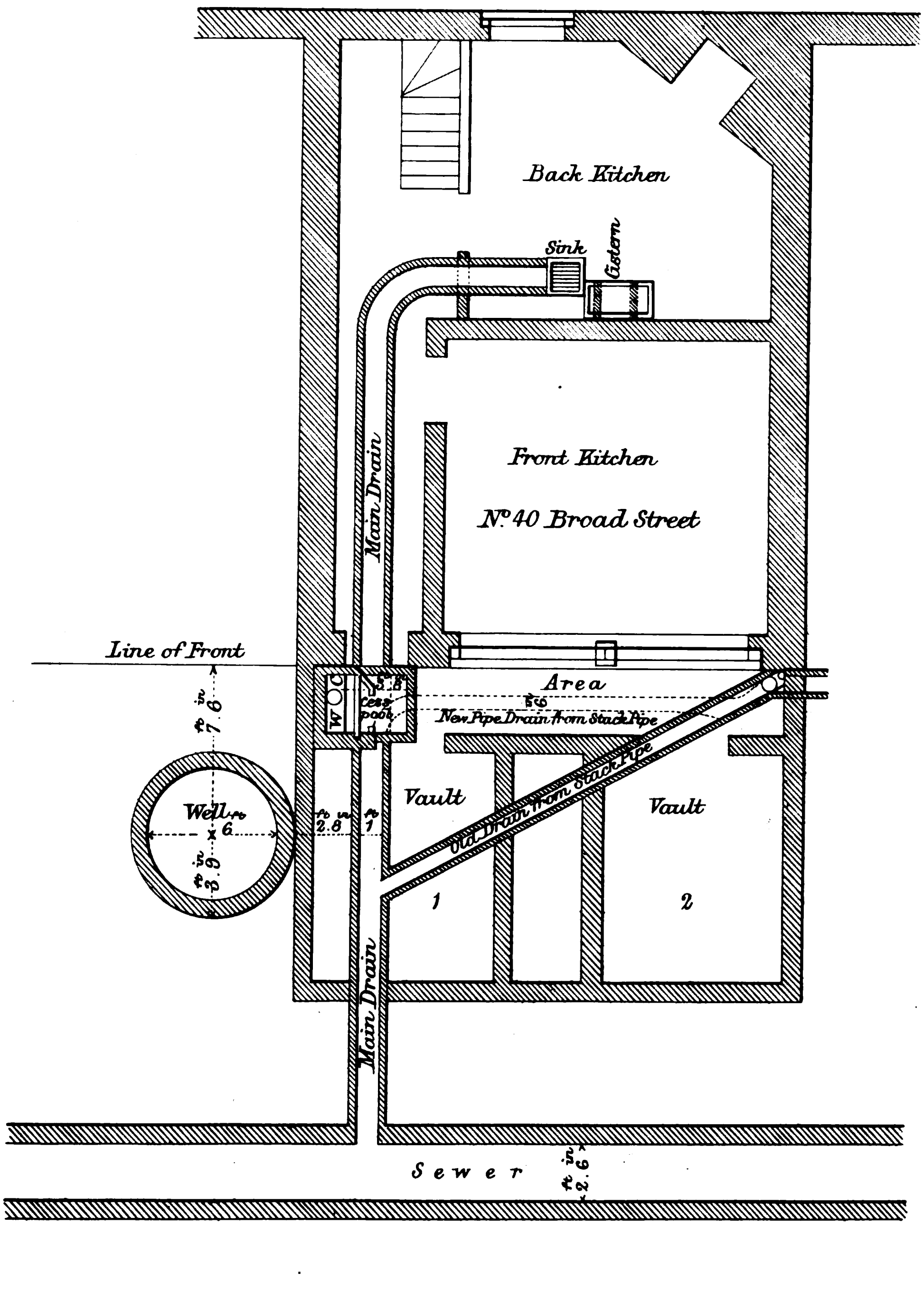
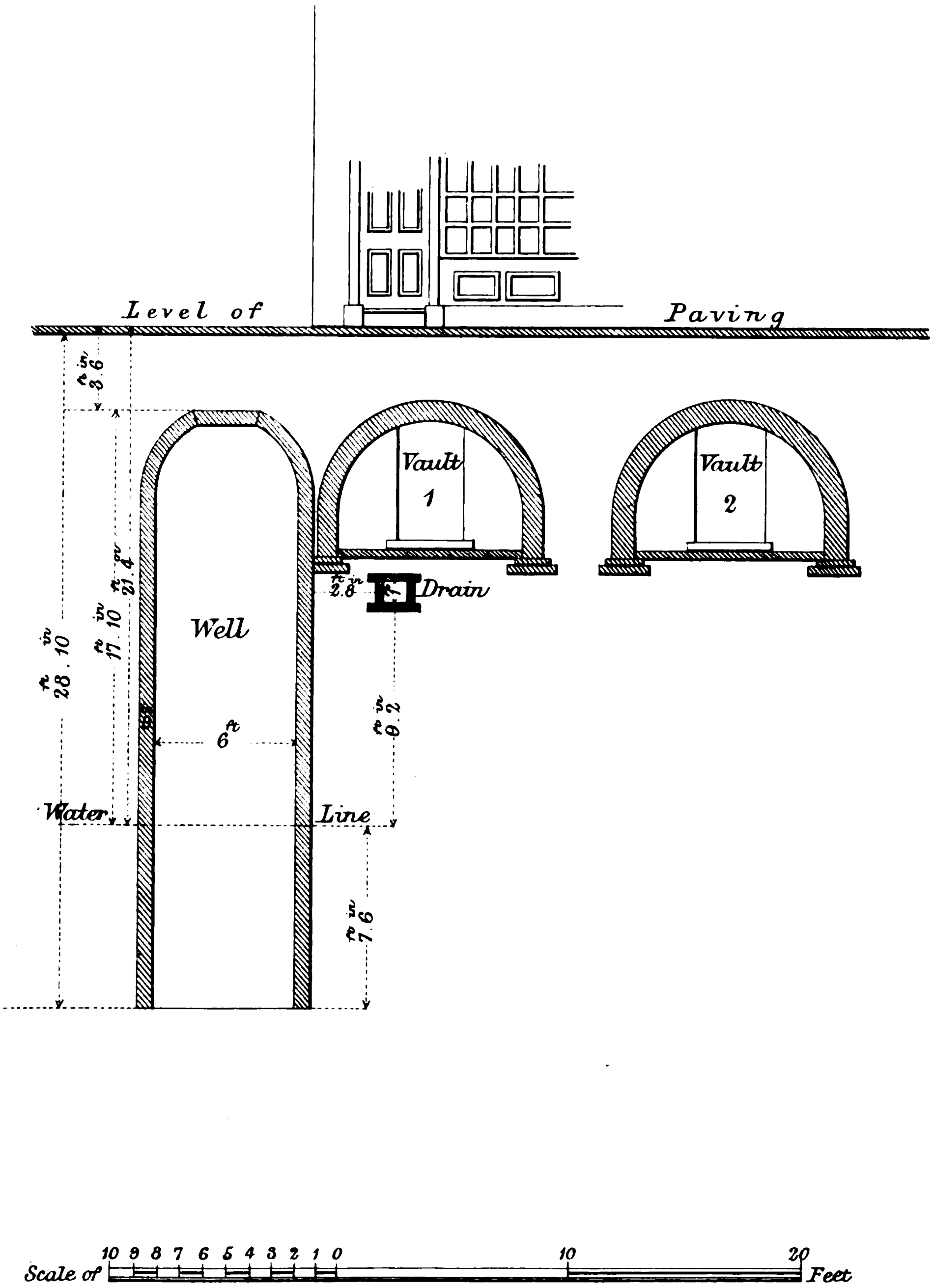


Stanford's Geog¹ Estab¹ Charing Cross



Stanford's Geog^l Estab^t Charing Cross, S.W.

ceptions, being single-hung, so as to open only at the bottom, a serious defect, which cannot be too strongly condemned. Probably not more than a dozen houses in the affected district are occupied by a single family, the subdivision of one dwelling among many families being the rule. The competition for rooms has been so great that a respectable workman can often only afford to have one for his whole family. The underground rooms or kitchens are frequently inhabited; in Broad Street, for example, in nearly two out of five houses. In many of the smaller streets half of the kitchens are occupied as dwelling and sleeping rooms, sometimes by a numerous family, but more commonly the number of persons in each kitchen is small. The ground floors of more than half the houses are occupied as shops. The population, taken generally throughout the district, is accumulated rather in the first, second, and third floors, the second floor being usually the most densely peopled. In Broad Street the average number of persons to a house is about 18, and to each floor 5½. But the greatest differences prevail, for even in Broad Street there are instances of 30 persons living in one house; in one of the smaller streets 54 persons were crowded into one dwelling. The unusual overcrowding of certain houses follows from the general statistics already detailed. In the " cholera area " the ratio is 17 and 18 persons to each house.

Now, in the close and complicated streets, in the densely packed dwellings, in the climax of overcrowding as compared with all London, in the character and occupations of the people, and in the general economy of the houses, conditions are found which, with other necessarily attendant evils, might be supposed to neutralise the advantages arising from the nature and elevation of the soil. Such an explanation, indeed, has already been offered by Dr. Baly in regard to the comparatively high rates of mortality from cholera observed in Bethnal Green and in St. Giles's, Holborn. Within very straitened limits, and with unfavourable external conditions, there is certainly to be found in the cholera area of St. James's a large number of that very class of persons, labourers, mechanics, artisans, journeymen, and tradespeople, who usually supply the most victims to the disease. But that this circumstance, combined even with defective domestic arrangements, is adequate to explain the actual outbreak appears doubtful; or why was not the presence of the cholera agent in this same district in 1832 and 1849, although then equally overcrowded, attended by the same lamentable consequences; and why did not cholera, which was present at the same time under the same meteorological conditions, and with closely corresponding local circumstances in the adjoining districts, ravage them to the same extent? In All Souls, Marylebone, in St. Anne's, Soho (excluding St. Anne's Court), in St. Giles's, and in parts of St. Martin's-in-the-Fields nearly similar spots could be pointed out, yet, as shown by the annexed table, the mortality in each was, compared with that of St. James's, very low.

TABLE showing the MORTALITY from CHOLERA in various parts of the METROPOLIS, with the Elevation, Density of Population, and General Mortality of the same.

Localities.		Hospital or Workhouse.	Deaths from Cholera to 10,000 Persons living, 1849.	Deaths from Cholera in 17 Weeks to 10,000 Persons living, 1854.	Elevation or Feet above Trinity High Water.	Persons per Acre, Census 1851.	Annual Deaths from all Causes to 10,000 Persons living, 1841-185[illegible]
London		—	60	45	39	30	246
Districts.	Bermondsey	W.	161	158	0	70	268
	Holborn	W.	35	5	53	238	246
	St. James's	W.	16	152*	58	222	206
Sub-district of St. Giles, South		W.	97	32	64	317	363
Sub-districts surrounding St. James's.	Mayfair	W.	15	23	56	95	181
	Hanover Square	—	4	9	64	45	163
	All Souls (Marylebone)	H.	24	28*	76	258	290
	St. Anne's, Soho	—	27	37	64	327	203
	Charing Cross in St. Martin's	H. W.	48	33	17	48	284
Sub-districts, St. James's.	St. James's Square	—	13	16	40	134	133
	Berwick Street	—	18	212*	65	432	224
	Golden Square	W.	16	217*	68	262	257
Cholera area of St. James's		W.	17·5	440	66	460	(?)

* Corrected by transferring certain deaths from All Souls, Marylebone, in which Middlesex Hospital is situated, to the localities in which the fatal attacks occurred. (See Registrar-General's Return.)

In certain instances within the cholera area the mortality bore direct relation to the density of the population. This is true chiefly of streets in the centre of the district, for towards its borders an overcrowded people with defective external and internal ventilation, and a large amount of general uncleanliness, did not suffer in the same degree as in the lower part of Wardour Street, in Peter Street from No. 20 to 32, in Walker's Court, and in Little Pulteney Street. Individual instances of extreme uncleanliness in both streets and houses, as No. 7, Husband Street, were sometimes associated with comparative impunity from the disease, whilst some of the wider streets, and well ordered and scantily filled residences were visited severely. It has already been mentioned that seven workmen engaged in the open air in the erection of Ingestre Buildings died; at least 30 other non-residents, visitors or workmen, besides about a dozen others who merely came at chop or coffee houses in the district, also died; yet none of these persons slept in it, or could have been much influenced by its permanent conditions. Lastly, as bearing on this subject, it must be noted that the average annual mortality of the Berwick Street and Golden Square sub-districts from all causes of death, is by no means high (see previous table), showing that no serious results ordinarily ensue from the acknowledged sanitary defects just described. The elevation is probably the chief cause of this general healthiness.

Finding then that the evils necessarily attending the most densely crowded population within the circle of metropolitan registration do not offer a clear and decided explanation of the aggravated results of cholera in this parish, we pass to such other local sanitary disadvantages as might or might not accompany this overcrowding, and so be obnoxious or otherwise to health, viz., the state of the cesspools, house drains, sewers, and water supply.

Dust-bins and accumulations in yards, cellars, and areas. —At the time of the visitors' inquiry, very careless arrangements were still found to exist in regard to these points, and at the period of the cholera visitation there were, undoubtedly, many nuisances of the kind, but on the best authority it may be stated, that cholera was most impartially distributed between the comparatively dirty and comparatively cleaner spots.

Cesspools, closets, and house drains.—The visitors' inquiry list sufficiently prove the insuperable difficulty of arriving at true results as to the existence or absence of cesspools. There is every reason to believe that they exist in large numbers. Originally such receptacles would be sure to be provided, and as an illustration of the abundance of these obnoxious pits in certain parts of the parish, it may be mentioned on the authority of the late Sir H. de la Beche, that when Derby Court, Piccadilly, was pulled down to clear a site for the Museum of Economic Geology, no less than thirty-two cesspools had to be excavated.

Such cesspools are frequently situated in the narrow front areas, kitchens, or vaults, there being generally no space available for such conveniences in the back yards. In the event of any obstruction or overflow, the entire basement must therefore be filled wih deleterious substances or gases. These cesspools are generally connected with the sewers by means of flat-bottomed brick drains, having in some cases the advantage of a bricklayer's water-trap in the area or vault. Of the faulty construction of these drains and traps, and of the defective state of repair and blocked-up condition of many of the cesspools, little doubt can exist after the discovery of all these defects in the inquiry conducted by Mr. Yorke, at No. 40, Broad Street. The house drains themselves are also of considerable age, and are probably in many cases in the decayed condition detected on the same premises.

Equally impossible is it to ascertain, without additional powers of search, the mode in which these house drains are connected with the sewers, but it may safely be stated, that for the most part it is a simple outlet or drain-mouth, without other trapping than the water-trap in the area. Frequently, when the original sewers are replaced by new ones situated at a greater depth, this opening is made near the *top* of the sewer arch instead of towards the bottom. In some houses, but certainly in the minority, water-closets with pipe drains and leaden air-tight flaps are substituted for the older arrangement.

Sewers.—Owing to successive alterations and additions, the sewerage of the district affected by the cholera is arranged in rather a complicated manner. Its plan, as it existed in the autumn of 1854, is laid down in the map prefixed to this Report, constructed on the authority of the one published in Mr. Cooper's Report to the Metropolitan Commissioners of Sewers. The older sewers, some of which were built as late as 1823, are left uncoloured. A new sewer constructed in 1851 is shaded blue, whilst the late extensive additions made in the winter of 1853–4 are tinted pink. The several systems appear to work as follows:—

a. Waterflow.—1. Starting from the high ground near the junction of South Row with Marshall Street there is a fall in the sewers in two directions, so that the drainage from the upper part of Marshall Street, South Row, and all the intermediate courts and streets to Carnaby Street flows westward through Tyler Street and Foubert's Place into the Regent Street sewer. 2. On the other hand the middle third of Marshall Street from South Row to Broad Street, Broad Street itself (including Dufour's Place) as far as Cambridge Street, Cambridge Street and the two Windmill Streets, form another line of flow, running south-east and then south again. 3. The eastern half of Broad Street, Poland Street, Berwick Street and its dependencies, Pulteney Court and all the small streets and courts east and south as far as Wardour Street and Little Pulteney Street ultimately run into the Wardour Street sewer. 4. The short piece of sewer in the lower part of Marshall Street, south of Broad Street, ends in a transverse line which follows Silver Street, and from a point opposite to Bridle Lane falls in two directions, westward to join the Golden Square sewers, through Upper James Street, and eastward by a pipe-drain to end in the Cambridge Street line already mentioned. 5. Great Pulteney Street has a sewer to itself, running south into a second transverse line, which occupies Brewer Street and Little Pulteney Street, and crossing above the Windmill Street line falls both ways from that point, viz., westward into the Golden Square system and eastward into the Wardour Street sewer.

b. Atmospheric Connexion.—Of the five systems of sewers just described, the first (pink) has atmospheric connexion with the second (blue) at the high level in Marshall Street near the end of South Row. The first and third appear to be connected atmospherically by the Great Marlborough Street line. The fourth (Silver Street) is connected with the second at the junction of Cambridge and Little Windmill Streets, and with the fifth (Brewer Street) through the Golden Square sewers. The fifth is further connected with the third (Wardour Street) at the end of Little Pulteney Street. Lastly, the second and third, occupying respectively the two halves of Broad Street, have only an indirect and circuitous atmospheric connexion.

At the period of the cholera outbreak it was very generally believed that the unusual mortality was in some way or other chiefly attributable to the sewers themselves, or to their alteration and extension in certain parts of the district in 1851 and in the winter of 1853–4. 1st. because of the disturbance of the ground of the old pest-field already alluded to. 2ndly. because of the general disturbance of the artificial soil, the removal of good gravel and the subsequent filling in with rubbish. 3rdly, on account of sundry diversions or changes in the previous current of the drainage. 4thly, because of the foul and loaded condition of the sewers and escape of noxious air from the numerous ventilators and untrapped gullies.

It is not easy to connect the general disturbance of the soil in 1851 and in the winter of 1853–4 with an outbreak of cholera in the autumn of 1854. Even in the case of the old pest-field such connexion is difficult to be conceived, for the reasons which have already been detailed at length. That the opening of old ground for the purpose of building new street sewers should be carefully timed and properly conducted is true, but the vague apprehension that this is necessarily attended with risk to public health may be quieted by the fact that such works were proceeding at the cholera period in various parts of the metropolis without appreciable evil results.

Before 1851 Marshall Street drained into Silver Street, and the whole of Broad Street, including Dufour's Place, drained into the Wardour Street sewer. At present the drainage of the former street flows three ways, its upper part westward through Tyler Street, its middle part eastward along Broad Street to Cambridge Street, and its lower part only into Silver Street. Only the eastern half of Broad Street now drains into Wardour Street. Moreover the sewers in the two halves of Broad Street are not directly connected. Hence, as Mr. Cooper has remarked, the diversion of the sewerage cannot have had much to do in itself with the increased mortality, the deaths being distributed pretty equally over the two districts east and west of Cambridge Street, and even over the two halves of Broad Street separated at the point where the new and old sewers approach without joining. But whether incidentally this diversion of the drainage could have had any injurious effect is a point for further examination.

Of the escape of foul, nauseating, and noxious vapours from the untrapped gully holes and ventilators throughout the district there can be no doubt. Particular evidence of this fact, as regards the 30th and 31st August, could easily be brought forward. Owing indeed to the previous long-continued absence of rain, and the great heat of the four previous days, this was the case all through the metropolis, even in parts lightly visited by cholera, as in Regent Street, in St. Giles's, Holborn, and in the northern parts of London. One cannot suppose then that the general condition of the sewers in this district was different from that in others where cholera was scarcely felt. But it remains to be asked, Were there any special circumstances or peculiarities in the sewerage of the affected districts?

The improbability of the pest-field soil contaminating the sewers has already been discussed. From the baths and wash-houses, the brewery, and certain factories a considerable quantity of hot water continually passes down through these sewers; it is quite certain that this might locally aggravate the smells from the sewer atmosphere by increasing its temperature and moisture. So also the acid fluids passing from time to time along them from factories in the neighbourhood might, by meeting with sulphide of ammonium, set free sulphuretted hydrogen, and thus add materially to the noxiousness of the escaping effluvia. But the detergent effect of a large quantity of hot alkaline and other waters unmixed with solid matter continually flushing the sewers must of necessity be a benefit. In particular it must be added, that there is no evidence whatever of baths and wash-houses, either here or elsewhere, being in any way specially concerned in increasing the intensity of cholera.

Of cow-sheds, grease-boiling houses, marine stores, and slaughterhouses, there are many, especially along the southern half of the cholera area. Their drainage must pass, some of it into the Wardour Street system, and the rest into the Golden Square system of sewers. One large establishment drains into the short piece of sewer at the lower end of Marshall Street near Silver Street. There is no surface drainage above, and the house drainage must be insufficient to keep the sewer clear from obstruction. Direct evidence is on record of the accumulation, during last August, of the blood offal and ordure of animals in the short piece of this sewer as far as its entrance into the Silver Street sewer, and even beyond this point. The presence of such accumulations must hold up the house drainage as far as the corner of Broad Street. There is no gully-hole along this part of the sewer, and no ventilator at the top. It forms, therefore, a closed and underground retort, 200 feet long, its inclined floor being partly choked with animal matter and refuse (the most prone of all to dangerous putridity), partly covered with the closet drainage from occupied houses, and empty only at its upper end. Its beak dips down into Silver Street, into which the products of its distillation must slowly fall. Spreading eastward and westward along Silver Street, and escaping partly at its gully-holes so offensively that sacks were frequently put over them by the inhabitants near whose doors they opened, the products would either be drawn along in the direction of the air-draught in the sewers, which, contrary to the water flow, tends towards the higher levels, or, by aid of gravitation or divers currents in the sewers, they might pass in opposite directions before escaping into the streets. In this way the local atmosphere during the cholera outbreak might be seriously tainted, or molecular decomposition, fermentation, or organic growth might extend itself along the contents of the loaded sewers of this overcrowded district wherever atmospheric connexion existed. It is impossible to say that this sewer-retort would generate any peculiar products, but it would certainly generate more products, and those more quietly than any ordinary sewer. Thus it might aggravate the mischief common to all sewerage, and might even constitute a focus of molecular or organic change, by which adjacent accumulations of filth might be more rapidly excited to active decomposition.

Without doubt the general taint of the atmosphere in the southern half of the cholera district may thus have been specially increased. It is important further to bear in mind that probably no such another example exists throughout the metropolis of large slaughtering premises draining into so short a closed sewer with insufficient head water to carry away the filth. It must also be remembered that in 1849 this arrangement did not exist, for the surface water and house drainage from a considerable district, including three-fourths of the sewage from the workhouse, then operated to wash away the refuse from the slaughter yard in question.

On general grounds therefore it would seem as if here was one local condttion probably most favourable to the intensity of a cholera outbreak, and special perhaps when considered both as to time and place. But there are difficulties in the way of viewing it as a satisfactory explanation of the outbreak itself. No direct under-ground atmospheric connexion can be traced between the Silver Street sewer and the old sewer in the eastern half of Broad Street, and the communication between them through the trunk lines of Wardour Street and Berwick Street is somewhat circuitous, although not many hundred yards about. Nevertheless, when the excessively calm and sultry character of the days immediately preceding the outbreak is remembered, an above-ground diffusion of the impure air might be supposed to have been concerned in aiding the spread of the disease, either directly or else indirectly, by inoculating other seats of mischief, such as overflowing cesspools, existing in that quarter. It has been alleged in the public journals that the deaths generally took place in houses opposite to gully-holes and ventilators, but as stated in our previous remarks upon the map, this was the exception and not the rule.

As to the probable entrance of the sewer air into some houses rather than into others, but little certain is known, for as already stated trustworthy evidence can be obtained only in a few cases as to the absence or presence of traps, or their efficiency or non-efficiency where they exist. In such important particulars it is a matter of regret that the present report must remain defective. In the case of No. 40, Broad Street, it is evident from Mr. York's account that the vertical stone in the water traps being erroneously placed could defend the interior of the house from the gases of the sewer; this may be an example of a very general rule. It is known also that when the main sewer was sunk, many house drains instead of being lowered were simply connected by an invert pipe entering too near to the top of the new sewer arch. It has been asserted that where houses had leaden flap-traps to the drains, no deaths from cholera took place, and vice versâ. In the upper part of Marshall Street, six houses are known to have had these flap-traps inserted, and in four the drains were properly lowered; in these no deaths took place. But opposite facts are to be met with. In two factories in Broad Street the closet accommodation, water supply, and traps are equally complete, yet in one, seven deaths out of 42 persons employed took place, in the other out of 30 none. In the large factory employing 200 people, of whom 18 died, the closets are well arranged and attended to daily. It is moreover shown by Mr. Whitehead that in Broad Street the kitchen population did not suffer so much nor yet so early as persons living on some other floors, but that the per-centage of mortality diminished from the ground floor upwards, with the exception of a slight increase on the third floor over the second. Of the 26 deaths in Little Windmill Street, the kitchens with inmates relatively as numerous, and drains as offensive as in Broad Street, did not supply a single one. In remoter streets a slight preponderance of deaths on the upper floor is observable. Hence it would seem that if the sewage gases operated at all, they would do so by diffusion into the street atmosphere rather through the house drains. But here also difficulties arise. If the air was so generally tainted, how did so many of the inhabitants escape? why did not the men employed in Huggins' brewery suffer, when out of 35 of those engaged close to that establishment in the construction of the then unfinished lodging houses called Ingestie Buildings no less than seven died? why did not the inmates of the workhouse suffer more than they actually did? why should adjoining houses and families living in one house and on the same floor, have presented similar contrasts?

Although therefore there must have existed abundant causes of an impure condition of the atmosphere in the sewers, drains, basements, and even courts and streets during the hot still days at the end of last August; although the general pernicious effects of this are undeniable, and though a comparison of the cholera area of St. James's in this respect with other districts may be unfavourable to the former, yet a minute inquiry into the details of the cholera outbreak shows that the precise influence of this extreme, if not special, foulness of the local atmosphere cannot be satisfactorily defined, and that it fails by itself to explain the apparent anomalies of the remarkable outbreak of cholera in this parish.

Public Water Supply.—The western half of the "Cholera area" in this parish is supplied with water by the Grand Junction Company, whilst the eastern part, corresponding very nearly with the Berwick Street registration subdistrict, is supplied by the New River Company. It is obvious therefore that the public water supply from these two companies either had some equal and simultaneous share in favouring the cholera outbreak, which seems very unlikely when we consider the suddenness and limited extent of that outbreak, or what is more certain, had no share at all.

The Grand Junction water has, according to Dr. R. D. Thomson, an average amount of 14·46 grains of solid matter in a gallon: the New River water at the reservoir, New River Head a normal quantity of 17·18 grains. But, during the cholera outbreak some of the water supplied by the New River Company collected from houses in the Soho district adjoining Berwick Street has been stated to have contained 30 grains per gallon.

It is right to mention here with proper emphasis that although no influence whatever was probably exerted by the public water supply in increasing cholera in St. James's parish, the condition of the water butts and cisterns as stated in the visitors' inquiry lists must have been exceedingly bad. Particular instances the Committee forbear to mention, but enough was revealed to make them hope for the speedy abolition of the cistern and for the consummation of the long-advocated plan of a constant supply. Often these butts and cisterns are without covers, and very frequently, owing to the smallness of the back yards, they are in close proximity to accumulations of dirt. As mentioned by Mr. Whitehead, their state was a frequent reason for having recourse to the well-water of the district for drinking purposes, to the character and effects of which we must next direct attention.

Well-Water Supply.—Besides the artesian well sunk near St. James's Church, Piccadilly, there are many wells, public as well as private, scattered through the parish, all of which must essentially derive their supply of water from the abundant land springs which exist in the sand lying above the clay. This sand it may be stated is continuous with beds extending all through the gravel districts westward across Hyde Park, and derives its water partly from the rain-fall on the open country and partly from the surface water and accidental drainage from the soil of the inhabited districts.

These pump wells vary in depth, but all of them are sunk down to the London clay, which serves as their bottom; the sides are built in brick, laid dry, through which the water readily enters, the arches are turned over with brick laid in mortar or cement, and covered in with a key stone, also secured in mortar or cement. A section of the well in Broad Street is shown with Mr. York's report, which may be read with advantage here.

Now there are two of these wells in the parish, one in Marlborough Mews in the north, the other in Little St. James's Street in the south, which are so rapidly fed from the water bed in the sand, that they cannot be pumped dry, whilst the majority of them, as those in Bridle Lane, Charles Street, Duke Street, and Broad Street, can be laid dry by continuous pumping in four or five hours. Since therefore into these last-named wells the natural supply finds a less ready entrance, it is obvious that the chances of soakage from the artificial soil, and the numerous impurities incidental to densely inhabited districts, are greatly increased.

In November 1854, in consequence of the relation then declared by Dr. Snow to have existed between the well-water in Broad Street and the cholera outbreak, Dr. Lankester was requested to report on the well-waters of this parish. In his report it was shown that the Broad Street well-water contained 96 grains of solid matter to the gallon, the Bridle Lane water 96 grains, and the Marlborough Street water 50 grains, whilst the water from Marlborough Mews (a quick-filling well) contained only 30 grains. The water from the Burlington Gardens well, which is also fed very rapidly, contained 32 grains per gallon, a fact supposed by Dr. Lankester to be exceptional, but coinciding nearly with the quick-filling well of Marlborough Mews. But it was desirable to ascertain if possible what was the standard composition of the water natural to the sand bed without admixture from a town soil. The artesian well-water in Piccadilly contained when first bored 40 grains per gallon and no organic matter (Everett); that in Trafalgar Square contains 67 grains per gallon (Graham), and Thames water a quantity varying from 14 to 38 grains: but neither of these analyses afforded the necessary data. Two specimens of water have therefore been procured from Hyde Park, one from a pump near Kensington Gardens, the other from the running pipe at the east end of the Serpentine. A sample from the Marlborough Mews well, one from a private well in Savile Row, and two samples from the Broad Street well have also been examined. Of the Broad Street samples the first was taken six weeks from the date of Mr. York's detection of a communication between the well and the cesspool of No. 40, during the whole of which period the well was closed; the second after the well had then been pumped out three several times and allowed to fill again. The results are stated in the following table, to which also is added the composition of Thames water taken at Kew, whence the Junction Company derives its supply.

ANALYSIS of WATER from

—	Spring at the Northern end of Kensington Gardens; collected 4th June 1855.	Hyde Park, near the Serpentine; collected 1st June 1855.	Marlborough Mews; collected 2nd June 1855.	Private Well; collected 5th June 1855.	Broad Street No. 1; collected 9th June 1855.	Broad Street No. 2; taken after Three Pumpings out of the Well, 14th June 1855.	The Thames at Kew; the Source of Supply of the Grand Junction Company.
Specific gravity - -	1000·454	1000·377	1000·438	1000·997	1000·998	1000·873	
GRAINS in IMPERIAL GALLON.							
Carbonic acid - -	8·214	9·170	14·299	13·888	26·374	24·644	5·39
Chlorine - - -	2·593	2·808	3·413	7·504	11·240	10·592	·84
Sulphuric acid - -	9·511	13·860	9·890	10·150	12·970	12·970	2·31
Lime - - -	6·051	11·765	10·280	17·542	23·998	23·347	7·42
Magnesia - - -	2·593	2·754	1·607	1·428	1·944	2·161	·56
Soda - - -	4·430	2·156	and potassa, about 6·500.	7·580	16·861*	16·861	·84
Potassa - - -	0	0	See Soda	0	0*	0	·56
Iron - - -	Trace	Trace	Trace	—	Considerable	Not quite so much.	(Peroxide), ·63
Phosphoric acid - -	Trace	Trace	Trace	Trace	Trace	Trace	(Silica).
Nitric acid - - -	Trace	Trace	Considerable	Considerable	Much	Very much	Trace.
Ammonia - - -	0	0	Considerable	Trace	†	†	·42
Organic matter - -	5·404	3·080	·432	5·404	5·404	4·755	3·08
Total estimated - -	38·796	45·593	46·421	63·496	98·791	95·330	22·05
Residue after evaporation, 212° Fahr. - -	45·388	50·404	56·000	80·388	107·015	105·933	—
Analysed by - -	W. J. Powell	T. J. Smith	P. Worsley	J. Ormsby	W. J. Powell	W. J. Powell	Graham and Hoffman.

* This was not estimated, but inferred from specimen No. 2.

† In specimen No. 2 the process for detecting ammonia was interrupted by an accident. Ammonia no doubt existed in both specimens.

It will be seen that the general result of these analyses is to confirm the differences already found by Dr. Lankester to exist between various well-waters in the parish. The quantity of chlorine, combined probably with sodium to form common salt, is remarkable, especially in the Broad Street water. It is so great indeed that it must be derived from the débris, refuse, and excreta necessarily accumulated in a densely-peopled district, and not from the waste water of the neighbourhood, which is supplied by the Grand Junction Water Company from the Thames at Kew, where the river water contains, as is shown, a very small quantity of chlorine.

Phosphoric acid exists either as a soluble phosphate or as a phosphate of lime dissolved in carbonic acid, and is present in minute quantity in all the waters. The nitric acid, which most likely exists in combination with ammonia and lime, and which is found in large quantity in the Broad Street water, would be derived from decayed animal matter, probably from mortar rubbish, or even the pest-field soil. The carbonic acid originates also from decomposing organic, chiefly vegetable, substances, and is either free or associated with lime or its salts. The sulphuric acid would also be combined with the lime magnesia to form sulphates; sulphate of lime is a natural constituent of nearly all spring waters. No sulphuretted hydrogen or sulphide of ammonium existed in any of the specimens; organic matter was found in all.

From a general comparison of the well-waters it would appear—first, that in the open park uncovered by houses the water of the sand bed is comparatively free from saline constituents, especially from chlorides and nitrates, though it contains a large quantity of organic matter; secondly, that when traversing with great rapidity and freedom of percolation through the soil of an inhabited district to feed a quick-filling well, it acquires a decided increase of saline ingredients, including both chlorides and nitrates; and thirdly, that in a particular well in which the rise of water is slower still more of these impurities were found, not only under the influence of percolation from an obstructed cesspool but also after the effects of such percolation had been to a great extent removed by improvements in the drains and repeated emptying of the well.

The contamination of the water in the well in Broad Street by filtration from a cesspool during the time of the cholera outbreak is rendered certain by the result of Mr. York's investigations made in April, for the condition of matters then revealed must have been of some duration. Nor is there anything wholly without parallel in these disclosures; 17 years ago this same cesspool was opened on suspicion of contaminating the well-water, and the suspicion proved to be correct. Many years ago closet soil was found running down the sides of the well in Warwick Street; gas has been detected in the Tichborne Street and Bridle Lane wells, and enormous quantities of black beetles were found in the well (since closed) in Marylebone Street.

The gross impurity of the water from the pump in Broad Street being fully established, it is equally true that it was in great repute through the neighbourhood for drinking purposes. Its use, indeed, was very general, from choice on the part of some, from necessity on that of others, as their own cisterns were foul and the water in them was liable to get heated and decomposed. It is remarkable that pump water so impure was so much liked; this might be partly explained by its low temperature, by the quantity of carbonic acid contained in it, and by the saline matter preventing its decomposition until after it had free access to the air; but evidence exists to show that when so exposed for a few days it became offensive, even in a few hours it lost its freshness.

It was Dr. Snow who first endeavoured to trace out a relation which, from previous researches in other quarters, he supposed might exist between the use of this well and the cholera outbreak in the surrounding districts. The result of his laborious inquiry was in favour of that supposition. Mr. Whitehead, entertaining at first adverse views, ended his special investigation of Broad Street by a remarkable confirmation of Dr. Snow's numerical results. For full particulars as to these two independent investigations reference must be made to their respective reports, which are inserted hereafter. A careful perusal of them is here recommended.

It is shown by Dr. Snow; 1st, that the outbreak, properly so called, was principally confined to the area about Broad Street pump. 2nd, that 61 out of 73 persons who died during the first two days had been accustomed to drink the pump water constantly or occasionally. 3rd, that the water was used in various other ways, and might so have been taken in cases where its use in the ordinary way could not be distinctly traced. 4th, that in the workhouse where the well-water was not used, only five deaths occurred, whereas 50 would have been a ratio proportionate to that of the neighbourhood around. 5th, that in a factory employing 200 people, where the water was drank daily, 18 people died. 6th, that 70 men employed at the brewery in Broad Street never drank the water and escaped cholera. 7th, that in a number of individual instances which were particularly investigated, the drinking of the water was followed by cholera; in one case a lady living quite away from the district who had the water sent out to her, died after drinking it; her niece also died under the same circumstances. 8th, that at any point decidedly nearer to another pump the mortality from cholera as a rule ceased; and that, in an inquiry extending over 48 fatal attacks which took place nearer to another pump, many apparent exceptions were found to be cases of death in persons who really had a preference to the more distant Broad Street water. 9th, that in a particular street containing 14 houses, the only four which escaped without a death were those in which the Broad Street water was never drunk. 10th, that this water was employed for drinking purposes only, and was used cold; a statement which we may so far anticipate as to say is confirmed by the experience of Mr. Whitehead, who met with but a single exception to this rule. From all these several facts Dr. Snow is of opinion that although the early cases of cholera and the later cases were due to some other mode of diffusion, the outbreak between the 31st August and the 10th September was attributable to the well-water as the medium of dissemination of the cholera poison. He believes, moreover, that the well-water must have been not merely generally contaminated by cesspool drainage, but specially with the evacuations of a cholera patient.

Mr. Whitehead's investigation of Broad Street shows: 1st, that of 90 fatal attacks among its resident population, 84 took place between 31st August and 6th September; 56 between 31st August and 2nd September, and 50 on September 1st and 2nd. 2nd, that of the 90 deceased persons, 45 positively drank the water shortly before illness; and that of only 13 altogether is it at all confidently said that they did not drink it. Moreover, that of the above-mentioned 84 the non-use of the water asserted of only 8, and of the 56 persons attacked between 31st August and 2nd September, it is positively affirmed of only two that they did not drink this water. 3rd, that undoubtedly of 100 persons residing in Broad Street who were attacked with cholera or diarrhœa (including dead and surviving) 80 drank the water, whilst 20 are affirmed not to have drunk it; whereas, out of 336 persons living in that street and who were not attacked with either disease, only 57 had drunk the water, whilst 279 had not. 4th, that there is a great probability that the numerical proportions were even more remarkable than this, all cases involved in any doubt having been rejected. 5th, that in regard to the two factories situated next door to each other, both equally well arranged in regard to other sanitary conditions (see page 488) the workmen of one in which the mortality was high had the water for drinking purposes, whilst those of the other never drank it, and entirely escaped, the former fact being strengthened by the circumstance that the family of the proprietor never used the water and did not suffer. 6th, that in addition to the contrast pointed out by Dr. Snow as regards the exemption from cholera, on the part of the 70 men employed at the brewery where the water was not drunk and the amount of suffering amongst the 200 persons engaged at a neighbouring factory where the water was drunk—a contrast even more remarkable is found between the workmen of this brewery, and those engaged on the closely adjoining unfinished lodging-houses called Ingestre Buildings, for amongst these latter the water was in use and cholera proved fatal to 7 out of 35. 7th, that of 97 people residing in 10 houses in which no attack occurred 87 did not drink the water at all, whilst the remainder did not drink it during the height of the outbreak, or drank it either in small quantities or mixed with spirits. 8th, that in a great number of particular instances narrated at length in Dr. Snow's report, pages 136 to 145 (paragraphs 4 to 15), the evidence of an injurious influence exercised by the water becomes more strict and searching. 9th, that the want of good sanitary arrangements in certain houses operated by compelling the residents to resort to the pump for drinking water, and that on the contrary in certain instances where the drains were in good order, the cisterns were clean, and the inhabitants did not send to the pump.* 10th, that through the district generally the aged and infirm when isolated escaped, not merely because they had more house accommodation, but because they did not use the water, having no one to send for it. 11th, and lastly, that on looking beyond Broad Street to certain cases at a distance from the pump a remarkable amount of evidence still presents itself in support of the facts observed in its immediate vicinity.

Not guided, however, by individual instances, but viewing the accumulated evidence of which the preceding is but a brief abstract, one is unable to avoid the conclusion that there existed some connexion between the use of the well-water in Broad Street, and the subsequent suffering of the neighbourhood from cholera.

The well-established exceptional cases mentioned by Dr. Snow and Mr. Whitehead as opposed to this conclusion, are comparatively few, and appear insufficient to neutralise the general result.

It is remarkable that of the two suppositions, first, that the air alone, and secondly, that the water more especially was concerned in exciting the disease, whilst the former appears less and less equal to explain individual cases, in proportion as these are examined more and more in detail, it is precisely in the variety and exactitude of its particular application to individual facts that the latter finds its most positive support. Moreover, in estimating the value of the facts put on record by Dr. Snow and Mr. Whitehead, it must be remembered that the former seized the important advantage of an early inquiry, and that the latter balanced the disadvantages of delay by his previous knowledge of the district, the people, and the outbreak, and by the gradual and cautious character of his investigation. It must also be borne in mind that the weight of both positive and negative evidence appears to be clearly and unmistakeably in one direction, viz., to show that the water had some preponderating influence in determining an attack. If it be supposed that the drinking of the Broad Street water by those who died was a mere coincidence dependent on, and to be expected from the fact that so many persons in the neighbourhood, especially in Broad Street, constantly drank it; it must be remembered that this fact of coincidence also bears with greater force on any mere atmospheric hypothesis; for whereas of those in Broad Street itself who during the great outbreak coincidently breathed the air, one only in ten died, on the other hand, of the coincident water-drinkers who of course were fewer in number, a much larger proportion was fatally seized. If some idiosyncrasis or resisting power be assumed to explain the escapes amongst the air-breathers, it must equally be admitted in aid of those of the water-drinkers who did not suffer, and it is obvious that the demands upon so unsatisfactory an explanation are much smaller in the latter than in the former case. If it be urged in explanation of an atmospheric influence, that cholera might be conveyed exclusively to some by a partial distribution of an impure air, it may be replied that no consideration of the streets, local levels, sewer grates, house drains, or direction of the wind will explain the existence of such partial atmospheric impurity, whereas the individual use of the water has been actually traced and its consequences may be not unreasonably inferred.

Anxious to give due weight to every fact and consideration that have offered themselves in this inquiry, the Committee is unanimously of opinion that the striking disproportionate mortality in the "cholera area" as compared with the immediately surrounding districts, which to quote the words already used at the commencement of this section of the report, constitutes "*the sudden, severe, and concentrated outbreak*," beginning on August 31st, and lasting for the few early days of September, was in some manner attributable to the use of the impure water of the well in Broad Street.

* In regard to four out of the six houses in Marshall Street, mentioned in p. 67, it has been positively ascertained that this was also the case. The then occupiers of the other two are now beyond reach.

In this conclusion the Committee finds support from the gradually accumulating evidence collected in other localities as to the important influence of contaminated water in increasing cholera, especially in the districts of the metropolis lying south of the Thames, wherein, as stated by the Registrar-General, "the balance of mortality is heaviest in "every district and in every week against the impure water "to an extent that leaves little room for doubt on the "mind." Moreover, alluding to the Registrar-General's inquiries, Dr. Sutherland has remarked, "it is difficult to "resist this statistical evidence of the predisposing effect "of the Battersea water, and of the loss of life which has "arisen from its use."

It will presently be discussed what may have been the manner in which the water from Broad Street produced its effects.

Hypotheses concerning the Outbreak.

The attentive observer of the history and accompanying circumstances of this remarkable cholera outbreak will readily trace in its principal features, with all its apparent anomalies and enigmas, an epitome of those wider visitations which have spread over large areas. For some time it probably will form a convenient arena within which the advocates of different hypotheses concerning the cause and mode of diffusion of the disease will find abundant materials for scientific disputation.

We may here briefly glance at the leading elements of such a discussion.

In the first place, the generally received opinion that the unknown cholera agent is material rather than dynamical, a poison rather than atmospheric, terrestrial, or electric influence, is strongly supported by the phenomena of this outbreak; for the affected district stood alone in its intense suffering, although embraced on all sides by closely-populated neighbourhoods which almost escaped; and no such influence could well be imagined to confine its operations to so small an area, overleaping or avoiding the surrounding people. On the contrary, all the facts seem to point to the introduction, importation, or invasion of a *material agent*, either gaseous, liquid, or solid, having specific poisonous properties.

Secondly. Supposing such a morbific material to exist, it would seem very unlikely that the total quantity necessary to produce such direful results as to destroy in three days more than 500 persons within so narrow a circle could have been conveyed at once, and as such, into the district by imported articles of either food or drink, both of which are distributed to the inhabitants not by exclusive arrangements but in common with surrounding parts. Neither could this *total* quantity well be conceived to have been carried to the devoted spot by atmospheric currents without leaving more evident traces of its passage over the neighbouring people, from whatever quarter it might have proceeded. On the contrary, all things favour the idea of its having been introduced in small quantity, and then having been *multiplied* within the cholera area itself.

Thus far inference is tolerably clear. Now, however, uncertainty begins, for, in the third place, the nature of this hypothetical material agent is absolutely unknown, whether it be organic or inorganic itself, living, decaying, or altogether unendowed with life.

Fourthly. Whether its multiplication, evolution, or growth takes place in favouring conditions externally to the human body and then its influence is exerted upon susceptible persons, or whether it is conveyed to the body in minute quantity, multiplies solely within it, and thus give rise to the phenomena of the disease, or whether its increase may take place both within and without the body, are questions involved in controversy, to which at present no one can satisfactorily reply. The first view, that of external multiplication, is the one most generally entertained; the second, the doctrine of internal development, has two modifications, one in which the poison is supposed to multiply exclusively in the blood by a true zymosis, the other, advocated by Dr. Snow, which supposes the increase to take place only on the internal mucous surface of the alimentary canal. The mixed hypotheses would, of course, include various combinations of these opinions.

Lastly, concerning the mode in which the morbid agent reaches the human body and enters into and acts upon its complex apparatus, differences of opinion also prevail, and the whole question is still undecided. It may be conveyed in the air we breathe, enter the system by the lungs, and so act as a poison in the blood, and this, whether it be developed only externally to the system or solely within it. On Dr. Snow's hypothesis, it enters in small quantity by the alimentary canal, and there alone developing itself originates its poisonous effects. On the mixed hypotheses above suggested the poison multiplying externally may be supposed to enter by the lungs and increase still further in the blood, or multiplying externally may gain access to the digestive organs and undergo further development therein.

Reverting now to the entire range of circumstance connected with the particular eruption of cholera now under consideration, we find, that the elevation and soil of the affected district are favourable to health; that overcrowding with its concomitant disadvantages was rather more marked than in adjacent districts; that local circumstances connected with the sewerage under the influence of peculiar and temporary meteorological conditions, may have caused a special impurity in the air; that the public water supply could not be accused of exercising any pernicious effects; lastly, that the well-water used for drinking was without doubt excessively impure.

Looking abstractedly at the possible media by which the cholera agent might be rapidly diffused beyond the limits of a household through an area so large as the affected district of St. James's, we are practically limited to two, viz., air and water, for solid bodies, such as food, clothes, or living domestic animals could not have formed adequate vehicles for its transmission; and its direct conveyance from person to person in the strict sense of contagion is a wholly inadmissible supposition. In this particular instance, reasons have already been given for believing that the explanation which refers this singularly sudden and severe explosion chiefly to the use of the impure drinking water is more conformable to the facts than that which refers it to atmospheric influences only. In what way then did this water operate? As the vehicle of a predisposing, an accessory, a collateral and specific, or a simple specific agency? Various hypotheses may be entertained.

1. The undeniably impure well-water, impregnated with matters from the cesspool and the soil, may have acted, not specially, but only as a predisposing cause of the outbreak by occasioning a gradual deterioration in the health of those who drank it, or a more sudden change in the condition of their fluids, either of which may have rendered them more liable to the invasion of the disease or less able to resist it if attacked; or the water acting as an accessory cause may directly have enhanced the activity or aggravated the effects of the real morbific agent.

In either case the true cholera agent or special cause of cholera would be supposed to be conveyed through the air, being generated solely under favouring conditions, *on surfaces exposed to the air* or *in the air itself*, previously rendered impure by exhalations from sewers, cesspools, masses of filth, or the human body; or being developed solely in the bodies of persons predisposed to the disease, or being increased *in both ways*.

2. The water may have acted collaterally and specifically by yielding something necessary to the development, disengagement, or operation of the true morbific agent; in a word, as the vehicle of one of a series of coefficients indispensable to the production of the disease.

On this hypothesis one or more equally necessary coefficients may have been conveyed through the air or by means of food, or might exist or be produced in the bodies of persons who were to be attacked.

Cases not traceable to the water may have been due to the combined action of the same coefficients conveyed in other media.

3. The water may have played a more direct part as the vehicle of a specific poison, and this in various ways.

a. Thus, as Dr. Snow believes, such poison may have entered it in the evacuations of some patient who had cholera or choleraic diarrhœa immediately attendent to the great outbreak, the poison being supposed thus to have been conveyed in minute quantities from one person to many, and then to have been multiplied *in their bodies* in contact with the alimentary mucous membrane.

Cases not traceable to the water he supposes to be due to some other mode of introduction of a minute quantity of the poison in the digestive tube, and its subsequent and sole development there.

b. Another mode in which the water might act as a medium for the transmission of a poison would be both by contamination of the well by a special agent in the intestinal or urinary excretions from a patient labouring under cholera or choleraic diarrhœa, and by subsequent multiplication or development *out of the human body as well as in its interior*, as for example, in the contents of the cesspool or in the impure water itself, with which latter it would then be distributed.

c. Again, without supposing the existence of any special poison in the cholera evacuations, the water of the well in Broad Street may have become impregnated by the cholera agent in another way, and so have become the vehicle of its transmission. Thus the cholera poison being multiplied by chemical change or organic growth, *external to the human body only*, may have reached the cesspool in the area of the house close to the well, either through the general atmosphere or through the sewer atmosphere, and may then have established itself and multiplied under favouring conditions of stagnation and high temperature either in the atmosphere of the cesspool, or on the surface of the impure accumulations in it, and have been finally washed over into the well by fluids cast into the cesspool at the time.

d. Lastly, the same processes might occur as are supposed in the last hypothesis, with the addition that having so gained access to the well the poison may have further increased or multiplied previous to its distribution in the impure well-water itself.

On either of these last three suppositions, cases not traceable to the water might be supposed to be produced by the contamination of other fluids or of bad food by some portion of the poison, gaseous, vaporous, or in dry particles, thus inhaled or swallowed into the stomach.

Other ways yet may be conceived in which the water of the well in Broad Street may have become impregnated with a specific poison capable of producing cholera, or may have indirectly contributed to determine an attack.

The Committee refrains, however, from expressing an opinion in favour of any hypothesis of its mode of action.

Two questions deserve some attention, viz., the nature of the contamination of the well-water and the relation of the local outbreak in St. James's to the general epidemic throughout the metropolis.

Nature of the contamination of the Well-water.—At the time of Dr. Snow's inquiry in the early part of September 1854, and indeed up to April 1855, when Mr. Whitehead's investigation was complete, the entrance of sewer or cesspool drainage into the well in Broad Street was not proved. All the evidence was to the opposite effect. Subsequently, however, as already explained, the basement of the house, No. 40, was found to have atmospheric connexion with the street sewer and the cesspool to be so choked and defective as to have allowed percolation into the soft black soil around and thence into the well itself.

Beyond this it is proved by the statements of Mr. Whitehead and Dr. Rogers that diarrhœa had affected certain inmates of that house just anterior to the cholera outbreak, and in particular it is pointed out by Mr. Whitehead that the great outburst followed immediately after there had been thrown into the cesspool, on the 28th, 29th, and 30th August, considerable quantities of water containing the diluted dejections of an infant who is registered as having died on the 2nd September of exhaustion after diarrhœa. Although singularly enough this case is published by the Registrar-General among the cholera deaths, there is necessarily a doubt as to the real nature of the attack. On the one side the previous history of the child, the presence of only certain symptoms, and the opinion of Dr. Rogers, the medical attendant, have great weight, whilst on the other it must be noted that cholera symptoms are rarely well marked in the young, and that the diarrhœa which prevails during a cholera epidemic is now generally admitted to be choleraic, and due to the same cause as cholera itself. There was, moreover, some probability that a child already prone to infantile diarrhœa might become the victim of a choleraic seizure.

Unfortunately no microscopic examination of the water was made earlier than September 3rd. On that day it was found by Dr. Snow to contain minute whitish flocculi, described by Dr. Hassall as destitute of organisation; it also contained some oval animalcules, but no portions of digested food are mentioned. Six weeks later Dr. Lankester discovered in it living and dead vegetable and animal organisms, together with shapeless débris.

It is evident, therefore, that microscopical and chemical analysis only confirm the matter-of-fact existence of much organic as well as inorganic impurity in the water, and that neither scrutiny has served to detect anything which could be pronounced peculiar to a cholera period or capable of acting as a predisposing, co-operating, or specific agent in the production of that disease. But this need not excite surprise, for although the dangerous character and serious influence of impure water in increasing the mortality from cholera in other localities is now unquestionable, no ingredient to which any special action could be assigned has yet been detected in such water by the most refined appliances of scientific research, nor, indeed, in regard even to the atmosphere itself during the cholera epidemic has the strictest investigation hitherto led to any satisfactory revelations.

If, however, we may found an argument upon the fact that other well-waters in the same neighbourhood containing much the same recognisable organic and inorganic impurities, did no harm, and that the Broad Street water itself in 1832 and 1849, when it was probably also extensively used for drinking, and must have been charged with very similar general impurities, produced no perceptible deleterious effects, we may admit the possibility that its apparently fatal influence in determining the brief but severe explosion last autumn was owing, not to a general impurity, but to the contemporary existence of some special contamination.

Relation of the local outbreak in St. James's to the general Epidemic throughout the Metropolis.—It is quite unnecessary to look beyond the cholera area of St. James's and St. Anne's to perceive that the well-water in Broad Street was not in all cases the means by which a choleraic seizure was determined; for, as already stated, there were persons within that area who died of cholera without having drunk the water,—some before, some after, and some during the great outbreak.

The occurrence of such independent cases is an important incident in the local visitation; but the questions suggested by them merge in the consideration of the general mortality throughout the metropolis, away from the neighbourhood of Broad Street altogether.

From the fact, more than once alluded to in this Report, that the height of the local outbreak in St. James's corresponded with the period of greatest mortality throughout the rest of the metropolis, it has already been inferred that probably some general conditions were at work simultaneously influencing the operation of the cholera agent throughout all London, and hence it follows that any conclusions arrived at concerning this local outbreak require to be checked or tested by a reference to the phenomena of the general epidemic. Rightly to employ this test, however, would demand, what is now quite unattainable, a uniform investigation of the whole metropolitan cholera field.

A comparison of the daily deaths in all London with those in St. James's and St. Anne's would illustrate the characters of suddenness and severity in the local outbreak even more forcibly than the weekly returns contrasted in the table at p. 486.

The simultaneous occurrence of these local outbreaks itself points to some general favouring condition, subject, however, in ways perhaps not always recognised, to certain much more directly influential local circumstances. Hence, although it is most unphilosophical to reject the broad conclusions founded on the study of a widespread epidemic, it is equally so to disregard such more limited deductions as may be derived from the investigation of a local outbreak, or to refuse the light which these latter may perchance reflect on the varied and often perplexing phenomena of a general visitation.

RECOMMENDATIONS OF THE COMMITTEE TO THE PAROCHIAL AUTHORITIES.

In making the following recommendations which naturally flow from the conclusions established in the preceding Report, the Committee cannot omit to remark that whilst the sanitary advantages of the parish of St. James's are mainly due to natural circumstances, the disadvantages are artificial and removable. The Committee is of opinion,—

1. That in carrying out any future improvements, or in making any public alterations in the parts of the parish affected by cholera last year, care should be taken to remember the importance of opening more direct lines of communication between several of the streets and of getting rid where possible of streets or courts closed at one end.

2. That the building of model lodging-houses be still encouraged in place of the existing residences for the families of working men.

3. That efforts be made to abolish slaughter-houses, cow-sheds, grease-boiling houses, store-houses for bones, and other offensive places of business from this and all other inhabited districts.

4. That attention should be frequently called to the state of the public sewer, especially near to any slaughter-yard or cow-shed, and also generally in very dry weather to the condition of the small or feeding sewers, and that means should be provided for flushing them when necessary. That such alterations as that suggested by Mr. York by which he proposes to convey a large supply of surface water into the lower end of Marshall Street sewer should be encouraged and carried out.

5. *That not only on the ground of their liability to special contamination, but from the fact of their constant habitual and unavoidable impurity, the surface wells of the parish be no longer allowed to be resorted to for drinking purposes.*

The Committee is even prepared to recommend that these wells be closed altogether, and that stand-pipes connected with the water mains be erected at certain places for public use.

The Committee would further impress upon the parochial authorities the desirableness of again reviving the discussion as to the propriety of sinking one or more artesian wells for the entire supply of the parish.

6. *That as a first duty, strenuous efforts be made to realise the long talked-of abolition of cisterns and the introduction of the method of constant supply.*

7. That a medical inspector of the parish be appointed, by whose aid important information would be continually collected, and the sanitary condition of its over-crowded portions incessantly watched, and whose duty it would be to forewarn the authorities of the existence of causes calculated to be detrimental to health, which under existing arrangements lie dormant or accumulate to produce some unexpected and overwhelming calamity. The position and duties of such an officer would enable him to teach the poorer inhabitants many useful lessons on matters relating to private and public health, and to discover and remedy many unsuspected causes of individual and public disease.

8. That a list or code of sanitary instructions be drawn up and printed for periodical distribution amongst the inhabitants of the parish.

Sub-Committee.
EDWIN LANKESTER, M.D., Chairman.
HENRY BIDGOOD.
RICHARD KING, M.D.
JOHN MARSHALL, F.R.C.S., Reporter.
HENRY WHITEHEAD, M.A.

25th July 1855. JEHT. YORK, Secretary.

APPENDIX No. 11.

THE WATER SUPPLY TO COUNTRY DISTRICTS.

COUNTY OF GLOUCESTER.—COALEY INCLOSURE.

College Green, Gloucester,
SIR, March 25th, 1874.

IN reply to your inquiries I beg to furnish you with the following information with regard to the water supply in the parish of Coaley.

The parish consists of about 2,463 acres, extending in length about 3 miles, from the brow of the Cotswold Hills, very nearly to the river *Severn*—the soil for the most part is Lias Clay and the water in the wells is brackish. The cottage inhabitants derived their chief supply of water for all purposes, from a brook which runs from the hills through the entire length of the village, and in its course receives many contaminations from drains, pigsties, &c.

In the year 1865–66, many cases of fever occurred, which the medical officer of the district considered were clearly traceable to the impure state of the water. Meetings of the landowners and inhabitants were held to consider the matter, and it was first debated whether a system of sewers, &c. should be provided, but it was ultimately decided that a good supply of pure water would be the best remedy for the evil.

There being on the hills, at the east end of the parish, a never-failing spring of pure water, in a field belonging to Lord Fitzhardinge, an application was made to his lordship for permission to utilise it, to which he kindly consented; and it was also decided to take advantage of the powers given by the Inclosure Acts, and to carry out the work under the inclosure of the waste and commonable lands in the parish, then about to be commenced.

Up to this stage the proceedings were entirely voluntary on the part of the landowners.

A meeting of the persons interested in the inclosure was held on July 6th, 1866, before N. Wetherell, Esq., an Assistant Inclosure Commissioner, at which meeting I had the honour of being appointed the valuer to act in the matter of the said inclosure; and the following resolution was passed as one of the instructions to the valuer; viz., "That "the valuer shall make for the use of the parishioners "sufficient watering places on such parts of the waste land "as shall be most convenient, and shall for this purpose "conduct to such places the water from other parts of the "lands to be inclosed, and shall erect there pumps or such "other engines as he shall find necessary for the convenient "user of the water."

The Inclosure Commissioners allowed the foregoing resolution.

A specification and plan were prepared by Mr. W. McLandsborough, C.E., of Cheltenham, and submitted to a meeting of persons interested, when it was resolved that the specification settled by the meeting should be adopted, and tenders advertised for.

The works consist of a receiving tank or reservoir at the spring head; from the tank the water is conveyed in cast-iron pipes in a nearly straight course through the parish, the line taken being in part the waste land by the side of the main road or street which was part of the land to be inclosed.

Stand-cocks or water-pillars are fixed in the most convenient situations, regard being had to the different centres of population.

The works were carried out under the direction of Mr. McLandsborough, C.E.

The costs amounted to about 750*l*. and were defrayed by rate levied on the persons claiming under the inclosure.

The annual cost of supervision and maintenance does not exceed 12*l*.

I remain, Sir, &c.
(Signed) JOSIAH CASTREE, Junr.

The Secretary to the
Rivers Pollution Commissioners,
1, Park Prospect, Westminster.

EXTRACTS from REPORT from SELECT COMMITTEE of the HOUSE of LORDS on IMPROVEMENT of LAND MINUTES of EVIDENCE taken on the 2nd of May and 24th of June 1873, pp. 42 and 348.

Mr. George Ridley, one of the Inclosure Commissioners, examined by the Chairman.—There is another thing arising out of a question which was put to me by a noble Lord, which I should like to mention to the Committee. If any alteration is made in the present legislation, there is another thing that I should like to have inserted in the definition of improvements, namely, the power of providing supplies of water.

391. For all tenants on the estate?

Yes, in some cases we do that, of course, now. If a farm house is being erected, we inquire about the water supply. The words in the Act are, "which will increase the agri-"cultural value of the land," but I think that that might be a very proper extension of the powers as a portion of a sanitary measure. I think that in any Sanitary Act that may be passed, a provision of that kind should be inserted, making the providing of water an improvement under the Act of 1864, just as they have put into one or two other general Acts, the Public Health Act of Scotland, and our own, a provision that the works for the distribution of sewage to increase the agricultural value of lands, shall be deemed to be improvements within the Act of 1864.

392. Then, for that purpose, it would be necessary to include towns under the Act of 1864, because it is mainly in towns that this particular improvement is required, is it not?

I can assure your Lordship that I think it is sometimes required in country districts. There are many villages where the supply of water is deficient, and I think it would be an improvement if our powers were extended to such cases; I venture to make that suggestion.

James Caird, Esq., C.B., one of the Inclosure Commissioners examined by the Chairman.—4158. Are there any points in which you think the Acts are capable of amendment, beyond those which you have already specified?

My colleagues, Mr. Darby and Mr. Ridley, with myself have talked the matter over, and we would suggest that in the case of charges for the supply of water to a village for sanitary purposes, it would be very advantageous, where the village belongs to an estate, that it should be included in the objects of the loan, the improvement being one that is for the convenience of the agricultural labourers resident on the estate.

4159. Would that include the convenience of other persons besides those resident on the estate?

Probably you could hardly make it a charge upon the estate where other persons were resident in the village, and therefore I should say where there were other persons not resident on the estate, the portion of the expenditure due to them must be excluded from the loan; then the storage of water has become more important the last two or three years, owing to the great difficulties which have been found in two dry seasons following each other, and I think it would be very well to make the storage of water one object for which improvements might be charged.

APPENDIX No. 12.

On the ANALYSIS of POTABLE WATERS.—By Dr. E. FRANKLAND, F.R.S., and H. E. ARMSTRONG, Esq.

Reprinted from the Journal of the Chemical Society, Vol. 21, p. 77.

ALTHOUGH the analysis of potable waters has received no inconsiderable amount of attention, the subject is surrounded with such formidable difficulties, that, at the time we undertook its investigation, it was generally regarded as one of the least satisfactory of analytical operations. The difficulties concentrate themselves chiefly upon the determination of the organic matters contained in all potable natural waters, and of the mineral compounds derived from the decomposition of these organic matters, viz., nitrous and nitric acids, and ammonia; the processes used for the estimation of the remaining mineral ingredients leaving little to be desired.

In the year 1856 Hofmann and Blyth* drew attention to the defects of the processes then in use, and showed that the loss experienced on ignition by the solid residue of a water could be made more nearly than before to represent the organic matters, by excluding from this loss ammoniacal salts, moisture, and hydrochloric acid, an improvement which they effected by the addition of a known weight of sodic carbonate to the water before evaporation. These chemists also pointed out the great desirability of determining the amount of nitrogen entering into the composition of the organic matters contained in waters, although they did not succeed in devising any process by which this could be accomplished. In 1864 Weltzien† described a new process for determining the amount of nitric acid in waters by the ignition of the water-residue with finely divided metallic copper. He also employed, for the first time, a process for the estimation of organic carbon, which consisted in acidulating the water with sulphuric acid, evaporating to dryness, and then igniting the residue with cupric oxide, as in an ultimate organic analysis. It is obvious, however, that this latter process could only make a distant approach to accuracy, because the sulphuric acid would not only expel volatile organic acids if present, but, by liberating nitrous and nitric acids, could scarcely fail to cause the oxidation and loss of other forms of organic matter. Nevertheless, Weltzien's memoir on the well waters of Carlsruhe is one of the most important contributions ever made to this branch of analysis.

In the following year W. A. Miller‡ gave an elaborate *resumé* of the processes which he considered to be most worthy of confidence, together with some important modifications and valuable suggestions; and in the same year Dr. Angus Smith§ recommended and described certain modifications in the use of potassic permanganate in the examination of water for sanitary purposes.

In the monthly examination of waters supplied to London, one of us had frequently occasion to notice the serious imperfections which still attached themselves to the best processes of water analysis hitherto employed for the determination of the organic matter and of the products of its decomposition. Since the autumn of 1866 we have been occupied with the critical examination of these processess, and with attempts to place this branch of chemical analysis upon a more satisfactory basis. In laying the results of our inquiries before the Society, it will be most convenient first to discuss the merits of the processes in general use up to the commencement of our investigation, and then to describe the method of analysis which we now venture to recommend in dealing with the particular class of constituents above mentioned.

The following is a list of the determinations which are usually made in the so-called partial analysis of potable waters, and which have been submitted by us to examination:—

1. Estimation of total solid constituents.
2. Estimation of organic and other volatile matter.
3. Determination of amount of oxygen required to oxidize the organic matter.
4. Estimation of nitrous and nitric acids.
5. Estimation of ammonia.

We will examine these seriatim.

I. *Estimation of total Solid Constituents.*—This operation is usually performed by evaporating a given volume of the water to apparent dryness, with a known weight of sodic carbonate, upon a steam bath; and, as the residue so obtained is generally employed for the determination of the organic and other volatile matters expelled on ignition, it is dried at 120°—130° C., before being weighed. This process involves two errors; in the first place the salts of ammonia are decomposed by the sodic carbonate, the ammonic carbonate formed being expelled during evaporation; and, secondly, urea, if present in the water, is slowly decomposed during evaporation with sodic carbonate, ammonic carbonate being expelled. The loss of weight in the solid residue arising from the latter cause is seen from the following determinations:—

I. 1·505 grm. sodic carbonate, and ·038 grm. urea, were dissolved in 1 litre of distilled water; the solution was evaporated on the steam-bath, and the residue dried at 100° C. The latter weighed 1·526 grm., showing a loss of ·017 grm., or 44·7 per cent. of the urea employed.

II. ·1 grm. sodic carbonate, and ·05 grm. urea, on being similarly treated, left a residue which weighed ·1205 grm., showing a loss of ·0295 grm., or 59 per cent. of the urea present.

It is difficult, if not impossible, entirely to avoid this loss, but it is much lessened by omitting the sodic carbonate, and drying the residue at 100° C. By this modification of the process, the elements of water which would be expelled at 120°—130° C. are sometimes retained in the residue, but as such water is in chemical combination, it may be fairly said to belong to the solid constituents. It is only in the residues of waters containing much calcic and magnesic sulphates and chlorides that the weight of the elements of water so retained is considerable. Its small amount in the case of Thames water is seen from the following determinations made upon three different samples:—

	Solid residue dried at 100° C.	Solid residue dried at 120°—130°C.
100,000 parts of Thames water gave	27·02 pts.	26·54
100,000 " "	26·70 "	26·20
100,000 " "	26·10 "	26·02

II. *Estimation of Organic and other Volatile Matter.*—This determination is effected by the gentle ignition in contact with air, of the solid residue obtained by evaporation and subsequent drying at 120°—130° C., as above described. After being allowed to cool, the residue is repeatedly treated with a saturated solution of carbonic anhydride in water, until, on being again dried at 120°—130°, it ceases to gain weight. The loss in weight experienced by a water residue on incineration, although now no longer regarded as an exact ponderal expression of the organic matter present in the original water, is yet considered by many chemists to afford at least an approximate indication of the amount of organic impurity. How far any reliance can be placed upon it in this respect may be

* Report to the President of the General Board of Health on the Metropolis Water Supply, by Hofmann and Blyth.
† Ann, Chemieu. Pharm. cxxxii, 215.
‡ Journ. Chem. Soc., vol. xviii, p. 117.
§ Estimation of Organic Matter in Water, by R. Angus Smith, Ph.D., F.R.S., 1865.

judged of by the consideration of the following sources of error which we have found in the examination of this process. We have already shown that urea, when present in water contaminated with sewage, is partially dissipated during evaporation with sodic carbonate; thus a portion of the organic impurity of a water may be lost before the determination of the "organic and other volatile matter" is made, but this error is still further increased in the case of urea, and probably also in that of other nitrogenous organic compounds, by the impossibility of expelling the whole of the organic matter on ignition, as is seen from the following experiments :—

I. A water-residue consisting of ·997 grm. sodic carbonate, and ·0205 grm. urea, lost on ignition ·003 grm.

II. A water-residue consisting of 1·542 grm. sodic carbonate, and ·039 grm. urea, lost on ignition ·011 grm.

III. A water-residue consisting of 1·505 grm. sodic carbonate, and ·038 grm. urea, lost on ignition ·016 grm.

The results of these experiments may be thus expressed :—

	I.	II.	III.
Percentage of organic matter expelled on ignition	14·6	28·2	42·1
" " " left in residue	85·4	71·8	57·9

It is probable that the organic matter left in the residue is in the form of sodic cyanate or cyanurate.

Another source of error which we have repeatedly encountered in the use of this process consists in a continued increase of weight by successive treatments of the incinerated residue with an aqueous solution of carbonic anhydride, until in some cases the weight of the incinerated residue even exceeds that which was observed before incineration. This remarkable phenomenon does not arise from any solid residue left by the solution of carbonic anhydride itself, because this source of fallacy was carefully eliminated, and moreover it occurs only with particular samples of water, but with these samples it is always observed when the determination is repeated. It occurs also in an equal degree when a solution of ammonic carbonate is substituted for one of carbonic anhydride. It is difficult to account for this increase in weight, but, when it occurs, the determination of the loss by ignition becomes impossible, because the analyst does not know when to discontinue the treatment of the residue with solution of carbonic anhydride. These facts show how difficult it is to interpret the meaning of the loss on ignition experienced by a water-residue; it may arise entirely from organic matter, or it may be exclusively due to the dissipation of mineral ingredients. On the one hand, there may be much more organic matter in a water than is represented by the total loss on ignition, indeed, we have not unfrequently observed in the analysis of waters, greatly contaminated with sewage, that the loss on ignition has actually been considerably less than the weight of the carbon alone contained in the organic matters. On the other hand, this determination may indicate the presence of a considerable amount of organic matter in a water which is wholly free from it. All that can be inferred from the loss on ignition is that, when it is large, the water is probably contaminated with animal or vegetable organic matter, or has been previously in contact with decaying animal matters.

III. *Determination of amount of Oxygen necessary to Oxidise the Organic Matter.*—The uncertainty which surrounds the determination of the organic and other volatile matter by the ignition of the dried water-residue, has led to attempts being made to estimate indirectly, by means of potassic permanganate, the amount of organic matter present in the water before evaporation. Potassic permanganate, when dissolved in water, readily yields oxygen to many substances capable of combining with this element; thus if it be added to water acidulated with sulphuric acid, and containing oxalic acid in solution, the latter is completely and rapidly converted into carbonic anhydride and water, at the expense of oxygen derived from the permanganate; and it is found that eight parts by weight of oxalic acid, in being thus oxidised, abstract almost exactly one part by weight of oxygen from the permanganate, the latter being converted into manganic sulphate. In undergoing this chemical change the rich violet colour of the solution of potassic permanganate, vanishes, and it is thus easy to ascertain, by the non-disappearance of the characteristic tint of the permanagate, when the oxidisation of the oxalic acid is complete. Now, a similar disappearance of colour occurs when the solution of potassic permanganate is added to an acidulated sample of potable water containing organic matter, and it has been assumed that, as in the case of the oxalic acid, the organic matter contained in the water is completely oxidised by the permanganate, which is thus thought to indicate the amount of oxygen required for this purpose. Dr. Letheby has even employed this reaction for the estimation of the *actual weight* of organic matter contained in a known volume of water, on the assumption that every eight grains of organic matter contained in a sample of water, rob the permanganate solution of one grain of oxygen. Such a method of ascertaining the actual amount of organic matter in a water, or even the amount of oxygen required to convert this organic matter into its final products of oxidation, would be invaluable on account of the extreme facility with which it can be applied; but, unfortunately, the further study of this process reveals its utter untrustworthiness.

By the addition of known weights of different organic substances to equal volumes of pure distilled water, the latter was artificially contaminated with a known proportion of each kind of organic matter. Every sample of water so contaminated was made to contain three parts of organic matter in 100,000. The amount of oxygen which this organic matter abstracted from the potassic permanganate was first carefully ascertained, and then the actual amount of organic matter present in the water was calculated, on the assumption that eight parts by weight of organic matter consumed one part by weight of oxygen from the permanganate. The same test was also applied to another sample of distilled water, from which all organic matter was carefully excluded, but to each 100,000 parts of which, three parts of sodic nitrite were added. The importance of the last experiment will be evident when it is remembered how frequently nitrites are present in potable waters. The amount of oxygen consumed was determined for two different periods of time, viz. :—First, for a period, at the end of which the acidulated and contaminated water remained tinted with permanganate for ten minutes after the addition of the latter; and secondly, for a period of six hours, during the whole of which time the permanganate was present in excess.

The results are contained in the following table, where they are compared with the known amount of organic matter present, and the known amount of oxygen, which that organic matter would require for its complete oxidation :—

1 Name of Substance, 3 parts of which were contained in 100,000 parts of water.	2 Oxygen absorbed in 10 minutes. (Experiment.)	3 Oxygen absorbed in 6 hours. (Experiment.)	4 Oxygen required to oxidize organic matter. (Calculated.)	5 Amount of organic matter present. (Calculated from Column No. 2.)	6 Amount of organic matter present. (Calculated from Column No. 3.)	7 Amount of organic matter actually present.
Gum arabic - -	·0102	·0350	3·55	·082	·280	3·0
Cane sugar - -	·0064	·0152	3·37	·051	·111	3·0
Starch - - -	·0143	·0302	3·55	·114	·241	3·0
Gelatin - -	·0792	·1836	6·76	·634	1·469	3·0
Creatin - -	·0080	·0172	6·59	·064	·138	3·0
Alcohol - -	·0093	·0164	6·26	·074	·131	3·0
Urea - - -	·0092	·0119	6·40	·074	·095	3·0
Hippuric acid - -	·0328	·0600	5·90	·262	·480	3·0
Oxalic acid, crystallised	·3747	·3750	·38	2·998	3·000	3·0
Sodic nitrite - -	·6910	·6913	0·00	5·521	5·530	0·0

From this table, it is seen that, of the nine kinds of organic matter operated upon, only one was completely oxidised by potassic permanganate, even after the lapse of six hours; whilst it will be remarked that urea, hippuric acid, and creatin—three organic substances likely to be present in water recently contaminated with sewage—suffer an oxidation which, even in the most favourable case, only reaches $\frac{1}{50}$th of complete oxidation; whilst if the attempt be made to calculate the amount of these substances present in the water, from the quantity of oxygen so absorbed, instead of finding three parts of each in 100,000 of water, we obtain only ·138 part of creatin, ·095 part of urea, and ·480 part of hippuric acid. On the other hand, the mineral salt, sodic nitrite, weight for weight, surpasses every form of organic matter experimented upon in the avidity with which it absorbs oxygen; and three parts of this inorganic substance in 100,000 of water would actually, by the mode of calculation above described, indicate no less than 5½ parts of organic matter. Thus it is evident, that for the estimation of the amount of organic matter in water, or the quantity of oxygen necessary to oxidise that organic matter permanganate of potash is utterly untrustworthy. The fallacy of the permanganate test has often been suspected, but it was imagined that, although not to be relied on for quantitative estimations, yet its rapid decoloration afforded positive evidence of the presence of organic matter in actual putrescence, and consequently in its most dangerous condition. We fear, however, that, even for this subsidiary purpose, the permanganate is not sufficiently trustworthy.

Fresh urine contains no organic matter in a state of putrescence, but, even when largely diluted, it decolorises the permanganate with almost the same rapidity as potassic nitrite. With all these defects, however, this re-agent may still be used in certain cases as a qualitative test where there is no opportunity for accurate analytical examination. Thus, if a clear and colourless water, decolorises much of the permanganate solution, the water ought to be rejected for domestic use as being of *doubtful* quality; for although such a water may be absolutely free from nitrogenous organic impurity, yet its decolorising action upon the permanganate would indicate with considerable certainty that it had been in contact with decaying animal matters. Should the water, however, instead of being colourless, be tinged of a yellow or brownish yellow colour, when viewed through a considerable stratum, as in a quart decanter, for instance, its capability of decolorising a considerable amount of permanganate solution ought not to be regarded with the same suspicion as a similar reaction with a colourless water, because the yellow tint of such waters is generally owing to the presence of peaty matter, which, though innocuous, has the power of decolorising potassic permanganate.

The depth of colour which a sample of water exhibits when viewed through a stratum some two feet in thickness has also been regarded as an indication of the amount of organic matter contained therein. It appears to be so regarded for instance by Dr. Letheby, who thus speaks of the use of this test:—"The oxidizable organic matter is "determined by a standard solution of permanganate of "potash, the available oxygen of which is to the organic "matter as 1 is to 8; and the results are controlled by the "examination of the colour of the water when seen "through a glass tube two feet in length and two inches "in diameter."*

The tinctorial power of many colouring matters is so great as to render them distinctly appreciable to the eye when their amount is far too minute to be detected gravimetrically; thus a litre of water distinctly tinted with ink or magenta, contains an amount of either of these colouring matters too small to be appreciated by the most delicate balance. The yellowish or brownish colour of water appears also to be of this character, for it may be removed completely by agitation with aluminic hydrate, and yet a considerable amount of organic matter is still left in the water. Thus a sample of water which had been so treated, and which exhibited the blue-green tint of distilled water when viewed through a thick stratum, still contained ·160 part of organic carbon in 100,000 parts. It is, therefore, evident that no reliance can be placed upon colour as an indication of the amount of organic matter in waters, for although a dark-tinted water probably contains a considerable amount of organic matter, it by no means follows that a colourless water may not contain even a larger proportion. Thus a sample of peaty water, possessing a decided brown tinge, contained but ·256 part of organic carbon in 100,000 parts, whilst a sample of water from North Wales, which had been in contact with the fine mud of the stamping engines of mines, was perfectly colourless, although it contained no less than ·544 part of organic carbon in 100,000 parts.

IV. *Estimation of Nitrous and Nitric Acids.*—The best process hitherto employed for this estimation is that proposed by the late Dr. Pugh. It depends upon the conversion of stannous chloride into stannic chloride in the presence of free nitric acid, whilst the latter is transformed into ammonia. The application of this process to water analysis has been described by Miller.† If nitrites be also present they may be converted into nitrates by the cautious addition of potassic permanganate to the water previously slightly acidified. The process is easy of execution and extremely delicate; but unfortunately, as Messrs. Chapman and Schenk have shown, stannous chloride is converted into stannic chloride by many organic substances containing oxygen, such as starch, sugar, &c. The following experiments prove that this effect of starch and sugar takes place to such an extent as to render the process entirely untrustworthy.

I. ·100 grm. starch was digested for 20 minutes in a sealed tube with 3 c.c. of stannous chloride solution, at a temperature of 170° C. Before digestion 3 c.c. of the same solution of stannous chloride required 17·85 c.c. of a standard solution of dipotassic dichromate to oxidize it. After digestion it required only 14·1 c.c. The oxidizing action of the starch was equivalent to that of ·00375 grm. of N_2O_5.

II. ·100 grm. sugar, similarly treated at 150° C., oxidised an amount of stannous chloride equivalent to 7·0 c. c. of the standard solution of dipotassic dichromate, corresponding to ·007 grm. of N_2O_5,

III. ·100 grm. starch, similarly treated at 150° C., oxidised an amount of stannous chloride equivalent to 4·2 c.c. of the standard dipotassic dichromate solution, corresponding to ·0042 grm. of N_2O_5.

IV. ·100 grm. starch, digested at 120° C., oxidised an amount of stannous chloride equivalent to 2·5 c.c. of the standard dipotassic dichromate solution, corresponding to ·0025 grm. of N_2O_5.

V. The last experiment repeated, with ·1 grm. of sugar instead of starch, at 120° C., gave results corresponding to ·0058 grm. of N_2O_5.

Experiments II., III., IV., and V. were made in order to ascertain whether the oxidising action of sugar and starch could not be prevented by operating at lower temperatures, but they show that these substances still oxidise very powerfully, even at a temperature below the minimum required, according to Pugh, for the performance of his reaction.

V. *Estimation of Ammonia.*—The determination of ammonia in potable waters is usually made by rendering the water alkaline either by baric hydrate or sodic carbonate, and then distilling off about one-fourth of its volume. In the distillate, the ammonia is then estimated either by neutralisation with a standard solution of dilute acid, or by Hadow's modification of Nessler's reaction. In its application to waters recently contaminated with sewage, this process is liable to considerable inaccuracy, owing to the gradual production of ammonia when an alkaline solution of urea is boiled. Thus the ammonia found exceeds that originally contained in the water. This error has already been pointed out by Mr. Chapman, who recommends that the ammonia determination should be made by the application of Nessler's solution directly to the water. We find, however, that the yellowish colour of many potable waters presents a formidable obstacle to success, unless the water be first decolorised as we recommend below; besides, waters containing chalk in solution become turbid on the addition of the Nessler test, and any turbidity is utterly fatal to accuracy in this determination.

Having thus pointed out the inaccuracies which attach themselves to the usual determinations in a water analysis, we will now describe the processes which we propose as substitutes for, or modifications of, those which have been hitherto employed. They may be thus enumerated:—

1. Estimation of total solid constituents.

2. Estimation of the carbon and nitrogen contained in the organic portion of the solid constituents (organic carbon and nitrogen.)

3. Estimation of nitrogen in the form of nitrates and nitrites.

4. Estimation of ammonia.

1. *Estimation of total Solid Constituents.*—Half a litre of water is evaporated to dryness as rapidly as possible in a weighed platinum capsule on a steam or water-bath; after drying the residue at 100° C., the capsule is again weighed. We have already given our reasons for the non-addition of sodic carbonate to the water before evaporation, and also for drying the residue at 100° instead of 120°—130° C. As we propose to abolish altogether the fallacious estimation of "loss on ignition," the retention of the elements of water in this residue is of no moment; they always exist there in the solid condition, and are hence quite legitimately included amongst the solid constituents.

2. *Estimation of Organic Carbon and Nitrogen.*—No process has yet been devised by which the amount of organic matter in water can be even approximately estimated, but we have now to describe a method by which the two most important elements—carbon and nitrogen—can be determined with considerable accuracy.

The estimation of the organic carbon in a water containing both carbonates and carbonic anhydride in solution is, as might be anticipated, an operation of more than ordinary difficulty. It is obviously necessary, in the first place, to expel both combined and dissolved carbonic anhydride, and this must be done in such a manner as to prevent the organic matter from being subject to the oxidising action which would necessarily result from the liberation of nitric and nitrous acids, which are probably never entirely absent from potable waters. We endeavoured to effect this by the addition of boric acid to the water during evaporation. Bloxam has shown* that for the

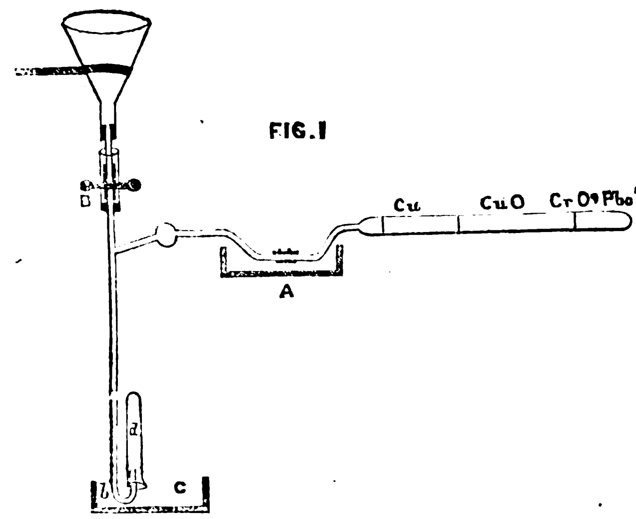
* Dr. Letheby's reports, on the Metropolitan Waters, to the Association of Medical Officers of Health.
† Journ. Chem. Soc., vol. xviii, p. 117.

* Journ. Chem Soc., vol. xii, p. 177.

expulsion of one molecule of carbonic anhydride from alkaline carbonates, six molecules of boric acid are necessary. Approximately this appears to be true also of the carbonates of the alkaline earths; nevertheless after the addition of six molecules of boric acid to each molecule of combined carbonic anhydride, we still found an amount of carbonate in the residue, which, though small, was sufficient seriously to vitiate the result of the subsequent determination of organic carbon. After many abortive attempts to overcome this difficulty, we found in sulphurous acid a re-agent, which not only completely expels carbonic anhydride from the water but also permits of the simultaneous determination of organic nitrogen with great accuracy, by completely removing, during evaporation, every trace of the nitrogen existing in the form of nitrates and nitrites, and thus leaving in the dry residue the organic nitrogen associated only with one remaining nitrogenous body, viz., ammonia. For the successful application of sulphurous acid to this purpose, it is not sufficient to add an excess of this acid to the potable water and then evaporate to dryness, since under these circumstances traces of carbonates are always found in the residue. It is, in fact, necessary after the addition of excess of sulphurous acid, to boil the water for two minutes in order to insure the complete expulsion of carbonic anhydride before evaporation on the steam-bath begins. If this precaution be observed, numerous experiments have shown that no trace of carbonic anhydride is evolved on adding hydrochloric acid to the dry residue. By availing ourselves of that admirable instrument the Sprengel pump, we are able to combine in one operation the determination of carbon and nitrogen in a water residue, by an analytical process of such simplicity and extreme delicacy, that we believe it will be found generally useful in the analysis of all organic compounds containing nitrogen, which are not volatile at ordinary temperatures. By this process ·000001 grm. of nitrogen and ·0000005 grm. of carbon are distinctly measurable quantities.

The following is the mode of conducting this operation:— As soon as possible after the collection of the sample of water, 2 litres are poured into a convenient stoppered bottle, and 60 c.c. of a recently prepared saturated solution of sulphurons acid are added. Should the water contain oxidisable or putrescible organic matter, this addition of sulphurous acid promptly arrests any further change, and the remaining operations may now be conducted at leisure. One half of this sulphurized water is now boiled for two or three minutes,* and unless it contained a considerable amount of carbonates, ·2 grm. of sodic sulphite is to be added during the boiling, so as to secure the saturation of the sulphuric acid formed during the subsequent evaporation. To secure the expulsion of the nitrogen existing as nitrates, it is also desirable to add a couple of drops of solution of ferrous or ferric chloride. The boiled water is then evaporated to dryness in a hemispherical glass capsule, of about 100 c.c. capacity, upon a steam or water bath, care being taken to keep the capsule well covered with a disc of filter paper stretched over a light cane hoop, and also to preserve the atmosphere of the room in which the operation is performed as free from ammonia as possible.† If the first-mentioned precaution be neglected, the access of floating particles of dust during the evaporation will introduce a considerable error into both carbon and nitrogen determinations. At one period of our investigations we feared that it would be necessary to perform the evaporation in vacuo, but we prove below that this would be an unnecessary precaution, for if the evaporation be conducted under paper, the amount of nitrogen introduced by atmospheric dust and ammonia (and this in the worst of all possible localities, the middle of London) only amounts to a maximum of ·00002 grm. per litre of water evaporated: consequently when this is deducted from the amount of nitrogen actually obtained by combustion the residual error is almost a vanishing quantity. The process of evaporation under a paper cover fitting tightly upon the edge of a glass dish *without a lip*, is in fact one of diffusion, in which the atmospheric air, constantly being exchanged for aqueous vapour, is filtered through a porous diaphragm.

The evaporation being completed, and the glass capsule placed upon a sheet of glazed paper, a few grammes of powdered plumbic chromate are to be introduced, and gently triturated with the dry residue by means of an agate or glass pestle. When the mixture has been made as perfect as possible, the contents of the capsule are to be transferred to a combustion tube, about 16 inches long and sealed at one end, the capsule is then rinsed two or three times with fresh quantities of chromate, which are also transferred to the combustion tube. The latter is then charged in the usual manner with granulated cupric oxide, and about 3 inches of bright copper turnings. The open end must now be drawn out before the blow-pipe, as shown in Figure I, and the tube being laid in a combustion



furnace, the drawn out extremity is to be connected with a Sprengel-pump by means of a piece of india-rubber tubing, care being taken that the extremities of the two glass tubes touch each other, or nearly so, within the caoutchouc connector. The latter being then plunged beneath water in the vessel A, and the furnace around the front part of the combustion-tube lighted, the pump is to be worked until the tube is exhausted as completely as possible, an operation which requires from five to ten minutes.* The flow of mercury is then stopped.

The recurved delivery end of the pump *b* dips into a mercurial trough C, and an inverted tube *d* filled with mercury is placed over it in a convenient position for receiving the gaseous products of the ignition. The combustion must now be conducted in the usual manner, care being taken that, when the organic matter begins to burn, the operation proceeds very slowly until the vacuum becomes considerably impaired; otherwise traces of carbonic oxide may be produced. A combustion usually lasts from three-quarters of an hour to an hour; at its conclusion, unless the water-residue contained much organic matter, no gas will have passed into the inverted tube. The pump is again set to work, and in from five to ten minutes the whole of the gases will be transferred into the vessel placed for their reception. Unless the heat of the furnace be excessive, the combustion tube will rarely collapse; but if it should do so, the metallic copper and granulated cupric oxide support the glass, and prevent any obstruction to the passage of the gases. In many scores of combustions made by this process, no single instance of vitiated result has occurred from this cause. The gases collected consist of carbonic anhydride, nitric oxide, and nitrogen. The separation and determination of these, by well-known methods, is exceedingly simple, and in a manometric gas apparatus, such as that described by one of us,† is the work of a few minutes only.

A simplified form of this apparatus, designed especially for the examination of all gaseous mixtures incident to water analysis, is described in the memoir immediately following the present, where the method of analysing these mixtures is also given. The weights of carbon and nitrogen contained in the corbonic anhydride, nitric oxide, and nitrogen gases, having been deduced from the respective volumes of these gases, the numbers so obtained are expressed in parts of these elements contained in 100,000 parts of the water. The nitrogen thus found may have been present in the water, first as a constituent of organic

* In operating with waters strongly contaminated with sewage, it is desirable that the flask in which this operation is performed should be furnished with an inverted Liebig's condenser, in order to prevent the loss of volatile organic constituents and ammonia. With all ordinary waters this precaution is unnecessary.

† The evaporation is now (1874) conducted under a glass shade, and the disc of filter paper is dispensed with.

* As it is obviously necessary that the leakage of atmospheric air into the pump should be rendered impossible, the caoutchouc pinch-cock, at B, should be enclosed in a wide piece of vulcanized tube, the annular space between the two tubes being filled with glycerine. The clamp is placed outside both tubes. The wide piece of tube is fastened upon the glass tube below the pinch-cock, by the aid of an india-rubber cork, whilst it terminates considerably above the joint; the interior caoutchouc joint is, therefore, entirely immersed in glycerine, and all possibility of leakage of air entirely prevented. We find, in fact, that by this arrangement the vacuum is still perfect after the lapse of several days. The calibre of the pump tube, which we prefer, is one millimetre, and it is advisable to allow the mercury to flow very slowly until the exhaustion is nearly complete, when a rapid stream is necessary to expel the remaining traces of air or gas.

† Journ. Chem. Soc., vol. vi, p. 197.

matter (organic nitrogen), and, secondly, as a constituent of ammonia. The latter, if present, is determined in the original water by Nessler's test, as described below, and the nitrogen existing in this form being deducted from that obtained on combustion, gives the amount, if any, of organic nitrogen present.

It is obvious that the accuracy of this method of combustion will depend in a great measure upon the perfection of the vacuum obtained by the Sprengel pump. In order to ascertain the error due to this cause, the following experiments were made:—

I. ·01 grm. sugar was burnt in the same way as a water residue. After absorption of carbonic anhydride, there remained ·019 c.c. of nitrogen at 0° C., and 760 mm pressure.

II. ·01 grm. sugar similarly treated gave ·013 c.c. of nitrogen at 0° C., and 760 mm. pressure.

If these numbers be referred to the residue of one litre of water (the quantity usually operated upon) the excess of nitrogen due to the imperfection of the Sprengel vacuum would be—

I. ·0024 part of nitrogen in 100,000 parts of water.

II. ·0016 part of nitrogen in 100,000 parts of water.

It will be seen that this error, which includes also any nitrogen retained or occluded in the cupric oxide, &c., is very insignificant; nevertheless it would be necessary to allow for it, if it were not included in another correction, which consists in evaporating a litre of distilled water,* acidified as usual with 15 c.c. of sulphurous acid, and containing about ·1 grm. of recently ignited sodic chloride. The residue from this water must now be burnt in vacuo in the usual manner, and the carbon and nitrogen deducted from the amount of these elements obtained from the residues of other waters submitted to analysis.

It is advisable that each analyst should perform several blank operations of this kind, so as to be able accurately to correct for the combined errors of his own manipulation and apparatus. In our own case we find these errors on the average of four blank analyses to amount to—

Carbon ·00032 grm. in 1 litre of water.†
Nitrogen ·000045 grm. in 1 litre of water.

It is scarcely necessary to add that, to insure a minimum in these errors, it is of the utmost importance, carefully to guard against every access of organic matter, and especially of nitrogenous compounds, to the water and the substances used in the analysis. Cupric oxide prepared from the nitrate should on no account be used, since, even after being actually fused, it evolves considerable quantities both of carbonic anhydride and nitrogen when ignited in vacuo. The oxide must be made by igniting sheet copper in a current of air, in a muffle or other convenient apparatus. This oxide, in a coarsely granular or scaly condition, should be at once transferred to a stoppered bottle, over the neck of which a small beaker is inverted to protect it from dust. The fused plumbic chromate should be heated to redness with frequent stirring for a couple of hours, and then carefully transferred to another bottle similarly protected. As these substances do not require to be either dried or ignited again before use, they should be transferred as required, from their respective bottles, direct to the capsules or combustion tubes, and any portion of them once removed from the bottle should on no account be returned there without being first ignited for two hours.

The extent to which this method can be depended upon for the determination of the minute amounts of carbon and nitrogen contained in a water residue was tested by the following experiments:—

I. ·0352 grm. sugar was dissolved in one litre of distilled water, together with about ·5 grm. of sodic carbonate, previously converted into sulphite, 15 c.c. of a saturated solution of sulphurous acid were then added, and the liquid boiled for three minutes. The residue left after evaporation to dryness on the steam-bath gave, on combustion, an amount of carbonic anhydride corresponding to ·01463 grm. carbon.

II. ·0347 grm. sugar similarly treated gave ·01386 grm. carbon.

III. ·0114 grm. sugar similarly treated gave ·00440 grm, carbon.

IV. ·0122 grm. sugar similarly treated gave ·00530 grm. carbon.

V. ·0115 grm. sugar ·0094 grm. ammonic chloride, and ·8 grm. sodic carbonate (previously converted into sulphite) treated in like manner, gave ·004344 grm. carbon, and ·0025415 grm. nitrogen.

VI. ·010 grm. urea, and ·8 grm. sodic carbonate similarly treated gave ·0017704 grm. carbon, and ·00463 grm. nitrogen.

VII. ·01025 grm. urea and ·8 grm. sodic carbonate treated as before gave ·00211 grm. carbon, and ·00357 grm. nitrogen.

VIII. ·0104 grm. urea and ·8 grm. sodic carbonate similarly treated gave ·0023865 grm. carbon, and ·004675 grm. nitrogen.

IX. ·0202 grm. urea, and one litre of solution of dihydric calcic dicarbonate boiled with 15 c.c. of sulphurous acid solution, and evaporated gave ·00452 grm. carbon and ·00887 grm. nitrogen.

X. ·025 grm. hippuric acid and ·5 grm. sodic carbonate (converted into sulphite) dissolved in one litre of water, boiled with 10 c.c. of sulphurous acid solution, and evaporated to dryness gave ·01386 grm. carbon, and ·00203 grm. nitrogen.

Expressed in parts per 100,000 of water evaporated, the following are the results of these experiments:—

		Calculated.	Found.
No. I.	Organic carbon	1·482	1·463
No. II.	" "	1·460	1·386
No. III.	" "	·480	·440
No. IV.	" "	·514	·530
No. V.	" "	·484	·434
	Nitrogen	·246	·254
No. VI.	Organic carbon	·200	·177
	" nitrogen	·466	·463
No. VII.	" carbon	·205	·211
	" nitrogen	·478	·357
No. VIII.	" carbon	·208	·239
	" nitrogen	·484	·468
No. IX.	" carbon	·404	·452
	" nitrogen	·942	·887
No. X.	" carbon	1·508	1·386
	" nitrogen	·195	·203

When it is considered that these results were obtained from very minute amounts of the respective organic matters, which were first dissolved in a large quantity of water, and then recovered by evaporation, and further, that some of the organic substances experimented upon are exceedingly prone to change, the correspondence of the experimental with the calculated numbers is as close as could be anticipated.* The following results, obtained with actual

* This distilled water should be previously purified by boiling, for 24 hours, with alkaline potassic permanganate. It should then be distilled, the first portions of the distillate being rejected so long as they show any reaction with Nessler's test Finally, this distillate should be slightly acidified with sulphuric acid and rectified.

† This error has, in the case of carbon, been since reduced to ·00006 grm. in one litre of water in consequence of improvements in the process (1874).

* Since the above was written several improvements have been made in the process, the following test experiments show that it has now (1874) attained a still greater degree of accuracy, a statement which is further corroborated by the results of very numerous series of analyses of water supplied to London, given in the diagrams facing pages 261 and 262 of this report.

To 100,000 parts of a sample of water, rendered as nearly chemically pure as possible, 1·957 part of sulphate of quinine was added. The following data compare the quantities of organic carbon and organic nitrogen thus actually added to the water with those afterwards found in two analyses:—

	Actually present.	Found by analysis. I.	II.
Organic carbon in 100,000 parts of water	·857 part	·912	·904
Organic nitrogen in 100,000 parts of water	·100 "	·0996	·098

To 100,000 parts of another similar sample of pure water ·9785 part of sulphate of quinine was added, and the following data compare as before the quantities of organic carbon and organic nitrogen added with those afterwards found in three analyses:—

	Actually present.	Found by analysis. I.	II.	III.
Organic carbon in 100,000 parts of water	·429	·435	·442	·440
Organic nitrogen in 100.000 parts of water	·050	·047	·048	·048

To 100,000 parts of another similar sample of pure water, ·09785 part of sulphate of quinine was added. The following numbers compare the quantities of organic carbon and organic nitrogen added with those actually found in three analyses:—

	Actually present.	Found by analysis. I.	II.	III.
Organic carbon in 100,000 parts of water	·048	·047	·050	·055
Organic nitrogen in 100,000 parts of water	·005	·006	·005	·006

The approximation of the experimental to the actual numbers is the more striking when it is remembered that the weight of nitrogen *actually determined*, in the litre of water used for analysis was in the last series, only ·00005 gramme,—a weight which could scarcely be appreciated by the most delicate gravimetrical methods:—

Applied to actual specimens of potable water, the accuracy of the method can, of course, only be tested by the uniformity of results obtained in duplicate analyses of the same sample of water. The following instances will suffice to illustrate this point.

waters, also tend to inspire confidence in this method of analysis:—

XI. Two litres of the same sample of water were successively analysed five days apart. They gave the following amounts of organic carbon and nitrogen in 100,000 parts:—

	I.	II.
Organic carbon -	1·030	1·010
Organic nitrogen -	·198	·207

XII. Three mixtures of sewage and distilled water were made in such proportions that 1 litre contained respectively 100 c.c., 10 c.c., and 1 c.c. of sewage. Some solution of dihydric calcic dicarbonate was added to the second and third to form a tangible residue. They were then treated with sulphurous acid in the manner above described, and evaporated to dryness. Their residues gave, on combustion, the following results per 100,000 parts of water evaporated:—

	100 c.c. sewage. 900 c.c. water.	10 c.c. sewage. 990 c.c. water.	1 c.c. sewage. 999 c.c. water.
Organic carbon in 100,000 parts of the mixture	·302	·033	·005
Organic nitrogen and nitrogen of ammonia	·330	·033	·004

It has been already stated that the nitrogen obtained on the combustion of a water-residue is made up of the organic nitrogen plus the nitrogen of any ammonia that may have been contained in the water, but that it includes no trace of the nitrogen which may have been present in the form of nitrates and nitrites, the latter having been completely destroyed during the evaporation with excess of sulphurous acid. Such an expulsion of the nitrogen of nitrates and nitrites is a remarkable reaction, and could scarcely have been predicted; indeed it takes place to a very partial extent only when a nitrate is dissolved in water, and evaporated with excess of sulphurous acid, in imitation of a natural water; neither is the result very different when sodic chloride or calcic or magnesic carbonate is added. Thus the residue from half a litre of distilled water to which had been added ·05 grm. potassic nitrate (= ·007 grm. nitrogen), ·0001 grm. ammonia, ·1 grm. sodic chloride, and 15 c.c. of a saturated solution of sulphurous acid, yielded ·00161 grm. nitrogen.

One litre of distilled water, containing ·1 grm. sodic chloride, ·1 grm. potassic nitrate (= ·014 grm. nitrogen), one drop of a strong solution of soluble glass, and 15 c.c. of a saturated solution of sulphurous acid, treated like a natural water, yielded, on combustion, ·00222 grm. nitrogen.

One litre of distilled water, containing ·1 grm. sodic chloride, ·1 grm. potassic nitrate, and 15 c.c. sulphurous acid solution, similarly treated, gave ·00259 grm. nitrogen.

The presence of a minute amount of iron, or of a phosphate, reduces to zero the amount of nitrogen retained from nitrates. Thus 1 litre of distilled water, ·1 grm. sodic chloride, ·1 grm. potassic nitrate (= ·014 grm. N.), 2 drops of a moderately concentrated solution of hydric sodic phosphate, and 15 c.c. of sulphurous acid solution, gave no nitrogen on combustion of the solid residue.

Half a litre of distilled water, containing ·1 grm. potassic nitrate and 2 drops of a solution of ferric chloride, evaporated with 10 c.c. of sodic sulphite solution and 15 c.c. of a saturated solution of sulphurous acid, gave no nitrogen on combustion.

One litre of distilled water containing ·1 grm. sodic chloride, ·1 grm. potassic nitrate, 1 drop of solution of ferric chloride, and 15 c.c. of sulphurous acid solution, gave no trace of nitrogen on combustion, and the same result was obtained in a duplicate experiment. Three drops of a solution of ferric chloride also removed all traces of nitrates from half a litre of a natural water when evaporated in vacuo, although the water contained no less than 2·466 parts of nitrogen as nitrates and nitrites in 100,000 parts.

* The nitrogen was also completely expelled during the evaporation of an artificial water, to which the following ingredients were added:—·01 grm. magnesia, ·1 grm. calcic carbonate, ·1 grm. sodic chloride, ·01 grm. potassic chloride, 1 drop of solution of soluble glass, 1 drop of solution of ferric chloride, 2 drops of solution of hydric sodic phosphate, ·1 grm. potassic nitrate, and 15 c.c. of sulphurous acid solution.

There is probably no natural water containing an appreciable quantity of nitrates or nitrites which does not also contain either iron or phosphoric acid; nevertheless, it is advisable to add one or two drops of ferrous or ferric chloride to the portion of water which is evaporated for combustion, in order to place beyond the possibility of doubt the complete expulsion of the nitrogen of nitrates and nitrites.

Since we began to use this process for the estimation of organic carbon and nitrogen in waters, Messrs. Wanklyn Chapman, and Smith have proposed a new method for the determination of the latter element in potable waters. Their process is founded upon a highly remarkable change which albumen and some other organic substances undergo during prolonged ebullition with an alkaline solution of potassic permanganate, by which their nitrogen is converted into ammonia. Unfortunately, however, this conversion is never complete; neither is there any guarantee that all the different forms of nitrogenous organic substances in water will thus yield up their nitrogen in the form of ammonia. That some such substances do not thus evolve their nitrogen when submitted to this process is evident from the following results, obtained with three bodies taken at random from a collection of chemicals:—

I. ·01 grm. strychnine, dissolved in one litre of distilled water (not previously purified), and distilled nearly to dryness with caustic potash and potassic permanganate, gave ·00032 grm. ammonia.

II. ·02 grm. narcotine, similarly treated, gave ·000312 grm. ammonia.

III. ·02 grm. quinine sulphate gave ·000728 grm. ammonia.

The following comparison of the amounts of ammonia actually obtained, with those which ought to be yielded by the weights of the respective substances operated upon, shows that in each case a large proportion of nitrogen was not evolved as ammonia:—

	Ammonia evolved. Calculated.	Found.
Strychnine - -	·00101 grm.	·00032 grm.
Narcotine - -	·00068 „	·000312 „
Quinine sulphate -	·00128 „	·000728 „

We have also tested the permanganate process by applying it to a form of nitrogenous organic matter which is very frequently met with in natural waters, viz., peaty matter.

Some peat, collected by one of us from Leyland moss at a depth of three feet below the surface, and placed immediately in a well-corked glass vessel, was digested at 100° C. for a couple of hours in distilled water, rendered slightly alkaline by caustic soda. 100 c.c. of the dark-coloured liquid so obtained was made up to one litre with distilled water, and after the determination of ammonia by ebullition with sodic carbonate, was submitted to the permanganate process so long as ammonia was evolved. Another 100 c.c. of the same liquid was acidified with sulphurous acid, boiled for two minutes, then evaporated to dryness in vacuo, and the dry residue submitted to combustion in vacuo. The following amounts of *organic* nitrogen per 100,000 parts of liquid were obtained:—

Permanganate Process.	Combustion Process.
·308	1·015

Another portion of the same liquid was acidified with dilute sulphuric acid; the copious brown precipitate which separated was collected on a filter, and, after being dried at 100° C., was reduced to fine powder. Two separate centigrms. of this precipitate were respectively submitted to the permanganate and combustion processes. Two equal volumes (100 c.c.) of the filtered liquid were also respectively treated by the two processes, the portion used for combustion being evaporated under paper upon a steam bath. The ammonia was determined in this liquid as usual. The following are the amounts of *organic* nitrogen obtained:—

	Permanganate process.	Combustion process.
·01 grm. of peat precipitate yielded of organic nitrogen -	·000052 grm.	·0001138 grm. N.
100,000 parts of filtrate from peat precipitate gave of organic nitrogen - - -	·108	·291

* Results of analyses expressed in parts per 100,000.

		I.	II.
Thames water as supplied to London - - - -	Organic carbon	·280	·285
	Organic nitrogen	·032	·035
Lee water as supplied to London -	Organic carbon	·157	·148
	Organic nitrogen	·026	·030
New River water as supplied to London - - - -	Organic carbon	·231	·239
	Organic nitrogen	·042	·042
Kent Company's water as supplied in London - - -	Organic carbon	·054	·056
	Organic nitrogen	·016	·017

200 c.c. of another sample of peat solution, treated by the two processes, yielded the following amounts of organic nitrogen per 100,000 parts of liquid :—

Permanganate process.	Combustion process.
·422	1·175

Two separate litres of an artificial water, made by diffusing some peat in distilled water for several days (without the addition of alkali), and then filtering, were treated by the two processes, and yielded the following amounts of organic nitrogen per 100,000 parts of water :—

Permanganate process.	Combustion process.
·022	·076

The extension of this comparison of the two processes to natural waters confirms, in a large majority of cases, the conclusion which is forced upon us by the above experiments, viz., that nitrogenous organic substances do not uniformly yield up the whole, or nearly the whole of their nitrogen in the form of ammonia when boiled with alkaline potassic permanganate; indeed, Wanklyn has recently discovered that, even in regard to albumen itself, his first statement in reference to this point requires modification, and he now states*, "The 'albuminoid ammonia' is not "the total amount of ammonia which the albumen is "capable of giving, but appears to be two-thirds of the "total quantity, being at any rate a constant fraction of "the total quantity." Neither the above nor the following results show, either that two-thirds of the total nitrogen is evolved in the shape of ammonia, or that the fraction of the total nitrogen evolved in the permanganate process is a constant one. We have tested the two processes side by side upon more than 100 different samples of natural waters, and we find that, as a rule, to which, however, there are some exceptions, the permanganate process gives results considerably below those obtained by combustion, as in the following cases :—

Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.	Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.
·006	·010	·002	·010
·006	·011	·002	·008
·006	·010	·003	·008
·002	·011	·016	·068
·016	·042	·003	·006
·002	·009	·001	·012
·006	·022	·002	·011
·000	·007	·000	·007
·013	·043	·011	·058
·012	·027	·024	·061
·006	·031	·030	·062

In some cases where, as a rule, the amount of organic nitrogen was very small, the two processes yielded accordant results, as in the following cases :—

Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.	Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.
·001	·001	·004	·004
·001	·001	·003	·004
·004	·004	·002	·001
·010	·009	·003	·004
·012	·012	·002	·001
·001	·001	·002	·002

In a few other cases, however, the amount of organic nitrogen obtained by the permanganate process was higher than that yielded by combustion, as for instance :—

Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.	Organic nitrogen in 100,000 parts of water. By permanganate process.	By combustion.
·010	·007	·004	·000
·009	·005	·002	·000
·005	·000	·003	·000

These last results are to some extent explained by the fact, that distilled water purified by boiling with alkaline potassic permanganate, for a long time after ammonia has ceased to be evolved, always yields ammonia when again treated with alkaline potassic permanganate. Thus in four experiments made with such purified water, the following quantities of ammonia per 100,000 parts of water were obtained :—

No. I.	·002 part	No. III.	·002 part.
No. II.	·001 „	No. IV.	·002 „

* Journ. Chem. Soc., vol. xx, p. 593.

3. *Estimation of Nitrogen in the form of Nitrates and Nitrites.*

This determination can be made with very great accuracy by a modification of a process proposed 20 years ago by Walter Crum, for the refraction of nitre.* It consists in agitating with mecury a concentrated solution of the nitrate or nitrite, with a large excess of concentrated sulphuric acid, when the whole of the nitrogen is evolved as nitric oxide. We find that, for the success of this process, it is absolutely necessary that no chlorides should be present, and also that the mixed liquids should be *violently* agitated with mecury, so as to break up the latter into minute globules.

The following determinations show the accuracy of this process :—

I. ·02 grm. of nitre gave 75·48 c.c. nitric oxide at 49 mm. mercurial pressure, and 16°·4 C.

II. ·01 grm. of nitre, dissolved in a saturated solution of sodic sulphate, gave 75·48 c.c. of nitric oxide at 24·2 mm. mercurial pressure, and 17°·8 C.

	Weight of nitrogen. Calculated.	Found.
No. I. -	·002772	·002897
No. II. -	·001386	·001424

It was ascertained that uric acid, hippuric acid, urea, and creatin when agitated with concentrated sulphuric acid and mecury gave no trace of gas.

The following is the mode in which this process is applied to the estimation of nitrogen existing as nitrates and nitrites in potable waters. The solid residue from the half litre of water used for determination No. 1 (estimation of total solid constituents)† is treated with a small quantity of distilled water, a very slight excess of argentic sulphate is added to convert the chlorides present into sulphates, and the filtered liquid is then concentrated by evaporation in a small breaker until it is reduced in bulk to two or three cubic centimetres. The liquid must now be transferred to a glass tube, Fig. 2, furnished at its upper extremity with a cup and stopcock previously filled with mercury at the mercurial trough, the beaker being rinsed out once or twice with a very small volume of recently boiled distilled water, and finally with pure and concentrated sulphuric acid in somewhat greater volume than that of the concentrated solution and rinsings previously introduced into the tube. By a little dexterity it is easy to introduce successively the concentrated liquid, rinsings, and sulphuric acid into the tube by means of the cup and stopcock, without the admission of any trace of air. Should, however, air inadvertently gain admittance, it is easily removed by depressing the tube in the mercury trough, and then momentarily opening the stopcock. If this be done within a minute or two after the introduction of the sulphuric acid, no fear need be entertained of the loss of nitric oxide, as the evolution of this gas does not begin until a minute or so after the violent agitation of the contents of the tube.

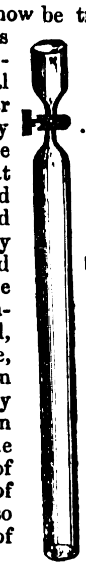


FIG. 2

The acid mixture being thus introduced, the lower extremity of the tube is to be firmly closed by the thumb, and the contents violently agitated by a simultaneous vertical and lateral movement, in such a manner that there is always an unbroken column of mercury, at least an inch long, between the acid liquid and the thumb. From the description, this manipulation may appear difficult, but in practice it is extremely simple, the acid liquid never coming in contact with the thumb. In about a minute from the commencement of the agitation a strong pressure begins to be felt against the thumb of the operator, and mercury spurts out in minute streams, as nitric oxide gas is evolved. The escape of the metal should be gently resisted, so as to maintain a considerable excess of pressure inside the tube, and thus prevent the possibility of air gaining access to the interior during the shaking. In from three to five minutes the reaction is completed, and the nitric oxide may then be transferred to a suitable measuring apparatus, where its volume is to be determined over mercury. As half a litre of water is used for the determination, and as nitric oxide occupies exactly double

* Phil. Mag., xxx, 426.

† If the water contain nitrites, a separate half litre should be taken for this determination, otherwise there is a risk of loss of nitrogen during evaporation. The nitrites in this half litre of water must be transformed into nitrates by the cautious addition of potassic permanganate to the slightly acidified water before the evaporation is commenced. Immediately after the action of the permanganate the water must, of course, be again rendered slightly alkaline.

the volume of the nitrogen which it contains, the volume of nitric oxide read off expresses the volume of nitrogen existing as nitrates and nitrites in one litre of the water. From the number so obtained, the weight of nitrogen in these forms in 100,000 parts of water is easily calculated.

4. *Estimation of Ammonia.*

Unless the amount of ammonia obtained by distillation alone, or with sodic carbonate, be considerable (above ·01 part in 100,000 parts of water), Hadow's modification of Nessler's process is all that could be desired for its accurate determination. But if a larger proportion than this be obtained, the presence of urea may be suspected, and it becomes necessary to make the Nessler ammonia determination directly, in the original water, without the intervention of distillation. For this purpose, however, the water should be colourless, and free from calcic and magnesic carbonates. Any tint which is appreciable in a stratum 6 or 8 inches thick would obviously vitiate the result of a colour-test; whilst if calcic or magnesic carbonate be present, the addition of the Nessler solution will infallibly produce turbidity; moreover, we find that the slightest opalescence in the water, under these circumstances, is absolutely incompatible with an accurate determination. Both these difficulties might be effectually removed by adding to the water, first a few drops either of ferric chloride or aluminic chloride in solution, and then a few drops of a solution of sodic carbonate so as to precipitate ferric hydrate or aluminic hydrate. The precipitate completely decolorises the water, and no turbidity is caused by the subsequent addition of the Nessler solution; but unfortunately the precipitate carries down with it an amount of ammonia which, in the case of the ferric hydrate, sometimes amounts to one-third of the total quantity present. Remembering the beautiful blue-green tint—the natural colour of absolutely pure water—which is presented by a reservoir of water that has been softened by Clark's process, we tried, upon peaty water, the effect of precipitating in it calcic carbonate, and found that the decolorisation was as complete as could be desired, and that no appreciable amount of ammonia was carried down with the precipitate. The amount of calcic carbonate present in a coloured water is rarely sufficient to enable the operator to carry out this reaction with sufficient rapidity and completeness; it is therefore best in all cases to add a few drops of a concentrated solution of calcic chloride, to half a litre of the water. The subsequent addition of a slight excess of sodic carbonate then produces a copious precipitate of calcic carbonate, which should be allowed to subside for half an hour before filtration. 100 c.c. of the filtrate is a convenient quantity to take for the direct Nessler determination of ammonia. To this volume of the filtrate 1 c.c. of the Nessler solution is added, and the colour observed in the usual manner (see Miller on the Analysis of Potable Waters. Jour. Chem. Soc., vol. xviii., p. 125). By this direct process the ammonia in fresh urine can be readily estimated, for this purpose 5 c.c. of the urine should be diluted with 95 c.c. of water free from ammonia. We have ascertained that known quantities of ammonia, added in the form of ammonic chloride to urine, can be determined with great accuracy.

The colour observations of the Nessler determination are best made in narrow glass cylinders of such a diameter that 100 c.c. of the water to be tested form a stratum about 7 inches deep. The depth of tint is best observed by placing these cylinders upon a sheet of white paper near a window, and looking at the *surface* of the liquid obliquely; thus, Fig. 3.

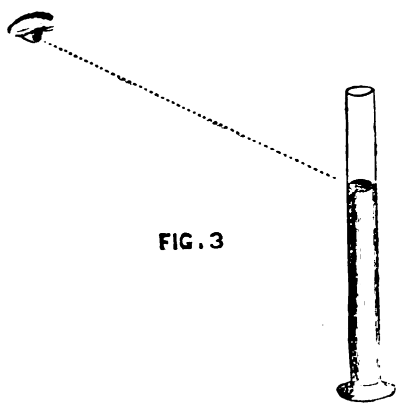


FIG. 3

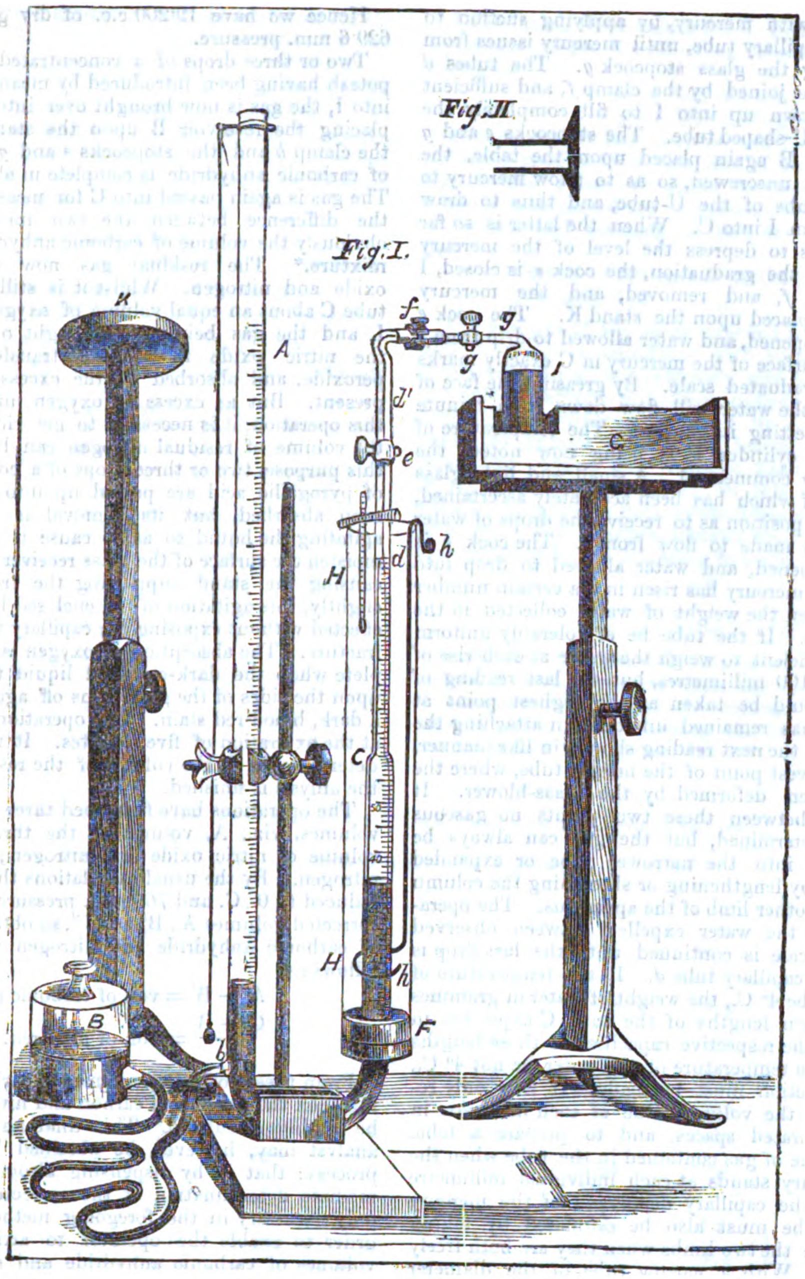
On a Simple Apparatus for Determining the Gases Incident to Water Analysis.—By Dr. E. Frankland, F.R.S.

The manometric gas analysis apparatus described by Mr. Ward and myself,* enables the operator to make all the gaseous determinations connected with water analysis with a rapidity, delicacy, and precision leaving little to be desired; nevertheless, as this instrument is also designed for the analysis of gaseous mixtures of greater complexity, its construction is more elaborate than is necessary for the investigation of such gases as require to be dealt with in water analysis. I have, therefore, devised a more simple and much less costly apparatus, which permits of the rapid and accurate analysis of such gaseous mixtures as require to be submitted only to the action of absorbents, a category which includes all the gases appertaining to ordinary water-analysis.

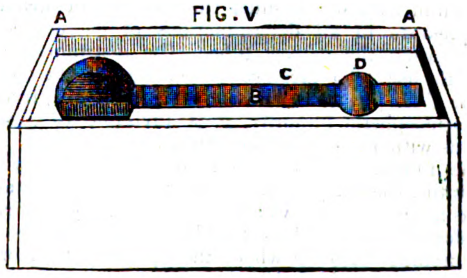
This apparatus is represented in Fig. 1.

A is a U-shaped glass tube 16 mm. internal diameter, supported in a perfectly perpendicular position by a convenient clamp. Its longer limb stands 1·1 metre high, its shorter limb 350 mm. measured to C. In the longer limb, just above the bend, is inserted a short glass tube *b*, 1 centimetre long, and 2 mm. internal diameter; it is attached to a doubly tubulated bottle, B, by a piece of strong caoutchouc tube 1½ metre long, and 2 mm. internal diameter. This bottle and tube serve for the supply of the apparatus with mercury. The shorter limb of the tube A is contracted at C and joined to a tube 220 mm. long, the bore of which does not exceed 1½ mm. To the upper extremity of C is joined the capillary tube *d*, *d'*, carrying a glass stopcock *e*. The upper extremity of *d*, *d'*, is bent horizontally, and is carefully cemented into the steel cap and clamp-joint *f*, the structure of which is shown in section in Figs. 2 and 3. *g*, *g*, represents a similar steel cap, glass stop-cock, and capillary tube connected with the small absorbing jar I, 100 mm. high, and 38 mm. internal diameter. The two steel caps permit of being joined gas-tight into a continuous capillary tube by a small screw clamp, Fig. 3, as originally devised by Regnault. The jar I stands firmly upon the shelf of a wooden mercury trough G. The construction of this trough is shown by Figures IV., V., and VI. It is 265 mm. long, 80 mm. broad, and 90 mm. deep outside measure. The rim A A is 8 mm. broad, and 15 mm. deep. The excavation B is 230 mm. long, 26 mm. broad, and 65 mm. deep. The shelf or bottom of the circular cavity on which the jar I rests is sunk to a depth of 20 mm. below the top of the trough C, or 35 mm. below the top of the rim A (Fig. vi). At D in the excavation are two slight lateral indentations for the convenient transference of tubes containing specimens of gas from their capsules to the trough.

* Journ. Chem. Soc., vol. vi, p. 197.



Both limbs of the U-shaped tube are graduated in millimetres from below upwards, care being taken that when the tube is placed perpendicularly the zeros on both limbs are exactly at the same level. H H is a glass cylinder fixed upon the tube C by a perforated caoutchouc cork F slipped over the top of the tube. To facilitate the placing of the cork and cylinder in position, the horizontal portion of the capillary tube *d* should be as short as possible. The cylinder H H serves to contain water intended to give, without delay, a definite tempera-

FIG. V


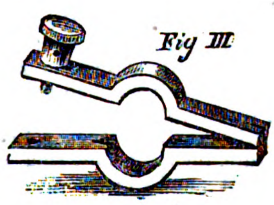


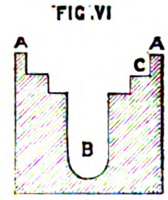
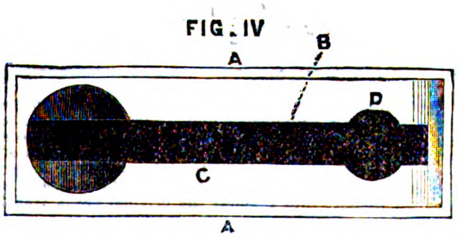
FIG. VI


FIG. IV


ture to gases which have to be measured in the limb C. To secure a uniform temperature in this column of water an agitator *h h*, consisting of a copper wire, flattened and bent into the form of a ring at its lower extremity, is employed. Before this instrument is ready for use, its shorter limb C requires calibration, which is effected with great facility and accuracy in the following manner. The instrument is filled with mercury, by placing the reservoir B upon the stand K, opening the clamp at *b*, and the stopcock *e*, after disconnecting *g* I at *f*. When mercury drips from the orifice at *f* the cock *e* is shut. The jar I is now to be filled with mercury, by applying suction to the orifice of its capillary tube, until mercury issues from it, and then closing the glass stopcock *g*. The tubes *d* and *g* must now be joined by the clamp *f*, and sufficient distilled water thrown up into I to fill completely the shorter limb of the U-shaped tube. The stopcocks *e* and *g* being opened, and B again placed upon the table, the clamp at *b* is to be unscrewed, so as to allow mercury to flow from both limbs of the U-tube, and thus to draw over the water from I into C. When the latter is so far filled with water as to depress the level of the mercury below the zero of the graduation, the cock *e* is closed, I is disconnected at *f*, and removed, and the mercury reservoir B again placed upon the stand K. The cock *e* is now cautiously opened, and water allowed to drip from *f* until the convex surface of the mercury in C exactly marks the zero of the graduated scale. By greasing the face of the steel cap at *f* the water will flow down it in minute globules without wetting its surface, The temperature of the water in the cylinder H H being now noted, the calibration may be commenced. A small and light glass flask, the weight of which has been accurately ascertained, is placed in such a position as to receive the drops of water when the latter are made to flow from *f*. The cock *e* is then cautiously opened, and water allowed to drop into the flask until the mercury has risen in C a certain number of millimetres, when the weight of water collected in the flask is ascertained. If the tube be of tolerably uniform bore, it will be sufficient to weigh the water at each rise of mercury through 100 millimetres, but the last reading of mercury in C should be taken at the highest point at which the calibre has remained unaltered in attaching the narrower tube, and the next reading should, in like manner, be taken at the lowest point of the narrow tube, where the bore has not been deformed by the glass-blower. It is obvious that between these two points no gaseous volume can be determined, but the gas can always be either compressed into the narrower tube or expanded into the wide one by lengthening or shortening the column of mercury in the other limb of the apparatus. The operation of weighing the water expelled between observed divisions of the scale is continued until the last drop is expelled from the capillary tube *d*. If the temperature of the water in H H be 4° C., the weight of water in grammes expelled from known lengths of the tube C expresses in cubic centimetres the respective capacities of those lengths of the tube. If the temperature of the water be not 4° C., the necessary correction must be made. It now only remains to calculate the volume-value of each milimetre in the different calibrated spaces, and to prepare a table showing the volume of gas contained in the tube when the apex of the mercury stands at each individual millimetre from zero to *d*. The capillary depression of the mercury in the narrow tube must also be estimated by taking several readings in the two limbs when they are both freely open to the air. With a narrow tube of the diameter recommended above, this capillarity will amount to about 3·4 millimetres, which must therefore be deducted from the pressure in all determinations of gaseous volumes made within the narrow tube. The instrument is now ready for use. To preserve the mercury in the open limb of the U-shaped tube, and in the reservoir B, from dust and atmospheric impurity, it is advisable to close their mouths with a loose plug of cotton wool.

The following is the mode of conducting, with this apparatus, the analysis of a gaseous mixture obtained in the combustion of a water residue. The gas is carefully transferred without loss to the jar 1 and thence for measurement into C,* where the apex of the mercury is brought to coincide with any millimetre mark. Let us suppose that the following observations are made:—

Height of mercury in C - -	250 mm.
Corresponding vol. of gas as per calibration table - - - -	19·200 c.c.
Height of mercury in A - - -	130·4 mm.
Temperature of water in H H - -	16°·4 C.
Height of barometer - - -	763·1 mm.

From these data the pressure upon the gas will be as follows:—

Height of barometer - - -		763·1 mm.
Deduct height of mercury column in A from height in C, viz.: 250—130·4 =	119·6	
Plus tension of aqueous vapour at 16°·4 C. = - - -	13·9	
		133·5 mm.
Pressure on dry gas - - -		629·6 mm.

In the calibration, the internal walls of C are moistened with distilled water; they are also ever afterwards kept moist, so that the gases when measured are always saturated with aqueous vapour.

Hence we have 19·200 c.c. of dry gas at 16°·4 C. and 629·6 mm. pressure.

Two or three drops of a concentrated solution of caustic potash having been introduced by means of a small pipette into I, the gas is now brought over into contact with it by placing the reservoir B upon the stand K, and opening the clamp *b* and the stopcocks *e* and *g*. The absorption of carbonic anhydride is complete in about three minutes. The gas is again passed into C for measurement, as before, the difference between the two measurements giving obviously the volume of carbonic anhydride in the original mixture.* The residual gas now consists of nitric oxide and nitrogen. Whilst it is still in the measuring tube C about an equal volume of oxygen is passed up into I, and the gas being now brought over into the latter, the nitric oxide is instantly transformed into nitric peroxide, and absorbed by the excess of caustic potash present. But as excess of oxygen must be employed in this operation, it is necessary to get rid of this gas before the volume of residual nitrogen can be determined. For this purpose, two or three drops of a concentrated solution of pyrogallic acid are passed up into I. The oxygen is soon absorbed, but its removal is much hastened by agitating the liquid so as to cause it again and again to moisten the surface of the glass receiver I. By dexterously causing the stand supporting the trough G to vibrate slightly, this agitation of the enclosed liquid can be readily effected without exposing the capillary tubes to the risk of fracture. The absorption of oxygen is known to be complete when the dark-coloured liquid thrown by agitation upon the sides of the glass runs off again without leaving a dark, blood-red stain. The operation is usually complete at the expiration of five minutes. It now only remains to determine, in C, the volume of the residual nitrogen, and the anlysis is finished.

The operations have furnished three uncorrected gaseous volumes, viz., A, volume of the three mixed gases; B, volume of nitric oxide and nitrogen; and C, volume of nitrogen. By the usual calculations these volumes may be reduced to 0° C. and 760 mm. pressure, and then from the corrected volumes A′, B′, and C′, so obtained, the quantities of carbonic anhydride and nitrogen may be deduced as follows:—

$$A' - B' = \text{vol. of carbonic anhydride.}$$

$$\frac{C' + B'}{2} = \text{vol. of nitrogen.}$$

From these corrected volumes of carbonic anhydride and nitrogen the weights of carbon and nitrogen can, of course, be readily calculated. This final and sole object of the analyst may, however, be obtained by a much shorter process; that is, by dispensing altogether with the intermediate determination of the corrected volumes, which is only necessary in the foregoing method of calculation, in order to enable the operator to arrive at the corrected volumes of carbonic anhydride and nitrogen. In fact, if the original gaseous mixture be treated, so far as volume-weight is concerned, as nitrogen, the calculations become greatly simplified. They depend upon the following data:—

1. The weights of carbon and nitrogen contained in equal volumes of carbonic anhydride and nitrogen gases measured at the same temperature and pressure, are to each other as 6 : 14.

2. The weights of nitrogen contained in equal volumes of nitrogen and nitric oxide are as 2 : 1.

Now, if we assume, for the purposes of calculation, that the gaseous mixture submitted to analysis consists entirely of nitrogen, and that two successive portions of this nitrogen are removed from it by the action of reagents, then, if A be the weight of the total gas calculated as nitrogen, B the weight after absorption of the first portion (CO_2), and C the weight after the absorption of the second portion (N_2O_2); further, if x and y represent respectively the weights of carbon and nitrogen actually contained in the gaseous mixture, then the following simple equations express the values of x and y:—

$$x = \frac{3\,(A - B)}{7}$$

$$y = \frac{C + B}{2}$$

* If the combustion of the water residue be not pushed on too rapidly every trace of sulphurous anhydride will be absorbed by the metallic copper in front of the cupric oxide, but it has occasionally happened in combustions, very carelessly made, that some sulphurous anhydride has escaped absorption. If such a result be suspected, it is only necessary to introduce two or three drops of a saturated solution of dipotassic dichromate into I before the original gas is transferred for measurement.

By the use of the logarithmic table given below for the reduction of cubic centimetres of nitrogen to grms. for each tenth of a degree centigrade by the formula $\frac{\cdot 0012562}{(1+\cdot 00367t)\,760}$ the labour of calculation is reduced to a minimum. An example will perhaps render the whole method of calculation here proposed more intelligible. For this purpose, let us suppose the following values to have been obtained from readings such as those described at p. 113*:—

Vol. of original gas = A.
19·200 c.c. of dry gas at 16°·4 C. and 629·6 mm. pressure.

Vol. after first absorption (of CO_2) = B.
3·342 c.c. of dry gas at 16°·7 C. and 324·5 mm. pressure.

Vol. after second absorption (of N_2O_2) = C.
1·631 c.c. of dry gas at 16°·9 C. and 298·4 mm. pressure

A =
log. 19·200 = 1,28330
„ 629·6 = 2,79906
log. $\frac{\cdot 002562}{(1+\cdot 00367\,t)\,760}$ for 16·4 C = – 6,19286
– 2,27522 = ·01885 grm.

B =
log. 3·342 = 0,52401
„ 324·5 = 2,51121
log. $\frac{\cdot 0012562}{(1+\cdot 00367\,t)\,760}$ for 16°·7 C = – 6,19241
– 3,22763 = ·001689 grm.

C =
log. 1·631 = 0,21245
„ 208·4 = 2,47480
log. $\frac{\cdot 0012562}{(1+\cdot 00367\,t)\,760}$ for 16°·9 C = – 6,19211
– 4,87936 = ·0007575 grm.

* Journ. Chem. Soc. vol. xxi.

Introducing these values for A, B, and C, into the above equations, we get the following values for x (carbon) and y (nitrogen):—

$x =$ ·007355 grm.
$y =$ ·00122325 grm.

If these results had been obtained by the combustion of the solid residue from one litre of water, then by moving the decimal point two places to the right, the values for x and y just quoted are transformed into parts by weight of carbon and nitrogen in 100,000 parts of the water; thus:—

Carbon ·735 part in 100,000 of water.
Nitrogen ·122 „ „

The analysis of the gases expelled from waters by ebullition in vacuo is performed with equal facility with this apparatus. In all but extremely rare cases these gases consist only of carbonic anhydride, oxygen, and nitrogen. The carbonic anhydride is absorbed by a few drops of concentrated potash solution as before described, and the remaining oxygen and nitrogen gases are then separated by means of pyrogallic acid. In this case the results are usually expressed in cubic centimetres at 0°C. and 760 mm. pressure. The volumes actually read off are reduced to this standard by the following formula:—

$$\frac{AB}{(1+\cdot 003665\,t)\,760}$$

in which A = the observed volume of gas in cubic centimetres, B = the pressure upon the dry gas, and t = the temperature at the time the volume was measured. A table is given below, showing the log. of (1 + ·003665t) 760 for each 0°·1 C. from 0° to 30°.

TABLE for the REDUCTION of CUBIC CENTIMETRES of Nitrogen to Grams.

Log. $\frac{\cdot 0012562}{(1+\cdot 00367t)\,760}$ for each tenth of a degree from 0° to 30°.C.

t. C.	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0°	—6,21824	808	793	777	761	745	729	713	697	681
1	665	649	633	617	601	586	570	554	538	522
2	507	491	475	459	443	427	412	396	380	364
3	349	333	318	302	286	270	255	239	223	208
4	192	177	161	145	130	114	098	083	067	051
5	035	020	004	*989	*973	*957	*942	*926	*911	*895
6	—6,20879	864	848	833	817	801	786	770	755	739
7	723	708	692	676	661	645	629	614	598	583
8	567	552	536	521	505	490	474	459	443	428
9	413	397	382	366	351	335	320	304	289	274
10	259	244	228	213	198	182	167	151	136	121
11	106	090	075	060	045	029	014	*999	*984	*969
12	—6,19953	938	923	907	892	877	862	846	831	816
13	800	785	770	755	740	724	709	694	679	664
14	648	633	618	603	588	573	558	543	528	513
15	497	482	467	452	437	422	407	392	377	362
16	346	331	316	301	286	271	256	241	226	211
17	196	181	166	151	136	121	106	091	076	061
18	046	031	016	001	*986	*971	*956	*941	*926	*911
19	– 6,18897	882	867	852	837	822	807	792	777	762
20	748	733	718	703	688	673	659	644	629	614
21	600	585	570	555	540	526	511	496	481	466
22	452	437	422	408	393	378	363	349	334	319
23	305	290	275	261	246	231	216	202	187	172
24	158	143	128	114	099	084	070	055	041	026
25	012	*997	*982	*968	*953	*938	*924	*909	*895	*880
26	—6,17866	851	837	822	808	793	779	764	750	735
27	721	706	692	677	663	648	634	619	605	590
28	576	561	547	532	518	503	489	475	460	446
29	432	417	403	388	374	360	345	331	316	302

TABLE of the ELASTICITY of AQUEOUS VAPOUR for each $\frac{1}{10}$th degree Centigrade from 0° to 30° (Regnault).

Temp. C.	Tension in Millimetres of Mercury.	Temp C.	Tension in Millimetres of Mercury.	Temp. C.	Tension in Millimetres of Mercury.	Temp. C.	Tension in Millimetres of Mercury.	Temp. C.	Tension in Millimetres of Mercury.
0	4·6	·6	4·8	·2	5·0	·8	5·2	·4	5·5
·1	4·6	·7	4·8	·3	5·0	·9	5·3	·5	5·5
·2	4·7	·8	4·9	·4	5·1	2·0	5·3	·6	5·5
·3	4·7	·9	4·9	·5	5·1	·1	5·3	·7	5·6
·4	4·7	1·0	4·9	·6	5·2	·2	5·4	·8	5·6
·5	4·8	·1	5·0	·7	5·2	·3	5·4	·9	5·6
3·0	5·7	·4	8·2	·8	11·8	·2	16·6	·6	23·0
·1	5·7	·5	8·3	·9	11·8	·3	16·7	·7	23·1
·2	5·8	·6	8·3	14·0	11·9	·4	16·8	·8	23·3
·3	5·8	·7	8·4	·1	12·0	·5	16·9	·9	23·4
·4	5·8	·8	8·5	·2	12·1	·6	17·0	25·0	23·5
·5	5·9	·9	8·5	·3	12·1	·7	17·1	·1	23·7
·6	5·9	9·0	8·6	·4	12·2	·8	17·2	·2	23·8
·7	6·0	·1	8·6	·5	12·3	·9	17·3	·3	24·0
·8	6·0	·2	8·7	·6	12·4	20·0	17·4	·4	24·1
·9	6·1	·3	8·7	·7	12·5	·1	17·5	·5	24·3
4·0	6·1	·4	8·8	·8	12·5	·2	17·6	·6	24·4
·1	6·1	·5	8·9	·9	12·6	·3	17·7	·7	24·6
·2	6·2	·6	8·9	15·0	12·7	·4	17·8	·8	24·7
·3	6·2	·7	9·0	·1	12·8	·5	17·9	·9	24·8
·4	6·3	·8	9·0	·2	12·9	·6	18·0	26·0	25·0
·5	6·3	·9	9·1	·3	12·9	·7	18·2	·1	25·1
·6	6·4	10·0	9·2	·4	13·0	·8	18·3	·2	25·3
·7	6·4	·1	9·2	·5	13·1	·9	18·4	·3	25·4
·8	6·4	·2	9·3	·6	13·2	21·0	18·5	·4	25·6
·9	6·5	·3	9·3	·7	13·3	·1	18·6	·5	25·7
5·0	6·5	·4	9·4	·8	13·4	·2	18·7	·6	25·9
·1	6·6	·5	9·5	·9	13·5	·3	18·8	·7	26·0
·2	6·6	·6	9·5	16·0	13·5	·4	19·0	·8	26·2
·3	6·7	·7	9·6	·1	13·6	·5	19·1	·9	26·4
·4	6·7	·8	9·7	·2	13·7	·6	19·2	27·0	26·5
·5	6·8	·9	9·7	·3	13·8	·7	19·3	·1	26·7
·6	6·8	11·0	9·8	·4	13·9	·8	19·4	·2	26·8
·7	6·9	·1	9·9	·5	14·0	·9	19·5	·3	27·0
·8	6·9	·2	9·9	·6	14·1	22·0	19·7	·4	27·1
·9	7·0	·3	10·0	·7	14·2	·1	19·8	·5	27·3
6·0	7·0	·4	10·1	·8	14·2	·2	19·9	·6	27·5
·1	7·0	·5	10·1	·9	14·3	·3	20·0	·7	27·6
·2	7·1	·6	10·2	17·0	14·4	·4	20·1	·8	27·8
·3	7·1	·7	10·3	·1	14·5	·5	20·3	·9	27·9
·4	7·2	·8	10·3	·2	14·6	·6	20·4	28·0	28·1
·5	7·2	·9	10·4	·3	14·7	·7	20·5	·1	28·3
·6	7·3	12·0	10·5	·4	14·8	·8	20·6	·2	28·4
·7	7·3	·1	10·5	·5	14·9	·9	20·8	·3	28·6
·8	7·4	·2	10·6	·6	15·0	23·0	20·9	·4	28·8
·9	7·4	·3	10·7	·7	15·1	·1	21·0	·5	28·9
7·0	7·5	·4	10·7	·8	15·2	·2	21·1	·6	29·1
·1	7·5	·5	10·8	·9	15·3	·3	21·3	·7	29·3
·2	7·6	·6	10·9	18·0	15·4	·4	21·4	·8	29·4
·3	7·6	·7	10·9	·1	15·5	·5	21·5	·9	29·6
·4	7·7	·8	11·0	·2	15·6	·6	21·7	29·0	29·8
·5	7·8	·9	11·1	·3	15·7	·7	21·8	·1	30·0
·6	7·8	13·0	11·2	·4	15·7	·8	21·9	·2	30·1
·7	7·9	·1	11·2	·5	15·8	·9	22·1	·3	30·3
·8	7·9	·2	11·3	·6	15·9	24·0	22·2	·4	30·5
·9	8·0	·3	11·4	·7	16·0	·1	22·3	·5	30·7
8·0	8·0	·4	11·5	·8	16·1	·2	22·5	·6	30·8
·1	8·1	·5	11·5	·9	16·2	·3	22·6	·7	31·0
·2	8·1	·6	11·6	19·0	16·3	·4	22·7	·8	31·2
·3	8·2	·7	11·7	·1	16·4	·5	22·9	·9	31·4

TABLE of LOG. $(1 + \cdot 003665t)$ 760 for each $\frac{1}{10}$th of a degree from 0° C. to 30° C.

t°.	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0 8	0·9
0°	2,88081	097	113	129	144	160	176	192	208	224
1	240	256	272	288	304	319	335	351	367	383
2	399	415	431	447	462	478	494	510	526	542
3	557	573	589	604	620	636	651	667	683	699
4	714	730	746	761	777	793	809	824	840	856
	871	887	903	918	934	950	965	981	996	*012
6	2,89027	043	058	074	089	105	120	136	151	167
7	182	198	213	229	244	0	275	291	306	322
8	337	353	368	384	399	415	430	445	461	476
9	491	507	522	538	553	569	584	599	615	630
10	645	661	676	691	707	722	738	753	768	783
11	798	814	829	844	860	875	890	906	921	936
12	951	967	982	997	*012	*028	*043	*058	*073	*088
13	2,90103	119	134	149	164	179	194	209	224	239
14	255	270	285	300	315	330	345	360	375	390
15	406	421	436	451	466	481	496	511	526	541
16	557	572	587	602	617	632	647	662	677	692
17	707	722	737	752	767	782	797	812	827	842
18	857	872	887	902	917	932	947	962	977	992
19	2,91006	021	036	051	066	081	096	111	126	141
20	155	170	185	200	215	229	244	259	274	289
21	303	318	333	348	363	377	392	407	422	437
22	451	466	481	495	510	525	540	554	569	584
23	598	613	628	642	657	672	687	701	716	731
24	745	760	775	790	804	819	834	848	863	878
25	892	907	922	936	951	965	980	994	*009	*024
26	2,92038	053	068	082	097	112	126	141	155	170
27	184	199	213	228	242	257	271	286	300	315
28	329	344	358	373	387	402	416	431	445	460
29	474	489	503	518	532	547	561	575	590	604
30	618	633	647	661	676	690	704	719	733	747

INDEX.

D.

E.

F.

G.

H.

S.

T.

Y.

Z.

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SIXTH REPORT

OF

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