H. ROFE.

FIRST REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1868 TO INQUIRE INTO

THE BEST MEANS OF PREVENTING THE POLLUTION OF RIVERS.

(MERSEY AND RIBBLE BASINS.)

Vol. I.

REPORT AND PLANS.

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

LONDON:
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PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1870.

[C. 37.]

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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 authorized and appointed, and do by these Presents authorize 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 authorize 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 authorize 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 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 directed 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 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 connection with the woollen and iron manufactories.

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

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

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

Your special points of enquiry 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 COMMISSIONERS.

Whitehall, 7th July 1865.

GENTLEMEN,

5072. 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.

House of Commons, 27th June 1865.

DEAR SIR,

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 authorized 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 authorized and appointed, and do by these Presents authorize 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 authorize 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 authorize 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.

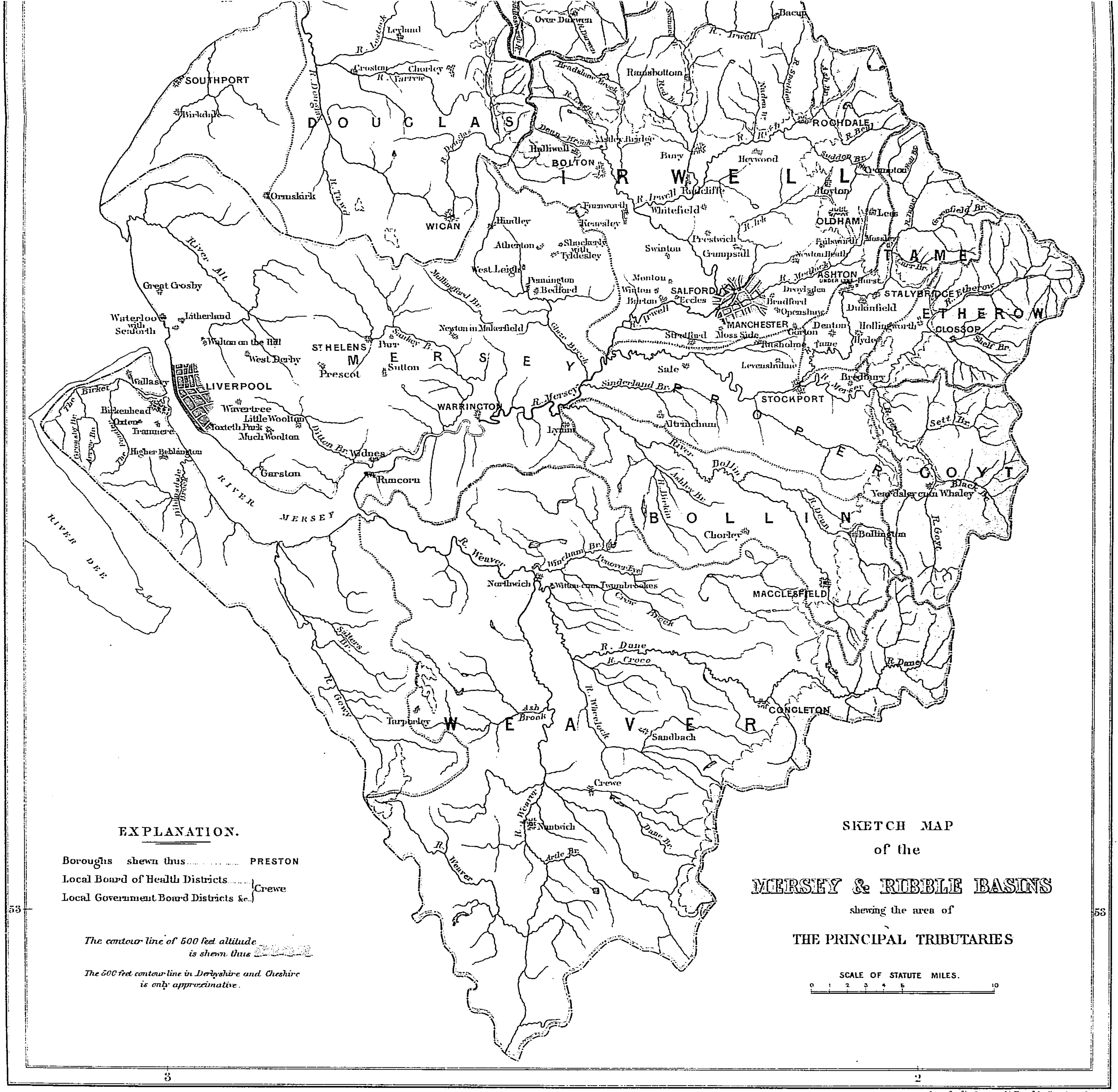
Given at Our Court at Saint James's, the twenty-second day of November, in the year One thousand eight hundred and sixty-nine, and in the Thirty-third year of Our Reign.

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.



SKETCH MAP
of the
MERSEY & RIBBLE BASINS
shewing the area of
THE PRINCIPAL TRIBUTARIES
SCALE OF STATUTE MILES.
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EXPLANATION.
Boroughs shewn thus PRESTON
Local Board of Health Districts
Local Government Board Districts &c.
Crewe
The contour line of 500 feet altitude is shewn thus
The 500 feet contour line in Derbyshire and Cheshire is only approximative.
D O U G L A S
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M E R S E Y
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Birkdale
Ormskirk
WIGAN
Leyland
Croston
Chorley
Over Darwen
Bacup
Ramsbottom
ROCHDALE
Heywood
Bury
BOLTON
Halliwell
Crompton
Royton
OLDHAM
Lees
Farnworth
Kearsley
Whitefield
Radcliffe
Prestwich
Crumpsall
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Hindley
Atherton
Tyldesley
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Bedford
Monton
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SALFORD
MANCHESTER
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Openshaw
Gorton
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Droylsden
ASHTON UNDER LYNE
Hurst
STALYBRIDGE
Dukinfield
Hollingworth
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Moss Side
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Levenshulme
Sale
Bredbury
STOCKPORT
Altrincham
Lymm
Great Crosby
Litherland
Waterloo with Seaforth
Walton on the Hill
West Derby
ST HELENS
Prescot
Sutton
Newton in Makerfield
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LIVERPOOL
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Birkenhead
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Little Woolton
Toxteth Park
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Stanford's Geogr! Estab! Charing Cross.


MORECAMBE BAY
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R. Calder
R. Irwell
R. Darwen
R. Douglas
R. Yarrow
R. Roch
R. Tame
R. Etherow
R. Lostock
R. Hodder
R. Medlock
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REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

May it please Your Majesty.

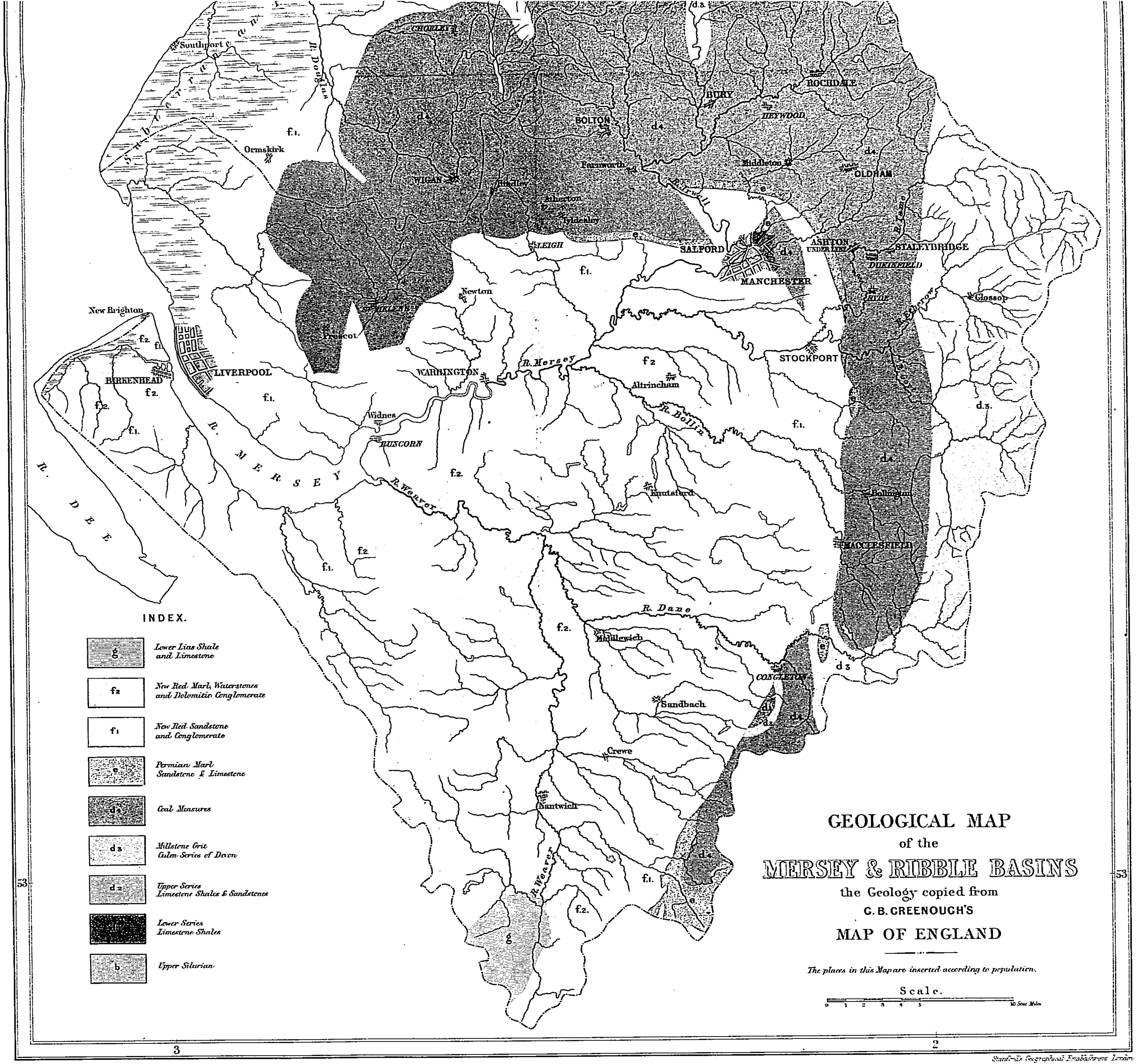
Introduction.

Your Majesty's Commission, which commands us to institute inquiries into the condition of certain rivers in England, and into the best means of remedying any evils arising out of the use or abuse of the waters passing down their channels, has opened out a very wide field of inquiry. We have not only to investigate the condition of the rivers and running waters, and, if they are in an impure or unwholesome state, to ascertain by observation, by inquiry, and, by analysis the causes of their pollution; but we have also to seek remedies for the evils we discover, paying due regard to those large interests of both population and capital which have become involved in the use and the abuse of river water, especially in the manufacturing districts of the country. To these subjects, has been added, at the request of Mr. Charles Neate, "the great question of the water supply."

The first and the third heads, under which our duties may be thus classified, required that we should visit each selected river basin, inspect the main seats of population and of manufacturing industry within it, and determine the character and amount of the impurities by which its rivers or streams are defiled. They also required that we should ascertain the quality and quantity of the water supplied to its towns; and the various uses, manufacturing as well as domestic, to which this water is devoted. Under the second head of our duties we have had to inspect all those places where any attempt has been made to purify water which has been polluted by sewage or refuse from manufactories. We have accordingly examined the different processes adopted at these places—*First*, with reference to their efficiency as means of cleansing water so contaminated; that is, either of extracting from it so large a proportion of the deleterious ingredients mixed with it, or of so far chemically transforming its polluting into non-polluting ingredients, as will justify its return into the ordinary watercourses of the country—*Second*, with reference to their cost; for upon this must depend, in great measure, the adoption of any of them as a general remedy for the evils complained of.

We have been compelled, in the course of our inquiry into the action of polluted rivers upon the health and comfort of the population in the *Mersey* and *Ribble* basins, to go somewhat beyond the strict limits of that particular investigation. Nevertheless, the causes of disease are so various and so many that it is extremely difficult to estimate the separate effect of any one of them; and it has been found impossible to form an exact opinion as to the influence which the state of its rivers may have exerted upon the health of this district, without a much more elaborate analysis of the statistics of disease and of mortality in the different South Lancashire towns than we have been able to undertake. The results, however, of such inquiries as we have thought it right to make on this subject will be found in the *Minutes of Evidence*—Vol. II. (parts 1 and 3),—accompanying this Report, and some of the conclusions to which we have been led by them will be stated in the sequel.

In order to carry out our instructions, we adopted the following course of procedure. Commencing at the estuary of the *Mersey*, we visited Liverpool, Widnes, St. Helen's, and Warrington, on the north side of the river; and Birkenhead, Wallasey, Tranmere, and Runcorn on its southern side. We then moved to Manchester, and, after the necessary inspections in that city and in Salford, visited Bolton, Bury, Rochdale, and Oldham in the valley of the *Irwell*, Stockport at the head of the *Mersey*, Ashton and Stalybridge on the *Tame*, Glossop on the *Etherow*, New Mills on the *Goyt*, Macclesfield on the *Bollin*, and Northwich and Congleton in the valley of the *Weaver*. Passing on to



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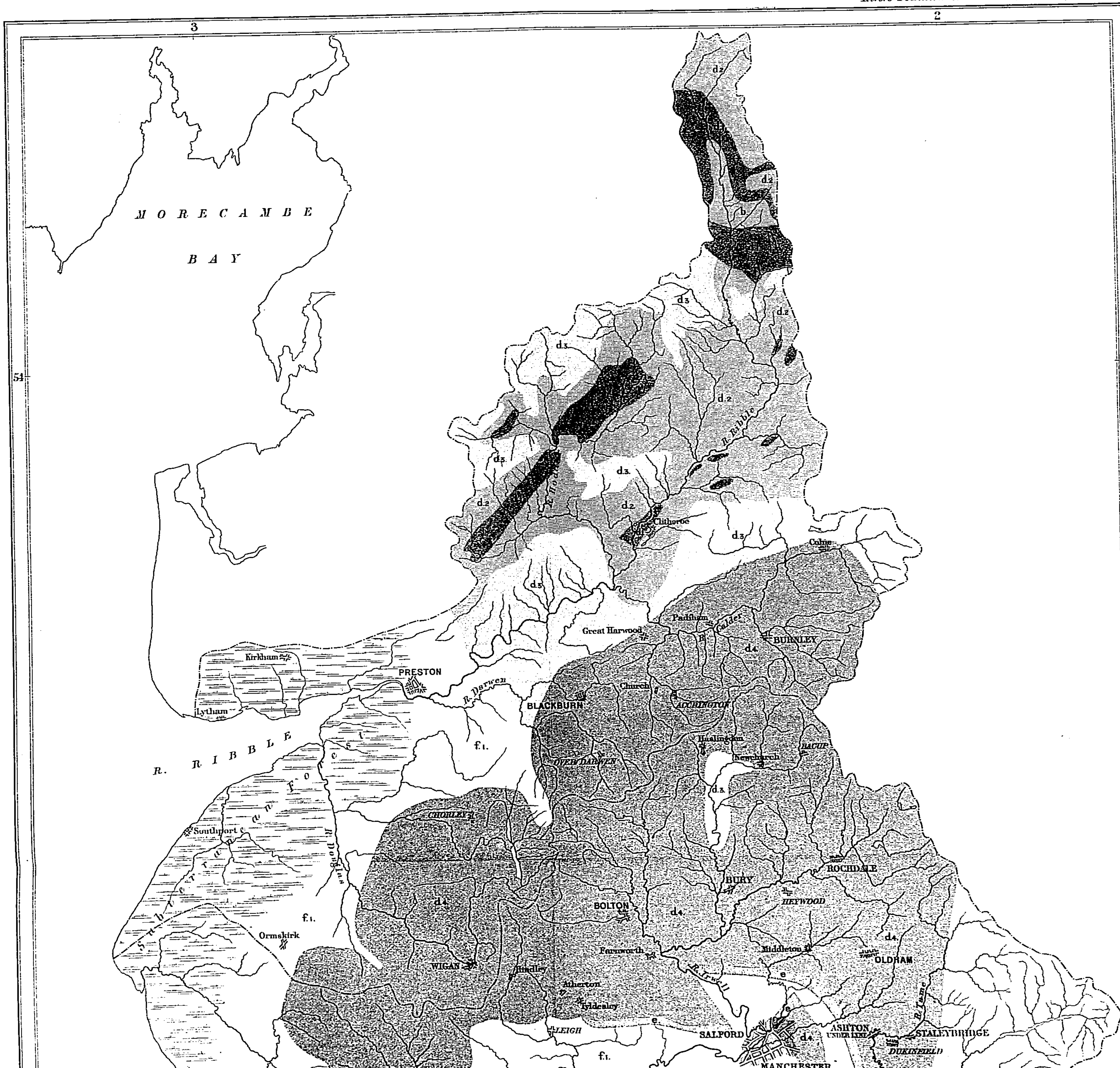

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MORECAMBE BAY
R. Ribble
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Great Harwood
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PRESTON
Kirkham
Lytham
R. Darwen
BLACKBURN
Church
ACCRINGTON
Haslingden
Newchurch
BACUP
OVER DARWEN
R. RIBBLE
CHORLEY
Southport
Ormskirk
WIGAN
Hindley
BOLTON
BURY
ROCHDALE
HEYWOOD
Middleton
OLDHAM
Farnworth
Atherton
Tyldesley
LEIGH
SALFORD
ASHTON UNDER LYNE
STALEYBRIDGE
DUKINFIELD

INTRODUCTION.

Preston we thence visited Blackburn, Wigan, Chorley, Accrington, Clitheroe, Over-Darwen, and Burnley on the *Ribble* and its affluents. We met the authorities at these places, read the Commission under which we are instructed, and explained at a public meeting the object of our appointment, and the character of the information we wished to obtain from both corporate bodies and individuals.

In every case the rivers and streams were examined, and, wherever it appeared desirable, samples of water were collected above and below the towns upon their banks. We took samples also of the sewage and other polluting materials entering them; and samples were also collected illustrative of the water supply throughout the district. The arrangements as to sewerage, the disposal of town refuse, and other matters affecting the health of the population, were also examined; the different manufacturing establishments having any special action upon the character of the drainage were inspected, and samples were taken of the refuse discharged from each into the sewers or streams.

In these tours of inspection we everywhere received the cordial assistance of the local authorities and manufacturers, the latter unreservedly exhibiting to us their various processes, and giving detailed explanations whenever required.

Data having been thus collected for a more elaborate inquiry embracing all the points upon which information of a detailed character was required, a series of questions was printed, and sent to all from whom we expected to obtain either information as to facts, or opinions or suggestions. A large mass of evidence has been thus obtained, much of which is the result of careful thought and consideration, bearing often upon the condition of particular localities, or showing the results of specific manufactures; but having also, in many instances, a direct reference to the general question of the disposal of refuse of all sorts.

Pending the return of answers to the questions thus circulated, visits were paid to all the places where attempts have been made to purify or utilize sewage, as the towns of Banbury, Bedford, Carlisle, Cheltenham, Croydon, Edinburgh, Norwood, Penrith, Rugby, Warwick, Worthing, the Lodge Farm at Barking, the Camp at Aldershot, and the Invalid Prison at Woking, where sewage is utilized by irrigation; Ealing, Leicester, and Northampton, where filtration, deodorization, or precipitation of sewage is attempted; Stroud, and Leamington, where sewage is deodorized, precipitated, and filtered, and a manure made from it; Lancaster, where an earth closet system is partially carried out on the suggestion of Mr. W. J. Garnett of Quernmore Park; Rochdale, where Goux's plan of scavenging is being tried; and the West Riding prison at Wakefield, and the Criminal Lunatic Asylum at Broadmoor, where Moule's earth closets are in use.

Having carefully examined the documentary evidence received in answer to our inquiries and compared it with the notes made during our tour of inspection, we then paid a second visit to the principal towns in the district under examination; fully advertising our intention, so that any person aggrieved by the condition of the river, had the opportunity afforded him of laying his complaint before us: and, having previously submitted to the authorities of these towns copies of the whole of the evidence elicited from the municipal bodies, we were in a position to inquire into any discrepancies of statement as to facts which that evidence exhibited, or any differences of opinion which had been expressed as to modes of remedying the evils the existence of which was admitted. The written statements previously obtained, corrected when necessary by the evidence procured on our second visit, are given in the volume of evidence attached to our Report; and they are presented in a somewhat different form from that usually adopted,—the object being both to diminish the bulk of the appendices, and to bring together all the evidence on each particular branch of the inquiry, so as to enable others to institute, without difficulty, comparisons between the conclusions we have arrived at and the evidence on which they have been based.

We have, of course, availed ourselves of the information contained in the reports of our predecessors on the rivers *Thames*, *Lee*, and *Aire* and *Calder*. The three Reports of the Commission appointed (5th January 1857) to inquire into the best mode of utilising the sewage of towns have also been carefully considered: and whenever any branch of our subject has appeared to us to have been already fully investigated under Your Majesty's Commission, we have not thought it necessary to go over the same ground again, but have contented ourselves with simple reference to the conclusions of the Commissioners, whenever we have had occasion to adopt them.

INTRODUCTION.

It will be seen that though our inquiries have had reference to those river pollutions which may be considered characteristic particularly of the *Mersey* and *Ribble* districts, yet we have had to deal with a great variety of subjects, to investigate the action of many influences upon the state of the rivers and streams, and to discuss the operation of a great many remedial measures, so that the following Report refers to the subject of river conservancy generally, as well as to the condition of the particular river basins to which it is professedly confined.

To these prefatory remarks we have now only to add that our present Report is arranged under two heads. The first part describes the district which we have been directed to examine, and then relates the various experiments made by ourselves and others on the purification of water which has been rendered unfit for use by mixture either with human excreta or with manufacturing refuse. The second part refers in detail to the whole subject of the water supply within the *Mersey* and *Ribble* basins.

PART I. DESCRIPTIVE.

Area of river basins.

PART I.—RIVER POLLUTION.

Section A.—Descriptive.

VALLEY OF THE MERSEY :—The rivers which find their way into the sea by the estuary of the *Mersey* have their rise, for the most part, on the central range of hills, dividing the waters flowing into the German Ocean from those flowing into the Atlantic. The *Mersey* proper is formed by the junction of the *Goyt* and the *Etherow*, two streams draining areas respectively of 44,960 and 38,240 acres. These two streams unite a few miles above Stockport, at which place the river, there called the *Mersey*, is joined by the *Tame*, flowing from the north, and bringing down the drainage of 38,080 acres. About twenty-five miles lower down it receives, also from the north, the water of the *Irwell*, which, having been joined at or above Manchester by the rivers *Medlock*, *Irk*, *Roch*, *Tonge*, and *Croal*, and by a variety of small brooks or streams, pours into the *Mersey* the drainage of 199,520 acres.

In addition to the water contributed by these rivers, the *Mersey* receives, by various small brooks on the north bank, the drainage of 126,720 acres; while on the south bank the *Bollin* discharges into it the drainage of 71,520 acres; and it receives directly from small brooks and streams the drainage of 68,480 acres.

The total area drained by the river *Mersey* before it discharges itself into the estuary is, as stated above, 587,520 acres. Runcorn Gap may be regarded as the head of the estuary, though the tide makes its way up the river as far as Warrington, about seven miles higher, but the stream between Runcorn and Warrington is nowhere very wide, and at Runcorn Gap it is narrowed to 470 yards and crossed by a bridge, while below, it opens out at once to a width of two or three miles, and is to all intents a salt water inlet in which the tide ebbs and flows. Below Runcorn the river *Weaver* discharges into this estuary on the south bank the drainage of 355,360 acres, as do also various small brooks the drainage of 114,560 acres, while on the north bank the water from 46,080 acres is poured into the tideway by various small streams.

The whole drainage area of the *Mersey* is therefore as follows:—

Above Runcorn	- -	587,520 acres.
Below „	- -	516,000 „
Total	- -	1,103,520 „

VALLEY OF THE RIBBLE:—The *Ribble* has its rise in the Yorkshire hills, near Ingleborough. At about two miles above Clitheroe, it forms the boundary line between Yorkshire and Lancashire, and when joined by the *Hodder* on the right bank, it runs for the rest of its course wholly through Lancashire. On the left bank, about half a mile below the point where it is joined by the *Hodder*, it receives the *Calder*, bringing down the drainage of 83,680 acres. Lower down, on the same bank, it is joined by the *Darwen*, draining an area of 36,480 acres, while the small streams flowing directly into the *Ribble* on the left bank above Preston drain an area of about 120,000 acres. On the right bank, in addition to the *Hodder*, which drains an area of 66,240 acres, several small streams bring down the drainage of 106,080 acres.

The whole drainage area of the river *Ribble* may thus be put at 412,480 acres. Five miles below Preston it widens out into an estuary, into which the *Douglas* discharges itself, having drained 109,760 acres. This river can therefore scarcely be regarded as a tributary to the *Ribble*.

A slight sketch of the geological structure of the district will explain the peculiar grouping of the population in portions of the two valleys of the *Mersey* and the *Ribble*.

The *Mersey* from a short distance below Stockport runs through strata belonging to the new red sandstone formation. On the south side of the river nearly the whole of its affluents are supplied from these strata; though others have, in some instances, their rise in the Derbyshire hills, which are there composed of the carboniferous limestone. On the north of the river, however, the red sandstone is but a narrow strip three or four miles wide, beyond which lies the great Lancashire coal-field, extending from Ormskirk on the west to the Yorkshire hills on the east, a distance of 30 to 36

PART I. DESCRIPTIVE.

Area of river basins.

miles. A branch from this field goes off towards the north, and occupies a large portion of the valley of the *Calder*, and another stretches away to the south as far down as Macclesfield, occupying the upper part of the valley of the *Bollin* and a portion of the valleys of the *Etherow* and *Tame*, while the great bulk of the field is spread over the valley of the *Irwell*, and occupies a large portion of the basin of the *Douglas*. Roughly estimated, this great coal field covers an area of 264,640 acres.

Tables are given below showing the area of the different valleys within the basins of the *Mersey* and the *Ribble*, and the population of each of them for decennial periods from 1801 to 1861. These, taken in connexion with the above geological description, show how much more rapid has been the increase of population on the coal-measures than on the red sandstone, and how much more densely populated is the former.

AREA AND POPULATION :—MERSEY BASIN.

—	Area.		Population.						
	Square Miles.	Acres.	1801.	1811.	1821.	1831.	1841.	1851.	1861.
Mersey proper—North Bank -	270	172,800	173,047	211,862	266,688	356,192	470,120	591,079	716,369
„ „ South Bank -	286	183,040	57,339	67,297	82,343	106,903	140,038	177,936	211,665
Etherow - - -	59¾	38,240	7,307	8,782	12,312	17,325	23,837	30,227	30,384
Goyt - - - -	70¼	44,960	9,287	11,768	12,999	13,924	14,360	15,261	17,790
Tame - - -	59½	38,080	29,095	35,884	45,702	64,746	87,226	99,420	111,123
Irwell - - -	311¾	199,520	253,327	318,772	414,280	555,724	690,432	853,103	1,014,569
Bollin - - -	111¾	71,520	29,114	35,865	44,545	56,986	63,142	70,756	70,101
Weaver - -	555¼	355,360	71,919	81,057	93,419	105,377	114,890	122,187	135,787
Total - -	1,724¼	1,103,520	630,435	771,287	972,288	1,277,177	1,604,045	1,959,969	2,307,788

AREA AND POPULATION :—RIBBLE BASIN.

	Square Miles.	Acres.	1801.	1811.	1821.	1831.	1841.	1851.	1861.
Ribble proper—Right Bank -	165¾	106,080	28,109	36,369	46,551	55,760	72,615	91,984	106,184
„ „ Left Bank -	187½	120,000	25,406	29,651	36,447	42,295	47,547	49,416	56,295
Calder - - -	130¾	83,680	36,824	45,603	61,782	70,702	80,656	94,008	118,725
Hodder - - -	103½	66,240	3,639	4,143	4,528	4,403	4,006	3,744	3,388
Darwen - - -	57	36,480	28,044	34,354	47,382	53,691	66,823	79,179	103,247
Douglas - - -	171½	109,760	44,471	54,405	66,008	74,342	85,952	94,681	101,337
Total - -	816	522,240	166,493	204,525	262,698	301,193	357,599	413,012	489,176

A brief comparison of the state of things in the valley of the *Weaver* to the south of the *Mersey*, with that in the *Irwell* valley to the north will make the contrast to which we allude more evident. The *Weaver* has a drainage area of 555¼ square miles, and its population in 1801 amounted to 129·5 per square mile; in 1851 this had increased to 219·8 per square mile, while in 1861 it had reached 244·3, somewhat less than double the number found there in 1801. The *Irwell* has a drainage area of 311¾ square miles, and the population in 1801 was 812·6 to a square mile, upwards of six times as dense as that on the red sandstone; in 1851 there were 2736·5 per square mile, and in 1861 the number was 3254·4, or four times that which occupied the same area in 1801, and upwards of thirteen times as many as are found on the same area in the valley of the *Weaver*.

Such a condensation of the population has necessarily had a very marked effect upon the condition of the rivers and streams especially in the coal districts. Not only is the amount of sewage which is thus poured into the natural drainage channels of the country increased in direct proportion to the augmentation of the population, but the demand for water for all sorts of purposes is enhanced to an extraordinary extent, and the water commonly becomes polluted by being used.

These two considerations embrace indeed within their limits the whole of the problem with which we have to deal. A certain quantity of water falls upon a given area, and upon that area circumstances have congregated a large and a rapidly increasing population. But the natural supply of water is a fixed quantity; and our problem therefore may be stated thus:—By what means can the largest *regular* supply of water be secured? and, how can this supply be maintained in such a state of purity as will admit of its reiterated employment for manufacturing and other purposes till it finds its way at last into the estuaries or into the sea in such a condition as to be neither injurious nor offensive to those living on its course or near the outfall?

We confine ourselves at present to the latter of these questions, leaving the former for discussion in the second part of this Report.

The tables of the population of the different valleys given above have enabled us to deduce the average numbers per square mile, and thus to show how the density of the

Part I.
Descriptive.
Irwell basin.

population and the rate of its increase are affected by the nature of the strata. But they give us at best a remote idea of the mode in which the population is distributed in the different valleys, and of the action which this distribution has had upon the purity of the rivers and streams.

In order, therefore, to bring this more prominently forward, we have caused a plan to be prepared on data furnished by Mr. H. Baylis, C.E., Borough Engineer, Bolton, showing the position of the towns in the valley of the *Irwell*, and illustrating the mode in which the manufacturing population clusters round the watercourses, following them to the very point where they commence in springs from the hill sides. We have not thought it necessary to prepare plans of all the valleys; one may be taken as the type of all: that which is true of the *Irwell* is true also of the *Calder* and the *Douglas;* and a particular description of the first from its source to its junction with the *Mersey* will apply with general accuracy to all the streams, small or great, flowing through the coal measures in the two great valleys of the *Mersey* and *Ribble*.

DESCRIPTION OF THE RIVER IRWELL.

The river *Irwell* has its rise at the Erewell Spring, about 2½ miles to the north of the town of Bacup, at an elevation of 1,325 feet above the level of the sea. About half a mile from its source it runs close by a few cottages known by the name of Nook End; and as a matter of course the ashes and refuse from these cottages are thrown into the stream, which is still a mere rivulet. The water has here a slight peaty discoloration, and the quality may be inferred from an analysis of a sample taken at a short distance above these cottages, the inhabitants of which get their drinking water from a stone trough by the side of the road, which receives the droppings of a spring. The results of this analysis are given in the table at page 15, after the words " The *Irwell* near its source, June 12, 1869." At this point the water is of excellent quality for all domestic purposes.

About 300 yards below these cottages the water is made use of to turn the wheel of the Old Clough mill, furnishing power to drive the machinery of a small cotton factory; and some 200 yards lower down, this water, together with all that can be collected from the springs bursting out of the small amphitheatre of hills forming the head of the valley, is taken up for the use of the Irwell Spring Dyeworks, and is thence transferred to printworks, some 200 yards lower down, belonging to the same firm, where the whole of the water is collected into lodges or settling ponds. These fulfil a double office; cleansing the water by allowing it time to settle and deposit any matter it may have collected in passing down from the springs, and collecting the whole discharge of the 24 hours to be used during the working period of the day. The water used for power is passed through a turbine, and is consequently uninjured, but the whole of that which is used in the dyeing and printing processes is returned uncleansed to the river, whence it is taken up by the Rosendale Industrial Company's dyeworks, and passed from these to the Higher Weirmill, belonging to the same company, where it drives the machinery of cotton works. Above this last-mentioned mill a few small streams fall into the river, having collected the drainage of the right side of the valley, which is not more than half a mile in width; and about 100 yards below the mill the *Deardend* and *Heald* brooks bring down the drainage of a considerable area on the left bank. Half a mile lower down, the water was, when we saw it, running through the sluices of the Dogpits mill, which was not working, though there was head enough to furnish power, and it was then taken up for that purpose by the Old Engine Mill, while to the right of the road the water furnished by two small brooks was made use of to work the machinery of the Broad Clough mills.

Here, at half-past eleven on a *Saturday* morning, the water from the lodge or settling pond was being passed into the river; it was of a yellowish brown colour, thick and muddy, but as it got nearer the bottom of the lodge, it carried with it into the river a filthy black sludge, smelling very offensively. About a quarter of a mile below the outlet of the Clough mills, we come to the Meadows mill, supplied from the river by a weir which turns the water into a large pond or lodge; the mill has also a supply from a small brook on the left bank. About 200 yards below Meadows mill, a cotton mill is placed on a small brook on the right bank of the river; and 150 yards lower down, another cotton mill is similarly placed on another small stream; while 100 yards below the outlet of this a foundry on one side of the river, and a cotton mill on the other, are supplied with water by a weir across the stream. And 200 yards lower down a cotton mill and a flour mill are provided with water in a similar manner.

At Bacup two small streams, the *Greave* and the *Tong* cloughs or brooks bring in the

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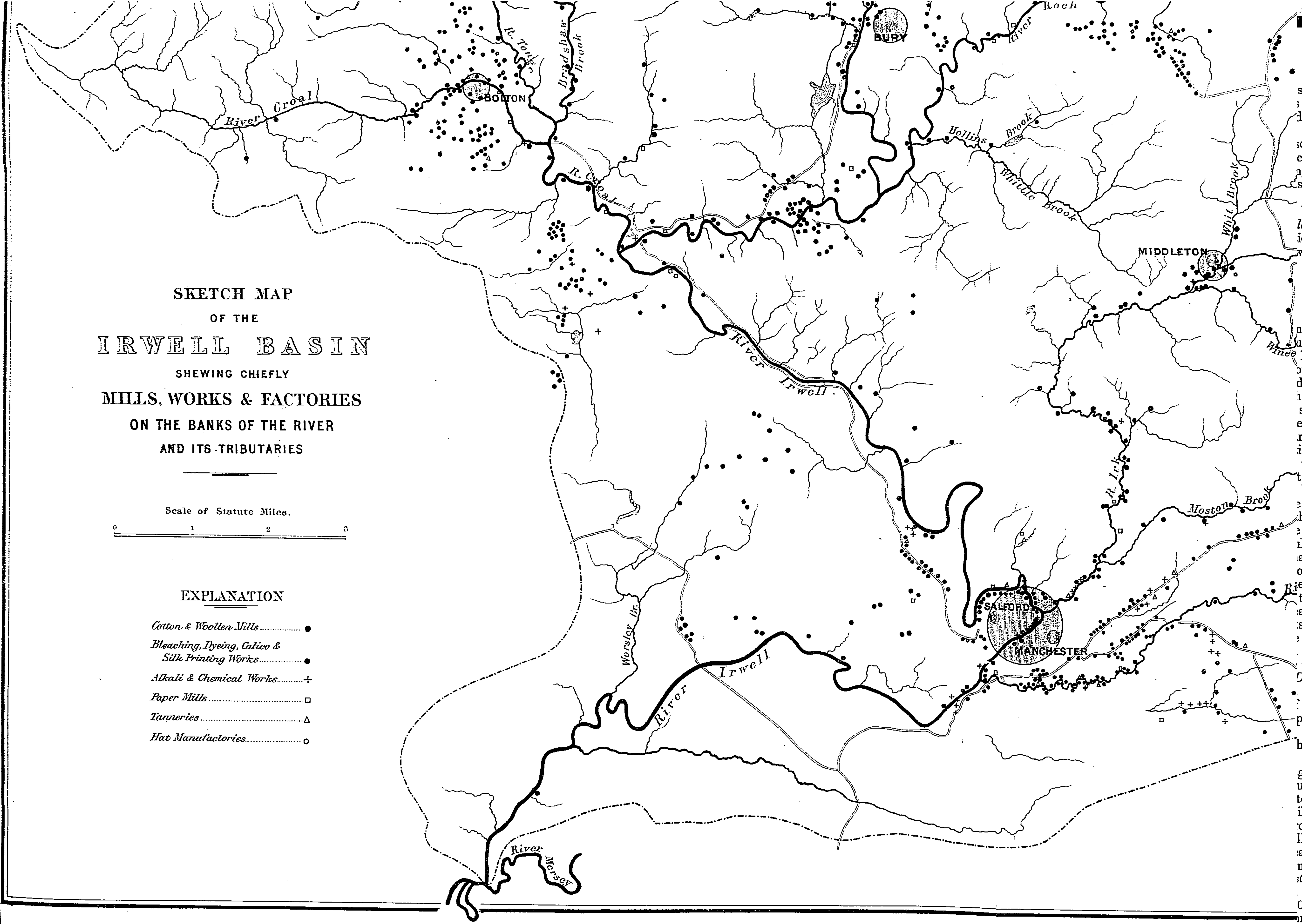
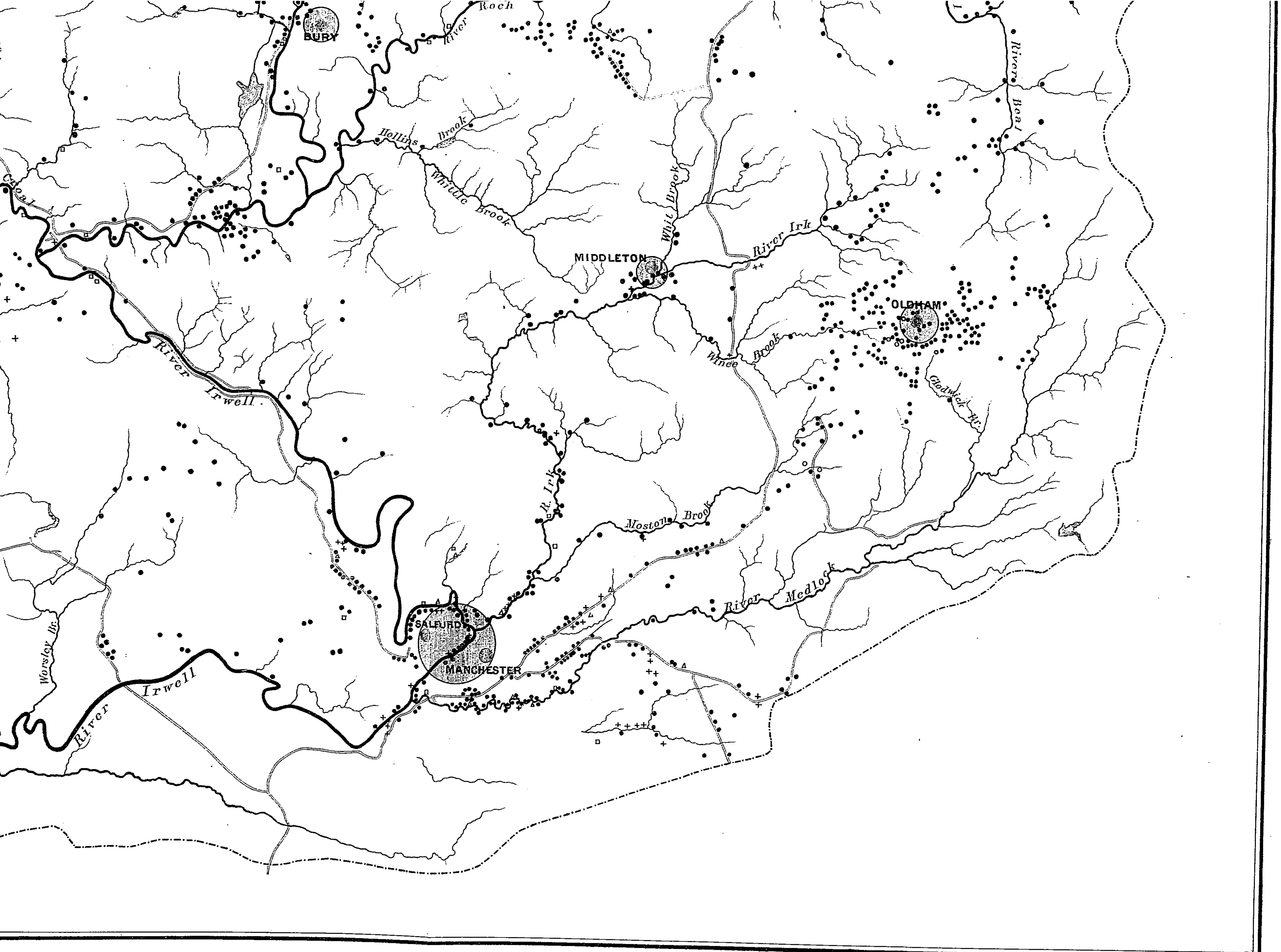
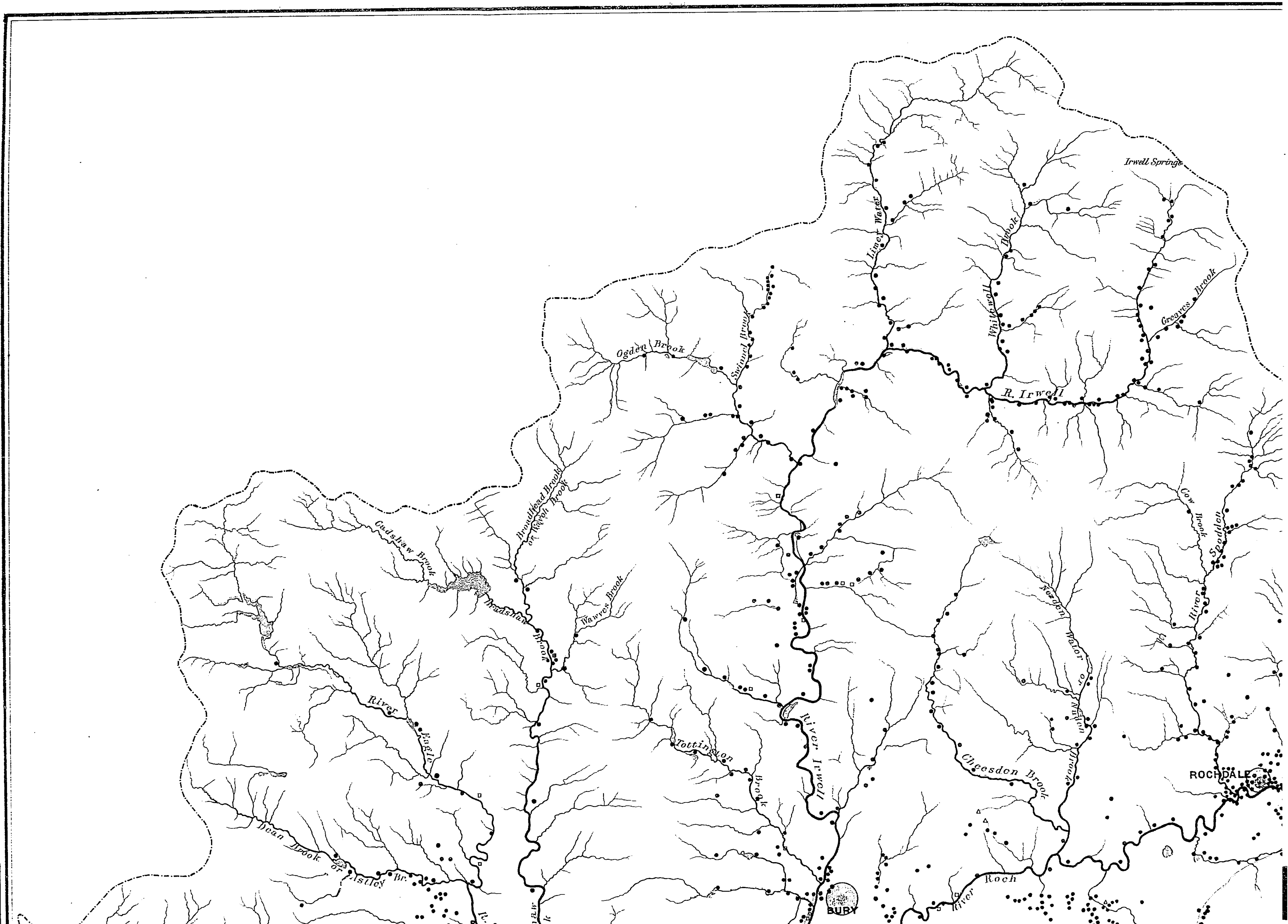




Stanford's Geographical Establishment, London.


Irwell Springs
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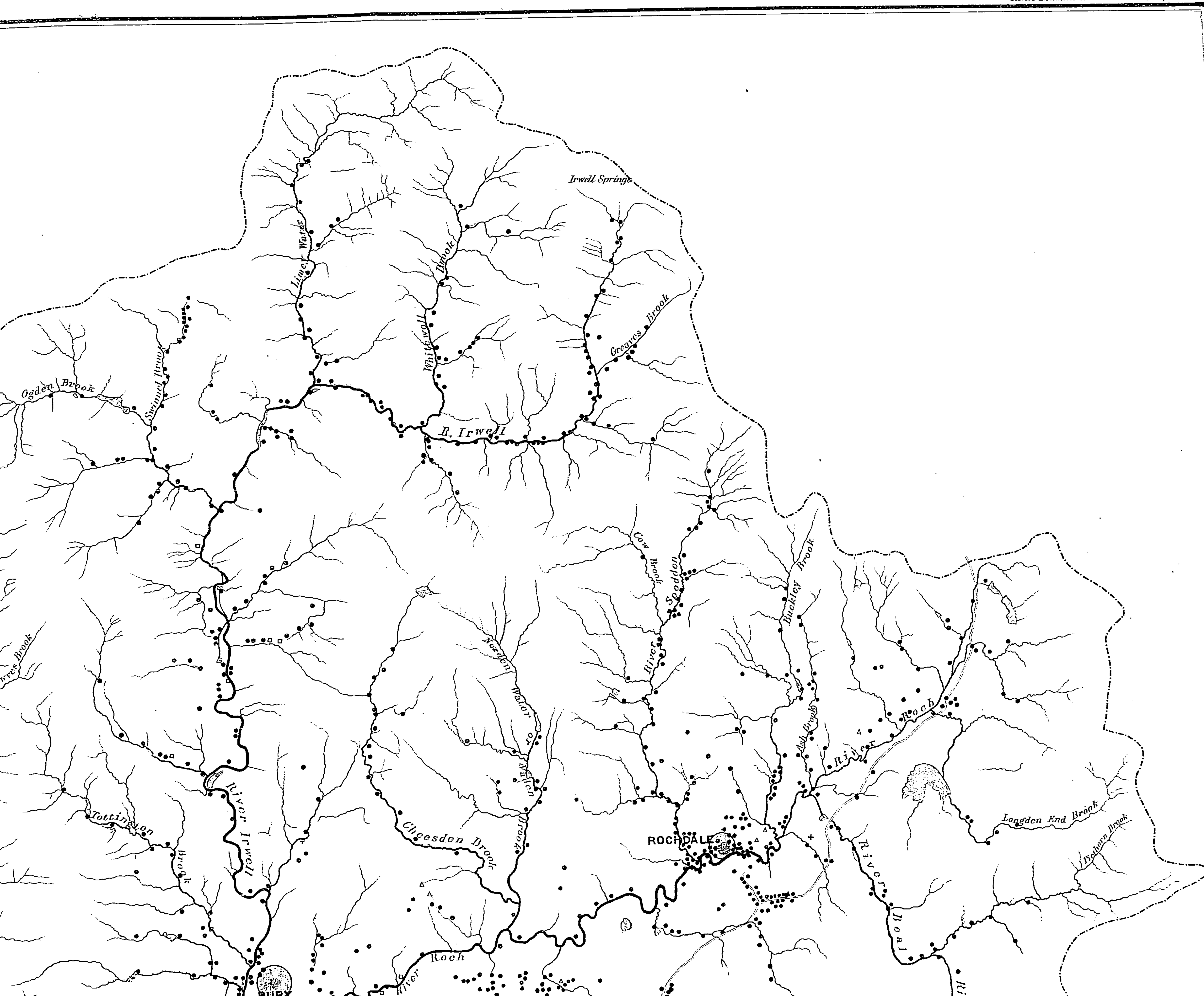
Whitewell Brook
Greaves Brook
R. Irwell
Ogden Brook
Swinnel Brook
Broadhead Brook or Wash Brook
Cadshaw Brook
Bradshaw Brook
Wawes Brook
Cow Brook
River Spodden
Norden Water or Naden Brook
River Eagle
Tottington Brook
River Irwell
Cheesden Brook
ROCHDALE
Dean Brook or Astley Br.
River Roch
BURY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R. Irwell
Cow Brook
River Spodden
Buckley Brook
Naden Water
Naden Brook
Cheesden Brook
River Irwell
Tottington Brook
ROCHDALE
Ash Brook
River Roch
Longden End Brook
River Beal
River Roch

Part I. Descriptive. Irwell basin.

drainage of about 1,000 acres of the left bank: advantage, however, has already been taken of the water of these streams to furnish power to six cotton mills and one flour mill; and as the lodges of these mills had been, as we were told, allowed to empty themselves in the morning at eight o'clock, not a drop of water was coming from these brooks into the river at the time of our visit, the whole being absorbed for the purpose of refilling these lodges. Bacup has a population of about 17,600; and is governed by a Board appointed in accordance with the provisions of the Local Government Act, which was adopted by the inhabitants in 1863. The area over which the Board exercise jurisdiction is 1,600 acres, or $2\frac{1}{2}$ square miles. Sewers and sewage tanks have been constructed at a cost of 12,500*l.*, but notwithstanding this expenditure complaints are sometimes made of the state of the river. It is said (Vol. II., *Minutes of Evidence*, part 1) to be polluted by town sewage to a considerable extent, and by refuse from turkey-red dyeworks; ground logwood is turned into the river in large quantities; it is also polluted by water from mines. Previous to the adoption of the Local Government Act, the river *Irwell*, and the *Greave* and *Clough* brooks were so choked that in certain instances archways of bridges were blocked, sufficient room not being left for the passage of storm water, and parts of the town were consequently flooded. Since the Board has been in operation, the beds of these rivers and brooks, within the limits of its authority, have been cleaned and lowered, so that the floods do not now continue for any length of time. Complaints it is said are seldom made of the state of the stream; judging, however, from the appearance of the bed of the river when we visited it, the term *stream* is a misnomer, except on Saturdays when the lodges are emptied for the purpose of getting rid of the weekly deposit of filth: then, indeed, if we are to believe the statements made by the inhabitants of cottages on the banks of the river, a black and fetid stream passes down the channel carrying with it every species of abomination. It is plainly beyond the power of the Local Board to deal with a state of things which is only very partially due to causes within the limits of its jurisdiction.

The river issues pure at Erewell spring within three miles from the centre of this town, and in this short distance it has served the purposes of 19 cotton factories, two dyeworks, one printwork, one saw mill, and two flour mills. That portion of Bacup through which the river flows, some of it being not yet sewered, is said to be especially unhealthy; small-pox was prevalent there in 1868, and the prevalence of disease is attributed to bad drainage and, in a small degree, to the state of the river. This is said, as we have before mentioned, to be polluted by "town sewage;" but Bacup is the first town on the stream, and it has only 60 water-closets, of which but one-third are connected with the sewers, and none of the privies have any communication with these sewers, or pass any of the matter they contain into the river direct. The term "town sewage" here therefore applies to the ordinary drainage from the sinks and gullies, which, carrying as it does with it a large proportion of the urine and slops from the houses, is no doubt both offensive and injurious. The only comfort which the Board can hold out to complainants is their conviction (a perfectly fallacious one) that the water of the river in passing through the boilers and condensers of steam engines, which it frequently does, gets rid of a large quantity of the offensive elements which have been poured into it (Vol. II., *Minutes of Evidence*, part 1). The Board say that the river is not polluted by solid refuse, but judging from what we saw this statement must be taken with some reservation. No doubt the heavier refuse from quarries is kept out of the stream, but ashes are still thrown in.

In the length of three-quarters of a mile within the town of Bacup, below the junction of the *Greave Clough*, there are on the river three cotton mills, two woollen factories, and two saw-mills. Just below the railway station the *Trough Dyke* joins the river, bringing down the drainage of several hundred acres of the left bank. This water, however, is appropriated to the uses of works upon the *Dyke*, and it furnishes power to two cotton mills, and water for all purposes to a large printwork.

Under circumstances such as those detailed above, it is not surprising that the members of the local board are desirous of a change. They believe it possible to prevent the chemical compounds used in dye-works from entering the rivers in their most noxious state. They say that logwood might be separated from dyewater, and kept out of the stream. They have established tanks for filtering sewage, and are willing, should the existing system prove a failure, to make other efforts to remedy an evil of the extent of which they are quite sensible.

A little below the entrance of the *Trough Dyke* the river changes its course, taking a bend to the right, and running in a direction a little to the north of west for about $4\frac{1}{2}$ miles. In this distance it receives one or two small streams from the left bank, each of which furnishes water to one or more mills; while on the right bank the *Whitwell* brook drains more than 4,000 acres, and is made use of for water power and other purposes by ten

PART I. DESCRIPTIVE. — Irwell basin.

cotton and seven woollen factories. The *Coupe* brook, which joins the river from the left bank, nearly opposite the mouth of the *Whitwell* brook, furnishes water to five woollen factories and some large printworks; while the *Limey water*, which comes in at the point where the river again bends to the southward, brings down the drainage of nearly 5,000 acres, and supplies water to two printworks, one bleaching establishment, eleven cotton, and three woollen factories. In the before-mentioned distance of 4½ miles there are on the main river nineteen cotton and seven woollen factories, one saw-mill, one pipe-clay work, one skin-dressing establishment, one printwork, two ironworks, and one gas work.

At the time of our visit there was little or no water in the channel of the river here; neither were the brooks to the right or left adding to the stream to any appreciable extent. The whole was being collected in the mill lodges.

Between New Church, which is situated on *Limey water*, and Ramsbottom, a distance of about five miles, the river is joined on the right bank by the *Ogden* bringing down the drainage of about 4,500 acres, and furnishing water to thirty-one cotton and eight woollen factories; while on the left bank below the mouth of the *Ogden*, but above Ramsbottom, two brooks, the *Dearden* and the *Shuttleworth*, join the river, the two together draining about 2,000 acres. On the first, two cotton mills, three woollen factories, and one printwork; and on the second, four cotton works, one woollen and cotton factory, one bleachwork, two paper mills, and a corn mill, are located. On the river, between New Church and Ramsbottom, there are thirteen cotton and three woollen factories, two which make a mixed fabric of woollen and cotton, two paper mills, two printworks, one bleachwork, and one saw-mill. Over a weir just above Ramsbottom bridge there was, at the time of our visits, a thin sheet of water running, but this was merely because the lodge of the next paper mill was full: the water was black and filthy.

Ramsbottom is under the control of a Local Government Board; it has an area of 298 acres (Vol. II., *Minutes of Evidence*, part 1), and a population of over 5,000. The Board say that there is no sensible pollution of the stream by the works within the limits of the district under their charge; the pollution, according to them, is caused by the people above them. As they admit, however, that the river is polluted by town sewage, by refuse from print and dye works, and from paper mills, and as there are print and paper works in the immediate vicinity of the town itself, while no special care is taken to prevent the pollution of the streams by refuse from these works, the opinion of the Board must be taken with some reservation. The Board do their best to keep sewage out of the river; they do not permit waterclosets to be constructed, and the very few which do exist are unconnected with the sewers. The privies also are in the same state; they are cleansed by a contractor when required, at a cost of about 45*l.* per annum. The Board affirm that the sewage has little or no manuring quality, because the "ash-pit" system is adopted in the district. This point is discussed in detail at pp. 23–30.

From Ramsbottom to Bury the distance is about six miles by the river. About two miles below Ramsbottom, the *Holcombe* brook flows into the *Irwell*, bringing down the drainage of about 3,000 acres of the right bank, and supplying water to six cotton works, one bleachwork, and a tannery. Two and a half miles below the mouth of the *Holcombe* brook, the *Lee* brook enters the river from the left bank; upon this there are three cotton and two woollen factories, two bleachworks, and one alkali work. One and a quarter miles lower down, the *Kuhler* brook enters the river, bringing down the drainage of about 5,000 acres of the right bank; the brook supplies water to five bleachworks, two printworks, and four cotton factories; and about half a mile lower down, on the same bank, the *Walshaw* brook enters the river after supplying the wants of five cotton works, one bleach, and one dye work. The *Irwell* itself, in the interval between Ramsbottom and Bury, supplies water to twelve cotton and two woollen factories, to five bleachworks, two printworks, one dyework, one paper mill, and two iron works.

The town of Bury occupies the ground between the *Irwell* and the *Roch*, on the left bank of the former. The town is not incorporated, but is governed under the provisions of a local Act passed in 1846, the jurisdiction of the Commissioners extending over an area of about 3,000 acres. The population is about 30,000. The Commissioners complain very much (Vol. II., *Minutes of Evidence*, part 1) of the state of both the *Irwell* and the *Roch*. They say that the improvements in the sewerage works of Bury and of the towns above have had an injurious effect on the water of both rivers, making it more offensive. They admit that the bed of the river has silted up to a certain extent, but they look to the floods caused by occasional heavy rainfall at the upper part of the *Irwell* to sweep away these obstructions, forgetting, as it seems to us, that the same floods will bring down the refuse of which they complain from the higher reaches of the river.

PART I. DESCRIPTIVE. — Irwell basin.

The rivers, they say, are polluted by town and village sewage, refuse from printworks, dye and bleach works, and papermills. They seem to think that the refuse from paper mills and from other manufactures has a purifying action on the water; but we are not disposed to admit the correctness of this fancy, we will not call it theory, nor do we at all assent to the doctrine that cinders and ashes put into a river improve the quality of the water. In Bury, as elsewhere, a large sum of money has been expended in improving the sewerage of the town, large mains have been laid in the streets, with subsidiary drains in streets, courts, and alleys. The main sewers discharge themselves into the rivers *Irwell* and *Roch* below the town. There are not many water-closets, but half of those which exist are connected with the sewers, and this is also the case with several of the ash-pits which receive the soil from the privies. The state of the rivers may be inferred from analyses of the water taken above the town during our visit to it in the summer of 1868. The results of these analyses are given in the table at page 15.

Two and a half miles below the mouth of the *Walshaw* brook the river *Roch* joins the *Irwell* on the left bank, bringing with it the sewage of Rochdale with a population of about 40,000, and generally that of the eastern portion of the basin. The analysis of the water of the *Roch* below Rochdale, given in the table at page 15, will afford some idea of the effect produced upon the *Irwell* by this addition to its volume.

Two paper mills, two cotton factories, one mill for grinding dyewoods, one bleachwork, and a vitriol work, have made use of the water of the river between Bury and the junction of the *Roch*. At this point the *Irwell* bends abruptly to the westward, and flows in a direction a little to the south of west for about 5 miles to the point where it is joined by the *Croal*, having passed through the town of Radcliffe at about a mile and a half below the junction of the *Roch*.

Radcliffe is under a local board of health; the district comprises an area of 2,533 acres, and the population is estimated at 10,500. A system of sewerage was completed in 1868, and the waterclosets, and sinks and gullies are, or are to be connected with the sewers, which, of course, discharge themselves into the river; but the Board contemplate the employment of a portion of the sewage in irrigation. The *Irwell* between the points where the *Roch* and the *Croal* respectively join it furnishes a supply of water to five printworks, five dyeworks, two bleaching establishments, two gasworks, two ironworks, one paper mill, one size-making establishment, one cotton factory, and one chemical work.

The *Croal* brings down the sewage of Bolton (which has a population of 86,000, increasing at the rate of 1,000 per annum), and the drainage of the western portion of the valley, which is as thickly covered with cotton mills, print and dyeworks, paper mills, bleachworks, and dwelling-houses, as any portion of the basin. The analysis of a sample of water taken below the town of Bolton, and given in the table at page 15, exhibits the character of the additions made to the water of the *Irwell* by that of the *Croal*.

At its junction with the *Croal* the *Irwell* bends abruptly to the eastward; and after a course of about 11 miles it is joined in the city of Manchester by the *Irk* on the left bank. Three-quarters of a mile lower down the *Medlock* unites with it, also flowing through the town, bringing down the sewage of Oldham which has a population of upwards of 80,000, in addition to all that is contributed by that portion of Manchester, the sewers of which discharge themselves into the river. The following is a list of the works situated on the river between the mouth of the *Croal* and that of the *Irk*: ten cotton factories; eight dyeworks; four bleachworks; three paper mills; two printworks; two flax mills; three ironworks; and one each of the following:—copper works; paintworks; tannery; chemical works; machine manufactories; oil and grease works; magnesium works; cattle-food factory; india-rubber works; wire mill; saw-mill.

It is hardly necessary to go into the detail of the different manufactories which are crowded on the banks of the *Irwell* in Manchester and Salford. It is sufficient to say that between the mouth of the *Irk* and the weir at Throstlenest there are no fewer than 51 different manufacturing establishments on the banks of the *Irwell* itself, in addition to all the others scattered about the town and on the banks of the various rivers and streams, all discharging themselves eventually into the *Irwell*. This enumeration of the factories both in Manchester and elsewhere on the banks of the *Irwell* itself, is however a very imperfect illustration of the manufacturing industry of this river basin generally. A more adequate impression of that is gathered from the statements in Vol. II.,—*Minutes of Evidence*, part 1,—regarding water supply, from which we learn that, in addition to those which have independent resources, there are no fewer than 10,500 factories and works of all kinds within the *Irwell* basin which are supplied from the waterworks of Manchester, Bolton, Bury, Bacup, Heywood, and Oldham alone.

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Irwell basin.

The population congregated on both sides of the river in the city of Manchester and the borough of Salford exceeds 500,000, and a rapid addition is being made to this number. Large sums of money have been expended upon public works of various kinds; and a system of sewerage has been carried out by which the ordinary drainage of both towns passes into one or other of the streams which intersect them, and finds its way ultimately into the *Irwell*. This drainage consists, in the first place, of the rainfall over an area of about 10,000 acres; and, in the second place, of the water brought in for the supply of the inhabitants, which, estimated at the rate of 20 gallons per individual, amounts in round numbers to 10,000,000 gallons per day. A portion of this has of course been employed for manufacturing purposes, and is passed into the streams in a more or less polluted state. The remainder reaches the sewers after use for various domestic purposes, some of it passing through privies and water-closets, and thence carrying with it large quantities of excrementitious matter. The condition of the different streams flowing through Manchester—the *Irk*, the *Medlock*, the *Cornbrook*,—and that of the *Irwell* which is the recipient of all that is brought down by these streams, as well as of much which is passed direct into it by the sewers, is thus described by the corporate authorities of Manchester and Salford.

The report from Manchester, or rather the reply made to our written questions, informs us that—

"The rivers before they enter the city are much polluted by the refuse from the works on their banks; they also receive the refuse from manufacturing works within the city; all the sewers have their outlets in one or another of the rivers, but the quantity of water discharged into the sewers is so great that it can hardly be said that the pollution of the river is materially increased from this cause. Many works empty their refuse into the sewers; these consist chiefly of dye and bleach works, paper mills, chemical works, bone works, tan yards, indian-rubber works, slaughter-houses, &c. The beds of the rivers have silted up to a considerable extent."

The Salford authorities say,—

"The river is polluted by town sewage, also by liquid refuse from dye and bleach works, calico and silk manufactories, chemical, print, gas, and other works. It is not polluted by slag or scoria, but cinders get thrown in above the borough to a great extent. The condition of the river is *indirectly* a source of ill-health and discomfort, and the condition of certain open watercourses acts in a *direct* manner on the health and comfort of the district."

The Manchester authorities, it would seem, are disposed to think that the abominable condition of the river is due more to the refuse poured into it before it reaches their town, than to that which is the product of 380,000 inhabitants, and of numerous manufacturing establishments in the town itself. They coincide with some of the corporate bodies higher up the stream in the opinion, that because privies and ash-pits are used instead of waterclosets (the contents being carted away, instead of finding admittance into the sewers,) the largest portion of that which constitutes the offensive and injurious element in "sewage" has been got rid of. That this is not the case we shall show hereafter; that the river is in a filthy state when it enters the corporate boundaries at Agecroft bridge we quite admit, but we shall show (page 17) that it is in a much worse state when it makes its exit from these boundaries over the weir at Throstlenest.

Throughout almost the whole course of the various streams which here pass over the weir, not only has the water been polluted from both house and mill by waste matters more or less in solution or suspension, but the river bed has been obviously made the recipient of furnace ashes, waste from spoil heaps of various kinds, and even earth removed in digging house foundations. This particular abuse, with its many consequent evils, will be referred to in detail hereafter: a mere mention of it will suffice for the present general account of what the traveller sees during his journey from Erewell Spring to Throstlenest.

The above description of the *Irwell* will serve for that of all the other streams which flow through the coal district of Lancashire. It is virtually a sketch of the state of the rivers and streams generally throughout the valleys of the *Mersey* and *Ribble*. We say *generally*, for the description is specially applicable only to such portions of the streams as are made use of for manufacturing purposes, or flow through densely peopled districts. The *Hodder*, and the upper part of the *Ribble* still continue sweet and clean, and the *Weaver*, which drains a large portion of the northern part of Cheshire, is comparatively pure. Looking, however, to the rapid increase of population, and to the development of manufacturing industry, it is impossible to say how soon the water of

these streams may be brought into the same condition as that of the *Irwell* and the *Darwen*.

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Documentary Evidence.

Water, the prime necessary for manufacturing purposes, is sought for, near cheap fuel, wherever it can be found. *Clean water* is essential to the processes of the bleacher, dyer, papermaker, &c., and either therefore it must be got from the springs, or that which comes from other sources must be so cleansed as to make it fit for use. It is not, consequently, a matter of surprise that everywhere we find factory above factory occupying sites on the stream up to within a few hundred yards of the point where the water issues from the hill side. The effect is, as we have seen on the *Irwell* and elsewhere, to absorb the whole of the stream which is the outlet of the drainage of the country, and to apply it to manufacturing purposes solely; to throw out of sight altogether the right of the dweller on the bank of a stream to the use of the water of that stream; and gradually to assume that the extent of the evil, or the magnitude of the profits which arise from the *abuse* of water in various processes of manufacture is a sufficient justification of the course followed up to the present time.

Before we proceed to describe the various methods in which these rivers are rendered unfit for domestic or manufacturing purposes, it may be well that we should give a summary of the evidence as to their present actual condition, which we have collected both from municipal and other corporate bodies, and from manufacturers and others.

SUMMARY OF DOCUMENTARY EVIDENCE.

The following is a fair abstract of the evidence alluded to. It will be found given in detail in Vol. II., *Minutes of Evidence*, parts 1 and 2.

Pollution of Water.—It is stated broadly and generally by every person who has given evidence on the subject, that the rivers (except close to their sources) are polluted and filthy, and that they are now in a worse condition than they used to be. The recollection of many people on every stream goes back to a time when they were in the habit of fishing where no fish can now exist. The fact, so full of significance as regards the importance of the manufactures carried on in these basins, that between the years 1831 and 1861 the population increased from 1,578,370 to 2,796,964, will of itself go far to account for the changed state of things.

The water issues from the hill side clear and bright. Even where the sources are taken up for the supply of towns lower down the stream, the "compensation water" which is allowed to flow down the original watercourse, comes to the first manufacturer who has works on the stream in a satisfactory condition. He gets for his purposes, whatever they may be, that which the people in the towns are glad to apply to domestic use. But in what state does this water pass away from his works? If it has been used merely as power, it has passed over the mill wheel without receiving any injury, but if, as is generally the case, it is taken up because it is pure and clean, by dyers, paper makers, or others who require such water, it issues at the tail of the works polluted in various ways; and a reference to the evidence of the different firms (Vol. II., *Minutes of Evidence*, part 2), and to the previous description of the state of the *Irwell*, will show that it passes down the stream to those below in every instance virtually *unfiltered*. Occasionally we have found an attempt made to strain it through coarse canvas, or to allow the more solid portions of the refuse to settle for a time in a tank; but the great majority of those who use the water allow it to pass away without any attempt to free it from the matters with which it may have got mixed upon their premises, whether such matters be innocent or noxious. In some instances, as in the case of the alkali works, a portion of the muriatic acid, which formerly issued into the air in the shape of gas, is now, in conformity with the Alkali Act, condensed by water, and passes into the stream, where it meets with the drainage from soda-waste, forming a most noxious and offensive liquid, destructive to vegetable life; in many cases, arsenic gets mixed with the water; in all, except when the water is used merely as a source of power, there is an addition, as we shall show more in detail hereafter, of some extraneous matter more or less offensive to the senses, rendering the water useless, without previous purification, to those lower down the stream.

Having passed sundry manufacturing establishments, and been enlarged by the junction of brooks, the stream becomes of some importance, and a town is built upon its banks. What account do the various municipal bodies give of the state of the

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Documentary Evidence.

stream as it comes to them? They all complain that the water is polluted by sewage, as well as by every species of manufacturing refuse; that it is most offensive to the sight and smell; that it is unfit for use; that even when used for steam engines it clogs up the boilers, and is injurious to the machinery. Many are of opinion that the streams in this state are directly injurious to health; be that, however, as it may, all pour every kind of refuse into the stream and convert it into a common sewer. Some, under the idea that by mixing ashes with human excreta they will obtain a sale for the former, and thus get rid of two evils at once, object to the use of waterclosets and insist upon the superiority of privies and ash-pits, but all pass a large quantity of putrescent excrementitious matter into the sewers, and empty these sewers into the streams. Even the manufacturers, who complain of the sewage of towns as that which is most injurious and offensive, do themselves, very generally, pass the excrements of their workmen into the stream without any hesitation.

The effect of this conversion of the rivers into common sewers is most injurious. All complain; even those who, while suffering from the inconvenience and annoyance which such a state of things entails, add to the nuisance by themselves following the general example. While they whose property happens to lie on the stream, even many miles below the towns, are sufferers in a variety of ways. Are they farmers? their cattle cannot drink of the stream passing through their meadows. Are they dwelling on or near the bank of the river? they are driven from home by the stench, which renders the place unbearable. Are they compelled by duty to remain on the spot? they are subject to perpetual annoyance, and, as alleged, in many instances to ill-health. Have they property? its value is often diminished; a house remains tenantless, land is unsaleable except at a reduced price. Of all these evils instances will be found in the volume of evidence appended to this Report.

Silting up.—Collections of rubbish, cinders, and other solid refuse are habitually thrown into the rivers. When the fall is rapid the ordinary flow of the water is sufficient to carry down a good deal of this refuse, but it finds a resting-place at the back of weirs, or wherever there is any check to the velocity of the stream; and the result almost everywhere is a steady rise in the river bed. Where the slope is small the practice is to take advantage of every flood, to open the sluices of the lodges, and of all places where silt or mud collects, and to allow the water to carry all this down to the lower reaches of the river.

In the towns, of late, the municipal authorities have exerted themselves in many instances to check the tendency to make the bed of the river the depository of every kind of solid refuse; but they complain that a flood is sure to leave behind it traces of the malpractices of people above them, in the shape of banks of rubbish, cinders, &c.; and as their authority does not extend beyond the municipal boundaries, they have no power to impose any check upon such practices. The millowners and others on the streams complain very generally of this "silting up," and in many instances deprecate the practice of throwing solid refuse into the streams; still, however, the practice prevails very generally, and several admit that they do make use of the river as the general scavenger.

A good deal of blame is generally cast upon weirs as being the chief cause of silting up. Of course a weir, by creating a still pool, gives a resting-place to all that is brought down the stream; and in the present state of the streams weirs are a nuisance, for the ponds above them are filled with every species of pollution; but if the river above were kept clean this nuisance would be abated. The evil of this kind arising out of the weirs would therefore have been trifling had not the people on the stream above constantly made use of the latter as a depository for refuse.

It must not be forgotten, however, that considerable mischief of another kind is sometimes done by weirs. Wherever one is built, in a sluggish river for navigation uses, or, in a more rapid stream for storeage purposes or power, the water thus dammed up hinders the drainage of lands lying near the level to which it is raised. No doubt this is an inconsiderable thing wherever land is valuable for building on, because the cost of carrying its drainage, however far, by a conduit issuing below the weir, is then a comparatively small tax upon its value. But in a purely agricultural district the injury, by hindering land drainage, done by weirs for the sake of mills and canals or river navigation is not unfrequently very serious, diminishing in a great degree the annual value of considerable areas of land. No examples of this kind of any importance in Lancashire have however been pointed out to us. Neither have we seen any examples of the use of river water for the purposes of irrigation by which a *valuable* agricultural result of weirs is elsewhere occasionally obtained.

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River Pollutions.

Having given this brief summary of the evidence laid before us, we now proceed to describe in detail the different noxious matters which are poured into the streams; elucidating by chemical analysis the nature of each and its influence upon the character of the river.

CLASSIFICATION OF RIVER POLLUTIONS.

River Pollutions may be classed under two general heads:—"Sewage" and "manufacturing refuse." Sewage is a very complex liquid; a large proportion of its most offensive matters is, of course, human excrement, discharged from waterclosets and privies, and also urine thrown down gully holes; but, mixed with this, there is the water from kitchens, containing vegetable, animal, and other refuse, and that from wash-houses containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of waterclosets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a vast variety of matters; some held in suspension, some in solution, but both present in such a condition as to render it impossible, in the present state of our knowledge, practically to cleanse and purify sewage so thoroughly as to make it safe for drinking, even when largely diluted with unpolluted water.

The second class of river pollutions includes all kinds of "manufacturing refuse." Of course in the towns of manufacturing districts a considerable proportion of this waste is passed into the sewers, as being the readiest way of getting rid of it, and then it merely adds other ingredients to the dirty mixture passing down these channels; but where the works are situated on or near a stream, and the water made use of in the process of manufacture is afterwards transferred directly to the river polluted by admixture with the special matters made use of in the different technical processes, such refuse matters can be treated separately as manufacturing pollution. They may be classified generally under the following heads:—

Pollution by dye, print, and bleach works.	Pollution by paper making.
" by chemical works.	" by woollen works.
" by tanneries.	" by silk works.

We have carefully investigated the action and extent of all these several sources of river pollution within the Mersey and Ribble basins; but before proceeding with our report on each, it is necessary to define as clearly as possible the difference between polluted and unpolluted water, and to state the results of our analyses of the river waters themselves, into which all these polluting materials have more or less been passed. Samples were taken at various points throughout the several river courses; and to the light which their composition throws both on the increasing foulness of the water as the river flows along and on its alleged power of self-purification with mere lapse of time and exposure to the air, we have now to direct attention.

Chemical difference between polluted and unpolluted water.—Absolutely pure water is not to be found in nature. Even at the moment of its condensation in the atmosphere from invisible vapour to visible cloud, water absorbs gases and becomes also contaminated with a fine dust which is everywhere floating in the air. When it falls to the earth as rain, it percolates through strata or flows over surfaces more or less soluble, and dissolves according to circumstances quantities of solid matter varying generally from about 3 lbs. to 50 lbs. in 100,000 lbs. of water. In addition to these inevitable impurities, natural and unpolluted water is not unfrequently turbid from insoluble substances suspended therein in a finely divided condition.

The following are the chief characteristics of unpolluted water:—It is tasteless and inodorous, possesses a neutral or faintly alkaline reaction, rarely contains in 100,000 lbs. more than $\frac{1}{2}$ lb. of carbon and $\frac{1}{10}$ lb. of nitrogen in the form of organic matter, and is incapable of putrefaction even when kept for some time in close vessels at a summer temperature.

Of the different kinds of pollution affecting rivers, animal organic matter as it occurs in sewage is that which renders water not only most offensive to the senses, but most likely to injure health both by its gaseous emanations and by its deleterious effects when used as a beverage. Rivers so polluted frequently contain from 1 lb. to more than 2 lbs. of organic carbon and from $\frac{1}{3}$ lb. to $\frac{3}{4}$ lb. of organic nitrogen in 100,000 lbs.

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Analytical determinations.

Pollution by vegetable organic matter, such as that caused by dye and print works, stands next as regards offensiveness; water so polluted being excessively unpleasant not only to the sight, but also, in warm weather, to the sense of smell. It often contains in 100,000 lbs. twice as much organic carbon as is present in water polluted by sewage, but owing to the comparatively small proportion of nitrogen in vegetable substances it rarely contains more than one-third of a pound of organic nitrogen. Chemical works contribute chiefly mineral impurities, which often communicate to water extreme hardness and other disagreeable and even poisonous properties.

Necessary analytical determinations.—Such being the nature of the most important kinds of pollution in these rivers, we have directed our chemical inquiries chiefly to the following particulars regarding them:—

(*a.*) The total amount of solid matters present in them *in solution*:—The most important constituents of these solid matters are—

1. Carbon in the form of organic matter.—Organic carbon.
2. Nitrogen in the form of organic matter.—Organic nitrogen.

There is no process known by which the *total weight* of organic substances in any sample of water or sewage can be ascertained;* but the determination of the two chief elements of the organic matter furnishes data from which its amount and character (animal or vegetable), may often be fairly inferred.

3. Ammonia in the form chiefly of carbonate of ammonia.

This ingredient is derived almost entirely from the decomposition of animal organic matters.

4. Nitrogen in the form of salts of nitric acid and nitrous acid.

Like ammonia, this ingredient is derived almost solely from the decomposition of sewage or animal matters. In determinations 3 and 4, chemical analysis becomes retrospective. Ammonia and the salts of nitrous and nitric acids do not in themselves contribute to the pollution of water, but their presence in considerable proportion denotes with certainty its anterior pollution by animal matters. As the sewage or manure matters which caused this previous pollution have, so far as chemical investigation can inform us, ceased to exist as such, the analytical determination of these substances has less significance as regards actual pollution, although it becomes of the utmost importance when the use of the water as a beverage is contemplated. See page 112, *et seq.*

5. Total combined nitrogen.

This determination sums up the whole of the analytical evidence against the water as regards both past and present organic contamination.

6. Chlorine.

The proportion of chlorine in water may often be used as an indication of the extent to which a stream has been contaminated with *sewage*, as distinguished from *solid* animal matters. The chlorine in river water is almost always combined with sodium as common salt, which is a large and essential constituent of urine, and consequently of sewage, whilst it is present in only comparatively minute quantity in solid manure. It is scarcely necessary to say, however, that the determination becomes valueless for this purpose in the neighbourhood of the sea and of natural deposits of salt, such as that existing in the valley of the *Weaver*, for instance. The normal proportion of chlorine, as common salt, existing in this country in waters which have never been polluted by excrementitious matters is about 1 part in 100,000 of water. Most of this is probably carried from the ocean to the land through the air as sea-spray or fine particles of salt, for we find that the unpolluted waters of an inland country like Switzerland contain only about ·2 part of chlorine in 100,000 parts. See analytical table, page 126.

7. Hardening constituents.

These consist chiefly of salts of lime and magnesia. As polluting agents they have no significance unless the water be required for domestic purposes. Their presence, however, in considerable quantity, renders it less applicable to certain manufacturing operations, and it would therefore have been inexpedient to ignore them. The salts of lime and magnesia decompose soap, forming 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. Carbonate of lime is the most common hardening

* The determinations of organic matter in water, formerly made by ascertaining the loss on ignition experienced by the residue left on evaporation, were entirely fallacious (see foot note, page 71); and the results obtained by oxidation with permanganate of potash are equally untrustworthy.

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River waters in summer.

salt, and a water 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. of the water when used for washing.

(*b.*) The total amount of solid matters *in suspension*:—In this it is very important to distinguish between organic and mineral matters. We have therefore determined—

1. The organic matters in suspension.
2. The mineral matters in suspension.

In the execution of these analytical operations, several of which involve processes requiring considerable skill and delicacy of manipulation, it affords us pleasure to acknowledge the effective aid which we have received from the assistants in the laboratory of the Commission, Mr. W. Thorp, Mr. J. J. Day, and Mr. F. Clowes.

Condition of the river waters in summer.—By means of the analytical processes just specified we have determined the degree of pollution in some of the more important streams in the valleys of the *Mersey* and *Ribble* during our visit to these river basins in the summer of 1868. The following table contains the results of these analytical determinations, to which, for the sake of comparison, we append the composition of water from one of the sources of the *Thames*, and from the same river at Hampton, above its junction with the *Mole*, after it has received the drainage of 840,436 people (First Report of Rivers Pollution Commission. River Thames, p. 8). These last results are extracted from the Appendix to the Report of the Royal Commission on Water Supply.

COMPOSITION of the WATER of LANCASHIRE RIVERS IN SUMMER.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Temp. C.	Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.			Suspended Matters.		
									Temporary.	Permanent.	Total.	Mineral.	Organic.	Total.
12°·8	The *Irwell* near its source, June 12, 1869.	7·80	·187	·025	·004	·021	·049	1·15	0	3·72	3·72	0	0	0
	The *Irwell* above Bury, June 24, 1868.	39·02	1·083	·059	·394	0	·383	4·32	8·45	10·49	18·94	—	—	—
	The *Roch* below Rochdale and above Bury, June 24, 1868.	43·30	4·518	·288	·512	·230	·940	4·57	8·83	7·57	16·40	2·82	3·18	6·00
	The *Croal* below Bolton, June 22, 1868.	69·20	·842	—	·972	1·368	—	10·08	6·22	19·45	25·67	8·20	2·92	11·12
	The *Medlock* near its source, July 22, 1868.	12·80	·166	·014	·004	·011	·028	1·29	·92	6·04	6·96	0	0	0
	The *Medlock* in Manchester just before its junction with the Irwell, but above the outfall of York Street sewer, June 17, 1868.	57·00	1·776	·748	1·660	0	2·115	10·82	15·55	5·43	20·98	10·90	7·86	18·76
	One of the unpolluted sources of the *Irk*, June 18, 1868.	19·78	·153	·001	·009	·061	·069	1·42	3·73	7·72	11·45	0	0	0
	The *Irk* just before junction with the Irwell, June 17, 1868.	58·20	1·192	·267	1·250	0	1·296	10·77	17·12	4·38	21·50	5·94	5·26	11·20
	The *Cornbrook* just before its junction with the *Irwell*, June 17, 1868.	142·90	4·209	·243	·852	·049	·994	38·97	6·46	61·24	67·70	38·46	25·94	64·40
21°	The *Irwell* below Manchester, June 17, 1868.	55·80	1·173	·332	·740	·707	1·648	9·63	7·88	15·04	22·92	2·71	2·71	5·42
	One of the sources of the *Mersey*, July 28, 1868.	7·62	·222	0	·002	·021	·023	·94	·71	4·61	5·32	0	0	0
23°·9	The *Mersey* below Stockport, July 27, 1868.	39·50	1·231	·601	·622	0	1·113	–	5·37	10·18	15·55	–	–	–
	The *Mersey* just above Warrington, May 26, 1868.	48·10	1·026	·224	·349	·498	1·009	–	4·23	14·71	18·94	1·34	·06	1·4
	Equal volumes of the water of the rivers *Calder* and *Brun* before they enter Burnley, August 11, 1868.	27·66	·181	·018	·003	0	·020	1·09	3·10	6·96	10·06	0	0	0
38°·2	The *Calder* below Burnley and after junction with the *Brun*, August 11, 1868.	40·40	1·076	·758	·020	0	·774	5·86	5·09	9·02	14·11	2·82	3·82	6·64
	Head waters of the *Thames*, March 18, 1868.	28·25	·014	·009	·000	·358	·367	1·04	17·00	4·90	21·90	0	0	0
	The *Thames* at Hampton, May 4, 1868.	27·87	·260	·024	·000	·196	·220	1·48	15·70	4·30	20·00	trace	trace	trace.

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The Thames as a standard.

The table is to be read as follows:—100,000 lbs. of the water of the river *Calder*, just below Burnley, contained *in solution* on August 11th, 1868, 40·4 lbs. of solid matters. Of these the organic portion contained 1·076 lb. of carbon and ·758 lb. of nitrogen. The above quantity of water also contained ·020 lb. of ammonia, whilst the total amount of combined nitrogen in every form was ·774 lb., and of chlorine 5·86 lbs. The same quantity of water contained in solution 14·11 lbs. of carbonate of lime, or their equivalent of other hardening ingredients (total hardness); of this 5·09 lbs. would be got rid of by boiling the water for half an hour (temporary hardness), whilst 9·02 lbs. would still remain in solution (permanent hardness). Finally, 100,000 lbs. of the water contained *in suspension* 6·64 lbs. of dry solid matters, of which 2·82 lbs. were mineral and 3·82 lbs. organic.

An inspection of the above analytical results shows the frightful extent to which, in comparison with the *Thames* at Hampton, the rivers mentioned are polluted by organic matters in solution. The principal facts are extracted and presented in the following table:—

COMPARISON OF THE RIVER THAMES WITH LANCASHIRE RIVERS.

—	Pollution in 100,000 lbs. of water.					
	Thames at Hampton.	*Calder* below Burnley.	*Medlock* in Manchester.	*Irk* in Manchester.	*Irwell* below Manchester.	*Mersey* below Stockport.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Organic carbon - -	·246	·895	1·610	1·039	·986	1·009
„ nitrogen - -	·015	·740	·734	·266	·307	·601

Taking the pollution of the *Thames* at Hampton = 1, the pollution of the Lancashire rivers will be as follows:—

—	*Calder* below Burnley.	*Irwell* below Manchester.	*Medlock* in Manchester.	*Irk* in Manchester.	*Mersey* below Stockport.
Organic carbon - -	3·6	4·0	6·5	4·2	4·1
„ nitrogen - -	49·3	20·5	48·9	17·7	40·1

Difference between polluted rivers in winter and in summer.—In interpreting the above results, it must be borne in mind that the Lancashire rivers at the time of our visit, and when the above samples were taken, were in an active state of putrefaction; gases of nauseous odour, the products of the decomposition of organic matter, were everywhere being abundantly evolved from the polluted streams.* This process transfers, to a considerable extent, the organic impurity from the water to the surrounding air; and obviously, in thus infecting the atmosphere, the water itself must be, to a corresponding extent, purified. Hence, in the winter, the same streams might be expected to contain a much larger total amount of organic impurity, although, owing to the increased volume of water, the proportion in 100,000 lbs. might not be augmented.

It appeared desirable to test by actual analysis the difference between these polluted streams in summer and in winter. For this purpose we revisited, during the winter of 1868–69, the principal rivers in the *Mersey* and *Ribble* basins, and collected fresh samples of the polluted waters; the analytical results obtained from these samples are given in

* When taking samples at Throstlenest weir, below Manchester, at 5 a.m. on July 21, 1869, we saw the whole water of the River *Irwell*, there 46 yards wide, caked over with a thick scum of dirty froth, looking like a solid sooty crusted surface. Through this scum, here and there, at intervals of six and eight yards, heavy bursts of bubbles were continually breaking, evidently rising from the muddy bottom; and, wherever a yard or two of the scum was cleared away, the whole surface was seen simmering and sparkling with a continual effervescence of smaller bubbles rising from various depths in the midst of the water, showing that the whole river was fermenting and generating gas. The air was filled with the stench of this gaseous emanation many yards away. The temperature of the water was 76° Fahr., and that of the air 54°.

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DESCRIPTIVE.

River water summer and winter.

the following table, to which, for comparison, is appended an analysis of *Thames* water taken at London Bridge:—

COMPOSITION OF THE WATER OF LANCASHIRE RIVERS IN WINTER.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Temp. C.	Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness.	Suspended Matters.		
										Mineral.	Organic.	Total.
10°·8	The *Cornbrook*, just before its junction with the *Irwell*, March 11, 1869.	76·90	4·129	·383	·922	·000	1·142	12·50	38·79	8·32	12·80	21·12
8·9	The *Irk*, just before its junction with the *Irwell*, March 11, 1869.	60·80	2·452	·352	·759	·000	·977	8·90	32·43	3·76	4·64	8·40
13·0	The *Medlock*, just before junction with the *Irwell* but above outfall of York Street sewer. Temperature of air, 5·3°, March 12, 1869.	53·00	1·820	·444	1·116	·000	1·363	7·40	28·90	10·96	5·20	16·16
5·1	The *Irwell* at Agecroft Bridge above Manchester, March 12, 1869.	41·80	1·378	·160	·142	·000	·277	8·10	16·37	2·68	·48	3·16
6·2	The *Irwell* at Throstlenest weir below Manchester, March 12, 1869.	44·60	2·104	·248	·230	·000	·437	7·40	19·76	1·84	·96	2·80
6·0	The *Mersey* below the weir just above Warrington, March 8, 1869.	28·36	·704	·094	·082	·052	·214	3·40	12·37	1·56	·74	2·30
6·3	The *Mersey* at Bank Quay below Warrington at low water, March 8, 1869.	29·04	·684	·115	·106	·011	·213	3·60	12·23	1·44	·36	1·80
7·0	The *Douglas*, about 400 yards below Wigan sewer outfall, March 9, 1869.	64·30	·749	·141	·260	·013	·368	4·00	19·07	1·88	·52	2·40
10·7	The *Darwen* below Blackburn and after junction with the *Blakewater*, March 10, 1869.	41·50	2·127	·295	·219	·000	·475	3·60	18·25	1·78	1·78	3·56
—	The *Thames*, mid-stream, London Bridge, low water, April 2, 1869.	34·40	·304	·034	·120	·167	·300	1·83	26·65	5·04	·36	5·40

The above analytical numbers are very instructive; they place beyond doubt the fact that these rivers contain, in solution at least, more polluting material in winter than in summer, although that material affects the senses to a much less extent. At the time of our winter visit the volume of water flowing down these streams (which were not in flood) was thrice as great as in the previous remarkably dry summer; nevertheless the *Medlock* and *Cornbrook*, for example, contained about the same polluting material in 100,000 parts, whilst the *Irk* contained a proportion about twice as large in winter as in summer. In the quantity of suspended matters, however, all the streams except the *Mersey* contained the largest amount in summer.

COMPARISON OF SUMMER AND WINTER SAMPLES.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Ingredients.	In Summer.				In Winter.			
	Irk in Manchester.	*Medlock* in Manchester.	*Cornbrook* in Manchester.	*Irwell* below Manchester.	*Irk* in Manchester.	*Medlock* in Manchester.	*Cornbrook* in Manchester.	*Irwell* below Manchester.
Organic carbon in solution.	1·192	1·776	4·209	1·173	2·452	1·820	4·129	2·104
Organic nitrogen in solution.	·267	·748	·243	·332	·352	·444	·383	·248
Suspended matters: Mineral	5·94	10·90	38·46	2·71	3·76	10·96	8·32	1·84
Suspended matters: Organic	5·26	7·86	25·94	2·71	4·64	5·20	12·80	·96
Suspended matters: Total -	11·20	18·76	64·40	5·42	8·40	16·16	21·12	2·80

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DESCRIPTIVE.

Alleged self-purification fo rivers.

Taking the impurity in the *Thames* at London Bridge on April 2, 1869, at low water = 1, the summer and winter pollution of the *Mersey* and *Irwell* and their tributaries is as follows:—

Ingredients.	The *Irk* in Manchester.	The *Medlock* in Manchester.	The *Cornbrook* in Manchester.	The *Irwell* below Manchester.	The *Mersey* above Warrington.
Summer.					
Organic carbon	3·9	5·8	13·8	3·9	3·4
Organic nitrogen	7·9	22·0	7·1	9·8	6·6
Mineral suspended matters	1·2	2·2	7·6	·5	·3
Organic suspended matters	14·6	21·8	72·1	7·5	·2
Winter.					
Organic carbon	8·1	6·0	13·6	6·9	2·3
Organic nitrogen	10·3	13·1	11·3	7·3	3·5
Mineral suspended matters	·74	2·2	1·6	·4	·3
Organic suspended matters	12·9	14·4	35·6	2·7	2·1

Let it be borne in mind that these figures represent not the relative *quantities* of polluting material passing down the river channels, but only the relative quantities *in 100,000 parts* of the waters thus examined. The quantity of water in the rivers was at least threefold when the winter samples were taken; and, to obtain an estimate of the relative quantity of filth which was then being carried seaward as compared with what was passing downwards in the summer time, the winter figures should therefore be multiplied by three.

Alleged Self-purification of Polluted Rivers.—At the time the winter samples were taken the rivers were not in a state of putrefaction; any purification which they underwent during their progress towards the sea was therefore produced at this time either by the oxidation of the polluting organic matter contained in solution, or by the subsidence of the suspended matters. It has often been stated, but so far as we know without any proof, that the organic matter contained in sewage and other similar polluting materials is rapidly oxidized during the flow of a river into which such materials are discharged. Thus, it has been asserted, (Report of Royal Commission on Water Supply, p. lxxix.) that if sewage be mixed with 20 times its volume of river water, the organic matter which it contains will be oxidized and completely disappear whilst the river is flowing "a dozen miles or so." We thought it very undesirable that a subject of such vital importance to our inquiry should any longer rest upon mere opinion, and we therefore determined to submit it to careful experimental investigation. During our winter visit to the basins of the *Mersey* and *Ribble* a very favourable opportunity presented itself for the solution of this important problem. The river *Mersey*, after receiving the drainage of many towns and manufactories above the Stretford Road bridge, flows thence 13 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 11 miles to its junction with the *Mersey* without further material pollution, and with but very unimportant unpolluted affluents. Lastly, the river *Darwen*, which is greatly polluted by the sewage of Over Darwen, Lower Darwen, and Blackburn, joins the *Blakewater* just below the latter town, and then flows 13 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 water at the top and bottom of the courses of these rivers at the places just indicated, viz.—1. The *Mersey* at Stretford Road bridge, and again just before its junction with the *Irwell*. 2. The *Irwell* as it fell over the weir at Throstlenest, and again just before 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

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DESCRIPTIVE.

Alleged self-purification of rivers.

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 matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.	Temperature of Water.
* *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.
„ 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.	43·0	2·374	·210	·250	0	·416	6·4	1·88	2·40	4·28	13·3° 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	·413	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	·043	·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.

* 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 $34\frac{1}{3}$ feet. At each fall the river is covered with foam for several hundred yards below the weir.

These numbers must not be interpreted too strictly, since it is evident that the proportions of the different constituents of river water, 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.	Reduction in 100,000 parts of Water. Organic Nitrogen.	Per-centage Reduction of Organic Elements. Organic Carbon.	Per-centage Reduction of Organic Elements. 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

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Alleged self-purification of rivers.

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 ·200 part of organic carbon and ·054 part of organic nitrogen. The temperature of the air during this experiment was about 20° C. These results indicate approximately the effect 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.
During a flow of 96 miles at rate of 1 mile per hour	·017	·023	6·4	28·4
During a flow of 192 miles at rate of 1 mile per hour	·067	·027	25·1	33·3

An examination of the gases dissolved in water containing organic matter in solution still further confirms the results of the above experiments upon the rivers *Irwell*, *Mersey*, and *Darwen*. 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 well 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 contained in the enclosed water determined, by boiling off the dissolved gases in vacuo. The following results were obtained:—

RATE OF OXIDATION OF SEWAGE IN WATER.

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	·080	·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

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Alleged self-purification of rivers.

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, that, so far from sewage mixed with 20 times its volume of water being oxidized 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 all 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 oxidized 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 when the latter is 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 oxidized. 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 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 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 oxidizing 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 decayed 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."

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 and 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 ten 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

* See Vol. II. (Minutes of Evidence), p. III.

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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 Matters 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	43·6
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	12·0
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.

We have submitted to analysis several samples of such mud, and find that they contain a large proportion of highly putrescible organic matter. The following will serve as examples:—

COMPOSITION OF RIVER MUD.

Ingredients.	Mud of the *Irk*.	Mud of the *Irwell* in Peel Park.	Mud of the *Medlock*, Dawson Street.
Organic matter - - -	6·63	8·25	5·30
Mineral „ - - -	25·98	19·40	19·96
Water - - - - -	67·39	72·35	74·74
	100·00	100·00	100·00

The organic matter in 100 parts of the mud of the *Irwell* contained 2·79 parts of carbon, and ·29 part of nitrogen. When collected it was disgustingly offensive.

We now proceed to consider the several sources of pollution to which the state of the rivers in the *Mersey* and *Ribble* basins is due. It has been already stated that the different forms of pollution which we have observed may be classified under two general heads, viz.:—

1. Pollution by sewage.—2. Pollution by manufacturing refuse.—As these two kinds of pollution differ widely in their character, and often in the remedies necessary for their removal, it will be convenient to consider them separately.

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POLLUTION BY SEWAGE.

Pollution by sewage.

We have already stated that of all the forms of pollution to which rivers are subject, that from sewage is the most objectionable; and although the contamination of the *Mersey* and *Ribble* from this source is often masked and overborne by the foul contributions of manufactories, still in many of the tributaries to these rivers, such for instance as the *Darwen* below Blackburn, the *Chor* below Chorley, and the *Tonge* below Bolton, and even the *Irwell* below Manchester, a large proportion of the sum total of pollution is of this character; and the evil is rapidly increasing, owing to the increase of population and to the more complete system of sewerage, which sanitary considerations are compelling most of the towns of these basins to adopt.

Comparison of the Privy and Watercloset Systems.—In the towns and villages of this district the midden or ashpit system prevails, and waterclosets are the exception. The alternative of watercloset or privy as the machinery for removing human excrement from dwelling houses necessarily comes within the scope of our inquiry. It is indeed forced upon the attention in South Lancashire by the different views regarding it which have been maintained and carried out by the authorities of the two chief towns of the county. In Liverpool the corporation are rapidly converting privies into waterclosets; they have already thus displaced 13,229 during the past six years at a cost of 37,719*l.*; and they forbid the erection of privies in connection with all new dwelling houses. In Manchester, on the other hand, the municipal authorities strongly insist upon the superiority of the privy; and indeed when applying for their Waterworks Bill they sought for power to make a charge of one guinea per annum for the first watercloset in a house, a sum which would obviously have prohibited the use of waterclosets in all houses below a certain class.

The defence of the privy, as the better arrangement of the two, is confidently urged, and is not without its plausibility.—Water-tight tanks or cesspools at a little distance from the dwellings, one to every household, which shall receive the whole solid and liquid excrement, to be there covered daily with the ash waste of the house fires, and thus kept so dry that foul effluvia will be hindered:—These, it is declared, can dirty neither soil, nor air, nor stream. The subsoil and standing ground of the dwelling houses cannot, it is alleged, be fouled by them, the air will not be made offensive, the river will not be polluted; and the contents of these tanks cleaned out periodically must place the whole excrement of the population at the disposal of the agriculturist. On the other hand the watercloset, draining immediately into a sewer and thence into the nearest natural watercourse, washes all this valuable matter, as quickly and completely as possible, clean away—a wholesome arrangement possibly, but a wasteful one; and moreover one which makes a direct and most serious addition to the pollutions of the river.—Such is the case put by the defenders of the privy system.

The marked distinction between the two methods which is thus asserted, disappears however when we inquire into their practical working. The privy system is in reality both wasteful and offensive. Neither the cesspool nor the ashpit is water-tight, and their liquid contents soak into the land around them. Sewers are necessary whether waterclosets exist or not; and chamber slops with most of the liquid excrement and other house drainage find their way into them notwithstanding the existence of a privy. And that which is collected in the privy tanks or cesspools is occasionally so soaked with rain water and at best so imperfectly dried up by the added ashes, that for the abatement of a nuisance it becomes necessary to give these middens connection with the town drains. The liquid part here too, therefore, drains away, and the remainder, while fouled for any other purpose, becomes of very little value agriculturally.

Even where the scavenging is organized and well directed, as it appears to be in both Liverpool and Manchester, much of the nuisance of the privy system seems unavoidable. Taking the latter town for an example of even better management than can be ordinarily expected, it is impossible for any one examining the poorer and even the second-class districts of the town to avoid the conclusion that most injurious accumulations of filth are suffered to exist. In spite of district inspection under an energetic and experienced chief, in spite of police assistance, and notwithstanding that the penny post enables every householder so easily to give notice to the scavenger, privies and ashpits are continually to be seen full to overflowing and as filthy as can be. Even in the outskirts and good districts of the town, long rows of houses stand back to back, separated by only a 10 or 11 yards interval; and this is divided by a mid-way narrow passage, on both sides of which the privies stand, singly, one to every house, or in pairs, each couple separated by an ashpit common to both. These middens are cleaned out whenever

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The privy system.

notice is given that they need it, probably once half-yearly on an average, by a staff of night-men with their attendant carts. Occasionally twenty or thirty "middens" are thus cleaned out in succession, the contents being wheeled along the whole length of the row, making the air offensive for several nights together, and creating a nuisance, none the less injurious because, the work being done when the people are asleep, the filthy smell is not perceived.

The contents of these ashpits are divided by the scavengers into so-called *dry* and *wet;* and it is a matter of serious importance that it is the latter or obviously filthy part alone which is carried to the manure depôt; the "dry" rubbish being carried to any place that may be in course of levelling in the outskirts of the town. Of course, such a division is most imperfectly made under such circumstances; and it follows that land is thus filled up with most objectionable stuff; and as building extends, the surface is gradually covered with houses which, on such a foundation, cannot fail to be unwholesome dwelling-places. There is now a "tip" in a ravine at Collyhurst, on the north side of Manchester, where land is thus being raised *fifteen* to *twenty* feet over many acres, by the gradual accumulation of filthy rubbish. A sample of water from a pool at the foot of this tip on the outer side of the Queen's road, which here crosses the ravine, taken a few days after rain, so that it represented the drainage water of this bank, and thus fairly indicated the nature of the stuff it had trickled through, and another sample taken at a later date yielded the following results on analysis:—

COMPOSITION OF DRAINAGE WATER FROM COLLYHURST "TIP."

RESULTS of ANALYSIS expressed in Parts per 100,000.

Dates of Collection.	Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral Matters in suspension.	Organic Matters in suspension.
June 12th 1869 -	1643·5	32·278	3·631	29·525	0	27·946	331·50	16·88	13·48
July 21st 1869 -	2310·4	22·591	5·257	15·440	0	17·972	440·0	54·36	26·52

It will be seen from the above numbers that these liquids contained a very large proportion of highly offensive organic matter. They were in fact much richer in putrescible materials than any water-closet sewage we have met with. The whole of the made land, indeed, here smells most offensively and can never be built upon without great risk to the health of those who shall occupy the houses. And this is no exceptional example connected with the privy system. What to do with the fouled ashes which it accumulates —filthy stuff, too poor for use as manure,—is one of the great difficulties of the local authorities almost everywhere in Lancashire. In Liverpool, indeed, wherever a privy exists the whole contents of the ashpit are taken to the manure barge, and it is only the dry ashes of water-closet houses that are used to level land; but in other towns the same necessarily imperfect division of the contents of the privy ashpit obtains which has been described as true of Manchester; and there cannot be a doubt that most mischievous results ensue as dwelling-houses are built over land thus levelled. (See Vol. II., *Minutes of Evidence*, part 3, *Q.* 290 to 292,—and 878 to 880,—also *Q.* 2616, 2789).

However perfect then in theory the ashpit privy may be as a means of house scavenging in towns, in practice it has been abominable; and though latterly improved by better organization and more vigorous superintendence, and the gradual adoption of various ingenious contrivances, it can never be otherwise than highly objectionable. Land must get soaked with drainage water from these cesspools—the air must get fouled with their stinking vapours—the sewers must carry from them to the river that which is most filthy and yet most valuable.

It was a good suggestion by an opponent of the system that its friends should picture to themselves the sites of Manchester and Salford, with all their dwelling-houses removed, and only the privies left—nearly 60,000 of them—rows, and streets, and crowds of them —scattered about almost as thickly in places as the heaps of manure upon a field that has just received a dressing from the dung-cart—each heap here, however, no mere deposit of a barrow load once a year, but a constant collection and continual soakage of filth, which has for years been polluting every corner to which air or water could have access. Is this the site on which to build a healthy town? Would it not be the first desire of every sensible man to sweep this filth away, to drain and aërate, and, if possible, sweeten this land before a single dwelling-place was built; at any rate, to put a final stop to the process which has accumulated so much dirt; to which, indeed, one may fairly attribute

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much of the responsibility for the high death-rate disclosed by the returns from most of the South Lancashire towns. The returns of the Registrar General, as well as the evidence given before us, show that typhoid fever, scarlatina, diarrhœa, and other zymotic diseases commit fearful ravages amongst the populations exposed to such pestiferous influences.

The privy system.

It is mainly, of course, because it affects the pollution of the river, that the privy and ash-pit method of removing human excrement from large towns has been described; and it must be clearly understood that the very small portion of advantage which it thus confers is won at the expense of great risk to health.

If we exclude from present consideration the various palliatives and remedies which have been recommended for the abatement of some of the evils connected with this system —and which will be described when we come to treat of the remedies for river pollution —the watercloset is practically the only alternative plan of house scavenging which is possible under the circumstances of large towns. Where it is systematically adopted, the town streets must of course be sewered with channels of smooth bore and constant fall, and these must be connected with every house by properly trapped branch pipes. This connexion is generally twofold; through the scullery sink and through the watercloset pan. No doubt a certain amount of risk is incurred from the possible escape of foul and even of specifically infected gases through these channels, which may thus carry either general ill-health or definite disease into the midst of the household. But the risk is diminished almost to zero, first, by that rapid flushing of the sewer which an abundant water supply ensures, so that they are kept constantly washed; secondly, by frequent artificial ventilation either through open street grids or into specially constructed ventilating shafts, so that there may be a draught inwards at every point excepting those at which an outward draught is permitted or created; and thirdly, by careful trapping. Notwithstanding, however, all these precautions, there will undoubtedly remain a small but indefinite amount of risk incurred by thus connecting, however indirectly, every house with every other in a locality. And to this drawback must be added, as especially coming under our consideration, the fact that the watercloset system directly and purposely pollutes the rivers by conducting as rapidly as possible all fœcal matter straight to the nearest natural watercourse.

To what then does a fair comparison of the rival systems lead? The former retains a good deal of excrementitious matter putrefying close by the dwelling houses, the latter washes it all away before putrefaction has commenced. The former saves perhaps one-fifth of the fœcal matter of the population, wraps it up in 10 or 20 fold its weight of ashes, and at much greater cost than it is worth, gets it carried to the land; the latter hitherto has carried the whole fœcal matter away, for whereas the former wastes four-fifths, the latter takes the whole directly to the nearest stream; in the former case, however, it is necessarily already putrid, in the latter case it is usually fresh.

To this comparison of the two, it may perhaps be as well to add at once, although it will be more properly discussed hereafter, that the conveyance of filth to the river is no necessary part of the watercloset system. All that is done by the watercloset, as contrasted with the privy, is to load the filth upon a self-acting vehicle which will take it wherever it is wanted; a vehicle which will carry it more cleanly, more cheaply, more immediately than can be done by any organization of man and horse and cart. The manure which must be collected from town privies by an army of scavengers and distributed from the depôt by barge or rail, to be afterwards loaded in carts and taken to the field, and spread abroad by hand, and covered by the plough, might, if water were the carrier, be virtually self-borne to the very place where it is wanted, taken almost direct from the watercloset to the field, and there washed in at once with really no labour at all among the very roots of the plants it is to feed. To this, however, we shall return. Meantime it must be added that apart from the final utilization of the fœcal matter, which is more easily accomplished under the watercloset than the privy system, the cleanly wholesomeness of the former, and its greater comfort and convenience, are gradually leading to its adoption everywhere in all houses above the rank of a mere cottage; and it is impossible to doubt that as in Liverpool, so in other Lancashire towns, whatever may be the difficulties in its way, it will ultimately become the rule.

At present waterclosets are in use to only a very small extent in the districts we have been examining. A tabular statement of the number of waterclosets and privies respectively in some of the largest towns of South Lancashire and North Cheshire is given below. And the quantity of artificial manure that is collected in these towns, with the price that is obtained for it, and the cost of collecting it per annum and per individual of the population may be read in the following table. It will be seen that on the whole a

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Pollution by sewage.
Waterclosets and privies.

population of about 1,330,000 use 120,000 privies and 45,000 waterclosets, no fewer than 30,000 of the latter being in Liverpool alone; and any person making the calculation will find that after deducting an average household for every one of the latter, there are obtained from 1,110,000 persons using 113,000 privies, 347,000 tons of manure realizing less than 5*d*., and costing to remove it a little less than 1*s*., per head per annum.

STATISTICS OF WATERCLOSETS AND PRIVIES.

Name of Town.	Population.	No. of Houses.	No. of Privies.	No. of Water Closets.	Tons of Manure from Privies.	Received for Manure.	Cost of Collecting Manure.	Per Head.		Name of River.	Ammonia in 100,000 parts of the River Water passing through the Town.	
								Received.	Cost.		Before entering Town.	On leaving Town.
						£	£	d.	d.			
Ashton (*a*) -	39,000	7,200	6,250	200	6,637	95	—	3·2	—	*Tame* - -	·211	·640
										{ *Spodden* - -	·002	} ·423
Rochdale -	46,000	9,000	4,000	300	4,500	—	1,300*	—	—	{ *Roch* - -	·322	
Bolton (*a*) -	77,000	15,154	6,890	300	22,465	1,567	3,172	5·	10·	*Croal* - -	·024	·972
										{ *Roch* - -	·512	} Sample lost in transit.
Bury (*a*) -	30,000	5,760	3,765	147	7,000	100	700	0·8	5·6	{ *Irwell* - -	·394	
Oldham (*a*) -	81,259	16,294	2,305	700	50,000	2,000	6,000	4·4	16·	*Medlock* - -	·004	1·020
										{ *Irwell* - -	·075	—
Manchester (*a*)	362,000	70,000	38,000	10,000	73,594	6,740	17,660	4·5	11·7	{ *Medlock* -	·019	1·660 } ·740
Salford (*a*) -	133,627	25,555	21,642	1,500	46,000	3,870	6,600	6·9	11·9	{ *Irk* - -	·220	1·250
Warrington -	30,000	6,000	4,500	500	5,060	—	150*	—	—	*Mersey* - -	·082	·106
Widnes (*a*) -	12,000	2,009	1,950	—	1,800	150	385	3·	—	,, - -	—	—
Runcorn -	14,000	2,620	2,500	20	5,000	—	300*	—	—	,, - -	—	—
Liverpool (*a*)	500,676	86,176	20,000	{ 2,150† 29,000	} 138,777	8,000	21,000	3·8	10·	,, - -	—	—
										{ *Darwen* - -	·300	} ·644‡
Blackburn (*a*)	75,000	15,000	13,500	700	—	257	1,638	·8	5·2	{ *Blakewater* -	·008	
Chorley -	19,000	4,000	2,000	200	5,000	100	290*	—	—	*Chor* - -	·001	3·176§
Clitheroe -	7,000	1,680	1,680	—	1,200	46	70*	—	—	*Ribble* - -	—	—
Preston -	93,000	17,241	16,000	2,300	30,000	—	1,431	—	—	,, - -	·018	·080
Southport -	20,000	3,050	3,050	1,050	9,000	740	1,000	3·3	4·6	- - -	—	—
										{ *Tame* - -	·630	} ·622
Stockport -	54,682	12,000	5,660	—	—	—	—	—	—	{ *Goyt* - -	·148	
										{ *Weaver* - -	·012	} ·017
Northwich -	1,187	280	150	60	—	—	—	—	—	{ *Dane* - -	·002	
Macclesfield	36,000	10,102	2,945	220	3,000	—	250	—	—	*Bollin* - -	·008	·142
Staleybridge	25,000	5,200	2,000	450	—	—	—	—	—	*Tame* - -	·040	·211
Glossop -	17,000	—	—	—	—	—	—	—	—	*Gorse Brook* -	·002	·140
Wigan -	41,000	6,700	1,500	210	—	—	800	—	—	*Douglas* - -	·078	·260

* The cost of collecting the manure is uncertain in these cases, because it is stated to be additional to the value of the manure (not declared) which belongs to the contractor, or because only a portion of the privies and ashpits are cleared by the authorities, the others being attended to by the householders themselves. The only effect of this fact, however, upon the table is, that in some of the smaller instances which it quotes while the tonnage of manure collected is put below the truth, the cost of collecting it both total and per head is also somewhat understated.

† Liverpool has 2,150 tank closets.

‡ Aug. 5, 1868. § Aug. 6, 1868.

(*a*) Only those marked thus are taken into the summation or calculation in the text.

That the very large collection of feeble manure from the several towns mentioned in this table does really very little to save the rivers is plain to anyone who visits them. Bolton receives its river water virtually clean, and hands it on in an extremely foul and offensive condition. Rochdale fouls the *Roch* and *Spodden*; and Bury makes a most obvious addition to the filth of both the *Roch* and *Irwell* passing by it. Over-Darwen adds most offensively to the pollution of its stream; and the *Blakewater* is entirely converted into sewage by the town of Blackburn. The *Irwell* and the *Irk* and *Medlock* come down already very foul, but the quantity of filth they bring is enormously increased as they pass through Manchester and Salford.

The last two columns of the above table showing the amount of ammonia, one of the most characteristic constituents of sewage, in the river waters before entering and again on leaving each town, prove the same thing by chemical evidence. These two columns also exhibit what is otherwise obvious enough, viz., that when the sewage of a large town enters a small river, as at Oldham and Chorley, for example, the polluting effect is enormously great as compared with that which results from the admixture of the sewage of a similar town with a large river, as at Warrington, Preston, and Stockport.

Nevertheless, its advocates still contend that the midden system preserves the neighbouring streams from sewage pollution. Thus, in their answers to our queries (Vol. II., *Minutes of Evidence*, part 1), the corporation of Manchester inform us:—

"All the sewers within the city have their outlets into one or other of the rivers, but the quantity of water discharged from the sewers is so great, in proportion to the sewerage matter, that it can hardly be said that the pollution of the rivers is materially increased from this cause. In Manchester water-closets in small houses hardly exist. In such houses privies and ash-pits are the rule, and water-closets the exception. If water-closets had been introduced into all the houses the state of the rivers in Manchester would long ere this have been intolerable." (See also the evidence of Sir Joseph Heron, the town clerk of Manchester. Vol. II., *Minutes of Evidence*, part 3.)

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Pollution by sewage.
Human excrements.

Chemical analysis does not confirm the assumption contained in this statement; indeed a consideration of the composition and properties of liquid and solid excrements leads to a very different conclusion.

Röder and Eichhorn give the following data respecting the amount and proportion of organic nitrogen in human excrements, their numbers being derived from the researches of Wolf and Lehman.

TABLE I.

WEIGHT in grammes of SOLID and LIQUID EXCREMENTS per PERSON per Day, and the Organic Nitrogen and Phosphates contained therein:—

—	*Fæces.*	Organic Nitrogen.	Phosphates.	*Urine.*	Organic Nitrogen.	Phosphates.
Men - -	150	1·74	3·23	1,500	15·0	6·08
Women - -	45	1·02	1·08	1,350	10·73	5·47
Boys - - -	110	1·82	1·62	570	4·72	2·16
Girls - - -	25	·57	·37	450	3·68	1·75

TABLE II.

WEIGHT in avoirdupois lbs. of SOLID and LIQUID EXCREMENTS per PERSON per Year, and the Organic Nitrogen and Phosphates contained therein:—

—	*Fæces.*	Organic Nitrogen.	Phosphates.	*Urine.*	Organic Nitrogen.	Phosphates.
Men - - -	120·45	1·39	2·62	1,204·5	12·04	5·28
Women - - -	36·08	·81	·86	1,083·9	8·61	4·38
Boys - - -	88·33	1·51	1·29	457·7	3·79	1·73
Girls - - -	20·07	·46	·29	361·3	2·95	1·40

TABLE III.

WEIGHT in cwts. of the EXCREMENTS of 100,000 PERSONS (37,610 Men, 34,630 Women, 14,060 Boys, and 13,700 Girls) per Annum, and the Organic Nitrogen and Phosphates contained therein:—

—	*Fæces.*	Organic Nitrogen.	Phosphates.	*Urine.*	Organic Nitrogen.	Phosphates.
Men - - -	40,372	468	881	403,730·2	4,037	1,638
Women - - -	11,045	250	268·2	334,541	2,653	1,354
Boys - - -	11,067	183	161·8	57,354·2	481	217
Girls - - -	2,453	56	36	45,012	360	171
	64,937	957	1,347·0	840,637·4	7,531	3,380

Thus, taking the last table as representing the excrementitious matters of a large town the proportion of organic nitrogen in the fæces to that in the urine is only as 1 to 7·87. Although the polluting powers of these two descriptions of excrement are not to be taken as proportional to the amount of organic nitrogen, because a large proportion of the nitrogenous organic matter of urine (the urea) is rapidly decomposed into carbonate of ammonia, which cannot be regarded as a polluting agent; nevertheless it must be borne in mind that the transformation of urea into carbonate of ammonia is attended by the development of myriads of living organisms, chiefly vibrios and bacteria, and that they rapidly set up putrefaction in other kinds of organic matter with which the changed urine comes into contact. It is, therefore, obviously a fallacy to suppose that by merely keeping solid excrement out of our rivers the sewage pollution of the latter is prevented. Indeed, there can be no doubt that, connected as the middens usually are with the sewers, no inconsiderable proportion even of solid excrement, partly in solution and partly in suspension, does actually find its way into the sewerage system.

But the relative polluting effect of sewage from midden towns, as compared with that from watercloset towns, is no mere matter of opinion founded on *à priori* argument. It can be made the subject of direct investigation, and being a matter of great importance to our inquiry, we have availed ourselves of every opportunity to examine analytically

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Pollution by sewage from midden towns.

the sewage of both classes of towns. The results of our analyses are embodied in the following tables:—

COMPOSITION OF SEWAGE FROM MIDDEN TOWNS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.	Remarks.
Liverpool* (Albert Dock sewer), May 15, 1868.	326·2	2·975	1·892	2·625	0	4·054	—	9·68	12·84	22·52	Chiefly privy sewage.
Manchester, mixture of Market Street and Downing Street, June 19, 1868.	58·3	1·895	1·796	4·080	0	5·156	—	26·22	24·82	51·04	Chiefly water-closet sewage.
Manchester, River *Tib* sewer June 19, 1868.	62·0	2·215	1·516	·380	0	1·829	—	23·18	11·22	34·40	Privy sewage.
Manchester, Shooter's Brook sewer, June 19, 1868.	45·3	1·288	·494	2·100	0	2·223	—	15·50	9·70	25·20	,, ,,
Manchester, Shudehill sewer, March 17, 1869.	91·2	4·397	1·540	3·525	0	4·443	—	23·48	29·20	52·68	Chiefly water-closet sewage.
Manchester, Market Street sewer, March 17, 1869.	37·9	3·757	1·777	3·000	0	4·248	6·5	11·36	17·88	29·24	,, ,,
Manchester, York Street sewer, March 17, 1869.	70·2	3·915	2·435	4·705	0	6·310	11·0	79·68	52·12	131·80	Privy sewage.
Manchester, Oxford Street sewer, March 17, 1869.	56·2	7·340	4·058	6·125	0	9·102	12·5	16·12	32·68	48·80	Chiefly water-closet sewage.
Manchester, Miller Street sewer, March 17, 1869.	60·2	5·786	2·650	4·865	0	6·656	21·5	15·32	19·44	34·76	Privy sewage.
Manchester, Junction Street sewer, March 17, 1869.	49·0	3·598	1·319	2·572	0	3·437	10·5	10·56	17·64	28·20	,, ,,
Manchester, Mitchell Street sewer, March 17, 1869.	31·1	1·989	·692	1·732	0	2·118	6·5	6·92	7·08	14·00	,, ,,
Salford, New Bailey sewer, March 15, 1869.	69·0	4·298	2·859	8·000	0	9·447	12·0	16·36	17·44	33·80	,, ,,
Salford, Wooden Street sewer, March 15, 1869.	419·6	11·012	7·634	6·640	0	13·102	20·5	18·88	26·44	45·32	,, ,,
Salford, Regent's Bridge sewer, March 15, 1869.	84·6	4·503	2·845	8·825	0	10·113	17·0	49·32	49·44	98·76	,, ,,
Salford, Ordsall Lane sewer, March 15, 1869.	87·2	2·911	2·242	5·452	0	6·732	13·0	9·12	9·00	18·12	,, ,,
Salford, Regent's Road Bridge, Princes Bridge, and Ordsall Lane sewers, June 18, 1868.	160·7	6·504	5·644	30·350	0	30·638	—	13·18	33·38	46·56	,, ,,
Salford, Crescent sewer, June 18, 1868.	67·5	2·278	1·762	6·450	0	7·074	—	5·90	6·78	12·68	,, ,,
Macclesfield, Hible Bridge sewer, March 16, 1869.	47·6	2·874	1·046	1·730	0	2·471	9·0	4·72	5·44	10·16	,, ,,
Macclesfield, Hill Street sewer, May 12, 1869.	56·7	7·430	2·493	5·140	0	6·726	10·9	9·80	46·20	56·00	,, ,,
Bolton, Church Bank sewer, June 22, 1868.	42·0	2·985	1·843	6·430	0	7·138	—	6·78	14·58	21·36	,, ,,
Bury, Pim Hole sewer, June 24, 1868.	53·5	2·118	·919	3·070	0	3·447	—	8·42	8·98	17·40	,, ,,
Preston, Aug. 10, 1868 -	63·7	3·720	1·014	3·232	0	3·676	—	20·90	21·06	41·96	,, ,,
Preston,† mixture of hourly samples taken at the outfall for 24 hours, May 5, 1869.	77·6	4·618	·678	2·554	0	2·781	10·1	25·28	27·72	53·00	,, ,
Preston, mixture of hourly samples taken at the outfall for 24 hours, July 1st and 2nd, 1869.	67·5	3·776	1·449	2·120	0	3·195	11·12	46·84	24·08	70·92	,, ,,
Preston, sewage collected at 11 A.M., July 2, 1869.	58·8	3·080	1·723	4·014	0	4·182	9·07	34·12	19·08	53·20	,, ,,
Preston, sewage collected at 12 midnight, July 2, 1869.	60·6	1·751	·512	1·312	0	1·592	7·32	4·14	4·46	8·60	,, ,,
Blackburn, Aug. 5, 1868 -	59·7	4·103	·460	1·426	0	1·634	—	13·38	28·30	41·68	,, ,,
Blackburn, March 10, 1869 -	72·6	4·834	1·088	3·475	0	3·950	8·3	9·24	16·16	25·40	,, ,,
Wigan, Aug. 7, 1868 -	129·1	5·555	2·058	11·820	0	11·792	—	15·70	31·10	46·80	,, ,,
Chorley, June 8, 1869 -	71·2	4·968	1·495	3·492	0	4·371	10·6	11·84	19·24	31·08	
Carlisle, Sept. 23, 1868 -	44·9	2·673	·505	1·912	0	2·080	—	5·24	4·64	9·88	,, ,,
Penrith, Sept. 24, 1868 -	53·5	5·111	1·899	10·395	0	10·460	—	5·88	11·88	17·76	,, ,,
Edinburgh, Sept. 17, 1868 -	100·8	5·351	1·895	10·690	·012	10·711	—	20·88	39·80	60·68	,, ,,
Edinburgh, sewage, *Foul-burn*, April 17th, 1869.	55·0	5·061	2·842	7·865	0	9·319	10·0	28·72	29·88	58·60	,, ,,
Edinburgh, April 16, 1869 -	62·2	6·106	3·613	9·510	0	11·445	13·3	11·32	28·08	39·40	,, ,,
Lancaster, Sept. 30, 1868 -	39·8	1·854	·357	1·600	0	1·675	—	19·48	7·64	27·12	,, ,,
Broadmoor Lunatic Asylum, Nov. 10, 1868.	56·2	6·085	2·050	7·900	0	8·556	—	5·56	22·64	28·20	Earth-closets partially used.
Average -	82·4	4·181	1·975	5·435	0	6·451	11·54	17·81	21·30	39·11	

* Although the substitution of water-closets for middens in Liverpool is now going on rapidly, yet the town must still be considered as upon the midden system.

† This and the following samples of the entire volume of Preston sewage were collected for us by Mr. E. Garlick, C.E., the Borough Steward and Treasurer. The average samples were obtained by putting one quart of sewage every hour during 24 hours into a suitable vessel; it is obvious, however, that the sewage so collected by no means represents the average composition, because during the night hours when the liquid was weakest the flow was necessarily much slower than during the day when the stronger sewage was delivered. True average samples would therefore be stronger than those actually collected and analysed. See Vol. II. (*Minutes of Evidence*), part 3.

PART I. DESCRIPTIVE.

Pollution by sewage from water-closet towns.

COMPOSITION OF SEWAGE FROM WATER-CLOSET TOWNS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.	Remarks.
* London average, May 1857	108·2	—	—	—		8·363	—	15·11	11·93	27·04	Nitrogen in suspended matter was to nitrogen in solution as 1:7·46.
,, June ,,	111·7							27·47	19·36	46·83	
,, ,, ,,	110·1	—	—	—	—	—	—	—	—	36·93	Savoy Street sewage.
,, ,, ,,	93·1	—	—	—	—		—	—	—	42·57	Mean of five other sewers. Samples taken in all states of weather.
London, Feb. 23, 1869 -	66·5	5·137	2·375	6·050	·000	7·357	—	15·48	18·84	34·32	
,, Feb. 27 ,, -	64·8	4·637	2·330	4·240	·000	5·822	—	19·72	16·08	35·80	
,, Mar. 2 ,, -	58·4	4·304	1·894	3·847	·000	5·062	—	80·08	41·24	121·32	
,, Mar. 5 ,, -	65·3	4·334	2·075	4·580	·012	5·859	—	17·72	21·56	39·28	
,, ,, 9 ,, -	67·8	3·842	1·986	6·042	·000	6·962	—	17·24	17·32	34·56	
,, ,, 13 ,, -	80·1	5·497	3·508	9·325	·000	11·187	—	11·36	19·24	30·60	
,, ,, 19 ,, -	71·1	4·934	2·924	7·083	·000	8·757	11·9	84·08	44·52	128·60	
,, ,, 23 ,, -	65·5	3·164	2·045	4·505	·000	5·755	11·8	16·68	24·96	41·64	
,, ,, 30 ,, -	68·2	4·654	3·823	5·250	·000	8·147	10·4	18·28	30·56	48·84	
,, April 3 ,, -	59·2	3·074	1·378	3·594	·000	4·338	8·1	28·08	23·96	52·04	
,, ,, 7 ,, -	64·0	4·208	2·511	5·525	·000	7·061	9·9	50·12	38·00	88·12	
,, ,, 10 ,, -	62·2	4·108	2·644	6·640	·000	8·112	10·6	16·92	24·16	41·08	
,, ,, 14 ,, -	68·1	5·989	3·201	7·985	·000	9·777	11·8	52·48	41·28	93·76	
,, ,, 17 ,, -	62·1	3·925	1·453	3·845	·000	4·619	9·5	82·08	26·84	108·92	
,, ,, 20 ,,	60·9	6·345	2·430	6·800	·000	8·030	9·6	32·40	28·68	61·08	
London, after extremely heavy rain, April 23, 1869.	63·1	3·905	2·438	5·075	·000	6·617	9·5	182·80	51·36	234·16	
London, April 28, 1869 -	67·1	5·427	2·975	6·382	·000	8·231	9·6	23·88	16·52	40·40	
,, ,, 30 ,, -	66·5	4·096	2·566	6·407	·000	7·842	15·1	19·60	15·96	35·56	
,, May 4 ,, -	40·6	3·026	·909	2·445	·000	2·923	5·1	71·32	18·64	89·96	
,, ,, 7 ,, -	68·7	4·913	4·977	6·175	·000	10·062	14·0	32·84	20·32	53·16	
,, June 23 ,, -	65·3	2·596	1·715	4·000	·000	5·010	8·6	18·48	27·80	46·28	Northern outfall at Barking.
Ealing (filtered) April 24, 1868	78·5	6·093	2·785	4·250	·076	6·361	—	—	—	—	In sewage works.
Aldershot May 1 ,,	93·4	16·335	2·694	13·054	·000	13·444	—	5·30	17·90	23·20	Outfall near irrigated land.
,, July 16, 1869	46·6	5·878	2·052	9·025	·000	9·484	9·5	6·72	14·28	21·00	
Northampton May 11, 1868	88·0	3·700	2·859	6·000	·000	7·800	—	66·72	16·40	83·12	Outfall at sewage works.
Leicester ,, 13 ,,	107·5	2·017	·809	2·083	·000	2·524	—	10·50	11·62	22·12	,, ,, ,,
Croydon - Dec. 11, 1869	41·2	2·565	1·134	3·635	·000	4·128	4·0	·84	4·10	4·94	At irrigation works.
,, - ,, 23 ,,	48·0	2·076	·749	2·684	·000	2·959	4·4	1·96	6·64	8·60	,, ,, ,,
,, - ,, 30 ,,	48·0	2·882	1·269	2·700	·000	3·493	4·3	3·80	10·80	14·60	,, ,, ,,
Norwood - Feb. 25, 1869	91·7	3·235	·699	2·030	·000	2·371	8·6	3·68	6·36	10·04	Outfall at sewage works.
,, Mar. 12 ,,	117·8	5·407	2·294	8·970	·000	9·681	8·9	4·08	14·96	19·04	,, ,, ,,
,, ,, 25 ,,	75·3	3·275	1·765	7·097	·000	7·610	8·5	5·88	8·36	14·24	,, ,, ,,
Worthing - July 17, 1868	99·1	1·104	·680	3·140	·019	3·285	—	6·14	9·22	15·36	,, ,, pumping station.
,, ,, ,, 15, 1869	57·6	2·312	2·021	3·717	·000	5·082	10·7	1·86	4·74	6·60	At irrigation works.
West Worthing July 17, 1868	59·6	2·281	1·107	7·370	.000	7·176	—	30·46	25·74	56·20	,, ,, ,,
Bedford (average of two collections) Sept. 10 and Oct. 10, 1868.	77·1	2·305	·986	3·500	·000	3·868	—	9·42	9·32	18·74	,, ,, ,,
Bedford, July 24, 1869 -	76·1	2·256	1·301	3·100	·000	3·854	10·9	8·16	13·68	21·84	,, ,, ,,
Banbury, Oct. 17, 1868 -	111·5	6·246	2·764	13·590	·000	13·956	—	3·90	8·62	12·52	,, ,, ,,
,, July 14, 1869 -	92·4	8·269	2·386	6·702	·000	7·905	8·7	9·56	20·12	29·68	,, ,, ,,
Rugby, July 13, 1869 -	52·6	5·505	2·322	7·276	·000	8·314	8·3	3·48	8·96	12·44	,, ,, ,,
Warwick ,, - -	66·9	5·133	1·680	2·439	·000	3·689	6·3	2·64	3·36	6·00	,, ,, ,,
Woking Prison, Apr. 21, 1869	72·1	7·155	1·948	14·410	·000	13·815	13·4	7·28	22·88	30·16	,, outfall.
,, May 14 ,,	72·6	6·413	2·136	10·350	·000	10·660	12·7	8·76	18·00	26·76	,, ,,
,, ,, 22 ,,	99·7	6·841	3·169	17·475	·000	17·560	21·5	28·72	20·12	48·84	,, ,,
,, ,, 25 ,,	75·8	7·733	3·891	14·800	·000	16·079	16·3	10·56	12·76	23·32	,, ,,
,, ,, 28 ,,	65·6	4·830	3·022	11·440	·000	12·443	14·2	3·20	7·24	10·44	,, ,,
,, July 9 ,,	91·1	7·945	2·946	25·960	·000	24·325	20·6	9·84	27·12	36·96	,, ,,
Stroud - Oct. 23 ,,	48·5	2·289	1·330	3·152	·044	3·970	7·3	15·15	27·85	43·00	,, sewage works.
Birmingham 10 Nov. ,,	114·5	6·255	2·414	3·420	·000	5·230	18·3	28·70	39·60	68·30	,, irrigation works. Iron, 9·81, copper, ·41.
Leamington Dec. 11 ,,	83·5	4·355	2·890	5·971	·000	7·807	11·0	96·24	56·28	152·52	At sewage works.
Average, exclusive of samples collected in 1857.	72·2	4·696	2·205	6·703	·003	7·728	10·66	24·18	20·51	44·69	

* These results are extracted from the "Report of Chemical Investigations by Prof. A. W. Hofmann, F.R.S., and Mr. H. M. Witt, F.C.S," Appendix No. 1 to Report on Metropolitan Drainage 1857. They show, when compared with our own recent analyses, that the London sewage is now considerably more dilute than it was 12 years ago, owing doubtless to the increased quantity of water supplied per head of population.

These analytical numbers show a remarkable similarity of composition between the sewage of midden towns and that of water-closet towns. The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter, whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage. For agricultural purposes, 10 tons of average water-closet sewage may, in round numbers, be

PART I. DESCRIPTIVE.

Pollution by manufacturers.

taken to be equal to 12 tons of average privy sewage. The average quantity of chlorine in 100,000 parts of water-closet sewage is 10·66, while in midden sewage it is 11·54. This difference is very significant; it shows that, assuming (which is probably approximately the case) all the urine to reach the sewers in both classes of towns, a larger number of individuals contribute to a given volume of sewage in midden than in water-closet towns. Chlorine in these cases represents common salt, and the latter again indicates the proportion of urine in the sewage. The proportion of chlorine, therefore, ought to give the proportion of average individuals (men, women, and children) contributing to each kind of sewage; and from this it would follow that the populations producing equal volumes of sewage in midden and water-closet towns are as follow:—

In water-closet towns - -	1,066
In midden towns - - -	1,154

The cause of this difference in the volume of sewage per head of population in the two classes of towns is obviously to be sought for in the somewhat increased quantity of water needed by and supplied to the former.

For proof that the sewage selected for analysis in the towns of the *Mersey* and *Ribble* basins was of average quality, see Vol. II., *Minutes of Evidence*, part 3.

The retention of the solid excrements in middens is not, therefore, attended with any considerable diminution in the strength of the sewage, although the volume even in manufacturing towns is somewhat reduced; neither is the case substantially different where earth-closets are substituted for the Lancashire midden, for the sewage from Broadmoor Lunatic Asylum, in which these closets are partially used, exhibits no exceptional degree of weakness. The results of the analysis of this sewage are given at the foot of the first of the above tables. It seems hopeless, therefore, to anticipate any substantial reduction of sewage pollution by dealing with solid excrementitious matters only.

POLLUTION BY MANUFACTURING REFUSE.

We have already stated that pollutions belonging to this category may be conveniently classified under the following heads:—

1. Pollution by dye, print, and bleach works.
2. „ by chemical works.
3. „ by tanneries.
4. „ by paper mills.
5. „ by woollen works.
6. „ by silk works.

Several of these forms of pollution have been very fully described by our predecessors, more especially those produced by tanneries, paper mills, and woollen works, to which, therefore, we shall not require to refer in much detail. The remainder we will now consider seriatim.

1. Pollution by Dye, Print, and Bleach Works.—The operations carried on in bleaching, dyeing, and printing calicoes involve the pollution of large volumes of water partly by mineral, but chiefly by organic matters. In most cases the colouring matters, which it is the object of the manufacturer to fix upon the tissues, are contained in but very small proportion in the dye stuffs employed; thus the weight of actual colouring matter in one ton of madder is not more than 2¼ lbs.; hence nearly the whole of these dye stuffs is refuse matter which, partly in solution, and partly in the solid condition, is carried by the goit of the mill into the adjacent stream. According to Mr. Robert Hammond (Messrs. Bradshaw, Hammond and Co.), Reddish Vale Printworks, near Stockport, who has kindly made some careful experiments for us on this point, only 25 per cent. of the madder used for dyeing goes into the stream in a state of suspension; the remainder, being rendered soluble in the processes of dyeing and garancine making, consequently enters the stream in solution: hence the large proportion of organic carbon and organic nitrogen in solution in the effluent water. Mr. Hammond states that 100 tons of ground Turkey madder root leave, after being used for dyeing, 48½ tons of dry spent madder. This when made into garancine, in the usual manner, and afterwards used for dyeing, leaves 25 tons of dry spent garancine. The returns show that this spent garancine is habitually put into the river or goit. With the exception of a small proportion of the mordants, and of the starch which is used in stiffening the finished goods, all the remaining chemicals find their way into the stream, since they are used in scouring, washing, and cleansing, and are not contained in the goods sent out of the factory. We may gain some idea of the extent of the pollution arising from the processes in question by considering the annual consumption of dye stuffs, chemicals, and other materials, in one such factory of about average size. (See also Vol. II., *Minutes of Evidence*, part 3, *Q.* 1046.

PART I. DESCRIPTIVE.

Pollution by printworks.

The Kinder Printing Company at Hayfield, Derbyshire, have their works situated on the *Kinder brook*, a tributary of the *Goyt*; they employ 250 hands and use annually—

Madder - - -	200 to 250 tons.	Lime - - about	30 tons.
Peachwood - -	3·8 tons.	Soap - - - -	44 „
Logwood - - -	26 „	Liquid arseniate of soda, containing 833·2 lbs. of metallic arsenic - -	19 „
Sumach - - -	7·9 „	Cow's dung - - -	157 „
Sulphuric and muriatic acids - - -	100 to 125 tons.	Starch* - - - -	49 „
Soda-ash - - -	50 tons.	British gum - - -	19 „
Bleaching powder -	14 „		

The quantity of polluted water sent out from these works is estimated at 500,000,000 gallons per annum. It is passed through a series of small settling tanks, and then strained through canvas to intercept the coarser particles of madder, which are either converted into garancine and re-used for dyeing, or (exceptionally in these works) put upon land or burnt. After passing the canvas strainer, the polluted water traverses rapidly a serpentine canal 258 yards in length, and then falls into a culvert which conveys it below the next printworks on the stream, the works of the Hayfield Printing Company.

The following analytical comparison of the water of the *Kinder brook* as it enters the Kinder printworks bright and clear, with the effluent dirty water as it falls into the culvert above mentioned, shows strikingly the great polluting power of a calico printwork, even after the slight subsidence and straining which are exceptionally carried out in the well-conducted works of the Kinder Printing Company. The results of our analysis of the effluent waters from four other dye, print, and bleach works are also added to the table:—

WASTE WATERS FROM PRINT WORKS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Metallic Arsenic.	Hardness.			Suspended Matters.		
									Temporary.	Permanent.	Total.	Mineral.	Organic.	Total.
Brook entering Kinder Printworks.	6·02	·246	·023	0	0	·023	1·10	0	2·56	2·82	5·38	0	0	0
Brook leaving ditto after straining and subsidence.	35·80	6·994	·313	·035	0	·342	2·80	·032	3·84	3·85	7·69	2·54	7·34	9·88
Water flowing into the *Irwell* from Messrs. Worrall's Dyeworks, Salford.	58·60	4·812	·235	·424	0	·575	—	*	—	—	—	10·22	19·98	30·20
Water flowing into the *Tame* from Messrs. Hoyle and Co.'s Bleach and Dyeworks at Dukinfield.	43·40	4·822	·238	·040	0	·271	4·50	·050	21·01	3·20	24·21	13·62	35·42	49·04
Water flowing into the *Ethcrow* from Dinting Vale Printworks.	76·20	1·792	·427	·090	0	·501	·29	*	5·88	11·05	16·93	5·30	20·74	26·04
Main drain of Mayfield Printworks, June 19th, 1868.	36·80	2·711	·281	·035	0	·310	—	·020	—	—	—	3·42	11·38	14·80

* Not tested for arsenic.

Assuming the sample of effluent water from the Kinder printworks to represent an average of the 500,000,000 gallons sent out annually, the above analyses show that 664 tons of solid matter in solution are yearly added to the stream besides 220 tons in suspension. These weights are, however, somewhat in excess of those returned by the Kinder Printing Company, and we therefore conclude that the effluent water was more than usually polluted on the occasion of our visit; indeed, the analytical results yielded by this, as compared with the remaining samples of effluent water, point to the same conclusion, at least as regards organic matters in solution, since in the other cases, although the affluent water was much more impure than the *Kinder brook*, the effluent water was considerably less polluted.

An inspection of the above analytical table shows that the prominent character of this form of pollution is, like that of sewage, organic matter; but the organic matter of dye

* The Kinder Printing Company state that the starch is used in the finishing of printed cloths to give them weight and stiffness, and none therefore is turned into the river.

PART I.
DESCRIPTIVE.

Pollution by printworks.

water is much less highly nitrogenised than that of sewage, and is therefore presumably less putrescible, and consequently less offensive. The polluted water of dye-works also differs strikingly from sewage in containing much smaller proportions of ammonia and, generally, of chlorine, which are the characteristic constituents of decomposed urine. Even the small proportion of ammonia present in the dye-water is doubtless due chiefly, if not entirely, to the liquid excrements of the workpeople. The following table exhibits at a glance the points of resemblance and difference between sewage and the effluent water of dye, print, and bleach works:—

COMPARISON OF TOWN SEWAGE WITH WASTE WATER FROM PRINTWORKS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Sewage.—Average of 15 midden towns.	82·4	4·181	1·975	5·435	0	6·451	11·54	17·81	21·30	39·11
Sewage.—Average of 16 water-closet towns.	72·2	4·696	2·205	6·703	·003	7·728	10·66	24·18	20·51	44·69
Polluted water from Dye, Print, and Bleach works. Average of five works.	50·2	4·226	·299	·125	0	·399	4·86	7·02	18·97	25·99

Amongst the mineral polluting materials of calico-printworks arseniate of soda alone demands especial notice. A return of this material has been made in only two instances, and then at our special request, but it is well known to the trade that the employment of this poisonous material is now all but universal in the madder styles of work. In order to fix the colouring matter of the madder root upon calico, it is necessary first to impregnate the latter with a material called a mordant, with which the colouring matter subsequently combines chemically, forming an insoluble compound which cannot be removed from the tissue by washing. After the application of the mordant to the calico it is necessary to remove the excess, and also to render the remainder, and really useful portion, which has penetrated into the interior of the cotton fibre, absolutely insoluble in water. Both these operations are effected by an operation which is technically termed "dunging," because formerly the mordanted calico was passed through a hot bath containing an emulsion of cow's dung. It was subsequently found that the dung bath could be advantageously replaced by a solution of phosphate of soda containing some phosphate of lime, and sulphate of lime in suspension, the requisite material being manufactured and sold under the name of dung substitute. Finally, about 15 years ago it was discovered that arseniate of soda increased both the economy and efficiency of the dung bath, and a mixture of cow's dung and arseniate of soda appears to have now to a great extent superseded the older mixtures in this part of the calico-printing process. Arseniate of soda, (a compound of arsenic acid and soda, containing from 30 to 33 per cent. of metallic arsenic) is excessively poisonous, and it is fortunate that the amount required in the calico-printing process is but small when compared with the vast volume of water with which it is mixed. Nevertheless, as seen above, analysis reveals a very appreciable proportion of arsenic in the effluent water from printworks. Thus the polluted water flowing from the Kinder Printing Company's works contains in 100,000 lbs. ·032 lb. of metallic arsenic equivalent to ·042 lb. of arsenious acid or white arsenic. Although this proportion is so small, that it would be necessary for an individual to drink no less than 138 gallons of the water in order to imbibe a fatal dose, yet it cannot but be considered undesirable that our rivers should thus become contaminated with such a poisonous ingredient. Indeed, about ten years ago, the Stockport Waterworks Company who at that time drew their supply from the *Mersey*, were alarmed at the appearance of arsenic in the mud of their filters, and still more by the detection of the poisonous element in the water which they supplied to one of their customers. They obtained a verdict against the proprietors of the Dinting Vale Printworks; but in consequence of a legal flaw, all the proceedings were futile, "and nothing resulted from "them except the expenditure of money on both sides to a very serious amount." (Vol. II., *Minutes of Evidence*, part 3, *Q.* 1031.)

That the streams of the *Mersey* and *Ribble* basins are becoming contaminated with arsenic partly from calico-printing works and other sources, but chiefly perhaps from the waste liquors of alkali works is sufficiently evident from the numerous cases in which, by special examinations for arsenic, we have detected that element. The results of these examinations are contained in the following table:—

PART I.
DESCRIPTIVE.

Pollution by arsenic.

ARSENIC IN RIVER WATERS.

Description.	Metallic Arsenic in 100,000 parts of Water.
United streams from Runcorn Soap and Alkali Co., and Hazlehurst & Co.'s Alkali Works falling into the Mersey at Runcorn, May 19th 1868 - - - -	·200
Sankey Brook, above St. Helen's. In flood after sudden and very heavy rain, May 23rd, 1868 - - - - - - - - - -	·005
Sankey Canal at St. Helen's, May 23rd, 1868 - - - - - -	Trace.
Honeypot Brook, flowing into the *Mersey* at Warrington, May 26th, 1868 - -	·032
The *Ribble* at Walton-le-Dale, before junction with the *Darwen*, July 31st, 1868 -	·004
The *Darwen*, just before junction with the *Ribble* - " " " -	·012
" " " " " " March 10th, 1869 - - -	·002
The *Calder* at Whalley, just above junction with the *Ribble*, Aug. 1st, 1868 - -	·024
The *Douglas*, one mile below Wigan sewer outfall, Aug. 7th, 1868 - - -	·036
The *Mersey* above Warrington - - - - March 8th, 1869 -	·002
The *Cornbrook*, just before junction with the *Irwell* - - " 11th " -	·012
The *Irk* " " " " " - - " 11th " -	·016
The *Medlock* " " " " " - - " 12th " -	·004
The *Mersey* at Stretford Road Bridge - - - - " 12th " -	·024
" " " junction with the *Irwell* - - - " 12th " -	·012
" *Irwell* at Agecroft Bridge, above Manchester - - " 12th " -	Trace.
" " at Throstlenest weir - - - - " 12th " -	·009
" " at its junction with the *Mersey* - - - " 12th " -	·009
" " at Barton Bridge - - - - - " 13th " -	·005
Macclesfield sewage, May 12th 1869 - - - - - - -	·004
The *Irwell* at Throstlenest Weir, May 13th, 1869 - - - - -	·024
" " its junction with the *Mersey*, May 13th 1869 - - - -	·018
Preston sewage, average of 24 hours, May 1869 - - - - -	·004
The *Darwen*, below Blackburn, June 10th 1869 - - - - -	·013
" " above Walton-le-Dale Bridge, June 10th 1869 - - - -	·020
" *Irwell*, at Throstlenest Weir, June 11th 1869 - - - - -	·018
" " " " July 21st 1869 - - - - -	·036
" " at junction with *Mersey*, July 21st 1869 - - - - -	·048

The above results seem to indicate that during its flow a river gradually gets rid of the arsenic which it holds in solution or suspension; thus the *Mersey* at Stretford Road Bridge contains ·024 part of arsenic in 100,000, and after a flow of 13 miles to its junction with the *Irwell* it contained only half this quantity, whilst at Warrington only ·002 part was found. Again, the *Irwell*, at Throstlenest Weir contained on May 13th ·024 part of arsenic in 100,000 parts, but after a flow of 13 miles to its junction with the *Mersey* this amount was reduced to ·018 part. These observations will, however, require extension before such a conclusion can be safely arrived at in the case of alkaline rivers such as the *Mersey*, *Irwell*, and *Ribble*, and indeed some of the above numbers do not favour this supposition. The assumption that the arsenic is thus gradually deposited in the mud of rivers is to some extent supported by the observations of Mr. Dugald Campbell, who found this element in the mud of several of the tributaries to the *Mersey* and other rivers. In some of the samples tested by us the arsenic was in solution whilst in others it was in suspension in the water. Besides the samples mentioned in the above table, 24 others were specially examined for arsenic, but no trace of this substance was found in them. For the further discussion of this subject, see page 38.

Bleaching operations are usually carried on in calico printworks, but also, occasionally, in separate factories. The pollution arising from them appears to be of a comparatively slight character, consisting chiefly of alkaline and slightly soapy liquids, solution of chloride of calcium, sulphate of lime in suspension, and traces of chloride of lime in solution. These are so copiously diluted with the water used in washing the bleached calicoes as to be admissible at once into streams, unless the effluent water be turbid, in which case filtration will be necessary.

2. Pollution by Chemical Works.—The chief chemical works carried on in the basins of the *Mersey* and *Ribble* are devoted to the manufacture of soda alkali, soap, colours, and oxalic acid. In the alkali works the principal raw materials are common salt, iron pyrites, limestone or chalk, coal, and black oxide of manganese; and the manufactured products are soda-ash (a crude carbonate of soda), soda crystals, caustic soda, bicarbonate of soda, sulphuric acid, strong muriatic acid, and chloride of lime or bleaching powder. The waste products are alkali waste (an oxysulphuret of calcium), dilute muriatic acid containing a considerable proportion of arsenic, burnt pyrites (chiefly

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peroxide of iron containing some sulphuret of copper), chloride of manganese containing arsenic, and chloride of calcium.

Pollution by alkali works.

The alkali waste is not thrown into the neighbouring river or stream, but it is stacked in enormous heaps from which there drains a liquid containing much sulphuret of calcium in solution, and possessing an odour like that of putrid eggs.

The burnt pyrites was formerly got rid of as rubbish, but it is now utilized, having been found to be of value as a source of copper.

The dilute muriatic acid is, as a rule, run into the nearest stream or canal. Messrs. Crossfield, Brothers, & Co., return as the amount of weak muriatic acid thus run away 500,000 gallons annually, sp. gr. 1·005, which would contain about one per cent. of real acid. Mr. A. E. Fletcher, one of the sub-inspectors under the Alkali Act, estimates the amount of free acid thus annually run to waste in the United Kingdom at 111,400 tons of real acid, or 371,133 tons of commercial liquid muriatic acid of 30 per cent. strength. This is 45·5 per cent of the total quantity made.*

The chloride of manganese, though containing a valuable material, has not hitherto been utilized to any appreciable extent, and is consequently discharged into the nearest stream. Mr. Fletcher informs us that 54,000 tons of black oxide of manganese are annually consumed in the United Kingdom. Nearly the whole of this finds its way into the rivers as chloride of manganese, 57,500 tons of real muriatic acid being partly combined, and partly mixed with it. According to the return of Messrs. Crossfield, Brothers, & Co., whose works are situated on the *Sankey canal* at St. Helen's, a single alkali work thus turns out annually as much as 1,060 tons of manganese in the condition of chloride.

The solution of sulphuret of calcium draining from the heaps of alkali waste meets in the adjacent river with the two waste products just mentioned, and undergoes in contact with the dilute muriatic acid and acid chloride of manganese a very unpleasant reaction, in which large quantities of sulphuretted hydrogen are given off into the surrounding atmosphere; some sulphur and sulphuret of arsenic are thrown into suspension as a fine mud, and the solution of sulphuret of calcium is transformed into a comparatively innocuous one of chloride of calcium. The chloride of manganese also remains in solution, and the stream continues strongly acid. Sulphuretted hydrogen is a gas of an exceedingly disagreeable odour. Breathed in a concentrated condition it rapidly destroys life, but the evidence of its injury to health, when it is diluted with large volumes of air, is doubtful. The chemist in his laboratory habitually inhales the diluted gas with apparent impunity. There can be no doubt, however, that this gas, even when excessively diluted, is one of the most unpleasant things which the sense of smell can encounter; moreover, it is very destructive to paintings, colour decorations, and many kinds of metal work.

The worst case of river pollution from alkali works that we have met with occurs in the *Sankey Brook*, which receives the waste products from the St. Helen's alkali works. Between St. Helen's and Warrington the exceedingly offensive smell of this brook can be perceived at a distance of from one to two miles from its banks. When the wind blows from the west it always unpleasantly surprises the passengers on the London and North-western Railway between Warrington and Kenyon Junction. Leaving injury to health out of the question, it is no exaggeration to say that this brook renders the country within two miles of its banks uninhabitable, except under a penalty of so much discomfort as few would be prevailed upon to endure.

The Rev. Frank George Hopwood, M.A., Rector of Winwick, who resides about three-quarters of a mile from the brook, thus describes its effects in Winwick Hall:—

"The nuisance and injury caused by the effluvium from the *brook* is of so serious a nature that, were I not compelled by circumstances to remain in Winwick, I should certainly remove my family from the constant annoyance caused by the stench. Not only does it beset us out of doors, but it penetrates into every room of the house. On one occasion this winter, in a few moments all the copper vessels were turned almost blue, and the clothes in the drying ground and in the laundry, with *the windows closed*, are discoloured, and have frequently to be re-washed. It makes this place perfectly odious. The nuisance is constant, as the prevailing winds are from the west and north-west.

"The condition of the *brook* is also a positive injury to the property near it. The water is rendered worse than useless for the land, the cattle, and for domestic purposes; and beyond this, if I wished to let this house (Winwick Hall) with such a nuisance besetting it, I should either be unable to let it at all, or should have to do so at far less than its real value."

The waste products poured into the *Sankey Brook* at St. Helen's render its waters strongly acid, and when it overflows its banks it carries destruction to vegetation in the neighbouring meadows, fertile fields being thus transformed for years into a wilderness. There appears to be no effectual remedy at common law for this intolerable nuisance and damage and some of the riparian proprietors, wearied with litigation, are now, at

* Vol. II., *Minutes of Evidence*, part 4.

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great expense, embanking the stream so as to prevent its poisonous waters from flowing over their land. They cannot, however, bank out the sulphuretted hydrogen, which injures their property and renders their homes uncomfortable.

The *Sankey canal* is chiefly supplied from the *Sankey Brook*. Mr. S. B. Worthington, the resident engineer of the Northern Division of the London and North-western Railway, complains of the rapid destruction of the iron work of locks and barges by the acid waters of the brook. He says (Vol. II., *Minutes of Evidence*, part 4):—

"The acid from the alkali works flowing into the brook and thence to the canal causes injury to the works of the canal. It destroys mortar and metal, and even stone itself. The effect is so serious that the lock gates are constructed entirely of wood; hard South American wood being used instead of iron for pins, bolts, &c. The boat owners also state that the vessels navigating the canal suffer from this cause, and no iron boats are used by the traders on the canal. I have seen sandstone taken from a watercourse through which such liquors run completely disintegrated, so that it would crumble in the hand. I have also seen a large iron casting which had been immersed for some time in the canal, and had become entirely altered in nature, being in fact as soft as lead or chalk, and having the appearance of graphite."

The following table contains the results of our analyses of the water of the brook and canal collected at several different points, to which are added the analytical results yielded by other samples, illustrative of pollution by alkali works:—

NATURE OF POLLUTIONS FROM ALKALI WORKS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Suspended Matters.	Free Muriatic Acid.	Oxides of Manganese and Iron.	Metallic Arsenic.
The *Sankey Brook* before entering St. Helen's, after sudden and excessively heavy rain, May 23, 1868.	30·80	1·174	·079	·011	·123	·211	3·13	·51	15·38	15·89	2·06	0	0	·005
Ditto, after junction with *Sutton Brook*, and after leaving St. Helen's, May 23, 1868.	407·25	1·443	·224	·350	·101	·613	196·24	—	—	—	19·11	68·51	—	—
Ditto, quarter mile above junction with *Sankey Canal*, May 25, 1868.	214·50	1·105	·205	·275	·098	·529	76·45	—	—	131·53	—	22·04	9·88	0
The *Sankey Canal* at St. Helen's, May 23, 1868.	239·25	·531	·063	·266	·381	·663	215·94	—	—	192·04	—	18·39	44·42	trace.
Ditto, at Hulme Lock, near Warrington, May 25, 1868.	179·25	·851	·085	·200	·130	·380	54·86	—	—	79·53	—	30·58	20·54	0
Ditto, below junction with *Sankey Brook* May 25, 1868.	189·00	·402	·148	·300	·176	·571	53·86	—	—	88·95	—	2·62	12·42	0
United sewers from soap and alkali works at Runcorn, May 18, 1868.	325·75	—	—	—	·123	—	637·88	—	—	—	—	588·20	15·10	·200
Sewage and waste products from chemical works at Widnes. Stream entering *Mersey* at Runcorn Gap, May 19, 1868.	1890·00	20·509	·755	·642	·024	1·308	699·30	—	—	—	30·96	0	—	1·500
The *Honey-Pot Brook*, flowing into the *Mersey* at Warrington, May 26, 1868. Receives sewage and drainage from alkali works.	234·20	2·443	1·081	1·616	·702	3·114	99·28	—	—	—	2·62	27·44	—	·032
Waste chloride of manganese liquor from Messrs. Deacon & Co.'s Works at Widnes, May 19th, 1868.	15685·0	—	—	—	—	—	—	—	—	—	—	—	—	15·000

These results show that the polluting materials are here almost entirely of a mineral character; and the great amount of free acid in the *Sankey Brook* and canal shows how rapidly destructive to iron work these waters must be. A sample of the mud taken from the *Sankey Brook* just before its junction with the *Sankey Canal* contained when dried at 100° C., 22·75 per cent. of free sulphur. A sample of sludge that had been recently dredged from the *Sankey Canal* near its junction with the *Sankey Brook* contained 3·97 per cent. of free sulphur after drying at 100° C. When it is remembered that sulphur is worth from 6*l.* to 7*l.* per ton, and that 100 tons of the dried mud of the *Sankey Brook* contain 22¾ tons, and that nearly as much passes into the air as sul-

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Pollution by soap and colour works.

phuretted hydrogen, some conception may be formed of the vast quantity of valuable, and, as we shall presently show, recoverable material which is thus thrown away and suffered to pollute both air and water to an intolerable degree.

It may appear surprising that the *Sankey Brook* which contains an appreciable amount of arsenic even before it reaches St. Helen's, and receives a large quantity of this element whilst passing through the town, is nevertheless perfectly free from it before it enters the *Sankey Canal* six miles lower down, near Winwick. When it is remembered, however, that below St. Helen's the *Sankey Brook* is acid and saturated with sulphuretted hydrogen, and that arsenic in presence of sulphuretted hydrogen is converted into sulphuret of arsenic, which is insoluble in water, the apparent anomaly is satisfactorily explained; the sulphuret of arsenic is deposited and accumulates in the mud of the brook, which we find on analysis to contain no less than 2·26 per cent. of arsenic. No such effect, however, would necessarily follow the admission of the waste arsenical liquors directly into rivers. The latter being usually alkaline, would retain the sulphuret of arsenic in solution even should this compound be formed. Thus the *Sankey Brook*, with its horrible pollutions, has the merit of arresting the arsenic of the St. Helen's Alkali Works, and of preventing its access to the *Mersey*.

In soap works the chief polluting agents are glycerin and common salt. The first results chiefly from the manufacture of curd soap: in what is termed *close* soap some of the glycerin is retained and sold in the finished product. In Messrs. Gossage's extensive soap works at Widnes about 100 tons of grease or fat are used weekly, yielding about 5 tons of glycerin, which is allowed to run into the estuary of the *Mersey*. 100,000 parts of the crude solution of glycerin collected at these works left on evaporation 14,807·2 parts of semi-solid residue, consisting chiefly of glycerin and common salt, but containing ·325 part of metallic arsenic (see pages 38 and 39). Glycerin being an innocuous, non-nitrogenous, organic liquid, miscible with water in all proportions, cannot be regarded as a very offensive polluting material; nevertheless it is desirable to keep it out of fresh water, more especially as it is generally turbid from suspended particles of fat, resin, or soap. Common salt in quantities such as are used in soap works can scarcely be regarded as a polluting material, unless it be discharged into a very small stream.

The pollutions arising from colour works consist chiefly of tinted liquids, frequently containing a considerable amount of organic matter in solution, and often rendered still more offensive by coloured solid matter in suspension. In works where aniline colours are manufactured the waste products are liable to contain arsenic, which, in the form of arsenic acid, is largely used in the production of magenta, aniline blue, and aniline violet, but is not a constituent of these colours. In all well-regulated works this waste of arsenic is prevented, as the arsenical product can be profitably converted into arseniate of soda for the use of the calico printer. So far as river pollution is concerned, however, the final result is the same, for the calico printer eventually turns it into the stream as above described. Nevertheless the quantity of the poisonous metal gaining access to rivers is reduced, inasmuch as the same arsenic serves the purposes of two manufacturers.

The following analysis of a sample of purple liquid draining into the *Mersey* from Messrs. Roberts and Dale's aniline colour works at Warrington will serve as an example of pollutions of this class:—

100,000 parts of the liquid contained—

Total solid matters in solution	348·000
Organic carbon	2·330
„ nitrogen	·969
Ammonia	3·430
Nitrogen as nitrates and nitrites	·369
Total combined nitrogen	4·163
Arsenic	·040

From a purely chemical point of view there is but little difference between this liquid and ordinary sewage, and it would doubtless be applicable to agricultural purposes if kept nearly free from arsenic.

The manufacture of oxalic acid from sawdust may be a source of river pollution chiefly of an inorganic kind. In the course of this manufacture a large quantity of sulphate of lime is formed, but as this substance is insoluble in water, and carefully separated from the valuable oxalic acid by filtration, the casting of it into running water is obviously unnecessary and easily avoided. More than one-half of all the oxalic acid used in the world is manufactured at Warrington by this process, in Messrs. Roberts and Dale's factory. We examined two samples of liquid flowing copiously from these works into the *Mersey*. Only one of these samples (No. 2.) was polluted, and this probably more from other chemical operations conducted in the same factory than from the oxalic acid process.

100,000 parts of the liquid pouring from each of these drains contained—

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Pollution by paper mills.

DRAINAGE FROM CHEMICAL WORKS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Samples from ;—	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Arsenic.	Hardness.			Suspended Matters.	
									Temporary.	Permanent.	Total.	Mineral.	Organic.
Drain No. 1 (neutral re-action.)	55·5	·367	·018	·022	·404	·440	—	—	6·72	11·53	18·25	—	—
Drain No. 2	316·0	1·662	·318	·100	·292	·692	6·65	·094	11·53	201·96	213·49	64·9	7·54

3. Pollution by Tanneries.—The nature of the polluting matters thrown into rivers from tanneries has been fully treated of in the Third Report of the former Rivers Pollution Commission, Rivers *Aire* and *Calder*, page xxxv. Tanning is carried on extensively at Warrington, Stockport, and Runcorn. According to the return of Mr. Robert Pierpoint, of Runcorn, he uses yearly 25 tons of lime, 100 tons of bark, 25 tons of valonia, 10 tons of gambir, and, besides fowl's dung, the excrements of 25 persons. In the process of depilation, 30 packs of hair are here obtained and sold to plasterers. In "fleshing," 4 tons of "fatty matter" are scraped from the hides and sold to size makers. There are 50 tanpits in these works, and the spent liquor from them is discharged into the estuary of the *Mersey*. In the Ocklestone tan-yard, of about the same size, at Runcorn, 52,000 hides are yearly submitted to the tanning operation, and the waste liquors are run into the Bridgewater Canal.

Samples of spent tan liquor, spent lime liquor, and the liquor flowing from the sewer of the Ocklestone tan-yard into the canal, yielded the following results on analysis; 100,000 parts containing:—

POLLUTING LIQUIDS FROM TANNERIES.

——	Spent Tan Liquor.	Spent Lime Liquor.	Liquor from Tan-yard Sewer.
Total solid matters in solution	8459·0	3186·5	848·5
Organic carbon	3182·17	205·94	79·48
Organic nitrogen	36·29	53·41	5·37
Ammonia	10·83	25·80	5·18
Total combined nitrogen	45·21	74·66	9·64

The large proportion of the elements of nitrogenous organic matter contained in these liquids proves them to be of a highly offensive character, nevertheless the quantity daily run to waste is but small, and, as we shall show below, there will be no difficulty in dealing with these liquors so as to prevent the pollution of the neighbouring streams.

4. Pollution by Paper Mills.—The nature of this form of pollution has been already minutely described in the First Report of the former Rivers Pollution Commission —River *Thames*, page 18. Next to the fouling of water by the washing of filthy rags, the discharge into rivers of the soda-liquor in which esparto grass has been boiled is the most formidable source of pollution from paper mills. Rivers polluted by this liquor carry a very persistent froth or scum which, below a weir or rapid, frequently covers the whole surface for many miles. We have investigated this form of pollution in a stream peculiarly subject to it, which, however, at the time of our visit, had been much improved in consequence of a judgment recently obtained by his Grace the Duke of Buccleugh and others against the paper makers on the *North Esk* River, near Edinburgh. The following are the results of our analyses of waste esparto liquor and of the water of the *North Esk* before and after pollution:—

PAPER MILL POLLUTIONS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.			Suspended Matters.		
								Temporary.	Permanent.	Total.	Mineral.	Organic.	Total.
Waste Esparto Liquor	4038·0	938·845	77·042	1·116	0	77·961	—	—	—	0	0	0	0
North Esk above Bank Mill, September 22, 1868.	13·98	·443	·050	·003	0	·053	1·09	0	7·11	7·11	—	—	·28
North Esk below Roslyn Castle and after passing five paper mills, September 21, 1868.	18·82	1·019	·080	·003	·004	·087	1·99	·74	8·87	9·61	—	—	—
North Esk at Dalkeith Palace after passing 8 paper mills. Temperature 14° C., September 21, 1868.	19·80	1·081	·101	·003	0	·104	1·89	1·91	7·55	9·46	5·20	11·72	16·92

PART I. DESCRIPTIVE.

Pollution by woollen works.

The case of the *North Esk* river strikingly illustrates the defects of the present remedy at law as regards river pollution. Here three wealthy riparian proprietors, stimulated by the horrible pollution of a river which flows through their parks and under the very windows of their houses—Dalkeith Palace, Melville Castle, and Hawthornden,—commenced proceedings in the year 1841, but not until the year 1866 did those proceedings reach the stage of a verdict in favour of the plaintiffs. Even at the time of our visit two years later, the nuisance, although greatly abated, had not been entirely removed; the remedies to be applied being still under the consideration of a chemical referee appointed by both parties to the suit.

5. Pollution by Woollen Works.—In the woollen trade the chief sources of river pollution are the washing, fulling, dyeing, and printing operations. The first three have been amply discussed in the report of the former Rivers Pollution Commission (Third Report, *Aire* and *Calder*, page 22), and it is therefore only necessary to allude here to the fourth. The printing of woollen warps is chiefly carried on in connexion with the manufacture of carpets; the colours are applied topically, that is, to the surface of the woollen threads, and are brought to the right consistency for this purpose by some thickening material, which is usually flour paste. The thickened colour is applied transversely by small travelling rollers to the warps stretched upon a large drum. The warps are then embedded in chaff in large boxes, and subjected for some time to a current of steam, the object of this process being to fix or render insoluble that portion of the colour which has come into actual contact with the woollen fibre. The proportion of colouring matter employed which does so become fixed is, however, very small, and consequently the process is unavoidably a very wasteful one as regards colouring material. After steaming, the warps are washed in vats, in which they are moved to and fro by machinery. In these vats the excess of colouring matter and the whole of the flour paste are removed from the warps, and the polluted water is then discharged into the neighbouring stream. These vat liquors are of various tints, but, unlike the colours of the spectrum which, when mixed, become colourless, the mixture of coloured vat liquors commonly communicates to the adjacent river a tint more or less resembling that of ink.

A sample of the waste water from one of these vats in Messrs. Bright and Co.'s carpet factory, at Rochdale, indicates a large proportion of nitrogenous organic matter, and ammonia sufficient to render it valuable for irrigation; arsenic was also present, as seen from the following analysis:—

100,000 parts contained:—	
Total solid matters in solution	103·10
Organic carbon	14·924
Organic nitrogen	·925
Ammonia	1·144
Total combined nitrogen	1·867
Arsenic	·012

A sample of soap suds from the same factory, consisting of a solution of soap and soda, in which wool had been scoured was found to contain ·028 part of metallic arsenic in 100,000 parts.

The analysis of a sample of wool suds (the liquid in which raw wool has been scoured) from Messrs. Kelsall and Kemp's Woollen Manufactory, in Rochdale, shows both the very noxious character of this liquid, and the great value which it possesses for agricultural purposes, as evidenced by the very high proportion of total combined nitrogen which it contains:—

100,000 parts of this liquid gave:—	
Total solid matters in solution	1099·4
Organic carbon	132·48
Organic nitrogen	9·88
Ammonia	54·61
Total combined nitrogen	54·85
Mineral suspended matters	870·95
Organic suspended matters	2611·65
Arsenic	Traces.

The unexpected presence of arsenic in these liquids led us to test for this element in specimens of soap and soda obtained from different tradesmen. As the result of this examination it was found that out of seven samples of soap, three contained traces; and out of twelve samples of soda-ash, eleven were contaminated with a sufficient quantity of the poisonous element to account for its presence in the two samples of polluting liquid just mentioned.

The question now arises, what is the source of the arsenic present in these articles? The answer to this question is obvious to anyone acquainted with the modern developments of the alkali manufacture in this country. The initiatory process in that manufacture is the production of sulphuric acid. Formerly this acid was made exclusively from volcanic sulphur, which was imported into this country chiefly from Sicily, and the sulphuric acid thus made contained no arsenic; but the imposition of a heavy export duty upon sulphur by the late King of Naples led chemists to search for another source of this element. They soon found that iron pyrites, a material which had hitherto been considered nearly useless, afforded an abundant supply of sulphur at a cost much less than that of the Sicilian article before its taxation. Thus sulphur has been gradually, but at length completely, replaced by iron pyrites in the production of sulphuric acid for the alkali manufacture. Unfortunately, however, iron pyrites nearly always contains a notable quantity of arsenic, much of which passes into the sulphuric acid obtained from this material. Dr. R. Angus Smith, Your Majesty's Inspector of Alkali Works, informs us (Vol. II., *Minutes of Evidence*, part 4), that 400,000 tons of iron pyrites are annually imported into this country for the alkali trade. At a moderate computation we thus annually import 1,600 tons of arsenic, a large proportion of which, there is every reason to believe, now finds its way into our rivers and streams. In the alkali factory the sulphuric acid is employed to decompose chloride of sodium in a closed furnace. The arsenic is here transformed into chloride of arsenic, which, being volatile, passes off to a great extent with muriatic acid gas to the condensing towers, where it is dissolved by water and becomes a constituent of strong liquid muriatic acid, which is afterwards used in the manufacture of bleaching powder; and also of weak muriatic acid, which, as we have already described, is run directly into the nearest watercourse. The disposal, in like manner, of the arsenic in the strong muriatic acid is only postponed; it ultimately finds its way into the rivers as waste chloride of manganese liquor. But to return to the non-volatile product of the action of sulphuric acid upon chloride of sodium, technically called "salt-cake," which still retains a certain small proportion of the arsenic originally present in the sulphuric acid. This salt-cake is afterwards mixed with crushed chalk or limestone and coal-dust, and the mixture is heated to incipient fusion in a reverberatory furnace. Here some of the arsenic must volatilize, indeed it might be expected that the whole of it would do so, did not the sequel prove this not to be the case; moreover the coal dust which also contains arsenic probably more than compensates for the loss. The product of this operation is termed "black-ash." It is afterwards lixiviated with water, and the lixivium being evaporated to dryness yields soda-ash. In some factories the crystalline granules of soda-ash, as they are deposited during evaporation, are fished out of the boiling liquor, and are afterwards sent into the market, as ash of first quality. The residual liquor being evaporated to dryness constitutes ash of the lowest quality, which will contain the largest proportion of arsenic, whilst the first quality ash may be comparatively or entirely free from the poison. In a series of samples, kindly supplied to us from a large chemical work, we have clearly traced the arsenic from the original iron pyrites through the different products just enumerated up to this point. A certain proportion of soda-ash is re-dissolved in water, and then allowed slowly to crystallize: the soda crystals thus obtained are a true carbonate of soda, and constitute the common "washing soda" of the shops. We have examined nine samples of washing soda obtained from as many oil shops, and found that only two of them contained the poisonous metal. The bicarbonate of soda again of the druggist is made from the soda crystals just mentioned. Two samples of this material were examined and found to be entirely free from arsenic.

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Pollution by arsenic.

Soda ash is extensively used in all bleaching and scouring operations, and thus arsenic is unconsciously introduced into a vast number of factories, as, for instance, that of Messrs. Bright and Co., at Rochdale; it is employed in the manufacture of soap, but is for the most part got rid of in the spent lye of soap works, a specimen of which, as stated at page 36, contained ·325 part of arsenic in 100,000 parts; hence, of seven samples of soap which we have examined, only three contained arsenic, and in but very minute quantity. As soap and washing soda are used in most households the poisonous metal is liable to gain admission into many dwellings; it is carried by the slops into the sewers, and, in London, is afterwards found in the sewage at Barking to the extent of ·004 in 100,000 parts.

We are by no means disposed to take an alarmist view of this wide distribution of arsenic amongst the community; indeed as we find it to be contained in very appreciable quantity in the rain which falls in London, being derived in this case from coal smoke, it is doubtless present in the rain water of all our large towns, and consequently cannot be entirely excluded from rivers; nevertheless its unnecessary introduction cannot but be regarded as, on many grounds, undesirable; and we believe that, so far as soda-ash and its derivatives are concerned, it might be easily prevented by submitting the "salt-cake" and "black ash" to a somewhat more prolonged roasting, by which the arsenic, now partially driven off, would be completely expelled. We trust that when the presence of this impurity becomes known to alkali manufacturers they will direct their attention to

PART I. DESCRIPTIVE.

Silting up.

remedy the evil introduced into their processes chiefly by the substitution of iron pyrites for sulphur.

6. Pollution by Silk Works.—To prepare raw silk for dyeing, the gum which naturally adheres to the fibre, is removed by boiling with a solution of soap. The gum constitutes about 25 per cent. of the weight of the silk; and about 20 lbs. of soap are used for discharging the gum from 100 lbs. of silk. Altogether about 40 lbs. of soap are used for each 100 lbs. of silk, and all the suds are thrown into the stream. The dyes used are chiefly those known as aniline colours, and being very expensive and capable of being applied to the silk almost without waste, but little goes into the rivers. We visited several of the silk dye-works at Macclesfield. In one of them 1,500 lbs. of soap were used weekly for "wetting" and "discharging." The dye vats contained about 340 gallons each, and 20 at most were emptied daily. The quantity of liquid being small, its purification will not present any formidable difficulties.

At the Langley silk printworks in Macclesfield, they use as dyewares, chiefly aniline dyes, gums, and mordants, with small quantities of indigo and madder. They also use 12 tons of soap annually; the suds are not treated for the recovery of grease. At the time of our visit an opalescent inodorous liquid was being discharged from these works into the *Bollin*. 100,000 parts of this effluent water yielded the following results on analysis:—

Total solid matters in solution - - - -	26·50
Organic carbon - - - - - -	1·489
Organic nitrogen - - - - - -	·153
Ammonia - - - - - - -	·026
Total combined nitrogen - - - - -	·174
Arsenic - - - - - - -	·012

SILTING UP OF RIVERS.

To the above description of what are strictly *river* pollutions there must now be added some account of the abuses which the river *channels* suffer in being made the recipients of solid refuse. This is a very serious and important division of the evils to which the present condition especially of the *Irwell* bears witness. The urgency with which a remedy is called for, though obvious enough throughout its course, culminates at Manchester, because it is there that the navigation uses of the river commence. Under ordinary circumstances the Throstlenest weir, which supplies the *Mersey* and *Irwell* navigation here would catch a comparatively small quantity of transported earthy matter, and comparatively little dredging would be needed to maintain the natural level of the bed at this point. It is but an insignificant quantity of mud which is brought down daily in the natural condition of a small river like the *Irwell:* the river bed in such a case, changes comparatively little from year to year. Where the channel is rocky it has long since been washed clean of any loose earth to which the water has had access: and even where it passes through less indurated material as alluvium or clay, the running water has already accomplished whatever disintegration or abrasion it is ordinarily capable of; and it is only very rarely and during heavy floods that any material alteration of the channel, either in position or in depth, is effected. Were the *Irwell* in its natural condition, therefore, comparatively little, and only occasional dredging would be needed above the weir at Manchester to keep its channel free. The circumstances of the *Irwell* are however, it is plain, from what we witnessed on our journey downwards from its source to this point, anything but natural. At a thousand places along its course and that of its affluent streams, mineral matter, much of it already in the condition of loose earthy waste, is thrown into the river bed for the express purpose of being carried away. At several manufactories upon its course, many thousand tons of coal are annually burned. Out of every eight tons of coal one ton of ashes has thus every year to be got rid of, and they have hitherto been very generally thrown into the river.* The result is seen in great shoals of black mud and ash, appearing at various points below the mills; it is also seen in the occasionally diverted course of the river, as when a great spoil heap on one bank sends the water with increased force against the opposite side below; and it is seen in the gradual rising of the river bed, which in flood time thus raises the level to which the injury then suffered by river side towns and villages extends.

* See the evidence of the Mayor of Salford, Vol. II., *Minutes of Evidence*, part 3, Q. 236. Also report by Mr. Thomas Part, Solicitor to the Trustees of the Bridgewater Navigation, *ibid*, part 4.

PART I. DESCRIPTIVE.

Silting up.

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Part I.
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Silting up.

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Part I.
Descriptive.

Silting up.

From a report (Vol. II., *Minutes of Evidence*, part 4) by Mr. R. W. Barnes, C.E., to the trustees of the Bridgwater Navigation, kindly forwarded to us by Mr. Fereday Smith, we learn that the bed of the *Medlock* at Hilton's Mill, Beswick, had risen two inches annually between 1858 and 1862, and 10 inches in all since 1862; and that the bed of the *Irk*, near Union Street, Manchester, has risen $1\frac{3}{4}$ inches annually, which corresponds closely with the ascertained rise of every extraordinary flood of late years. We also learn that the bed of the *Irwell* between Albert Bridge and Throstlenest weir has risen on an average $7\frac{3}{10}$ inches since 1862, being at the rate of $1\frac{1}{2}$ inches per annum. On the other hand we are informed that at Bacup on the headwater of the *Irwell*, at Bolton and Sharples on the headwater of the *Croal* and *Eagley Brook*, and at Middleton near the source of the *Irk* the Local Boards of Health have been careful to forbid the casting of solid refuse of all kinds into the river channel, which accordingly has in these places very sensibly improved of late years. At Bacup in particular the channel is declared to be clean; and whereas an ordinary flood used formerly to inundate the neighbouring streets, they were dry and safe in the extraordinary flood of 1866.

We have selected, from a number of cross sections accompanying Mr. Barnes' report, examples both of the gradual or general growth of the evil of silting up, as in the case of the *Irwell* passing through Manchester, and of the occasional shoals and obstructions at various points, which the river suffers higher up. These are given on the annexed sheet, and so far as mere inspection of the localities enables us we can certify their general accuracy.

No. 1, a cross section of the *Irwell* at the new bridge from Water Street, Manchester, shows the natural river bed at that point, and the lines of level which it had assumed in 1860, 1862 and 1867 respectively. This may be taken as an illustration of the ultimate effect upon the navigation at the foot of the river, of the various acts of obstruction which it suffers by the throwing in of earthy matters throughout its course above. The character of these again may be gathered from the following sections of shoals and weirs, higher up the river and its affluents.

No. 2, for instance, was taken across the River *Medlock* at Fairbottom Bobs, Bardsley, near Oldham, where there is, as will be seen, a shoal below the weir, chiefly a deposit of coal pit refuse. It is reported to us as having been much enlarged since 1862, being now 20 inches higher than it was then; and more than half the weir, which in 1862 was clear, is now silted up level with the top.

No. 3 is a section taken across the same river opposite Hilton's Mill, Holt Town, Manchester. The river is here confined between walls. There is a shoal extending two-thirds across the river bed which is now 10 inches higher than it was in 1862; and whereas the sewer of the mill is now three-quarters full of deposit, in 1862 it was entirely free.

No. 4 exhibits a shoal on the *Irwell* below Bealey's weir, now extending many yards further down the channel than it did in 1862, and joining on to the right bank of the river. Higher up again, at Messrs. Wilson's factory, a deposit has narrowed the river, directing the current against the opposite bank, which has been washed away, bringing with it earth and trees, now lying in the river bed.

Nos. 5 and 6 are sections on the *Bradshaw Brook* near Bolton, taken at Bridge End, Bradshaw, and below Firwood Bleachworks. They show how river-side accumulations take place, to be partially removed in floods, to the great injury of the channel lower down. Immediately above Thicketford Bridge at this point there is a strip of land between the road and the river on its right bank, about 30 yards wide and several hundred yards long, on which an immense mass of cinder and furnace ash has gradually accumulated, being carted from the ground-level at the farther end to the top of the ridge-like heap, which has thus grown until it forms a steep bank on the outer bend of the brook, 15 or 20 feet high, and dipping directly into the water. The heap is being quarried on its landward side, and some of the material is being used for roads; but every flood must wash down large quantities from the other side of it into the river bed.

No. 7 represents a section of the *Whitbrook*, a tributary of the *Irk*, at Lee Fold Bridge, Middleton. The bottom of the drain from Kenyon's mill here, which was 1 foot above the bed of the stream in 1820 was 9 inches below it in 1862, having risen 1 foot 9 inches in 42 years; and it is now 15 inches below the present bed of the river, showing a rise at this point of 6 inches in five years. The whole bed of the brook has been here raised by deposited material, and is thus gradually choking the archway of the bridge, and the brook side is obviously encroaching upon the stream by continual additions of house rubbish and road scrapings.

SECTIONS REPRESENTING THE SILTING UP OF THE RIVER CHANNELS.

Nº 1. IRWELL

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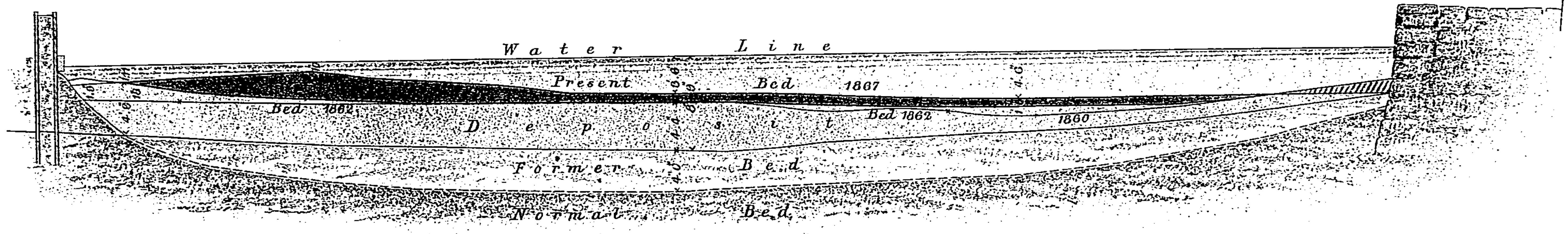
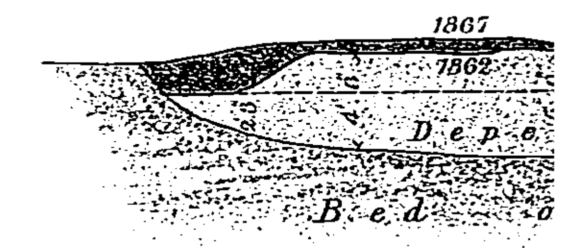


Nº 5. BRADS

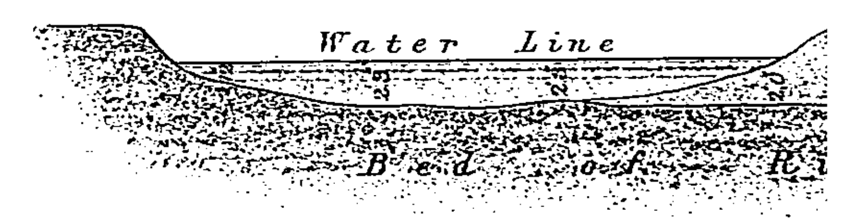


Nº 2. MEDLOCK

SHOAL BELOW WEIR AT FAIRBOTTOM BOBS.

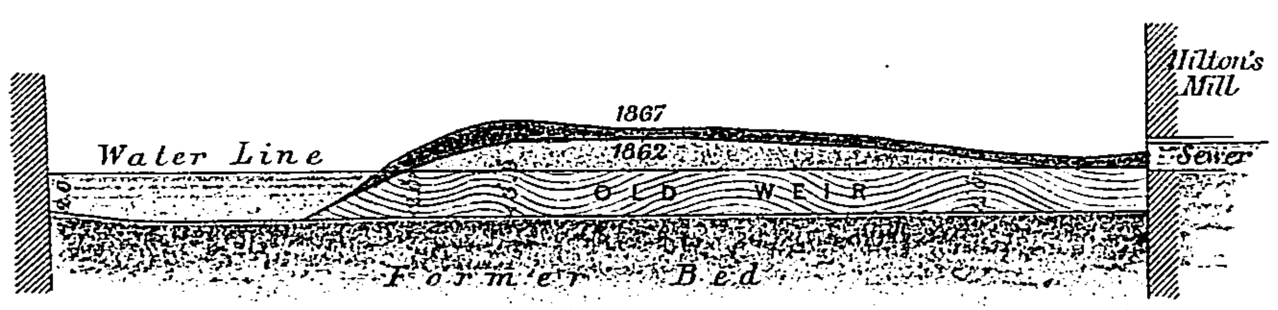
Nº 6. BRADSHAW BROO

BELOW FIRWOOD BLEACH WORK

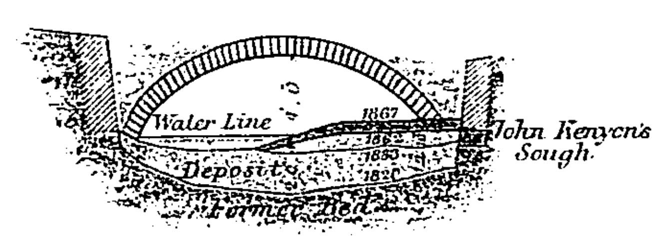


Nº 3. MEDLOCK

SHOAL BELOW HILTONS MILL.



Nº 7. LEE-FOLD BRIDGE, WHIT BROOK.



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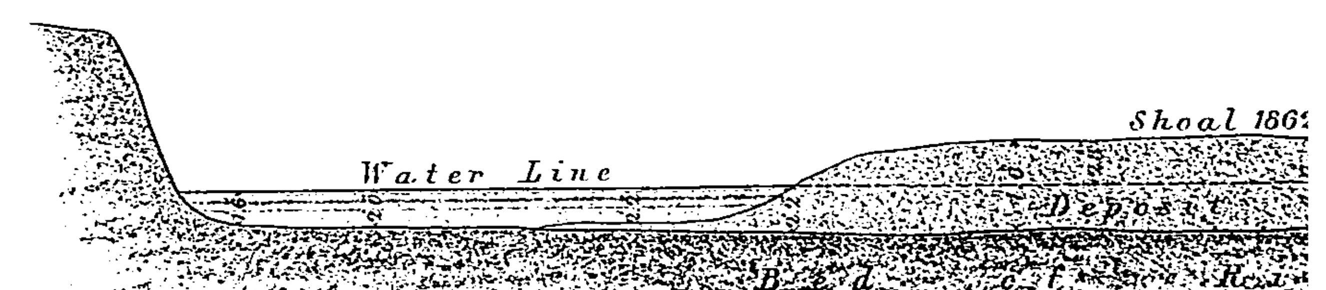

Nº 4. IRWELL

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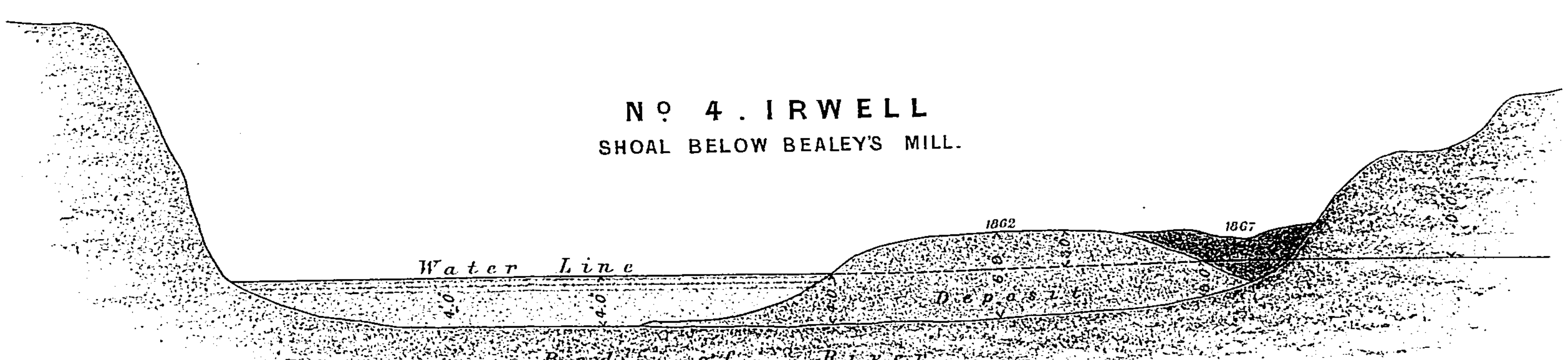

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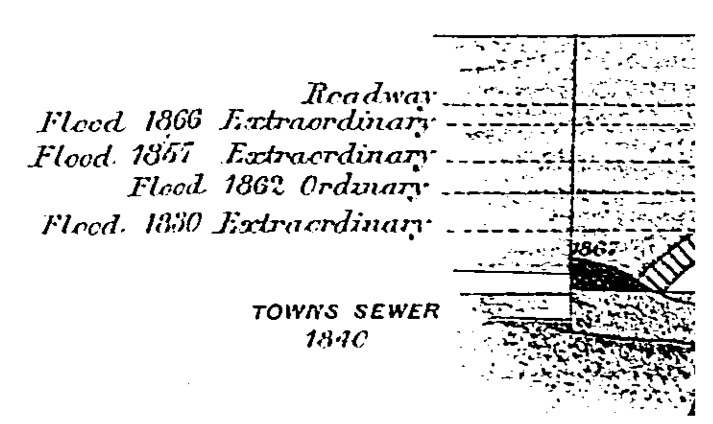
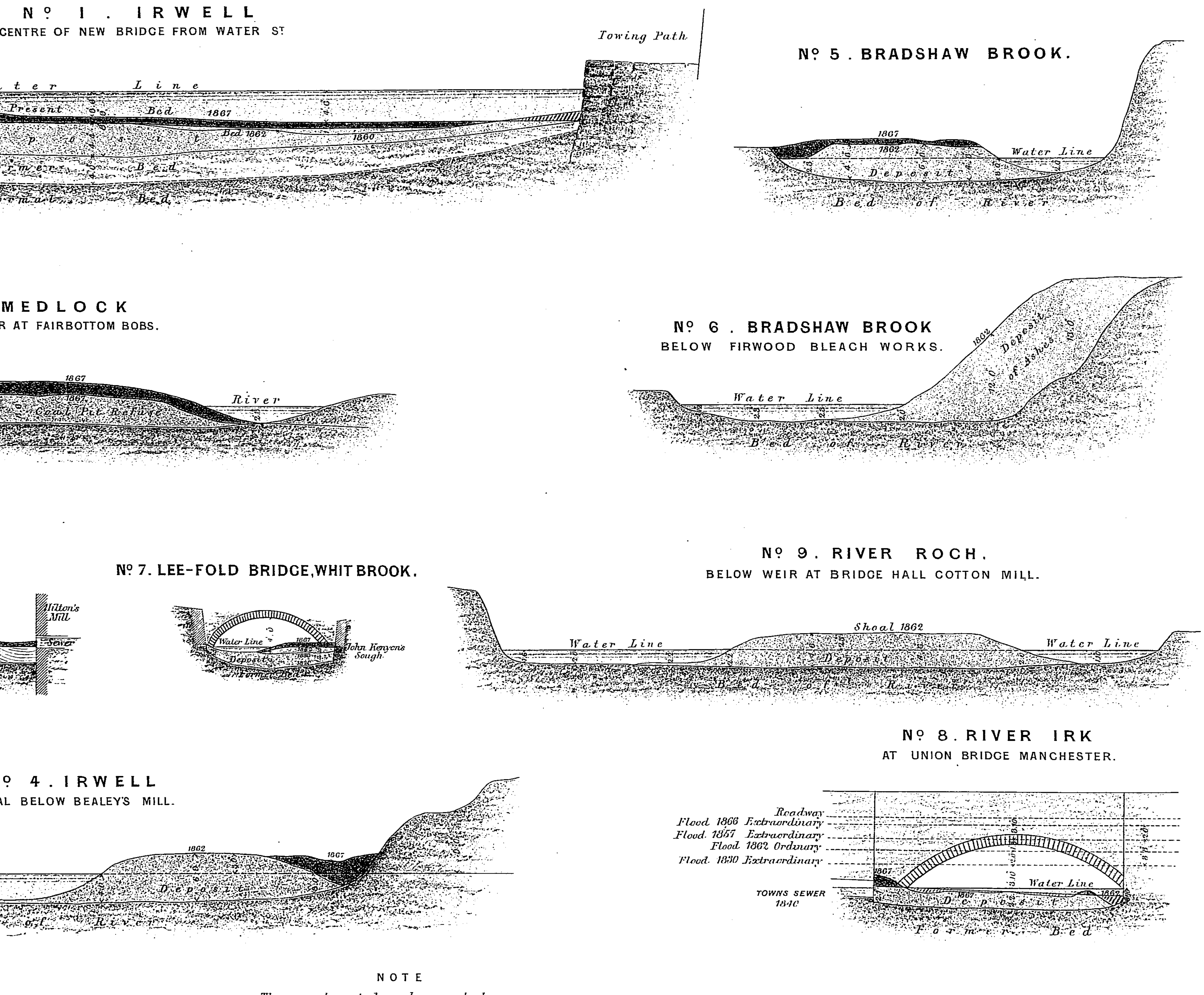


NOTE

The scored parts have been washed away.

SECTIONS REPRESENTING THE SILTING UP OF THE RIVER CHANNELS.



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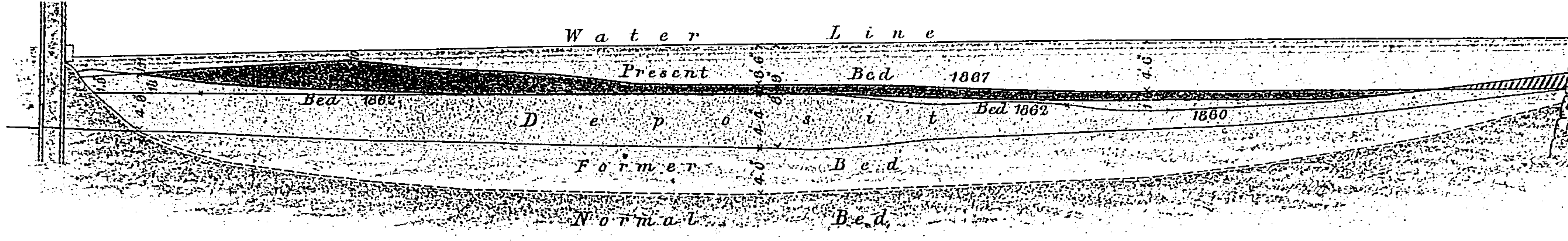

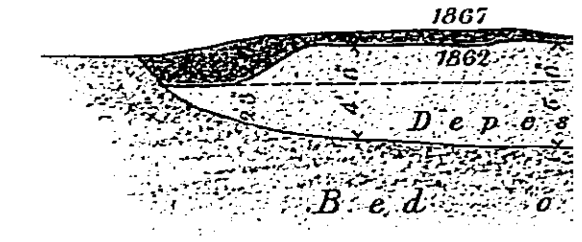

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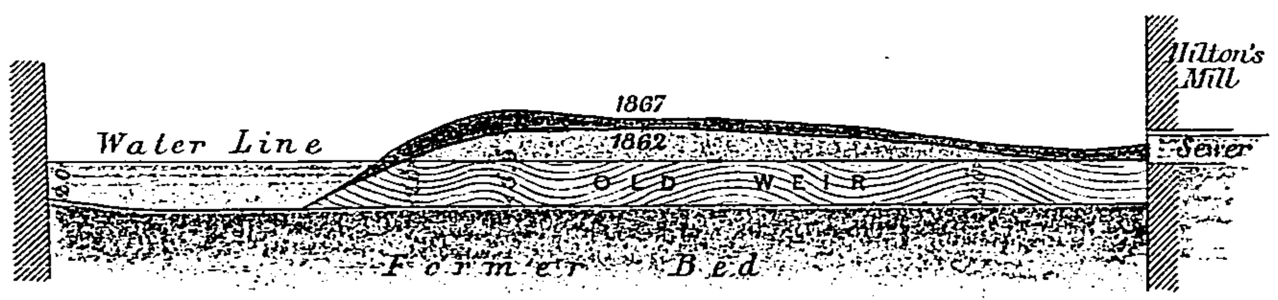

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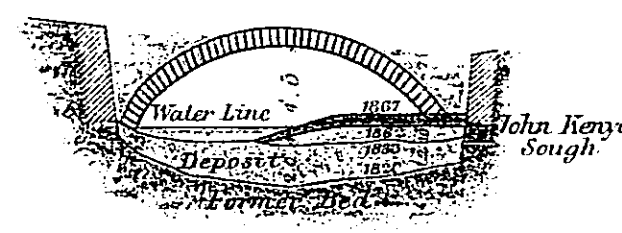

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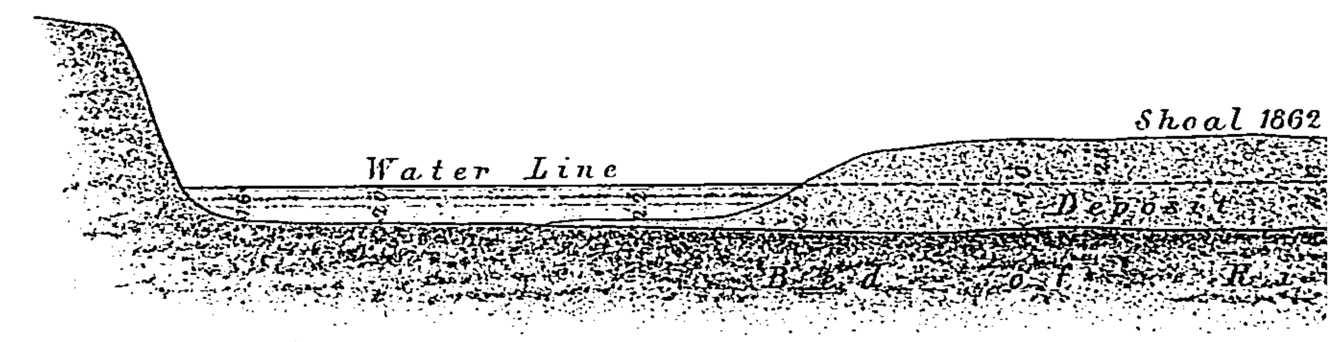
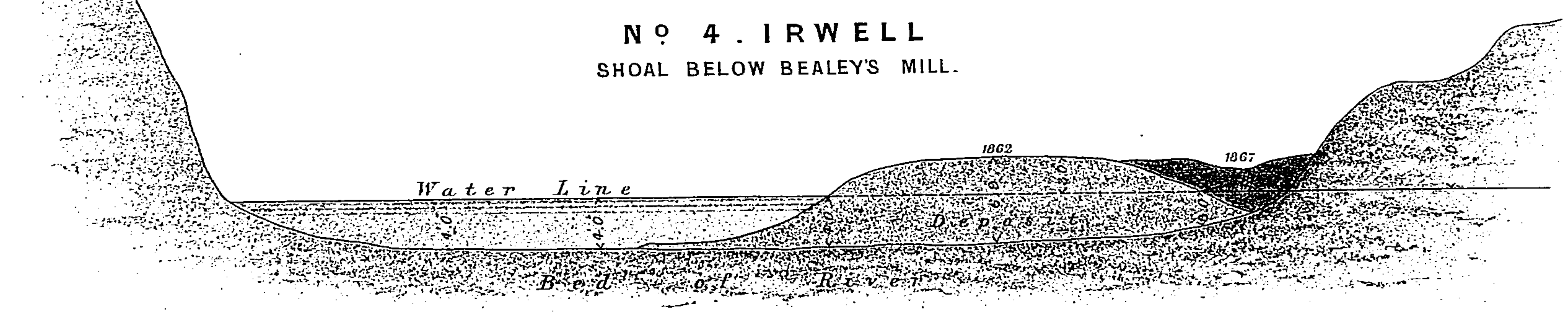


Nº 4. IRWELL

SHOAL BELOW BEALEY'S MILL.



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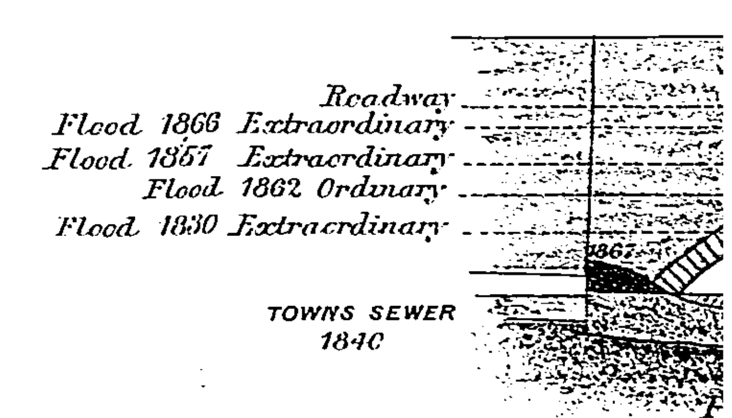

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The scored parts have been washed away.
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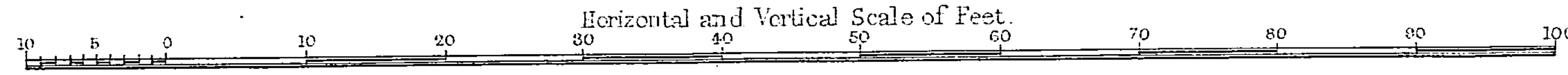
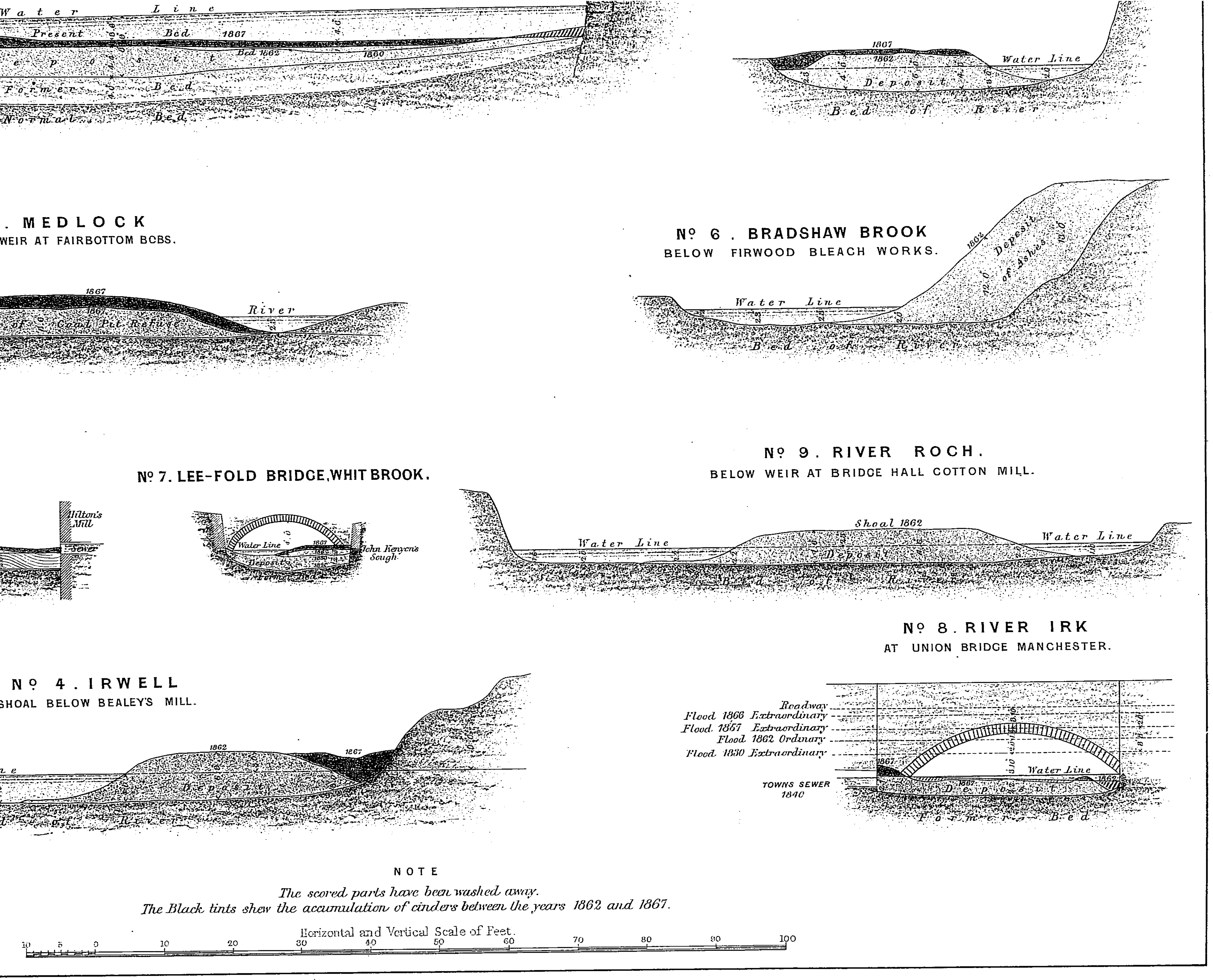
Horizontal and Vertical Scale of Feet.





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PART I. DESCRIPTIVE.

River regulations in Prussia, France, and Belgium.

No. 8, a section of the *Irk*, at Union Bridge, Manchester, shows that the town sewer which was 6 inches above the river bed in 1840 is now 3 feet 6 inches below it, proving an average yearly rise of $1\frac{3}{5}$ inches of the bed of the river here. Since 1830 the "extraordinary flood line" has risen 3 feet 8 inches, being at the rate of nearly 2 inches per annum, corresponding closely to the rise in the river bed.

No. 9 represents a section of the *Roch*, at Bridge Hall woollen mill, upon the left bank of the river above Heap Bridge, on the road from Bury to Heywood, and shows the existence of a large shoal in the midst of the river channel. This shoal is now a good deal scattered, and lies in patches of transported stones and gravel, sand, and furnace ash at various points in the river bed below the weir.

Other examples might be shown in the *Roch* and other tributaries of the *Irwell*, equally illustrative of the enormous quantity of solid matters which is now thrown into the river channels, to the destruction of all the uses which a river serves. The actual position of the river course has in many places been diverted in this way to the injury of riparian proprietors. The millowners, who are the principal offenders, are also sufferers by the consequent raising of the river bed; towns and villages are injured by the higher level of the floods; lands are depreciated in value by the increased difficulty of draining them; the whole district suffers by the destruction of the navigation.

Such then is our report of the several sources of pollution to which the present filthy condition of the running waters in the *Mersey* and *Ribble* river basins is due. Before we proceed to discuss the remedies which it may be desirable to apply to the existing state of things, we must allude to statements made by a "Committee of Millowners" on the rivers *Mersey* and *Irwell* and their tributaries, which will be found in Vol. II. (*Minutes of Evidence*) part 4. These gentlemen draw a marked distinction between what they term "sewage pollution" and "trade pollution;" that is, between ordinary sewage and the refuse of manufacturing industry. They admit that the chemical agents employed by the manufacturers are deleterious to the water, and render it unfit for the domestic use of the inhabitants, but they affirm that these have no tendency to produce disease when the refuse water is exposed to the atmosphere; and they insist that their action is rather antiseptic or disinfectant than injurious. While, therefore, they urge the necessity of excluding sewage pollution from the streams, they are not disposed to admit the necessity or advisability of any special dealing with "trade pollution."

They also lay great stress on the magnitude of the interests involved, which they estimate in the Lancashire coal district at 100 millions of pounds sterling per annum. And in an interview with us they pressed upon us, as a fact, that in foreign countries, such as Prussia, France, and Belgium, with whose produce they had to compete in the markets of the world, no regulations exist tending to hamper the action of the manufacturers in dealing with the streams.

From what has been already said, it would seem that the plea brought forward in behalf of the beneficial action of "trade pollution" is hardly borne out by facts. There may be certain cases where, with reference to particular chemical agents, some disinfectant action may result; but when no sewage is admitted into the stream, there will be no use for these disinfectants, and their action must then, as stated by the millowners, be simply deleterious. A reference, however, to several instances of the mode of dealing with "chemical refuse" will show that processes may be adopted, the result of which will be to make that which has hitherto been a source possibly of ill-health and certainly of discomfort, a means of returning profit to the manufacturer; while in other instances the means of abating the nuisance, of which persons lower down the stream complain, are generally so simple and inexpensive as in no respect to justify the fear expressed by the millowners of the result of legislative interference.

We have taken some pains to ascertain the correctness of the statements made by the committee as to the absence of regulations for the maintenance of the purity of water in Prussia, France, and Belgium, and we find that in all these countries the regulations are much more strict than any which have been in operation here.

The regulations in force in these countries will be found in Vol. II., *Minutes of Evidence*, part 4; but the following brief summary of the modes of action of these Governments will show the nature of the supervision exercised by them over the rivers and streams, and the importance which they attach to the purity of their waters.

In Prussia, though there are no special regulations for the inspection of factories in order to prevent the pollution of running waters, there are very simple means of interference in every separate case of pollution by manufacturing refuse. Thus, by the statute of July 1st 1861, most of the processes which are likely to pollute water require a special police licence; and by a statute passed as far back as 1843, no water applied to dyeing, tanning, fulling, or other similar purposes, is to be suffered to enter a river, if thereby the means of procuring clean water be endangered to the neighbourhood; and by a regulation dating from October 28, 1846, the owners of such works as impregnate the water used in any manufactory with materials hurtful to meadow land, must, in accordance with the judgment and direction of the police authorities, precipitate their materials in subsidence ponds, or otherwise, under penalty of a fine.

PART I. DESCRIPTIVE.

Influence on health.

In Belgium there are various local regulations, having the force of law, which impose a penalty upon those who pollute rivers either by throwing in solid materials which may impede the course of the stream, or by allowing liquid matter which may foul or corrupt the water to flow into it. Manufactories which produce such refuse are bound to construct reservoirs sufficiently large to contain a day's supply of this refuse, in order that sufficient settlement may take place, and the supernatant liquid only is allowed to be run off. In many districts weirs, either temporary or permanent, cannot be constructed without permission of the authorities.

In France there are old regulations applicable generally to all *navigable* rivers, prohibiting the erection of mills and weirs, as well as the pollution of the water by solid refuse, such as gravel, straw, and dung; and power has been given to the local authorities to watch over the state of the smaller streams, and to prevent the pollution of the water by the steeping of flax and hemp, or by the refuse of manufacturing establishments.

The persons in the *Mersey* and *Ribble* basins who lay the greatest stress upon the difficulty, if not impossibility, of taking any steps to abate the nuisance which they are inflicting upon their neighbours, seem to be those who from the extent of their business and the size of their establishments must presumably be deriving the largest returns from their capital, and must therefore have it most in their power to encounter a difficulty which, after all, is only one of degree. Whether, however, this be so or not, we cannot understand that the magnitude of a nuisance is any reason for continuing it; neither can we admit that any man can plead the enormous extent of his business as giving him a right to injure his neighbours.

INFLUENCE OF RIVER POLLUTION ON HEALTH.

This is the last division of the descriptive part of our Report. Questions relating to this branch of the inquiry were addressed to all the municipal bodies and boards of health within the *Mersey* and *Ribble* basins, and answers have been very generally received. The authorities were asked whether the river, stream, or canal passing through or by their town was a source of ill-health or discomfort. They were also requested to supply us with the annual rates of mortality within their boundaries since the last census of the population. Information was also desired from them as to the existence of any districts within their towns especially unhealthy, and as to any special causes of ill-health which might be there in operation. Questions were asked also as to any special liability to floods and consequent injury to health,—as to the number of cellar dwellings still inhabited within the place,—as to the sufficiency of the sewerage and drainage works,—as to the density of population, the adequate provision of privies and water-closets, the sufficiency of the water supply, and other points bearing generally on the health of the people. Having before us the opinion of the authorities on the subject, together with the actual statistics of mortality within the respective jurisdictions,—having received information on all the other points just enumerated,—and having already made ourselves acquainted with the condition of the running waters throughout the basin, we were not without hope that we should be able to determine with some confidence whether or not the death rate, or the liability to ill-health, in any town was influenced by its proximity to a filthy river. The result, we regret to say, has not confirmed our anticipations. There needed no inquiry whatever to enable us to say with confidence that the river is often a source of great discomfort; a summer day spent on the banks of the *Irwell* or the *Mersey* in any of the towns through which either river passes, is of itself sufficiently conclusive on that subject; but the evidence before us has not enabled us to say whether the filthy river is also the occasion of disease. This is partly owing to the incompleteness of the health statistics laid before us. It is with astonishment we find that *Boards of Health* in several large towns, and many smaller ones, in Lancashire have not been able to inform us of the death rate within their districts, still less to give us information of the health within particular

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subdivisions of those districts. But our difficulty arises not only from the deficiency of evidence,—it is due also to the certainty at which we very soon arrived, that there are many other causes affecting health which entirely dominate, and thus, if it exists, effectually conceal the mischievous influence of a polluted river. It will be seen on reference to Volume II., *Minutes of Evidence*, part 1, that, in answer to question 17 of the first series addressed to corporate bodies and boards of health, these authorities very frequently express the belief that the river is a source of ill-health as well as of discomfort; but the facts which they proceed to describe in answer to other questions fail to justify their opinion. The excessive density of population in some localities; the constant employment of the mothers of young families in mills; the general adoption of the privy system, inevitably unwholesome in the midst of a densely-populated town;—the prevalence of any one of these conditions will of itself exert at least as great an influence on health as that which may be due to the emanations of a neighbouring river; and when several of these conditions obtain in one place more than in another the greater or less filthiness of the river is a variation comparatively so slight in the sum total of causes affecting health, that no separate effect from it can be detected.

In the following tables we have collected the principal sanitary facts regarding 24 towns, arranged in four classes. In the first, are placed towns like Liverpool and Birkenhead, on a wide tidal estuary, or like Walton and West Derby where nothing like a river exists; which therefore may be pronounced altogether free from the mischievous influence whose effect we desire to ascertain. In the second table we enumerate Preston, at the head of an estuary, where a large body of tidal water mingles with the polluted river; Bolton, Macclesfield, Blackburn, Oldham, Chorley, and Wigan, towns at the head of their respective rivers, not receiving filthy water, but only sending it filthy from them, where the influence of river pollution cannot therefore be so great as it is in towns midway upon the river course. In the third table are placed Manchester, Salford, Rochdale, Bury, Stockport, Burnley, and Accrington; towns which are under the full influence, whatever it may be, of a polluted stream, and where, if anywhere, its effects ought to be visible. Lastly, Warrington, St. Helen's, Widnes, and Runcorn, have been classed by themselves in the expectation that the special influence of such pollutions of both air and water as are characteristic of the chemical and alkali manufactures might be traceable in these towns.

The following are the tables:—

—	I. Towns unaffected by River Pollution.					II. Towns only partially affected.						
	Liverpool.	West Derby.	Walton-on-the-Hill.	Tranmere.	Birkenhead.	Bolton.	Macclesfield.	Preston.	Blackburn.	Oldham.	Chorley.	Wigan.
Mortality per 1,000:												
1861	29·0	—	16·0	—	—	31·6	27·0	31·00	27·26	27·01	24·4	33·40
1862	30·4	—	20·0	—	—	25·7	27·0	28·43	26·56	27·81	26·0	29·34
1863	33·0	—	13·0	19·81	—	27·4	26·0	25·25	20·83	30·88	19·8	29·79
1864	36·0	—	18·0	20·77	24·39	29·1	23·0	28·68	22·84	21·57	20·0	27·00
1865	36·4	—	20·25	18·37	21·37	28·5	27·0	31·48	26·47	29·57	21·7	28·98
1866	41·7	20·0	21·0	19·52	22·44	30·0	30·0	32·00	29·34	29·70	29·0	33·70
1867	29·4	19·0	31·0*	18·04	20·02	29·0	24·0	28·61	25·37	25·11	26·1	43·36
1868	29·1	18·1	24·0	16·0	24·42	24·88	27·0	—	26·1	24·38	21·0	—
Area - - Acres	5,210	5,561	1,910	1,059	1,684	1,840	3,014	2,819	3,680	4,665	3,613	2,170
Population - No.	500,676	25,000	5,400	14,500	54,000	77,000	36,000	93,000	75,000	81,259	19,000	41,000
Houses - - No.	86,176	6,100	900	3,700	8,000	15,154	10,102	17,241	15,000	16,294	3,500	6,700
Cellar dwellings No.	1,349	0	0	3	Few.	383	28	Few.	240	241	128	0
Population per acre: No.	96+	4·5	2·8	13·7	32·0	42·0	12·0	33·0	20·0	17·4	5·0	19·0
„ house, No.	5·8	4·1	6·0	4·0	6·7	5·1	3·6	5·3	5·0	5+	5·4	6·0
Expenditure on sewerage works -	£ 900,000	£ 38,400	£ ?	£ 11,760	£ ?	£ 28,000	£ 33,234	£ 50,000	£ 90,000	£ 21,000†	£ 12,000	£ 24,000
No. of privies -	20,000	3,300	?	2,000	3,400	6,890	2,945	16,000	13,500	2,305	2,000	1,500
No. of water-closets	†29,000	1,200	?	2,000	4,200	300	220	2,300	700	700	200	210
Daily water supply: Gallons per house	116	?	?	140+	250	100+	110+	110	?	120	100+	—
Average mortality -	33·1	19·3	20·4	18·75	22·5	28·3	26·4	29·3	25·6	27·0	23·5	32·22

* The mortality of a large additional pauper population has affected the return in this and after years.
† Liverpool has also 2,500 tank closets.

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—	III. Towns on Polluted Rivers.								IV. Towns exposed to Pollutions from Chemical Works.			
	Manchester.	Salford (Borough).	Salford (Proper).	Rochdale.	Bury.	Stockport.	Burnley.	Accrington.	Warrington.	St. Helens.	Widnes.	Runcorn.
Mortality per 1,000:—												
1861	30·4	24·68	26·76	25·5	—	—	27·11	36·0	24·02	—	—	—
1862	30·3	26·06	28·89	22·3	30·17	—	22·94	37.0	25·23	—	—	—
1863	32·6	27·16	29·41	23·6	23·78	—	22·34	20·0	24·49	—	—	—
1864	30·6	26·18	28·74	25·4	24·26	—	24·70	22·0	43·61	—	—	—
1865	35·5	28·59	32·78	29·2	24·57	—	32·85	31·0	26·24	—	—	—
1866	34·6	28·54	33·28	24·0	26·38	—	30·00	26·0	29·38	—	26·3	—
1867	31·4	28·03	32·32	24·4	24·80	—	24·89	26·0	26·00	—	22·0	—
1868	32·1	30·53	34·34	24·8	25·30	32·00	29·99	—	26·00	—	22·0	—
Area - - - Acres	4,203	5,208	1,329	1,131	3,079	2,178	1,131	3,425	1,340	6,580	3,000	1,290
Population - - No.	362,823	133,623	75,122	45,000	30,000	54,682	30,500	17,688	30,000	40,000	12,000	14,000
Houses - - - No.	70,000	25,555	14,820	10,400	5,750	12,000	5,738	4,400	6,000	7,920	2,009	2,620
Cellar dwellings - No.	2,658	746	746	480	32	1,000	117	Few	Few	?	12	?
Population per acre - No.	86·3	25·4	54·2	40·0	9·7	25·0	26·0	5·1	22·4	6·0	4·0	9·4
„ per house - No.	5+	5·2	5·2+	5·0	5·2	4·5	5·2	4·0	5·0	5+	6·0	5·0
Expenditure on sewerage works - - - -	£ 340,000	£ 26,000	£ 4,153	£ 6,500	£ 25,000	£ 29,000	£ 17,000	£ 6,300	£ 20,000	£ 4,700	£ —	£ —
No. of privies - - -	38,000	28,775	17,535	4,000	3,765	} 5,660	{ 2,500	2,000	4,500	6,000	1,950	2,600
No. of water-closets - -	10,000	1,500	538	300	147		500	Few	500	250	0	20
Daily supply of water: Gallons per house - -	83	—	74	60	60+	?	100	80	?	23+	?	?
Average mortality - -	32·2	27·47	30·8	24·9	25·64	32	26·85	28·2	28·1	—	23·4	—

It is plain, on a very slight examination of these tables, that they are full of anomalies, dependent, in all probability, chiefly upon the influence of circumstances which it is impossible for them to represent. Even the density of population, on which, as much perhaps as anything, the mortality would (other things equal) depend, cannot be accurately represented here; and other circumstances relating to the poverty and habits of the people, also producing their effect, are left altogether untold. The series of figures which professes to state the population per acre represents it in every case in the most favourable light,—the truth in every case is imperfectly told and much more imperfectly in some cases than in others. If the whole area over which the Board of Health presides were in every case fully occupied, then these figures would be much more trustworthy, and one could judge with something approaching to accuracy how far the declared mortality returns might be attributed to density of population. But the whole area is not built over; Walton, for instance, is little more than a village in the midst of its three square miles of territory; Chorley is a small town within its five square miles; Accrington is very similarly placed in the midst of a large outlying district; and St. Helen's, though a town of 40,000 inhabitants, is yet placed in the midst of an area greater than that of Liverpool with its 500,000. Nevertheless, each of these towns may have densely populated districts within it; and may even have an average density of population over its occupied area, equal to that of Liverpool or Manchester. And yet the density of population ascertained by assuming the equal distribution of the whole number over the whole area is only 2·8, 5, 5·1, and 6 per acre respectively, while Liverpool and Manchester, whose areas are more completely occupied, have an average density of population of 96 and 86 per acre. One instance has been thus taken from each of our tables to show that the returns, though in every case they state the fact, yet do not necessarily convey the whole truth.

It is proper also to refer to the circumstance that the areas from which the mortality returns are given are not always conterminous with those from which the population returns are given. It thus follows that a district whose mortality is recorded may include country villages and people living in especially healthy circumstances; so that its figures cannot fairly compare with those of places which correspond more accurately to the area occupied by the town. Here too, therefore, it is only within limits, which we desire carefully to point out, that the figures in our table can be accepted as strictly true.

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Recurring to the influence of mere density of population,—this may be illustrated as well from the case of Salford as from any other of the examples given. Salford contains three districts which are for the most part near to the river and all subject to any mischievous influence which the river may exert. Salford proper is a densely populated area where many other circumstances, besides the neighbourhood of a stinking river, combine to enhance the death rate. Broughton is a scattered suburb also lying more or less along the river side, populated, however, by a better conditioned and generally wealthy class. Pendleton is on higher ground and farther from the river than either Salford or Broughton; the other circumstances of its population lie midway between the conditions just described. The following is the table of mortality for the three districts respectively during the past eight years:—

MORTALITY RETURNS OF THE BOROUGH OF SALFORD.

Date.	Salford.	Pendleton.	Broughton.
1861 - -	26·76	22·24	14·72
1862 - -	28·89	20·92	16·51
1863 - -	29·41	24·12	17·24
1864 - -	28·74	22·09	16·20
1865 - -	32·78	22·37	15·26
1866 - -	33·28	21·78	14·03
1867 - -	32·32	21·55	16·27
1868 - -	34·34	25·69	17·73
Average -	30·81	22·59	16·0

In the third Table given above, the average of the three districts is compared with Salford proper, and a similar contrast is apparent. If, however, we compare even the latter, *i.e.*, the average circumstances of Salford proper, with those of specially selected districts within itself, the mortality of the selected districts, although they do not suffer more than the rest of the borough from the influence of the river, comes out with terrible distinctness. We extract the following passage from the evidence of Dr. E. J. Syson, the Medical Officer of Health, given in his Report for 1866. Vol. II., *Minutes of Evidence*, part 3. He says:—

"The districts calling for special attention are:—Back Hampson Street, Birtle Square and Courts, Canal Street, Cook Street, Garden Street and Courts, Queen Street and Courts, Springfield Lane, and Wood Street.

"The mortality of Cook Street ranges from 41·47 to 62·80, and is on an average for seven years nearly 50 per 1,000, or 5 per cent. This I attribute to a variety of causes. First: one great evil is overcrowding; many of the dwellings are old and somewhat dilapidated buildings of three storeys high, with, in several cases, cellar dwellings, the upper rooms being sub-let to fustian cutters, who carry on their occupation in the garrets; and the lower rooms and cellars are occupied chiefly by hawkers and itinerant vendors of various commodities. Cleanliness in their persons and habitations is with them a matter of small moment, the back yards and other appurtenances, being used in common, are always in a filthy and objectionable condition. Again: the street is thoroughly enclosed on both sides by works, so that anything like adequate ventilation is entirely out of the question, the only ventilation being from above. The main sewer is formed or constructed of metallic tubes; these, I believe, carry off refuse water from some part of the adjoining gasworks; and the street grids being all trapped the sewer is always charged with gaseous emanations, which, being forced up the side or branch drains, permeate the cellars and lower portions of the dwellings, and give rise to general and repeated complaints; even small stench trap grids in the cellar areas are not proof against the emission of these foul and unwholesome emanations. Further: the cellar dwellings are most, if not all of them, objectionable and unfit for human habitation; some of them, if situate in open localities where sanitary improvements are not so urgently called for, might perhaps be passed over for a time, but in a place where a breath of pure air seldom or ever reaches they should not be tolerated.

"With regard to the other seven streets, which I have specially mentioned, I suspect the death rate is to some extent influenced by overcrowding, but principally to the domestic habits and condition of the people. The streets are all well sewered and paved. In the Queen Street district and Birtles Square, however, there are many very confined courts (*culs de sac*) where ventilation is as defective as possible."

This extract sufficiently explains the difficulty of estimating apart the influence of the river upon health in the presence of morbific influences so much more powerful than itself.

If, again, we turn to the evidence which is afforded by the weakest and most sensitive of those who are exposed to these various influences—if we take out of the mortality returns those relating to children under five years of age, we learn from the Sanitary Report of 1866 that the proportion of the whole deaths which they exhibit had been 45·38 per cent. for the previous year, which was 4·54 below the average of the previous six years. And when the returns of Salford, Pendleton, and Broughton are taken separately it is found—

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"That of those under five years one dies out of every 64 of the inhabitants in the Salford district, and one in 94 in the Pendleton district; whilst in the Broughton district only one in 231, or one-fourth of the number in the Salford district. Those having a knowledge of the several districts, and of the class of inhabitants residing in each, will draw a pretty conclusive inference that many infants are lost through parental or other neglect or mismanagement, or overcrowding, or a combination of all or some of these causes."

These remarks will probably suffice to show the limits within which the figures in our tables throw any light on the question we are considering—the influence of the river upon health.

Taking the tables in succession, we find that Liverpool, 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 poor streets, has a death rate exceeding 33 per 1,000; while Birkenhead, on a recent site covered with new streets, has a death rate of only 24; and the river, in both cases altogether harmless, runs between.

In the second table Preston stands by itself, and being situated on a tidal river, cannot be fairly compared with any other town upon that list. But Bolton, in the same table, may be contrasted fairly enough with Chorley. The latter has now turned its filthy water on to land, but it formerly suffered much in the same way as Bolton, and yet its death rate has always been considerably the lower of the two.

In Table III. again, including towns undoubtedly exposed to whatever evil influence a filthy river exerts, Manchester and Salford proper have a death rate of 32·2 and 30·8 respectively; Salford, including its suburbs, has a death rate of only 27·47; and Rochdale, notwithstanding that its river is quite as bad and quite as big in proportion to the number living on it, has a death rate of only 25. The differences here must be due to other circumstances, of which in all probability density of population over a great area is one,—a probability which is heightened by the contrast, which, as we have seen, Salford by itself exhibits, when it is compared with Broughton, one of its outlying suburbs.

We do not, however, desire to convey the impression that the stench of a foul river is not depressing to health, and does not render a population less able to resist the other causes of disease to which it may be exposed. Nor do we desire to take this particular influence out of the class of direct morbific agencies to which it undoubtedly belongs. All that this discussion of the returns we have received must be taken to have established is, that on a comparison of towns which differ from one another in the intensity of many other more powerful influences, for evil or for good, the alleged virulence of this particular agency altogether disappears.

The only instance in the fourth table where the mortality returns are fully given is that of Warrington, the death rate here being high. The river is certainly not a pleasant neighbour, but there are other agencies at work within the town, as the imperfect drainage, especially of the Cheshire side of the town, and the prevalence of the privy system in an old fashioned and imperfect form, to which probably some of the excessive mortality may be due. Warrington was classed with Widnes, St. Helens, and Runcorn in a separate table, under the impression that it would help, with them, to illustrate the influence, or possibly to illustrate the harmlessness, of such pollutions of the air, as are experienced in the neighbourhood of alkali and chemical manufactories. The failure of the other towns to supply mortality returns spoils this part of our plan. The table, nevertheless, is allowed to stand in order that by the startling blank which it exhibits, the need of attention to records of this kind may be impressed upon the attention of the authorities.

Section B.—Remedies.

In the first portion of our Report we have given a full account of the state of the rivers and streams in the two great valleys of the *Mersey* and the *Ribble*; and we have discussed at some length the causes which have brought them into their present filthy condition; we have now to consider the various means either of removing these causes, or of remedying the evils arising out of them.

Before, however, we enter upon this discussion, it may be as well to recapitulate what the evils are against which it is sought to provide a remedy.

They are, first, the presence of solid refuse in the channels of rivers and streams, including cinders, ashes, spent dye woods, and the sweepings from streets and roads.

Second, the pollution of the water of these rivers and streams by the introduction of sewage, especially of that which forms the most offensive portion of sewage, namely, human excrements.

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Third, the pollution of water by liquid manufacturing refuse; of which, under various heads, an account has already been given.

The ash-pit.

These are all evils arising out of the use or abuse of the streams, or of the water passing down them. A difficulty much less amenable to remedies has indeed forced itself upon our notice in the course of our inquiries, namely, the scanty amount of the supply of water for the wants of the population. We will, however, first consider the methods calculated to remove the evils stated above, leaving the question of water supply to be discussed in the sequel.

The first matter complained of is the presence of a large bulk of solid refuse in the channels of the rivers and streams. When we consider the enormous amount of coal consumed, and remember that for every 8,000 tons, 1,000 tons of cinders and ashes are produced, the difficulty of dealing with this quantity of refuse is by no means trifling; and it is not to be wondered at, that people residing on or near a stream should be tempted to make use of the water as the easiest means of getting rid of this sort of rubbish; the effect, however, is to transfer a nuisance from one part of the river to another, to raise the bed of the stream, to render floods more injurious, and to impede navigation.

In 1862, an Act of Parliament was passed "to protect the waters of the *Mersey* and "the *Irwell*, and of certain of their tributaries from obstruction and pollution." We were informed that this enactment had been to a great extent inoperative, as the Bridgwater Trustees, whose interest in the preservation of the navigation led them to press for the passing of the Act, had never been able to enforce its provisions.

The remedy seems to us in this case simple enough, all that is necessary being merely to find some method of carrying out an Act of Parliament. Practically, however, it is by no means so simple as it appears to be, for it requires the action of an executive body of such independent position as would enable it to disregard the many influences which would be brought to bear upon it. As however a similar body will be required to carry into action remedies for the other matters complained of, we leave the organization of this to be discussed hereafter.

The next evil complained of is the pollution of the river water by sewage and by the liquid refuse of manufactories. This is indeed the principal cause of offence, for even if solid refuse were entirely excluded from the river, there would be no sensible amelioration in the nauseous condition of its water, if liquid refuse were still suffered to flow into it. Any discussion of the remedies possible under this division of our subject must of course include all methods for the prevention of the evil complained of which may have been suggested, as well as all plans for the correction of the evil where it already exists. We now proceed accordingly to review the various contrivances which have been suggested (1) for the prevention of pollution by town sewage; the various plans for (2) the purification or amelioration of town sewage; and the methods by which (3) liquid refuse from manufactories may be cleansed before its discharge into streams.

POLLUTION BY SEWAGE.

I. PREVENTIVE PROCESSES.—Many suggestions have been laid before us embracing contrivances by which, as is alleged, human excrement can be kept out of the sewers, and consequently out of the streams into which the latter discharge themselves; but to all these there is this special objection, that they are but modes, often complicated and cumbrous, of dealing with a portion, really a scanty portion, of the excremental refuse which is poured into the streams in a liquid form.

The common privy and ash-pit, and some of the modifications which they have undergone since the attention of the authorities has been turned to the condition of these ordinary receptacles of filth, must be named among the contrivances alluded to. It would, however, be unnecessary for us to comment upon the inefficacy of this method of dealing with human excrement, were it not that it has found so many supporters among the authorities of numerous Lancashire towns. The present condition of the rivers and streams which is co-existent with the general prevalence of these very receptacles, shows clearly that this mode of dealing with human excrements has but little action in keeping the river free from fæcal matter; indeed, as already stated in the descriptive part of this report, the privy only professes to receive a portion, and that the least injurious portion, of the excreta; the greater part of the urine, and the whole of the fluid refuse from the kitchen and the house generally, is passed direct into the sewer; and as rainwater finds admission to most of the ashpits, except a few of those more recently constructed, this must act upon the soluble portion of the solid refuse, and carry it into the sewer by the drain which nearly always connects the ashpit with the sewerage system. It is true that in some towns the ashpits do not communicate with the sewers, and are, in fact, simply enlarged cesspools; but these are exceptional cases, and the state of the rivers in the vicinity of these towns is in no marked respect more satisfactory than elsewhere.

PART I. REMEDIES.

Dry-earth closet.

If then the privy and ashpit does not succeed in keeping human refuse out of the streams, all those modifications of it, such as Moule's dry earth system, Goux's system, &c., of which we will give a brief description as exhibited to us in action, are liable to the same objection. None of them proposes to deal with other than the solid excrement mixed with so much of the urine as is passed at the same time; they are, in fact, but modes in which a portion of the human refuse can be made temporarily inoffensive, so as to admit of its retention on the premises till it can be removed by human labour; the object of some being to retain the fæces in such a condition as may render them more valuable as manure, while that of others is merely to prevent the offensive smell, considerable mechanical ingenuity having been displayed in the applications of the disinfecting material.

We will first refer to such attempts as have been made to improve the privy and ashpit by placing them more immediately in connection with each other; with the view of absorbing much of that which now drains away. To this end the Manchester Corporation recommend an ashpit under one roof with the privy, and furnished with a side grating through which the ashes of the house are thrown and directed on to the filth below, whilst at the same time all large and coarse rubbish is kept out. To this end also Mr. Beech has devised an arrangement which has been adopted in one of the poorer streets of Manchester:—A space is left in front of and below the privy seat, under which the house ash is thrown and necessarily alights exactly where it is wanted. The flooring and seat are both hinged, and fold back out of the way when the scavenger comes to clear the pit out. The whole filth, dry and wet, is then thrown out of the doorway directly into the street, and when the pit is empty, floor and seat fold down again into their original position, and take their place without having been soiled during the removal of the pit contents. Mr. Morrell has also patented a contrivance for effecting the same object, a description of which will be found in Vol. II., part 4.

The only methods however which can rightly profess to wholly correct the evil of river pollution by town drainage are those which claim to remove the whole of the human excrements directly from the house. But at the very outset they have, as already stated, to confess a failure. It is only privy stuff with which they deal; all the other liquid household waste, chamber slops and laundry slops, are thrown down the back yard grid or scullery slop-stone and find their way through these sinks to the nearest watercourse.

The Dry-earth Closet.—The so-called dry-earth closet is much the best of these plans; and it is undoubtedly capable of being made an admirable scavenging expedient, so far as privy refuse is concerned. Of this we convinced ourselves at the Broadmoor Criminal Lunatic Asylum, where a large number of earth closets have been introduced, and are worked to the satisfaction of Dr. Meyer, the resident medical officer. At Wakefield prison too, all the lower cells are provided with earth closets; and although the closeness of a confined and narrow room was perceptible (the prisoners having been kept in till a later hour than usual on our visit), there was no offensiveness recognizable of the special kind that might have been expected. Here, however, the plan has been found applicable only to the cells on the male side of the house, in which separate vessels for the urine are provided. The earth for the Wakefield prison is dried in a kiln and supplied weekly to the closets, and the pans are removed as soon as filled; their contents, taken to a shed, are turned and pulverized, and used in the prison garden with advantage. At Halton in Buckinghamshire, a pretty country village of 50 or 60 cottages, the roadside chalky soil is used successfully in the dry-earth closet with which every cottage is provided. For this purpose it is screened and dried upon a kiln floor about 9 feet square; 100 bushels of coke being used in this way per annum for the 50 closets in the village. When hot and dry the earth is carried to the hopper in the back wall of each privy, which holds about 60 lbs.,—enough for 40 uses of the seat. The floor beneath is cemented so as to hold the liquid as well as the solid excrement; and the seats are hinged and on springs, so that on rising from them a portion, about $1\frac{1}{2}$ lb., is discharged from the hopper, and thrown upon the mass below. We came, without notice, one evening into the village, and examined about a score of these cottages, and found everything as clean and sweet as possible. Seats and floors in front, hoppers and cesspool floor behind, were all clean; and there was nothing to be seen but white dry earth, and no smell was perceptible. Moreover we were told that the cesspool, cleaned out as required three or four times a year, furnishes a material, which, after lying in a heap for some months under a shed is put upon the kiln again and used a a second time. Last year 70 tons of stuff were taken out of the privies of the 50

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"Eureka" system.

cottages; 30 tons however had been used twice, so that only 40 tons were available for use upon the land; and it had proved a capital fertilizer, producing an abundant crop of grass where the manure had been applied.

In all these cases, however, the chamber slops are kept separate; and independently of that the success depends not upon the people using the privies, but upon an officer whose business it is to look after them and keep them clean. Even at Halton one man is set apart for this work who attends to the kiln, to the provision of dried earth, to the keeping the hoppers full, and to the removal of the manure. Elsewhere we have known earth closets introduced for the use of cottagers accustomed to the old privy seat and cesspool; and, requiring special service and attention which the average man or woman will not give, they soon became filthy and offensive. Add to these circumstances the enormous aggravation of all the difficulties of the plan when not fifty but fifty thousand households have to be provided with the necessary appliances and induced to work them properly, and we can have no hesitation in pronouncing the dry-earth system, however suitable for institutions, villages, and camps, where personal or official regulations can be enforced, entirely unfitted to the circumstances of large towns.

At Lancaster, indeed, an attempt has been made by a neighbouring landed proprietor, Mr. W. J. Garnett, of Quernmore Park, to get the house scavenging of the town done upon a modification of this plan, and to deal with the whole excrement of the household upon the dry-earth system. By constant and even daily collection in tubs and pans the whole excrement is collected from a large number of houses, and the payment of 1*d.* a week per house is said to secure the collection of the chamber slops as well as of the privy contents. Nearly one-tenth part of the town is thus dealt with. Earth is sent round daily, and thrown into the privy holes, and when the pit is full the whole is taken to a depôt where it is mixed with material derived partly from street sweepings and ash-pit refuse; and being thereafter piled beneath a shed built upon a farm near the town, the whole is soaked with the collected urine.

A sample carefully taken being analyzed in our laboratory proved to contain —

Organic matter and ammonia containing ·207 of total combined nitrogen	6·671
Mineral matter containing ·326 of phosphoric acid	66·782
Water	26·547
	100·000

These figures indicate a practical value certainly much below that at which we had been led to estimate it by mere inspection; and it is manifest, from the very small amount of total combined nitrogen, that much of the urine escapes preservation. An inordinate quantity of earth appears also to have been added to the excrementitious matters, since more than 93 per cent. of the finished manure consisted of nearly worthless mineral matters and water.

The "Eureka" System.—Some mention should be made of the plan of dealing with human excrement which was carried out a few years ago at Hyde, near Manchester, although it has been abandoned owing to the great local nuisance which the manufacture created, and the insufficient returns realized by its promoters, and we have not, therefore, had an opportunity of examining it. It has been thus described by Mr. J. B. Lawes, F.R.S. and Dr. J. H. Gilbert, F.R.S.*:—

"Some few years ago a company contracted to carry out what they called the '*Eureka system*' here. They provided boxes to fit in at the back of the privy or closet of nearly every house, leaving scarcely a water-closet in the place. Some disinfecting or deodorising mixture is put into the box before it is placed in its position, and the box is exchanged for a fresh one after a certain number of days, according to the number of individuals frequenting the place; and it is stipulated that neither extraneous water nor any other than human excretal matters should be accumulated in these receptacles. The boxes, when removed, are covered with closely fitting lids, and so transported in close vans to a manure manufactory close to the town. Here the matters are first well mixed, and then strained to remove rags, which are washed and sold for paper-making. More disinfectant is then added, and the matter concentrated by distillation, the distilled water being sold to dyers and bleachers. The residue thus thickened is then mixed with coal ashes, which are collected in the houses in casks left for the purpose, and before being used are re-burnt in a reverberatory furnace, and finely ground. On visiting Hyde in 1863, it certainly appeared that the mode of collection and preparation adopted was attended with, at any rate, very little unpleasant odour, and it was maintained by the advocates of the system that its adoption had been successful in a sanitary point of view; though, even at that time some difference of opinion existed, and a controversy on the subject was in progress." "The opposition had reference not to the mode of collection, but to the conducting of the manufacture so near to the town. But whether or not

* "Notes on the Composition, Value, and Utilization of Town Sewage," reprinted from the Journal of the Chemical Society, March and April, 1869. (Harrison & Sons, St. Martin's Lane.)

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Goux's system.

the plan of collection and removal may have proved successful, so far as the avoidance of nuisance and injury to health are concerned, the process of manufacture seems unfortunately to offer but little prospect of successful utilization, so far at least as can be judged from the results of an analysis made at Rothamsted, of a sample of the manure obtained direct from the works. It was found to contain only between 1 and 2 per cent. of ammonia. Such a manure, although it might be useful enough when applied in quantities of many tons to the acre, would obviously be not worth more than its carriage beyond the distance of a very few miles. Besides the great dilution of the more valuable manure matters by the admixture with ashes, a little consideration of the habits of the people is sufficient to account for the small quantity of ammonia found in the manure; for it is obvious that little of the urine beyond that passed once a day with the fœces would reach the boxes, and so find its way into a manure thus collected and prepared."

The plan has at length been abandoned for both of the reasons referred to by Messrs. Lawes and Gilbert.

Goux's System, described in detail in Vol. II., *Minutes of Evidence*, part 4, is one of a somewhat similar kind, differing from the Eureka plan mainly in the subsequent treatment of the excrement. This is not dried by heat, but allowed to ferment along with the drying and absorbent material used in its collection. The filth is collected from house to house in tubs lined with a layer of absorbent material, and these tubs are removed at short intervals, as experience declares to be required. Gathered at a depôt, the whole contents, ordure, liquid, and the fibrous lining are cleared out and turned over, and the vessels are sent back to the privies. Each of the receiving tubs is filled to a certain depth with dust, chaff, house sweepings, ash, or other absorbent stuff. A conical core smaller than the tub is then pressed down upon this layer, and the space between it and the outside vessel is filled in like manner with similar absorbent refuse matters. The core is then removed and the tub is taken to the privy and placed below the seat. Every day one-fifth or thereabouts of the tubs are taken to the works, empty vessels being put in their places. The contents are collected on a floor, sprinkled with a little sulphuric acid, and after a certain amount of fermentation and consequent destruction of the fibrous matter, the whole becomes a homogeneous, inoffensive, but feeble manure, which may be very fairly described in the words used by Messrs. Lawes and Gilbert about the Eureka failure. We saw the system in operation to a certain extent at Rochdale; where in August 1869 according to the Report of the Sanitary Committee of the Town Council who had charge of the experiment, 342 closets were then being treated on this plan.

It must be remembered, as regards all these expedients, not only that it is but a part of the excrementitious matter which is dealt with; but that even as regards that portion of the excrement which they do remove, they so entirely depend upon efficient cleanly superintendence and direction, that wherever they have merely had the average man to work them they have failed. Moreover, this very frequent collection of filth by hand from houses, and its removal sometimes through the cottages themselves, almost necessarily under the eye and nose of the household, whatever may be the importance of the economic object aimed at, is universally condemned by our domestic habits as nasty and offensive. They can never be an entire success, and in competition with the water-closet, a jury of average householders will certainly condemn them for lack of cleanliness and comfort.

The above account of these, which may be termed "preventive processes," will be sufficient to justify the statement we have made of their inefficiency to hinder the pollution of the rivers and streams; they do not of course profess to have any remedial action upon water which has been polluted.

We have now to discuss those processes whose object has been to *purify* sewage.

II. THE PURIFICATION OF SEWAGE.—The cleansing of sewage has engaged the attention of many chemists and others during the past ten or fifteen years; and various plans, some exhibiting great merit and ingenuity, have been proposed for dealing with the offensive liquid. We have had opportunities of seeing in actual operation upon a large scale, several of the most promising of these plans, which all belong to one or other of the three following categories:—

1. Treatment with chemicals.
2. Filtration.
3. Irrigation.

1.—Purification of Sewage by Chemical Agents.—The valuable constituents of sewage present to the chemist a mine of wealth, which, despite so many failures, has constantly stimulated him to renewed efforts for their extraction in a portable and consequently marketable form.

PART I. REMEDIES.

Treatment with lime.

The chief valuable ingredients of sewage are first, the different forms of combined nitrogen, and second, phosphoric acid. The money value of these constituents *dissolved* in 100 tons of average sewage is about 15*s*., whilst the *suspended matters* contain only about 2*s*. worth of them.

There is but little difficulty in extracting the suspended matters by filtration, but as these do not contain quite one-seventh of the total valuable constituents, the process, though simple, has never been remunerative; and inasmuch as it still leaves much putrescible organic matter in solution, the mere extraction of the suspended matters of sewage, although doubtless tending to mitigate nuisance, does not produce any substantial diminution of the polluting quality of the liquid. The operations of the chemist have, therefore, been directed chiefly to the soluble constituents of sewage; and have had for their object, either the precipitation in a solid form of the valuable, but offensive, ingredients, so as to convert them into portable manure, or, secondly, the rendering them inoffensive by the action of disinfectants. Although these operations have not been altogether unsuccessful, they have hitherto entirely failed in purifying average sewage to such an extent as to render it admissible into running water. We have formed this opinion both from observations of the polluting effect of such chemically purified sewage upon the streams into which it was admitted, and from the amount of putrescible organic matter revealed by the chemical analysis of the sewage after treatment.

The following is a description of those processes belonging to the chemical category which we have witnessed in operation:—

(*a*.) *Treatment with Lime.*—This process was doubtless first suggested by the ingenious operation devised by the late Dr. Clark, of Aberdeen, for softening certain hard waters. It has been applied to sewage upon an extensive scale at Tottenham for the manufacture of "Tottenham Sewage Guano;" at Blackburn, and especially at Leicester, in the production of the so-called "Leicester Bricks" (the name under which the manure was sold). In all these places the plan has been a conspicuous failure, whether as regards the manufacture of valuable manure, or the purification of the offensive liquid.

We have witnessed the process at Blackburn, and on two occasions at Leicester, where it is still used, the machinery employed at the latter place being very perfect and efficient.

At both places the method obviously failed in the purification of the sewage to such an extent as to render it admissible into a river. At Blackburn especially the river below the outlet of the limed sewage was in a most offensive condition of putrefaction, our note made at the time of our visit being as follows:—"Horribly offensive turbid blackish "stream disengaging most offensive gases, with black masses of putrid mud floating on the "surface."

The operation is exceedingly simple, and, as carried out at Leicester, consists in mixing with the sewage, as it arrives at the works, a certain proportion of milk of lime; the mixture is then violently agitated by appropriate machinery on its way to large reservoirs of subsidence, in which a copious deposit of highly putrescible mud takes place, whilst the supernatant liquid flows off in a comparatively clear though still somewhat milky condition. The floors of the reservoirs of subsidence slope from two opposite sides towards the centre, where there is a gutter, from which a Jacob's-ladder elevates the slush into a shoot, through which it is conveyed to pits, where it slowly dries, partly by evaporation and partly by soakage into the surrounding soil.

During our first visit to Leicester on May 13th, and to Blackburn on August 5th, 1868, we took samples of the sewage before and after treatment with lime, and the following table exhibits the results of the analysis of these samples:—

TREATMENT OF THE SEWAGE OF LEICESTER AND BLACKBURN WITH LIME.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
Leicester sewage - -	107·5	2·017	·809	2·083	0	2·524	10·50	11·62	22·12
" " after treatment.	85·9	1·514	·452	2·552	0	2·553	12·10	4·70	16·80*
Blackburn sewage - -	59·7	4·103	·460	1·426	0	1·634	13·38	28·30	41·68
" " after treatment.	66·0	2·619	·412	1·956	0	2·022	6·34	6·98	13·32

* At the moment when this sample was taken it did not (judging from its appearance) contain nearly so much suspended matters, it is therefore believed that the process of deposition from the liquid went on after the collection of the sample.

PART I. REMEDIES.

Sillar's process.

During a second visit to Leicester, however, we submitted the lime process to a much more searching investigation side by side with another chemical plan (Sillar's), and it will, therefore, be convenient to describe the results of these two sets of experiments together.

(*b*.) *Treatment by Sillar's Patent* or "*A.B.C.*" *Process.*—The specification of this process is given by the patentees Messrs. W. C. and R. G. Sillar and W. G. Wigner as follows:—

"We add to the sewage to be purified a mixture consisting of the following ingredients:—Alum, blood, clay, magnesia, or one of its compounds, by preference the carbonate or the sulphate, manganate of potash, or other compound of manganese, burnt clay otherwise known as ballast, chloride of sodium, animal charcoal, vegetable charcoal, and magnesian limestone. Of these substances the manganese compound, the burnt clay, chloride of sodium, and magnesian limestone may be omitted, and it is not essential that both animal and vegetable charcoal should be used. If any of the ingredients named should from any cause be present in sufficient quantity in the sewage it may of course be omitted from the mixture. The proportions in which the ingredients are to be used vary according to the nature of the sewage to be purified, as, for instance, if a large proportion of urine is present we increase the proportion of clay, if the sewage is much diluted we slightly increase the proportion of alum and blood, if it contains a large proportion of street refuse we decrease the proportion of clay.

"For ordinary sewage the following proportions have answered well:—

Alum - - - - -	600 parts.
Blood - - - - -	1 "
Clay - - - - -	1,900 "
Magnesia - - - - -	5 "
Manganate of potash - - -	10 "
Burnt clay - - - - -	25 "
Chloride of sodium - - - -	10 "
Animal charcoal - - - -	15 "
Vegetable charcoal - - - -	20 "
Magnesian limestone - -	2 "

"These substances are mixed together and added to the sewage to be purified until a further addition produces no further precipitate. The quantity required will be about four pounds of the mixture to one thousand gallons of sewage. In many cases it is preferable to mix the above compound with a small quantity of water, and add it in a liquid state to the sewage. The sewage must then be thoroughly mixed with the compound and allowed to flow into settling tanks. The greater part of the organic and other impurities will be immediately separated in the form of large flakes, which rapidly fall to the bottom, leaving the supernatant water clear and inodorous, or nearly so. The water may then be allowed to flow away into a river, or be disposed of in any other way, and the sediment or mud allowed to accumulate at the bottom of the tank. In some cases it is preferable to add the compound of manganese to the water after the sediment produced by the other ingredients has been allowed to subside. The sediment will be found to possess the power of precipitating a further quantity of sewage; it must therefore be pumped or otherwise taken from the tank and mixed with fresh sewage, the sediment being allowed to subside in the same way as before. The sediment may be used five or six times over in this way. When the sediment no longer possesses the power of precipitating the impurities in the sewage it must be removed from the tank and allowed to dry; when partially dry a small quantity of acid, by preference sulphuric acid, may be mixed with it, which will retain all the ammonia in a soluble form. When dried the sediment will be a valuable manure."

Our experiments at the Leicester sewage works were so arranged that one-half of the sewage could still be treated with lime as usual, whilst the remaining half was submitted to Sillar's process under the superintendence of the patentees. In this way we were able to ascertain not only the extent to which the sewage was ameliorated by the new method, but also the comparative effect of the old lime process when applied to one-half of the same sewage.

The experiments extended over three days. On the first day a sample of the sewage as it arrived at the deodorizing works was taken at 1.30 p.m., and samples of the effluent liquid, after treatment by the lime and Sillar processes respectively, were collected at 5.40 p.m. and 6.10 p.m., the intervals of time being those calculated as necessary for the passage of the sewage through each of the two processes. On the second day, hourly samples of the raw sewage were taken from 10 a.m. to 9 p.m.; but during the morning an accident happened to a portion of the apparatus which vitiated the experimental results, and consequently the samples, after treatment, were taken only from 4 p.m. to 8 p.m., in the case of the lime process, and from 4 p.m to 9 p.m. in that of Sillar's process. On the third day all the samples were taken hourly, from 10 a.m. to 5 p.m. After our departure from Leicester on the first day the duty of taking the samples was entrusted to Mr. W. Thorp, the principal assistant in the laboratory of the Commission.

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Sillar's process.

Submitted to analysis these samples yielded the following results:—

TREATMENT OF LEICESTER SEWAGE BY LIME AND BY SILLAR'S PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
LEICESTER SEWAGE.									
July 30, 1868.									
Sewage before treatment, 1.30 p.m. -	111·0	3·745	·722	1·650	·021	2·102	28·78	28·78	57·56
" purified by lime, 5.40 p.m. -	88·0	2·870	·247	2·125	·024	2·021	3·38	2·62	6·00
" " by Sillar's process, 6.10 p.m.	117·0	2·778	·297	2·000	·000	1·944	2·30	3·82	6·12
July 31, 1868.									
Sewage before treatment, 10 a.m. to 9 p.m.	112·0	3·536	·747	1·800	·000	2·229	18·50	29·58	48·08
" purified by lime, 4 p.m. to 8 p.m.	90·0	2·608	·340	1·800	·000	1·822	1·90	·94	2·84
" " by Sillar's process, 4 p.m. to 9 p.m.	125·0	2·305	·373	2·500	·000	2·432	1·22	3·14	4·36
August 1, 1868.									
Sewage before treatment, 10 a.m. to 5 p.m.	108·0	2·752	·103	2·250	·000	1·956	22·18	37·70	59·88
" purified by lime, 10 a.m. to 5 p.m.	97·0	2·233	·159	2·000	·000	1·806	4·30	2·26	6·56
" " by Sillar's process, 10 a.m. to 5 p.m.	119·0	2·039	·296	2·500	·000	2·355	1·26	1·50	2·76

Before proceeding to interpret the results of the analyses, it is necessary to premise that the strength of sewage as regards dissolved constituents, is ascertained by two analytical determinations, viz., "total solid matters in solution" and "total combined nitrogen." A comparison of the numbers under these heads, obtained from the samples of raw sewage collected on each of the three days of the experiments, and on the occasion of our first visit to Leicester (May 13th, 1868), shows that the sewage of this town is much below the average strength, being less than one-third as strong as London sewage, and that it does not seem to vary in strength between very wide limits:—

COMPOSITION OF LEICESTER SEWAGE.

Ingredients.	May 13th.	July 30th.	July 31st.	Aug. 1st.
	lbs.	lbs.	lbs.	lbs.
Total solid matters in solution in 100,000 lbs. of sewage.	107·5	111·0	112·0	108
Total combined nitrogen in solution in 100,000 lbs. of sewage.	2·524	2·102	2·229	2·014

But although the strength of the sewage, separated from suspended matters, was thus tolerably uniform, its quality on the last day of the experiments differed widely from that which it possessed on the previous occasions, the organic matter in the sample collected on the third day having become so much decomposed that a large proportion of the nitrogenous constituents had become converted into mineral compounds. This anomaly in the sewage of the 1st of August is clearly seen from the following comparison of the organic carbon and nitrogen contained in the different samples of raw sewage after filtration from suspended matters:—

COMPOSITION OF FILTERED LEICESTER SEWAGE.

——	May 13th.	July 30th.	July 31st.	Aug. 1st.
	lbs.	lbs.	lbs.	lbs.
Organic carbon in 100,000 lbs. of sewage.	2·017	3·745	3·536	2·752
Organic nitrogen in 100,000 lbs. of sewage.	·809	·722	·747	·103

In regard to clarification both processes produced a very considerable, and on the whole, nearly equal effect. On the first day the effluent liquids were nearly equally clear, on the second day the limed sewage was decidedly superior to its rival, whilst on the third

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day the sewage treated by Sillar's process was much clearer than the limed liquid. These statements rest upon the following comparison of the quantities of suspended matters remaining in 100,000 lbs. of the effluent sewage, as well as upon ocular observations made during the three days' experiments:—

Suspended Matters.

	After Lime Process.	After Sillar's Process.
1st day .	6·00 lbs.	6·12 lbs.
2nd " .	2·84 "	4·36 "
3rd " .	6·56 "	2·76 "

Of the soluble constituents of sewage, the most important are those given in the above analytical Table under the heads "Total Solid matters in Solution," "Organic Carbon," and "Organic Nitrogen;" and the following Table shows the manner in which the sewage is altered in these three respects by being submitted to the two processes. The numbers all refer as usual to 100,000 lbs. of sewage.

PURIFICATION EFFECTED BY LIME AND BY SILLAR'S PROCESS.

At Leicester.	Total Solid Matters in Solution. Removed.	Total Solid Matters in Solution. Added.	Organic Carbon. Removed.	Organic Nitrogen. Removed.	Organic Nitrogen. Added.
LIME PROCESS.	lbs.	lbs.	lbs.	lbs.	lbs.
1st day - - - -	23·0	—	·875	·475	—
2nd " - - - -	22·0	—	·928	·407	—
3rd " - - - -	11·0	—	·519	—	·056
SILLAR'S PROCESS.					
1st day - - - -	—	6·0	·967	·425	—
2nd " - - - -	—	13·0	1·231	·374	—
3rd " - -	—	11·0	·713	—	·193

The numbers show that whilst the lime process considerably reduces the amount of dissolved impurities in sewage, Sillar's process markedly augments it. The explanation is obvious: in the lime process all the material added in solution is again precipitated in the solid form, but in Sillar's process considerable quantities of dissolved chemicals are added which are not afterwards precipitated. It is also probable that in both processes certain constituents present in the suspended matters of the raw sewage are dissolved, whilst other constituents already in solution are precipitated; there is thus finally left in solution a balance of solid matter which in the case of lime is less, but in the case of the new material, greater than the amount present in the raw sewage.

Both processes have the effect of diminishing the organic carbon, and on each of the three days the diminution effected by Sillar's process was notably in excess of that brought about by the lime process.

The material, however, which it is of the greatest importance to remove from the dissolved constituents of sewage, is nitrogenous organic matter, because it is this kind of organic matter which enters rapidly into putrefaction, and becomes an active agent in the pollution of rivers. This material is represented in the analytical results by organic nitrogen. It is precisely here that both processes signally fail (although the lime process is slightly superior to the other) in accomplishing such an amount of purification as would render the sewage admissible into an open watercourse. The raw sewage on the third day was, as already mentioned, very far advanced in decomposition, and the effect of both processes upon this sewage was actually to increase the amount of organic nitrogen in solution; that is, the amount of organic nitrogen dissolved from the suspended matters of the sewage was greater than that precipitated from solution by the chemical re-agents added. Leaving out of consideration this result, which must be regarded as abnormal, the following table shows the amelioration effected by the two processes:—

PER-CENTAGE OF ORGANIC NITROGEN REMOVED.

At Leicester.	Lime Process.	Sillar's Process.
1st day - - - - -	65·79	58·86
2nd day - - - - -	54·48	50·07

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It may be stated therefore in round numbers that, as regards putrescible organic matter, the application of either process would render it possible to double the amount of purified sewage admitted into a river without increasing the pollution. Although this is by no means an unimportant result, yet it falls far short of what is required to restore our sewage-polluted rivers to a satisfactory degree of purity.

An inspection of the Analytical Table (p. 54) shows that the effluent sewage after treatment by the new process invariably contains more ammonia than the raw sewage: thus, on the first day 100,000 lbs. of sewage contained 1·650 lb. of ammonia before treatment, and 2 lbs. after treatment; on the second day, 1·8 lb. before and 2·5 lbs. after treatment; whilst on the third day it contained 2·25 lbs. before and 2·5 lbs. after treatment. The origin of this additional ammonia is not difficult to understand; in the first place, alum enters largely into the composition of the material used in the "A.B.C." process, and as nearly all alum now manufactured is ammonia-alum, containing 3·7 per cent. of ammonia, it is probable that this is one source of the additional quantity of ammonia. But it cannot be the only source, unless we are to assume the use of such a large proportion of alum as would render the process economically impracticable. The second, and probably the chief source of the additional ammonia, is to be sought for in the action of the chemical re-agents upon the nitrogenous organic matters contained in the raw sewage, partly in suspension and partly in solution. The possibility of such a liberation of ammonia is seen in the case of the limed sewage of the first day; here no ammonia was added in the re-agent, nevertheless there was an increase of ·475 lb. in each 100,000 lbs. of sewage. Such an addition to the amount of dissolved ammonia has no significance as regards the pollution of rivers, but it has an important bearing upon the applicability of the process to the economical production of a solid manure, because it indicates not only that the ammonia already in solution in the raw sewage is not precipitated, but also that some of the suspended nitrogenous matters are decomposed with the liberation of ammonia, representing so much valuable material abstracted from the solid manure.

Notwithstanding this loss of nitrogenous organic matter in the process of deodorization, the "A.B.C." method of treatment still yields a solid manure of much greater value than that obtained by the lime process—a circumstance which is explained, to a great extent, by the acidity of the mud from the former process, and the alkalinity of that from the latter. The lime mud thus loses ammonia in drying, whilst the other, especially if still further acidified, cannot suffer this loss.

Both samples of mud submitted to analysis were first dried in the sun, with free exposure to the air, so as to imitate, as nearly as possible, the process of drying such manure which is usually employed on the large scale. By analysis, the following results, expressed in per-centage numbers, were obtained:—

Composition of Sewage Mud.

At Leicester.	Dry Mud from Sillar's Process.	Dry Mud from Lime Process.
Mineral matters - - - -	54·772	37·413
Organic and other volatile matters - -	45·228	62·587
Carbon - - - - -	24·994	18·865
Phosphoric acid - - - -	·496	·147
Total nitrogen - - - -	1·943	·849
Ammonia - - - - -	·185	·090

It is thus evident, that in the three valuable constituents of manure, viz., in ammonia, in other forms of combined nitrogen, and in phosphoric acid, the manure obtained by Sillar's process is greatly superior to that resulting from the treatment with lime. Unfortunately, some doubt is thrown upon the source of the increased amount of phosphoric acid present in the manure obtained by the former process, because bone-black, in, to us, unknown quantity, entered into the composition of the precipitating material used, and thus an uncertain amount of phosphoric acid was added to that which was actually derived from the sewage.

The value of the two manures as estimated from the above chemical composition is as follows:—

	Per Ton. £	s.	d.
Manure from lime process - -	0	13	$6\frac{1}{4}$
Manure from Sillar's process - -	1	13	$0\frac{3}{4}$

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Remedies.
Sillar's process.

The value of the solid manure obtained by treating the Leicester sewage with lime has already been estimated, from the analysis of Voelcker and Versmann, by Hofmann and Witt, who give the following numbers:—*

	Voelcker. s.	d.	Versmann. s.	d.
Value per ton -	15	5	17	0

That these values exceed our estimate is partly due to the circumstance that Hofmann and Witt assigned a value of 1*l.* per ton to non-nitrogenous organic matter, whilst we regard it as worthless. Such is the value of these deposits as estimated from chemical analysis; but experience has warned the manufacturer of these feeble manures that the value indicated by chemical analysis cannot be counted upon in the market. Thus, the dry Leicester mud although, its indicated value is 13*s.* $6\frac{1}{4}$*d.* is actually sold for 1*s.* per ton!

In conclusion, the results of the experiments may be thus summarised:—

1. The "Sillar" and lime processes remove to a great and nearly equal extent the suspended matters contained in sewage.
2. Sillar's process increases the amount of dissolved solid matters in sewage, but reduces the quantity of putrescible organic matter. The lime process reduces both the amount of dissolved solid substances and the quantity of putrescible organic matter; the reduction of the last being about the same as that effected by Sillar's process, viz., rather more than one-half.
3. Both processes fail in purifying sewage to such an extent as to render it admissible into running water.
4. For the manufacture of solid manure from sewage, Sillar's process is greatly superior to the method of treatment by lime, although it fails to extract from the liquid more than a very small fraction of its valuable constituents.

Since the above experiments were made, the chemical treatment, as described in Sillar's specification, has been supplemented by a subsequent process of filtration (not intermittent) through animal charcoal, sand, and gravel. At the request of the patentees we recently (Dec. 11, 1869), inspected this process at Leamington, where it has for some months been carried out upon the whole sewage of the town. We took half-hourly samples, for six hours, of the sewage before and after treatment, but unfortunately a fall of rain augmented the quantity to such an extent as to render the filtration of the whole volume of sewage after chemical treatment impossible. A large and unknown proportion was allowed to flow unfiltered into the *Leam*, and consequently no satisfactory average sample of effluent water from the filters could be collected. We have, however, analysed the samples taken before and after treatment by the *chemical part of the process*, and the results are contained in the following table:—

Purification of Sewage by Sillar's Chemical Process.

Results of Analysis expressed in Parts per 100,000.

At Leamington.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
Raw sewage - - - -	83·5	4·355	2·890	5·971	0	7·807	11·00	96·24	56·28	152·52
Ditto after treatment with chemicals, but before filtration.	94·3	2·803	1·334	4·660	0	5·172	9·50	6·68	4·12	10·80

The proportional amount of cleansing here effected is substantially the same as that observed at Leicester, as is seen from the following comparison:—

At Leicester and Leamington.	Per-centage of soluble Organic Pollution removed. Organic Carbon.	Per-centage of soluble Organic Pollution removed. Organic Nitrogen.	Per-centage of suspended Organic Matters removed.
At Leicester:			
Best result - - - - - -	34·8	58·9	96·0
Worst " - - - - - -	25·8	50·1	87·4
Average - - - - - -	30·3	54·5	91·7
At Leamington - - - - - -	35·6	53·8	92·7

* Report on the Main Drainage of the Metropolis, by Hofmann and Witt, 1857, p. 19.

PART I. REMEDIES.

Lime and chloride of iron.

The patentees stated, and with reason (See letter Vol. II., *Minutes of Evidence*, part 4), that the greatly increased volume of sewage which, owing to heavy rain, flowed through the works during our experiments, rendered the result, even of the chemical treatment, less satisfactory than usual, whilst, as above mentioned, the effect of the subsequent filtration could not be ascertained at all. We propose, therefore, to investigate the new process again under more favourable conditions of weather. In the meantime the above results must be regarded as representative of foul weather working, and of only the partial application of the new process.

(*c.*) *Treatment by Lime and Chloride of Iron.*—At Northampton this process is applied to the sewage of 40,000 people; 4,400 houses are here connected with the drains, and 2,800 are undrained. The excellent and constant water supply of 600,000 gallons daily, or 15 gallons per head, is derived chiefly from deep wells in the oolite. (Our analysis of this water is given at page 125.) The sewage works are situated about half a mile from the town. Each million gallons of sewage is here mixed with 12 bushels of lime, and about six gallons of chloride of iron (in hot weather more, in cold weather less). The lime is added first and then the chloride of iron. The defecated sewage is afterwards submitted to upward filtration through a stratum of calcined iron ore 8 inches thick; but we consider that beyond the separation of suspended matters, which would be equally effected by subsidence, this latter operation is nearly useless. The effluent sewage, after a flow of 1½ mile through a culvert, in which it becomes mixed with about one-sixth of its volume of spring water, is discharged into the river *Nen*, in a nearly clear and apparently innocuous condition. We examined the stream for about one-third of a mile below the outfall, and could perceive no sewer fungus or other sign of sewage pollution. Nevertheless, analysis shows that the sewage discharged into the stream still contains in solution a large amount of putrescible organic matter; but the putrescence of this matter was doubtless delayed, by the chloride of iron used in the treatment, until the stream had flowed beyond the point where we examined it. It is well known that chloride of iron possesses this property in a very remarkable degree,* but the putrefaction of the disinfected sewage is only delayed and not ultimately prevented. In fact, the river *Nen* does eventually become putrid in consequence of the discharge into it of the Northampton sewage, and an injunction has been granted by the Court of Chancery restraining the Improvement Commissioners from discharging the sewage of the town into the river after the First of June 1870.

The chloride of iron in solution is manufactured on the premises at a cost of 6*l.* per ton. A sample of it which we brought away with us contained in 100,000 parts,—

Iron as perchloride - - - - - - -	4413·7
„ protochloride - - - - - -	9124·3
Total iron - - - - - - -	13538·0

The following table gives the results of our analysis of the sewage before treatment, and as it issued from the deodorizing works. Our samples were taken at 2 p.m., when the sewage arriving at the works would doubtless be less concentrated than at an earlier hour, whilst, as we were informed, the discharge into the *Nen* would represent the sewage in its worst condition.

TREATMENT OF NORTHAMPTON SEWAGE WITH CHLORIDE OF IRON AND LIME.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
Sewage before treatment -	88·0	3·700	2·859	6·000	·000	7·800	66·72	16·40	83·12
„ after „ -	88·5	1·845	1·779	5·000	·000	5·897	·92	0·04	·96

(*d.*) *Treatment with crude sulphate of alumina, and subsequent filtration through coke.*—This process, which is known as Bird's, is carried out at Stroud, in Gloucestershire. From 150,000 to 200,000 gallons of sewage are daily treated with 6 cwt. of pulverized clay, to which 120 lbs. of sulphuric acid have been added some days previously. The sewage is made to turn a small waterwheel which regulates the delivery from a hopper of the sulphated clay or crude sulphate of alumina, which falls into the stream of sewage on its passage to a settling tank whence it flows under a second hopper, from which it receives a second dose of the sulphated clay. Thence it flows into a depositing tank, and afterwards through three coke filters. The coke is renewed in the first filter every fortnight and in the last every month. The foul coke is burnt under the boiler.

* Report on the deodorization of sewage by Hofmann and Frankland, presented to the Metropolitan Board of Works, August 12, 1859.

PART I. REMEDIES.

Sulphate of alumina.

We visited the works on October 23rd 1869, and took half-hourly samples of the sewage from 9·10 a.m. to 12·10 p.m., and of the effluent water from 10·10 a.m. to 1·10 p.m. The samples of each were mixed together and a specimen of each average sample was then taken for analysis. The analyses of both average samples are appended; it is evident from them, first, that the sewage was very weak, and second that the effluent liquid, though much improved, was still not of the degree of purity which would render it admissible without nuisance into a clean river. Moreover, if stronger sewage were treated the effluent water would doubtless be still more objectionable. It was always somewhat turbid but nearly inodorous.

TREATMENT OF STROUD SEWAGE WITH CRUDE SULPHATE OF ALUMINA.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
Sewage before treatment -	48·5	2·289	1·330	3·152	·044	3·970	15·15	27·85	43·00
„ after „ -	53·5	2·203	·692	2·275	·033	2·598	1·88	2·20	4·08

(*e.*) *Treatment with a mixture of Sulphate of Iron, Lime, and Coal Dust:—Holden's Process.*—Letters Patent, dated 10th November 1866, and sealed 5th January 1867, were granted to Henri Adrien Bonneville, of the County of Middlesex, Patent Agent, for an invention of "An improved manure obtained by an improved process of purifying "foul waters," being a communication from Jules Houzeau and Eugène Devedeix, of Paris, Manufacturers. This process has recently been carried out on a considerable scale with a portion of the sewage of Bradford, Yorkshire, by Mr. Angus Holden of that town, and has hence become commonly known as Holden's process. The patentee thus describes the nature of the invention:—

"The invention communicated to me relates to an improved process of using mineral substances or such as are of vegetable origin combined with lime in order to obtain the purification of those waters which come from factories, households, closets, gutters, and sewers, in fine, all such foul waters as are now thrown away as useless. To effect this the following materials are used:—

"1°. The lignites in general (a production of vegetable origin) arising from the decomposition of plants which have not entirely undergone the coal transformation, friable or not, whatever may be the colour.

"2°. An imitation of the lignites, which may be obtained by means of pit coal in a pure state, the ashes of said pit coal after burning, or the coke resulting from the carbonization of this pit coal, and finally charcoal and all artificial coals, sulphate of iron, commonly called copperas.

"3°. Clay, commonly known as potter's clay, which is mixed with the substances indicated in the above-mentioned paragraph.

"4°. Lime, which must always be used concurrently with one of the above-mentioned substances, and after being slacked.

"The proportion of lignites to be employed varies between 4 and 6 drams or thereabouts (about 2 to 3 grammes) per quart, and that of the lime between 2 and 6 drams or thereabouts (about 1 to 3 grammes) also per quart, according to the nature of the waters to be treated; that of the pit coal, of the ashes, coke, and all natural and artificial charcoals, is from 4 to 12 drams or thereabouts (about 2 to 6 grammes) according to their richness, and limewhite is always added in the above given proportions.

"One of the above-mentioned products is made use of either by throwing it into the water to be purified, or by reducing it into a dissolution, the density of which varies according to the greater or lesser purity of the waters to be treated, always adding limewhite to it. The two mixtures thus being performed a coagulation takes place, which settles almost immediately, leaves a sediment or residue, which has seized upon the organic matter, and the water becomes limpid.

"The deposit or residue being properly dried, may be used to great advantage for agricultural purposes as manure, the proportion of which varies according to the greater or lesser density of the liquid purified."

We saw this process in operation, and took samples of sewage and effluent water on the 5th and 6th of October 1869. We were informed that 130,000 gallons of sewage

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REMEDIES.

Holden's process.

were being daily treated. The sewage was conducted from the Bradford outfall sewer by a branch conduit, and having been mixed with sulphate of iron, lime, and coal dust was passed into a series of subsidence tanks, in flowing through which it occupied about 20 minutes. The effluent water which issued from the last of this series of tanks was of a yellowish tint and perfectly transparent. Subsequently, Mr Holden forwarded to us average samples of sewage and effluent water taken hourly during several hours, on the 2nd of December. We have submitted all these samples to analysis, and the following table contains the results obtained:—

TREATMENT OF BRADFORD SEWAGE BY HOLDEN'S PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Date.	Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
1869. Oct. 5	Sewage before treatment, 4·45 p.m.	79·9	6·303	·577	1·845	·008	2·104	6·49	14·95	36·05	51·00
,, ,,	,, after ,, 5 p.m -	170·4	3·578	·868	1·520	·367	2·487	6·78	0	0	0
,, 6	,, before ,, 9 a.m. -	74·6	3·602	·655	1·615	·000	1·985	5·53	12·20	38·45	50·65
,, ,,	,, after ,, 9·15 a.m.	173·3	3·479	·700	·914	·148	1·601	5·62	0	0	0
Nov.	,, before ,, average of 12 hours, Dec. 3, 1869.	95·0	9·505	·926	2·771	·000	3·208	6·80	21·70	64·80	86·50
,, ,,	Sewage after treatment, average of 12 hours, Dec. 3, 1869.	144·4	5·858	1·215	1·279	·265	2·533	6·50	trace	0	trace

An inspection of the above table shows that whilst this process, like most of those already mentioned, separates the whole of the suspended matters, it not only fails to remove the putrescible organic matters in solution, but actually (as measured by the organic nitrogen contained in these organic matters) increases their quantity. This it does by causing some of the putrescible organic matter in suspension in the original sewage to pass into solution. The effluent water could not therefore be admitted into rivers without causing pollution. Further, the very large amount of lime and sulphate of iron added, not only enormously increase the amount of solid matter in solution, but, by their mutual decomposition into hydrated oxide of iron and sulphate of lime, communicate to the effluent water a degree of permanent hardness so excessive as to render its admixture with water to be afterwards used for manufacturing purposes extremely objectionable.

We have already stated (page 27) that the manure value of the suspended matters in sewage is less than one-seventh of that of the matters in solution, and as Holden's process only extracts the suspended matters, for a certain small amount of ammonia which adheres to them is to a great extent dissipated during the subsequent drying of the manure, it follows that the manure manufactured by this process can have no considerable value, a conclusion which is confirmed by the analysis of a sample of the subsided mud which we brought away with us and allowed to dry spontaneously in the air; 100 parts of this air-dried mud contained,—

Mineral matters containing ·3 part of phosphoric acid -	50·35
Organic and other volatile matters containing ·004 of ammonia and ·555 of organic nitrogen - - - - -	43·01
Water - - - - - - - -	6·64
	100·000

The ammonia contained in the mud before drying was equivalent to ·009 per cent. in the air dried mud.

A manure of the above composition may be considered as practically worthless.

2.—**Purification of Sewage by Filtration.**—The process of filtration through sand, gravel, chalk, or certain kinds of soil, if properly carried out, is the most effective means for the purification of sewage to which reference has yet been made; indeed, irrigation, as now carried out, owes no inconsiderable amount of its success to the contemporaneous effect of the filtration of the sewage through the soil of the irrigated fields; for it is precisely in those cases in which the sewage is absorbed and disappears in porous land, that we have observed, in the effluent water from drains, the most complete purifying effect.

Excellent examples of this kind of purification are met with in London itself. Chemical analysis shows that the water-bearing gravel of London is supplied almost exclusively by

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Filtration.

sewage, and the water pumped from the shallow wells in London is little else but filtered sewage. Now, although this water cannot be used for domestic purposes without great risk to health, it is so bright, colourless, and sparkling, and contains moreover such a minute proportion of organic matter, that the most fastidious could not object to its admission into running water. The large quantities of nitrates and carbonic acid, the products of the oxidation of fæcal matters, which this water contains, impart to it a cool and agreeable taste, which notoriously causes it to be preferred by many of the inhabitants of the metropolis, to the much purer but more tasteless water supplied from the *Thames* and the *Lee*. The ornamental lake in St. James's Park being fed from a well upon Duck Island sunk into the water-bearing gravel may be correctly described as filtered sewage mixed probably with a certain proportion of water from the neighbouring *Thames*; if therefore this water, being stagnant, is perfectly inoffensive, *à fortiori* it might be admitted in any quantity with impunity into a running stream. The purification thus effected consists in the separation of suspended matters, and in the transformation of the putrescible organic matters in solution into innocuous mineral compounds, such as ammonia and salts of nitrous and nitric acids.

The following table contains the results of our analyses of the water supplied to the lake in St. James's Park from the well upon Duck Island, and also of the water pumped from a well in the Royal Institution, which has long been considered as excellent drinking water by the domestics of that Institution, but which is nothing but sewage filtered through a few feet of gravel:—

COMPOSITION OF SEWAGE PURIFIED BY NATURAL FILTRATION.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**
Water from well on Duck Island - -	100·1	·548	·105	·408	·885	1·326
,, ,, in Royal Institution -	93·7	·440	·085	·001	4·355	4·441

We have become acquainted with only one instance in which simple artificial filtration has been resorted to for the purification of sewage. This occurs at Ealing, and the process is carried on as follows:—

The sewage is received into two deposit tanks, each 64 feet long by 10 feet wide, and 8 feet deep. These deposit tanks are divided each into five chambers by planks having small openings to admit of the passage of sewage water; in the fourth chamber a rough filter of gravel or burnt ballast is formed, through which the sewage passes by ascension. Between the deposit tanks and the first set of filter beds, are two iron baskets containing charcoal closely packed; after passing through these baskets, the sewage is received into the first set of filters, and rises through 18 inches of burnt clay ballast, which is now used in preference to gravel and sand.

The water then flows over the weir at the end of the first set of filters into chambers containing wire baskets filled with burnt clay ballast, and is led by iron pipes into the second set of filter beds, where all the heavier suspended matter contained in the sewage water is deposited, the liquid then rising through 2 feet of burnt clay ballast.

The capacity of the deposit tanks and of the spaces under the filter beds which are employed as deposit chambers, amounts to 17,500 cubic feet. The area of filters in deposit tanks is 240 superficial feet; that of the first set of filter beds is 630 superficial feet, and that of the second set of filter beds is 1,000 superficial feet. There is thus a total area of 1,870 superficial feet; and the sewage in its transit passes in all, through 7 feet 4 inches of filtering materials.

The soil collected in the deposit tanks and filters is removed through cast-iron valves placed 13 feet apart, and drops into vaults below, and is afterwards mixed with the dust and ashes collected by the scavenger, and sold for manure.

The process as thus carried out entirely fails to transform the soluble putrescent organic matters into innocuous mineral compounds. This failure is due partly to the filters being far too small for the volume of sewage dealt with, and partly to the circumstance that the filtration is performed upwards instead of downwards. For efficient purification by filtration, it is essential that atmospheric oxygen should have frequent and free access to the

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Filtration.

interior of the filter, a condition which is entirely excluded in upward filtration. Nevertheless the filtered sewage was being run into the *Thames* by permission of the Board of Conservators under the following certificate extracted from a report dated October 1868, by Mr. Charles Jones, Surveyor to the Local Board of Health, Ealing:—

"London Hospital, March 21st, 1868.

"The sample of liquid contained in the bottle marked A, 16th March 1868, which was sent here on the 16th of March, is a very weak solution of carbonate and sulphate of ammonia, with a little calcareous and organic matter and common salt.

"The total amount of these matters is only about 56 grains per imperial gallon, and therefore the liquid is perfectly harmless to animal and vegetable life, and is not offensive.

(Signed) Hry. Letheby."

On the occasion of our visit to the sewage works at Ealing, one month later we were informed that a mean daily volume of 400,000 gallons of sewage, from a population of about 7,500, was being treated. The time of its transit through the series of filter beds was only 10 minutes. The suspended matters were of course to a great extent arrested, but the effluent liquid retained nearly all the original amount of soluble putrescible organic matter, and was totally unfit to be admitted into running water, as is evident from an inspection of the following analyses of the samples which we collected at the time of our visit:—

Treatment of Ealing Sewage by Filtration.

Results of Analysis expressed in Parts per 100,000, and including both suspended and dissolved Matters.

Description.	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.
Sewage as delivered at works April 24, 1868	115·5	27·848	2·930	7·000	·000	8·695
" flowing from last filter " "	78·5	6·093	2·785	4·250	·076	6·361

The causes of the failure of sewage filtration at Ealing are sufficiently obvious; they are, first, the inadequacy of the mass of filtering material; and, secondly, the absence of all provision for the frequent aeration of that material. We find, from experiments given below, that the efficient purification of 400,000 gallons of sewage per day by filtration would require at least 40,000 cubic yards of filtering material, whilst the Ealing filters contain only 60 cubic yards.*

Moreover, even that vast mass of material would not exercise its purifying effect unless it were frequently aerated, which is best effected by dividing it equally between two filters, and allowing the sewage to flow upon them alternately for 6 or 12 hours, thus giving the alternate 6 or 12 hours for aeration. In order that this latter process may be effected, it is of course necessary that the effluent water should flow freely off from the bottom of the filter, so that as the last portion of each dose of sewage sinks into the filter, it may draw atmospheric air into the pores of the material from the surface downwards.

Finding from preliminary trials that filtration, properly conducted, is a most efficient means of purifying sewage, we made an extensive series of experiments in order to determine—first, the best material to be used as a filtering medium; second, the amount of sewage which can be effectively purified per cubic yard of material; and third, the best mode of conducting the filtration. For this purpose the filtering material was placed in glass tubes 16 feet long and 2 inches internal diameter, and in glass cylinders 6 feet long and 1 foot in diameter.

The first set of experiments was made with two of the long glass tubes charged, the one with sharp siliceous sand, the other with a mixture of equal parts of sand and coarsely powdered chalk. London sewage from the outfall of the Regent Street and Victoria Street sewers in Scotland Yard was passed continuously upwards through one of these tubes so as to exclude aeration, and subsequently downwards in successive doses through both, so as to cause the air to follow the sewage down the tube between each two consecutive doses. The effluent water was submitted to analysis once a week. The following table shows the results of the experiments in which upward filtration was employed:—

* The following is our authority for this statement, being an extract from a letter addressed to us, dated December 1, 1869, by the Surveyor to the Local Board of Health:—"The number of cubic yards in the first set of filters at the Ealing Sewage Works is 47, and in the second 74 yards. As these filters are used in pairs it may be assumed that the Ealing sewage passes through 60 yards of filtering material."

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Remedies.
Downward filtration.

Upward Filtration of London Sewage through Fifteen Feet of Sand at the Rate of 3·6 Gallons per Cubic Yard per Twenty-four Hours.

Results of Analysis expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**
Effluent water, Oct. 11, 1869 -	76·0	3·745	1·149	3·170	1·788	5·548
" " Oct. 19, " -	69·5	3·161	·856	4·080	·236	4·452
" " Oct. 25, " -	72·0	2·912	·961	3·750	·270	4·319
" " Nov. 1, " -	89·1	4·359	2·017	5·276	·000	6·362
" " Nov. 8, " -	95·0	3·608	2·177	6·037	·000	7·148
" " " 15, " -	78·5	2·660	1·433	5·691	·000	6·119
" " " 22, " -	83·5	2·162	1·201	4·524	·000	4·927

These results show that the process of *upward* filtration through sand is inefficient in the purification of sewage from soluble offensive matters. The large amount of organic carbon, and especially of organic nitrogen, exhibited in the above analyses shows that on no occasion was the effluent water in a condition fit to be admitted into running streams. They also show that nitrification (the generation of nitrates and nitrites) took place only so long as the pores of the sand still contained air with which they were of course filled at the commencement of the experiment.

The following set experiments was then made in the same tube still charged with the same material; the conditions of filtration being altered from the continuous and upward system to the intermittent and downward system. A similar set of experiments was also made with the second tube filled with the mixture of sand and chalk as above described.

Downward Filtration of London Sewage through Fifteen Feet of Sand.

Results of Analysis expressed in Parts per 100,000.

Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.
Average composition of sewage before filtration* - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**
Filtration at rate of 2·8 gallons per cubic yard per 24 hours.						
Effluent water, December 21, 1868 -	82·8	·993	·187	·030	3·227	3·439
" " 28, " -	88·1	·849	·166	·022	4·468	4·652
" January 4, 1869 - -	85·2	·893	·140	·013	4·489	4·639
" " 11, " - -	91·1	1·013	·110	·020	4·830	4·956
" " 18, " - -	77·0	·854	·179	·020	4·554	4·749
At rate of 4·2 gallons per cubic yard per 24 hours.						
Effluent water, January 25, 1869 - -	60·2	·936	·140	·012	2·265	2·415
" February 1, " - -	86·3	·766	·078	·025	5·105	5·204
" " 8, " - -	94·2	·892	·102	·020	5·155	5·273
" " 15, " - -	80·6	1·311	·089	·015	4·156	4·257
At rate of 5·6 gallons per cubic yard per 24 hours.						
Effluent water, February 22, 1869 -	69·9	·827	·110	·015	3·617	3·739
" March 1, 1869 - -	86·8	·711	·078	·010	4·727	4·813
" " 8, " - -	79·1	·664	·136	·012	3·431	3·577
At rate of 11·2 gallons per cubic yard per 24 hours.						
Effluent water, March 15, 1869 - -	70·0	1·261	·522	1·680	2·841	4·746
" " 22, " - -	56·4	·537	·107	·064	2·484	2·644
" " 30, " - -	76·0	2·007	2·096	4·790	·035	6·076
" April 5, " - -	70·7	1·948	1·041	3·195	·812	4·484

* These figures give the average results of 21 analyses of the sewage used during the continuance of these and the following experiments. It need scarcely be stated that in reality the composition of the sewage varied considerably during the course of the experiments. The variation may often be traced in the total solid matters and total combined nitrogen in the effluent water. It was obviously impossible to make the analyses of the sewage contemporaneously with those of the effluent water so as to admit of a strict comparison between the two. The following numbers show the maximum and minimum results obtained in the 21 analyses of sewage just referred to. The whole series of these analyses is recited on p. 29, where it will be seen that the low minimum of ·909 of organic nitrogen occurred on only one occasion, and that the next lowest number was 1·378:—

—	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.
Maximum - - -	80·1	6·345	4·977	9·325	·012	11·187	15·1
Minimum - - -	40·6	2·596	·909	2·445	·000	2·923	5·1

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DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH FIFTEEN FEET OF SAND AND CHALK.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**
Filtration at rate of 2·8 gallons per cubic yard per 24 hours.						
Effluent water, December 21, 1868 -	101·6	·720	·164	·042	4·980	5·179
„ „ „ 28 „ -	99·8	·705	·179	·037	4·165	4·375
„ „ January 4, 1869 - -	101·6	·825	·109	·030	3·934	4·068
„ „ „ 11 „ - -	100·0	·697	·102	·035	4·103	4·234
„ „ „ 18 „ - -	89·8	·736	·136	·100	2·658	2·876
At rate of 4·2 gallons per cubic yard per 24 hours.						
Effluent water, January 25, 1869 - -	89·2	·740	lost	·027	3·295	—
„ „ February 1 „ - -	86·9	·742	·098	·025	3·927	4·046
„ „ „ 8 „ - -	103·5	·828	·091	·040	4·430	4·554
„ „ „ 15 „ - -	105·8	·976	·085	·035	3·843	3·957
At rate of 5·6 gallons per cubic yard per 24 hours.						
Effluent water, February 22, 1869 -	85·0	·518	·093	·020	3·117	3·226
„ „ March 1, 1869 - -	102·9	·687	·103	·017	3·585	3·702
„ „ „ 8 „ - -	96·1	·541	·080	·010	3·733	3·821

These results prove that the process of intermittent downward filtration, through either sand or a mixture of chalk and sand, effects a very satisfactory purification of sewage when the sewage treated amounts to 5·6 gallons per cubic yard of filtering material in 24 hours, but that the purification becomes uncertain and unsatisfactory when the rate of filtration is doubled, that is, when the sewage treated amounts to 11·2 gallons per cubic yard in 24 hours. These experiments also show that the process of purification is essentially one of oxidation, the organic matter being, to a large extent, converted into carbonic acid, water and nitric acid: hence the necessity for the continual aeration of the filtering medium which is secured by intermittent downward filtration, but entirely prevented by upward filtration.

Up to the rate of flow of 5·6 gallons per day of 24 hours per cubic yard of filtering material, all the samples analysed were sufficiently purified to be admitted into any stream without any apparent pollution of the latter; the undiluted effluent sewage being clear, colourless, or nearly so, and sparkling. Only as a source of drinking water could a stream into which such purified sewage flows be condemned.

These experiments reveal the true cause of the comparative freedom of rivers from excremental pollution, whilst the fever-breeding cesspool system was in full operation. The liquid dejecta of our towns, doubtless, found their way to streams then as now, but they were compelled to soak through many feet of porous and more or less aerated soil, where the organic matter became oxidized. Even in our most densely populated towns, Liverpool for instance with a population of nearly 100 per acre, the area of soil falling to each person, assuming it to be only 1 yard deep, is ten times more than is necessary for the purification of each person's sewage, for even assuming each person to be an adult, furnishing 30 gallons of sewage (of the quality of London sewage) per day, each cubic yard of soil would then receive in 24 hours only ·62 gallon of sewage.

As this purifying action of soils has an important bearing upon the question of sewage irrigation, we thought it desirable to extend these experiments to natural soils and to perform them upon a somewhat larger scale. For this purpose we had a number of glass cylinders blown, 6 feet long and $10\frac{1}{4}$ inches in diameter. These cylinders were open at both ends, they were placed perpendicularly with their lower ends resting in a shallow earthenware tray. A glass tube open at both ends passed down the axis of the cylinder to within about 3 inches of the lower extremity. The object of this tube was to allow air or gas to escape freely from the lower part of the cylinder so that the passage of the sewage through the filtering material might not be retarded. A layer of small pebbles about 3 inches deep was placed at the bottom of the cylinder; upon this rested a stratum about 5 feet thick (about 3 cwt.) of the soil to be experimented upon; and finally, in some cases, a layer of fine sand about 1 inch deep was put upon the top of the soil, to prevent the coarse suspended matters in the sewage from passing into the soil. This still left ample space at top for the sewage, which was poured into the cylinder in equal quantities night and morning. The effluent water, collecting in the earthenware tray, flowed off into a vessel conveniently placed for its reception.

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The effluent water was analytically examined weekly, the sewage being always allowed to pass through it at least a week before the first sample was collected. The same rule was also observed whenever the rate of filtration was altered.

The first soil submitted to experiment was a very porous gravel taken from a field at Beddington near Croydon, which had been under sewage irrigation for 5 years. After drying at 100° C. (212° F.), and after the separation of 7·45 per cent. of stones, it yielded on analysis the following per-centage numbers:—

Insoluble residue containing 93·21 per cent. of silica, 3·97 per cent. of alumina, ·8 per cent. of iron, and ·41 per cent. of lime - - - - - -	87·90
Silica - - - - - - -	·65
Peroxide of iron - - - - - -	·23
Alumina - - - - - - -	·78
Lime - - - - - - -	1·79
Phosphoric acid - - - - - -	trace.
Carbonic acid - - - - - -	1·80
Ammonia - - - - - - -	·0079
Organic carbon - - - - - -	1·235
Organic nitrogen - - - - - -	·122
Nitrogen as nitrates and nitrites - - - -	·00056
Loss on ignition - - - - - -	5·99

A layer of sand was placed upon this soil at the top of the glass cylinder. The weekly analytical examinations of the effluent water yielded the following results:—

DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH BEDDINGTON SOIL.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.		
								Temporary.	Permanent.	Total.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**	**10·4**	—	—	—
At rate of 3·8 gallons per cubic yard per 24 hours.										
Effluent water, December 14, 1868 -	106·7	1·027	·468	·016	3·802	4·283	9·93	—	—	—
„ „ 21, „ -	135·0	·984	·376	·010	4·567	4·951	10·42	—	—	—
„ „ 28, „ -	125·0	·771	·111	·007	4·520	4·637	10·42	—	—	—
„ January 4, 1869 - -	119·3	·800	·148	·015	3·960	4·120	9·43	—	—	—
„ „ 11, „ - -	133·2	·672	·093	·015	5·527	5·632	9·53	—	—	—
„ „ 18, „ - -	121·0	·564	·069	·020	5·150	5·235	8·84	62·67	21·97	84·64
„ „ 25, „ - -	110·1	·649	·097	·005	4·217	4·318	6·95	56·71	19·48	76·19
„ February 1, „ - -	114·3	·537	·101	·010	4·299	4·408	9·53	53·92	25·08	79·00
„ „ 8, „ - -	124·8	·653	·078	·007	5·582	5·666	9·80	44·85	40·27	85·12
„ „ 15, „ - -	127·0	·934	·105	·010	4·904	5·017	10·50	48·78	31·76	80·54
At rate of 7·6 gallons per cubic yard per 24 hours.										
Effluent water, February 22, 1869 -	99·2	·542	·063	·012	3·506	3·579	7·50	48·94	15·88	64·82
„ March 1, 1869 - -	100·2	·535	·078	·005	2·411	2·493	10·20	52·22	17·19	69·41
„ „ 8, „ - -	100·0	·503	·066	·003	2·908	2·977	8·84	—	—	67·12
At rate commencing with 15·2 gallons per cubic yard per 24 hours, and gradually diminishing to 7·6 gallons.										
Effluent water, March 15, 1869 - -	68·2	·919	·106	·002	trace	·108	10·06	—	—	—
„ „ 22, „ - -	74·6	·637	·094	·008	·000	·101	10·50	—	—	—
„ „ 30, „ - -	79·9	·646	·116	·006	·503	·624	9·65	—	—	—
„ April 5, „ - -	95·1	·618	·103	·006	2·445	2·553	10·60	—	—	—
„ „ 12, „ - -	112·3	·569	·112	·006	6·040	6·157	10·28	—	—	—

These results show how rapidly the process of nitrification (the conversion of ammonia and animal organic matter into nitrates) takes place in the Beddington soil, and how satisfactorily the sewage is purified even at the rate of 7·6 gallons per cubic yard of soil per diem. But when this rate was doubled the nitrification ceased, and the pores of the soil became blocked up so that they would no longer transmit the whole volume of sewage supplied and also afford time for aeration; for a while, however, the organic matter, which would otherwise have been oxidized, was retained by the soil, and its oxidized products appeared in the effluent water a month later, after the rate of filtration had been reduced. The effluent water was always clear and nearly colourless at the rate of 3·8 and 7·6 gallons per cubic yard per diem. In respect of organic matter, the filtered sewage actually equalled, or even surpassed in purity on four occasions, the water which is sometimes supplied to London for domestic purposes, as is seen from the analysis of the effluent

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sewage on January 18th, February 22nd, and March 1st and 8th, and the analysis of the water supplied to the metropolis in January and February 1869:—

COMPARISON OF FILTERED SEWAGE WITH LONDON DRINKING WATER.

Description.	Organic Carbon in 100,000 parts.	Organic Nitrogen in 100,000 parts.
Effluent sewage, January 18 - - - - - - -	·564	·069
" February 22 - - - - - - -	·542	·063
" March 1 - - - - - - -	·535	·078
" " 8 - - - - - - -	·503	·066
Water delivered by the Southwark Company, January 8, 1869 - - -	·515	·080
Ditto on February 5, 1869 - - - - - -	·686	·079
Water delivered by the Chelsea Company, February 5, 1869 - - -	·475	·067
Water delivered by the Grand Junction Company, February 5, 1869 - -	·607	·068
Water delivered by the Lambeth Company, February 5, 1869 - - -	·526	·058

The next soil experimented with was a light sand of bright red colour from the New Red Sandstone at Hambrook in Gloucestershire.

The analysis of this soil, after sewage had been passed through it for three months, gave the following results:—

Insoluble residue containing 91·97 per cent. of silica and 7·76 per cent. of alumina and peroxide of iron - - - - -	80·86
Soluble silica - - - - - - - -	·16
Peroxide of iron - - - - - - -	9·97
Alumina - - - - - - - -	1·16
Lime - - - - - - - -	·57
Manganese - - - - - - - -	trace.
Carbonic acid - - - - - - - -	·34
Loss on ignition - - - - - - -	5·00
Ammonia - - - - - - - -	·30
Nitric acid - - - - - - - -	traces.
Moisture - - - - - - - -	1·47
	99·83
Organic carbon - - - - - - -	·014855
" nitrogen - - - - - - -	traces.

No layer of sand was placed upon this soil in the glass cylinder. The weekly chemical examination of the effluent water gave the following results:—

DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH HAMBROOK SOIL.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**	**10·4**
At Rate of 4·2 Gallons per Cubic Yard per 24 Hours:—							
Effluent water, Feb. 22, 1869 -	79·2	2·542	·234	·225	3·579	3·998	2·8
" " March 1, " -	88·0	·939	·137	·020	1·664	1·817	5·5
" " " 8, " -	107·5	·871	·100	·062	·967	1·118	10·5
" " " 15, " -	119·5	·901	·126	·119	2·636	2·859	—
" " " 22, " -	123·9	·687	·121	·149	4·340	4·584	8·6
" " " 30, " -	114·9	·811	·106	·122	3·469	3·675	8·6
" " April 5, " -	125·7	·779	·123	·150	4·118	4·365	9·0
" " " 12, " -	116·1	·924	·146	·137	2·943	3·201	10·0
" " " 19, " -	107·0	1·379	·205	·084	1·635	1·909	9·3
" " " 26, " -	114·5	1·317	·261	·075	2·659	2·982	9·8
" " May 3, " -	121·4	1·174	·171	·077	3·528	3·762	10·4
" " " 10, " -	120·8	1·266	·168	·052	3·795	4·006	9·9
" " " 17, " -	114·7	1·183	·113	·084	3·685	3·867	9·8
At Rate of 6·2 Gallons per Cubic Yard per 24 Hours:—							
Effluent water, May 24, 1869 -	116·0	·850	·177	·141	3·470	3·763	10·1
" " " 31, " -	101·1	1·155	·237	·178	1·666	2·050	10·5

The Hambrook, unlike the Beddington soil, had not been previously submitted to the action of sewage, and it is therefore not surprising that it should at first exhibit a somewhat irregular effect. Thus, it obviously contained a store of organic matter which was washed out by the first application of the sewage; hence the very large amount of

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organic carbon, organic nitrogen, and nitrogen in the form of nitrates and nitrites, contained in the first sample of effluent water. On the other hand, a large proportion of the common salt contained in the sewage was absorbed, and hence the reduction of the proportion of chlorine from about 10 parts originally contained in 100,000 of the sewage to 2·8 parts. It was only after the lapse of a fortnight that this absorption of common salt ceased, and the proportion of chlorine rose to 10·5 parts in 100,000.

The small amount of nitrates, nitrites, and ammonia, cotemporaneous with little organic nitrogen, in the effluent water after the first washing out of the soil, indicates an absorption and retention of organic matter by the Hambrook soil. Nevertheless this action must have been subsequently reversed, as the soil gave on analysis but mere traces of organic carbon and nitrogen. The possibility of such an absorption, and the extent to which it may take place in some soils, is seen in the remarkable results obtained in the next experiment made with soil from the sewage farm at Barking.

The analysis of this soil, after removal of 9·4 per cent. of flint stones, gave the following numbers:—

Insoluble in acids.	Silica - - - - - -	77·65
	Peroxide of iron - - - - -	1·58
	Alumina - - - - - -	4·96
	Lime - - - - - -	2·68
Soluble in acids.	Silica - - - - - -	·89
	Peroxide of iron - - - - -	1·93
	Alumina - - - - - -	·93
	Lime - - - - - -	1·00
	Loss on ignition - - - - -	5·12
	Water expelled at 100° C. - - - -	1·48
	Ammonia - - - - - -	·022
		98·242
	Organic carbon - - - - -	·968
	Organic nitrogen - - - - -	·121

The results obtained by the analysis of the effluent sewage from a cylinder filled with this soil covered with a layer of sand are contained in the following table:—

DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH BARKING SOIL.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.		
								Temporary.	Permanent.	Total.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**	**10·4**			
At Rate of 3·8 Gallons per Cubic Yard per 24 Hours:—										
Effluent water, Dec. 21, 1868 -	152·9	2·231	1·058	·048	6·735	7·833				
" " " 28, " -	88·4	2·262	·320	·156	·000	·448				
" " Jan. 4, 1869 -	90·5	2 179	·201	·250	·000	·407				
" " " 11, " -	88·1	2·223	·212	·320	·000	·475				
" " " 18, " -	84·1	2·235	·367	·410	·000	·705				
" " " 25, " -	89·7	2·387	·297	·642	·000	·826				
" " Feb. 1, " -	85·2	2·690	·297	·790	·000	·948				
" " " 8, " -	90·1	3·364	·401	·890	·000	1·134	10·5	43·37	7·70	51·07
" " " 15, " -	92·9	3·467	·571	1·527	·000	1·829	11·6	43·52	7·55	51·07
" " " 22, " -	91·2	4·414	1·041	2·093	·000	2·765	10·4	36·74	5·49	42·23
" " March 1, " -	88·8	4·206	·897	2·848	·000	3·242	9·3	43·82	5·78	49·60
" " " 8, " -	72·8	3·677	·691	2·122	·000	2·439	7·7			46·95

These highly remarkable results show that there are soils in which the process of nitrification either does not take place at all or goes on with great difficulty. The Barking soil is one of these, and it moreover possesses the valuable property of absorbing a large amount of fertilizing ingredients from sewage. It is scarcely possible to overrate the agricultural value of this property in a soil which is destined for irrigation. This quality, however, greatly detracts from its efficacy as a continuous purifier of sewage filtered through it. The application of 3·8 gallons per diem to each cubic yard for about 12 weeks showed a continuous increase of organic impurity in the effluent water, which at the end of that time was rapidly approaching in quality to unchanged and unpurified sewage.

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The next soil submitted to experiment was a light yellowish brown loam from the marlstone of the lower oolite near Dursley, in Gloucestershire. As the former experiments were made in the warm atmosphere of the laboratory, and the soils in the glass cylinders were to some extent exposed to light, it was deemed advisable in this case to place the cylinder in darkness, and to expose it to all the vicissitudes of a winter temperature. The result proves that the nitrifying or purifying power of a soil is not interfered with by moderate cold or by darkness.

This soil contained no stones. After sewage had passed through it for three months, it was analyzed with the following results:—

Insoluble in acids.	Silica - - - - - - -	42·89
	Peroxide of iron and manganese - - -	trace.
	Alumina - - - - - - -	8·69
Soluble in acids.	Silica - - - - - - -	·37
	Peroxide of iron - - - - - -	18·41
	Protoxide of iron - - - - - -	2·35
	Alumina - - - - - - -	4·19
	Lime - - - - - - - -	4·53
	Magnesia - - - - - - -	trace.
	Carbonic acid - - - - - - -	8·45
	Water expelled at 100° C. - - - -	4·76
	Loss on ignition - - - - - -	4·55
		99·19
	Organic carbon - - - - - -	2·0755
	Organic nitrogen and nitrogen as ammonia - -	·2922

This soil being placed in the glass cylinder without any layer of sand upon it, was treated as before with London sewage, and the effluent water submitted to analysis with the following results:—

DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH DURSLEY SOIL.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.
Average composition of sewage before filtration - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**	**10·4**
At Rate of 4 Gallons per Cubic Yard per 24 Hours.							
Effluent water, March 8, 1869 - -	61·9	·427	·127	·014	1·815	1·954	5·8
„ „ 15, „ - -	65·1	·494	·057	·015	1·712	1·781	—
„ „ 22, „ - -	—	·446	·095	·012	1·133	1·238	9·75
„ „ 30, „ - -	78·6	·508	·120	·002	1·851	1·973	8·57
„ April 5, „ - -	85·2	·412	·091	·010	2·438	2·537	9·50
„ „ 12, „ - -	92·7	·423	·081	·018	3·408	3·504	9·82
„ „ 19, „ - -	103·0	·455	·106	·013	4·971	5·088	9·42
„ „ 26, „ - -	116·3	·419	·068	·010	8·166	8·242	9·75
„ May 3, „ - -	120·4	·486	·072	·015	8·739	8·823	10·07
„ „ 10, „ - -	125·5	·423	·135	·015	7·546	7·693	10·00
„ „ 17, „ - -	120·3	·469	·056	·016	5·870	5·939	10·37
At Rate of 7·5 Gallons per Cubic Yard per 24 Hours.							
Effluent water, May 24, 1869 - -	111·0	·493	·136	·016	4·975	5·124	10·75
„ „ 31, „ - -	112·6	·457	·154	·010	4·879	5·041	10·12
At Rate of 9·9 Gallons per Cubic Yard per 24 Hours.							
Effluent water, June 7, 1869 - -	107·9	·691	·179	·107	4·384	4·651	10·02
„ „ 14, „ - -	113·7	·568	·114	·160	4·960	5·206	11·35
„ „ 21, „ - -	120·8	·546	·162	·090	5·517	5·753	11·62
At Rate of 12·4 Gallons per Cubic Yard per 24 Hours.							
Effluent water, June 28, 1869 - -	111·4	·915	·270	·326	5·182	5·720	10·62
„ July 5, „ - -	108·9	·792	·174	·322	4·628	5·067	13·76
„ „ 12, „ - -	105·0	·872	·247	·167	4·015	4·400	13·20
„ „ 19, „ - -	108·4	1·126	·180	·383	3·634	4·129	13·30
„ „ 26, „ - -	110·5	1·281	·363	·549	3·080	3·895	13·26
„ Aug. 2, „ - -	105·1	·676	·130	·225	3·685	4·000	11·60
„ „ 9, „ - -	102·4	1·192	·348	·555	3·042	3·847	13·66
„ „ 16, „ - -	100·1	·838	·336	·540	2·839	3·620	11·20
„ „ 23, „ - -	92·8	1·181	·430	·650	2·379	3·344	10·90
„ „ 30, „ - -	97·9	·843	·252	·400	2·544	3·125	10·90
„ Sept. 6, „ - -	83·9	·885	·336	·587	2·628	3·447	10·00
„ „ 13, „ - -	95·9	1·545	·442	·632	2·491	3·453	12·50

PART I.
REMEDIES.

Downward filtration.

These analytical results show that the Dursley soil surpasses all the others experimented upon, in its power of purifying sewage. Whilst one cubic yard of sand or of Hambrook soil cannot continuously and satisfactorily purify more than 4·4 gallons of London sewage per 24 hours, one cubic yard of Beddington soil can cleanse 7·6 gallons, and one cubic yard of Dursley soil no less than 9·9 gallons in 24 hours, which is equivalent to the cleansing of nearly 100,000 gallons of sewage per day by an acre of this soil, provided the drains for the effluent water are six feet deep. Even when the rate of filtration amounted to 12·4 gallons per cubic yard in 24 hours, the sewage was greatly ameliorated, though not quite satisfactorily cleansed. At the conclusion of the long series of experiments there were no symptoms of clogging up or diminution of activity, and the effluent water was always bright, inodorous, and nearly colourless.

The cleansing power of a soil seems to be more closely connected with physical condition, as regards porosity and fineness of division, than with its chemical composition Thus, the Beddington and Barking soils, whilst similar in chemical composition, are most widely dissimilar in their action upon sewage. Again, sand and Hambrook soil act very similarly upon sewage, whilst they differ considerably in chemical composition; and lastly, the Hambrook and Dursley soils do not differ very widely in their chemical composition, nevertheless the latter has more than twice the purifying power of the former.

A large proportion of the waste land of Great Britain is covered with peat; it was therefore important to ascertain how this substance would behave with sewage. A sample of peat from Leyland Moss near Preston, which may be regarded as a fair specimen of Lancashire peat, was submitted to experiment in the manner already described. No layer of sand was placed upon the peat. The following table contains the weekly analysis of the effluent liquid. The peat was cut from a field which had been heavily manured with guano and farm-yard manure, and the analytical results show that this dressing exerted a great influence upon the effluent water for the three first weeks of the experiments.

DOWNWARD FILTRATION OF LONDON SEWAGE THROUGH LEYLAND PEAT.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.
Average composition of sewage before filtration - - - -	**64·5**	**4·386**	**2·484**	**5·557**	**·000**	**7·060**	**10·4**
At Rate of 4 Gallons per Cubic Yard per 24 Hours.							
Effluent water, May 31, 1869 - -	138·8	2·517	2·224	9·250	·694	10·536	40·07
„ „ June 7, „ - -	115·3	2·557	—	6·667	1·225	—	32·85
„ „ „ 14, „ - -	77·1	2·479	2·180	5·125	·447	6·848	21·17
„ „ „ 21, „ - -	43·8	2·600	1·087	3·631	·000	4·077	13·67
„ „ „ 28, „ - -	40·5	2·039	1·223	3·119	·000	3·792	12,25
„ „ July 5, „ - -	45·5	2·150	·956	4·225	2·088	6·523	12·40
„ „ „ 12, „ - -	57·8	2.134	·981	4·000	2·372	6·647	11·20
„ „ „ 19, „ - -	62·7	2·122	1·071	4·047	4·675	9·079	11·76
„ „ „ 26, „ - -	69·8	2·050	1·246	4·063	4·197	8·789	·12·92
„ „ Aug. 2, „ - -	91·7	2·292	1·172	4·042	4·884	9·385	16·40
„ „ „ 9, „ - -	64·7	1·972	·931	3·777	4·119	8·160	13·40
„ „ „ 16, „ - -	65·1	1·971	·388	4·550	6·677	10·812	12·88
„ „ „ 23, „ - -	60·7	1·515	·357	3·150	4·378	7·329	13·20
„ „ „ 30, „ - -	60·5	1·894	·217	3·200	3·621	6·473	12·58
„ „ Sept. 6, „ - -	57·5	1·858	·183	2·587	3·926	6·239	12·06

These analytical results show that, although the action of Lancashire peat upon sewage is for a couple of months but slight and unsatisfactory, yet the subsequent steady improvement of the effluent water encourages the hope that this material would, after a somewhat longer education, become an efficient purifier of sewage filtered through it at the rate of 4 gallons per cubic yard per 24 hours.

These experiments upon the filtration of sewage through various materials leave no doubt that this liquid can be effectually purified by such processes, and that probably any variety of porous and finely divided soil may be employed for this purpose. Our experiments also appear to show that if the soil be not overdosed with sewage, it will retain its efficiency for a long, if not for an unlimited period of time, and its pores will not become clogged up. With a properly constituted soil well and deeply drained, nothing more would

PART I. REMEDIES. — Irrigation.

be necessary than to level the surface and to divide it into four equal plots, each of which in succession would then receive the sewage for six hours. In this way the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate estimate, be cleansed upon five acres of land if the latter were well drained to the depth of six feet.

Nevertheless there are three formidable objections to the general adoption of this process:—First, it is entirely unremunerative, the amount of sewage applied to a given area of land being probably in such a case too great to permit of the growth of any ordinary agricultural crop. 2nd, the whole of the manure ingredients of the sewage would be absolutely wasted. And 3rd, the collection of solid fæcal matters upon the surface of the soil with no vegetation to make use of them would probably give rise to a formidable nuisance, especially in hot weather. We also entertain doubts as to the process being equally successful under ordinary management on a large scale, since the sewage would be likely to pass through the land in an unequal manner, in some places reaching the drains very rapidly, in others passing through the soil too slowly. This, we believe, to have been the cause of the comparatively partial purification of the Chorley sewage which in June last we saw passed upon and through several acres of fallow land, roughly broken up. The following analyses of the sewage and effluent water show that there was here no nitrification, and consequently but an imperfect purification of the liquid.

IRRIGATION ON FALLOW LAND.—CHORLEY.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
Chorley sewage as it flowed upon fallow land, June 8, 1869 - - -	71·20	4·968	1·495	3·492	·000	4·371	10·57	11·84	19·24	31·08
Effluent water, June 8, 1869 - -	51·30	1·872	·445	1·117	·000	1·365	6·92	trace	trace	trace.

From all these experiments then it appears that the action of the filter must not be considered as merely mechanical. The process carried on in it is also chemical. Filtration, properly conducted, results in the oxidation and transformation of offensive organic substances in solution, as well as in the mere mechanical separation of the suspended solid matters which, when in motion, sewage conveys with it. If the process could be carried one step further, and those harmless inorganic salts, which are carried off by the effluent water of a perfect sewage filter, in too dilute a solution to be profitably extracted, could be converted into something positively useful, the remedy would be complete. We should have succeeded in not only abating an injurious nuisance, but in realizing a product which would help to refund expenses. This farther step is possible in the great majority of cases, and it is to the plan of using sewage in irrigation, as being in reality a filtration of the best kind, *plus* a conversion of its filthy contents into valuable products, that we have now to direct attention.

3. Purification of Sewage by Irrigation:—We have still to discuss what may be called the agricultural remedy for the nuisance created by town sewage. In the first place, irrigation involves filtration. The acre allotted for the drainage water of 100 people may be a gently sloping square of 70 yards, or thereabouts, and the 2,000 gallons daily from these people will then have to trickle 70 yards abreast for 70 yards down the slope in 24 hours. The quantity delivered every hour thus need not be more than half a gallon for every lineal foot across the slope, and this half gallon need not travel faster than at the rate of eight feet per hour, in order to traverse the surface of the land within the day. No doubt in the actual work of irrigation frequent intervals of rest are needed by the land, and it may not be oftener than one day in three or four that the growing crop will bear this liquid dressing; moreover it is impossible in practice to regulate the distribution of water over land with any such uniformity as, for the purpose of illustration, we have supposed; but even if the watering were many times as great in quantity at a time as we have assumed, and the motion many times as rapid, it seems plain that the network of leaf and root through which sewage in irrigation passes (supposing it to sink beneath the surface as well as trickle over it) must retain all the coarser suspended matters. And no ordinary filter in a tank, considered as a mere sieve or strainer, can be equal to it in the quantity of active surface brought to bear within a given time on a given quantity of the material to be cleansed.

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But a filter, as has been already shown, is not a mere mechanical contrivance. It is a machine for oxidizing, and thus altogether transforming, as well as for merely separating the filth of dirty water. And in this respect especially irrigation necessarily includes filtration. Sewage traversing the soil undergoes a process to some extent analogous to that experienced by blood passing through the lungs in the act of breathing. A field of porous soil irrigated intermittently virtually performs an act of respiration, copying on an enormous scale the lung action of a breathing animal; for it is alternately receiving and expiring air, and thus dealing as an oxidizing agent with the filthy fluid which is trickling through it. And a whole acre of soil 3 or 4 feet deep, presenting within it such an enormous lung surface, must be far superior as an oxidizer for dealing with the drainage of 100 people, to any filter that could be practically worked for this purpose.

To this item in the character of both irrigation and filtration as chemical processes, there must be added another cleansing agency also of a chemical kind, in which the former has very greatly the advantage. We refer to the actual appetite for certain dissolved impurities in filthy water, which soil, whether in a tank or covering a field, owes both to general surface attraction and to the chemical affinities which some of its ingredients possess. This appetite is doubtless very limited in its amount, but it is directly proportional to the quantity of material exercising it. The superior capability of this kind which the soil of a field possesses, in comparison with that in a limited filtration tank depends partly on the immensely greater quantity of cleansing material which an acre drained perhaps 4 feet deep necessarily brings to bear upon the filthy fluid; but also and especially on the fact that in the former case this appetite is, except in winter time, always kept alive and fresh by the action of plant growth in constantly removing the deposited impurities, and rebuilding them into wholesome organic structures.

Considered then merely as a mechanical and chemical agency for cleansing the drainage water of our towns, it seems plain that a sufficient extent and depth of porous soil to be used in irrigation, having periodical intervals of rest during which the soil drains and becomes refilled with air, certainly must be the best possible strainer, oxidiser, and filter of water which, like the sewer water of our towns, contains nauseous organic impurities, both suspended and dissolved.* That it is so, analyses of effluent waters have satisfactorily proved, as will be illustrated at length hereafter. Meanwhile we have further to consider the last great advantage of the soil over all other filters, in that it *utilizes* a considerable proportion of the substances which they only separate, or at best transform.

This is the second point in our discussion of the agricultural remedy for river pollution, so far as that is due to the influx of town sewage. Sewage filth is "fertilizing matter," and therefore valuable as a manure. Every one is familiar with the idea that the fertility

* Owing to the defective processes of chemical analysis formerly employed in the investigation of water, the effect of irrigation in removing the *dissolved* organic impurities in sewage has hitherto remained unknown. Indeed, as tested by those fallacious processes, the effluent water from irrigated meadows was represented as containing nearly as much organic impurity as the sewage before application, and in some cases actually more. Thus, at page 46 of the Third Report of the Commission appointed to inquire into the best mode of distributing the sewage of towns (1865), the following analytical results (translated into parts per 100,000) are given:—

Average amount of organic matter in solution contained in the sewage and effluent water at the irrigation works, Rugby, in the seasons 1862 and 1863.

Results of analysis expressed in parts per 100,000:—

SEASON 1862. MAY TO OCTOBER, BOTH INCLUSIVE.	Organic matter.	SEASON 1863. NOVEMBER 1862 TO OCTOBER 1863 BOTH INCLUSIVE.	Organic matter
Five-acre field.		*Five-acre field.*	
Raw sewage - - -	11·19	Raw sewage - - -	11·93
Effluent water - -	10·26	Effluent water - -	10·66
Ten-acre field.		*Ten-acre field.*	
Raw sewage - - -	10·86	Raw sewage - - -	11·86
Effluent water - -	11·19	Effluent water - -	10·66
The two fields.		*The two fields.*	
Raw sewage - - -	11·01	Raw sewage - - -	11·89
Effluent water - -	10·80	Effluent water - -	11·04

Upon these results the Commissioners found the following statement (p. 47):—"Of matter in solution, on "the other hand, a gallon of drainage water contained sometimes more and sometimes less, but on the "average much about the same amount, both organic and inorganic as a gallon of the sewage."

There can be no doubt that these results and the statement founded upon them, so far as it relates to organic matter, are erroneous, and that the cause of the fallacy lay chiefly in the absence of nitrates in the raw sewage, and their presence in large quantities in the effluent water. As these nitrates are partially volatile on ignition, the loss of the volatile portion during the analytical determination of organic matter, by burning in contact with air, as formerly practised, would, of necessity, increase the loss of weight, and consequently the apparent quantity of organic matter. Other serious sources of fallacy also attach to these attempts to determine the total *weight* of organic matter in sewage or water.

Part I. Remedies.

"Man" as farm stock.

of a farm depends very much on the quantity of the live stock kept upon it. It is, in fact, an established maxim in agriculture that, apart from the use of imported and manufactured fertilizers, the maintenance of fertility depends very much upon the live stock which the farmer keeps upon the land, and the quantity of manure which he can thus apply to it.

The fertility of the 23,370,502 acres in the hands of English farmers is thus dependent on the 19,821,863 sheep, 3,706,641 cattle, and 1,629,550 pigs which, according to the statistical returns just issued by the Board of Trade,* are kept on English farms; a number which, calculated wholly as sheep,† amounts in food-consuming and therefore manure-producing power to as nearly as possible two sheep per acre over the whole area of the enclosed land in England. Taking 1,141,996 agricultural horses into account, we may say that the whole farm-stock of this country is less than five sheep to every two acres in the hands of English farmers.

We have, however, omitted all reference to another resident animal of the greatest food-consuming power; for whose maintenance indeed all these acres and all this live stock are owned and cultivated. Nearly one-third of the live stock of this country is mankind! In 1869, there were in England 20,658,599 of "man;" and he consumes not only the produce of all these acres, and of all these cattle, sheep, and pigs which are maintained upon them, but imported food as well, to the extent of two-fifths of the estimated quantity of our home-grown wheat, and probably one-twentieth or more in excess of our home-grown meat. A creature of such great powers of consumption ought according to all the analogies to be of corresponding agricultural value as a fertilizer. If, leaving out of consideration the products of respiration, excrement be just the food of an animal *minus* its growth, then on the ground of both these elements of the calculation, man ought to be the very best farm-stock we have. He is not only a much better fed animal than a sheep, but he takes much less out of his food. Bread and beef are better food than grass and turnips; and the growth taken out of these several rations is much less in the former case than in the latter. The population fed on bread and beef does not increase in number, and that is virtually in total weight, more than two per cent. per annum, whereas the "population" fed on grass and turnips increases in weight at least 30 to 50 per cent. within the year. A sheep builds its whole weight of body out of the food of 18 months. The average age of man in England is rather more than 40 years, and the weight of his body at death is all that he has saved out of all the food he has consumed during the whole period of his life. On every ground, therefore, we ought to anticipate the superiority of man to sheep as a manure-producing animal for farm use.

And it is worth while to compare the two species further. So far as England is concerned, although the sheep population varies considerably from year to year, they are upon the whole as nearly as possible alike in number; and in the month of June, when the agricultural returns are made up, and when lambs are not above half grown, they are probably also very nearly alike in weight. The average carcase weight of the sheep sold at Smithfield is barely 80 lbs., which would correspond to a live weight of 140 lbs.; and that may be considered also as the average weight of the adult man. Comparing then their respective rations, their relative wastefulness of food, their weight and number, we might reasonably expect that English men ought at the very least to be as efficient as English sheep in the maintenance of English fertility. But what is the fact? The sheep is the very best live stock known to English agriculture, and man is virtually good for nothing. What would the English farmer do without his flock? Over all the oolitic, chalk, and gravel soils—the light land districts of the country,—to be deprived of the assistance of the sheep would be the ruin of the agriculturist. Man, on the other hand, is, as live stock, we repeat it, virtually useless to him. The excrement of a sheep is worth, at least, five shillings a year to the farmer. In South Lancashire the excrement of man does not realize fivepence per annum individually. The following, extracted from a former table on page 26, shows, as regards the leading towns of which particulars have been given to us, (1) the population—deducting the estimated number using water-closets; (2) the tonnage of manure removed from privies, more than three-fourths of which must be ash and cinder waste; (3), the value annually received for it at the depôt from the farmer; and (4), the value thus received per head of the population annually:—

* The above are the published returns for 1869. In 1868 there were in England 23,038,781 acres returned as occupied; there were 3,779,691 cattle, 20,930,779 sheep, and 1,981,606 pigs,—numbers which calculated wholly as sheep amount to 47,572,137 sheep, corresponding to a very little more than two sheep per acre of the enclosed land in this country. No returns of the horses employed on farms were obtained in 1868. We publish the returns of both years in illustration of the very considerable variations which take place from year to year in the farm live stock of the country, while mankind steadily increases in number every year.

† That is, putting cattle of all ages as equal to six, pigs as equal to two, and horses equal to eight, sheep apiece.

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"Man" as farm stock.

QUANTITY AND VALUE OF TOWN MANURE.

Name of Town.	Population using Privies.	Tons of Manure annually.	Money received.	Value per Head.
			£	d.
Liverpool - - - - -	350,000	138,777	8,000	5·5
Widnes - - - - -	12,000	1,800	150	3·
Salford - - - - -	120,000	38,600	4,000	8·0
Manchester - - - - -	300,000	73,594	6,740	5·4
Bolton - - - - -	75,000	22,465	1,567	5·
Bury - - - - -	29,000	7,000	100	0·8
Oldham - - - - -	77,000	50,000	2,000	6·2
Ashton under Lyne - - - -	37,000	6,637	95	3·2
Southport - - - - -	15,000	9,000	740	8.3
Total - -	1,015,000	347,873	23,392	5·5

The sum of 23,392*l.*, which is here quoted as representing the money value of all the house waste of about 1,000,000 people, is indeed all that is received from 1,236,000, that number being the whole population of the towns named, and that sum being all that is received for what the scavenger collects; so that the annual value individually of man as farm stock in Lancashire may be put down as less than 4½*d.*; and this supposes the ash and cinder waste with which the excrement is mixed to have no share in the valuation.

If, indeed, in place of taking all England as our field, we thus confine ourselves to the *Mersey* basin, the agricultural worthlessness of the immense stock of man here "folded on the land" becomes a perfect scandal. The area of the district whose drainage runs past Liverpool is 1,103,520 acres, of which, according to the proportion between the total and the occupied acres of Cheshire and Lancashire given in the agricultural returns, we may suppose that 685,000 acres are in the hands of farmers. The whole farm stock (excluding horses) of this district counts, upon the data already quoted, as 1,750,000 sheep, equal to rather more than 2½ sheep per acre,—considerably above the average farm stock of England. The population, on the other hand, was in 1861, 2,307,788, and in 1868, according to the experience of its growth during the last 30 years, it must have been 2,650,000, one-half more than the actual farm stock of the district.

One-eighth of the population of England is congregated here; one-eighth of the food produced in England or imported to it is here consumed. The growth waste of all that population, the débris of all that consumption, which ought to fertilize the land, go to pollute the river. Nowhere is fertility more wanted, nowhere is pollution more injurious: nowhere, it may be safely said, is the contrast between the means of fertility and their result so shameful.

Three hundred and forty thousand tons of dirty ashes are carried out from a population of one and a quarter million, living in the nine towns mentioned in our table. If all the houses in the river basin are equally productive with those of Liverpool and Manchester, there must be nearly 600,000 tons produced within the area, equal to a dressing of manure over probably about 20,000 acres, less than one-thirtieth of the acreage occupied by the farmers of the district. No doubt the general fertility is to some extent benefited by this contribution from the towns, though, as it is used chiefly in potato cultivation, its produce is sold off the farms, and adds but little, therefore, to their permanent fertility; but the result, even on the most liberal estimate, is ridiculously small when contrasted with what all the agricultural analogies would lead us to expect. The existing plan of scavenging is, in fact, an utter failure agriculturally. That which is the especial opprobrium of the water-closet system is almost equally true of the privy and the ashpit. Not one-seventh of the excrement of man is carried to the field: the liquid part drains directly to the sewer or sops the land on which the houses stand; and even the solid part, mixed with the ash waste with which it is carried to the manure depôt, first receives a washing which soaks most of its valuable part away. And all this is permitted, and indeed defended, in a district containing thousands of acres of waste moss land and peat bog on its lower levels, large tracts of second-rate pasture land below the level of many of its towns, and abundance of poor land higher up, all of which would well repay the application of manure.

We have not been travelling out of our record in thus referring to the possible agricultural value of town waste, for nothing will more hasten the adoption of irrigation as the most efficient cleanser of town sewage than a belief in its powers to fertilize the land. Instead, however, of any further discussion of the probabilities of this subject, we shall now describe those places where sewage has been actually turned to agricultural account.

PART I. REMEDIES.

Sewage irrigation at Edinburgh.

EXAMPLES OF SEWAGE IRRIGATION.

1. The sewage meadows near Edinburgh. These have long been quoted as an example of the largest produce known to agriculture, yielding grass of a somewhat coarse and "washy" character, but perfectly well adapted for cow food. These meadows cannot, however, be named as a good example of the agricultural remedy for the nuisance created by town sewage; for it is poured over them in such enormous quantity that the soil has not fair play given to it as a cleanser, and the water therefore leaves the grass land still filthy and offensive. Even here, however, we have a remarkable illustration of the purifying power of soil and plant. Thus, on April 16th, 1869, when the early crop of grass was being cut, and the meadow land was in full spring growth, three samples of the sewage were taken, No. 1 being of the water in the *Foul Burn*, as it poured, probably 700 tons an hour, over plot No. 11 on the map of the Craigentinny Estate. No. 2 was taken at the foot of this same bed, the water having poured at that rate in half an hour over less than an acre of land. No. 3 was taken at the foot of beds Nos. 45 and 46, the tail water of No. 11 which poured on at their head having in the meantime taken about an hour to traverse one and a half acres of land. This sample represents the water of the *Foul Burn* as it flowed into the sea. It was not by any means clean, but how much of its filth had been removed during irrigation by the action, for an hour and a half, of two and a half acres of land on many hundred tons of very foul sewage is plain from the following table:—

RAW AND EFFLUENT SEWAGE, EDINBURGH.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Date and Number of Sample.	Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrates.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
No. 1, April 16/69 -	62·20	6·106	3·613	9·510	0	11·445	11·32	28·08	39·40
„ 2 „ „ -	65·50	4·797	2·086	10·579	0	10·798	9·76	16·64	26·40
„ 3 „ „ -	51·60	3·340	·682	1·989	0	2·320	1·28	4·24	5·52
No. 4, April 17/69 -	55·00	5·061	2·842	7·865	0	9·319	28·72	29·88	58·60
„ 5 „ „ -	54·80	4·061	1·988	3·100	0	4·541	5·56	7·40	12·96

On the following day, after a night's rain, when the sewage therefore was more dilute, a sample, No. 4 in the above table, was taken from the *Foul Burn* at Lochend just as it left the pumps, at the rate of about 20 tons an hour, pouring over a plot of Italian ryegrass, 40 yards wide and 44 yards down the slope. It was taking about an hour to traverse this plot of one-third of an acre. A second sample, No. 5 in the above table, was taken at the foot of this plot. The composition of these samples is given above; and comparing No. 1 with No. 3, and No. 4 with No. 5, the cleansing agency of the soil, however incomplete, is very apparent. In point of fact more than three-fourths of the whole filth soluble and suspended was taken out of the water of the *Foul Burn* by one hour and a half of irrigation in the first case, and nearly two-thirds of the filth in 20 tons of sewage was taken out of it in the latter case, by irrigation over about one-third part of an acre of the light sandy soil of the Lochend Farm.

The Edinburgh experience, however, is rather one of agricultural profit from the use of sewage, than of that perfect abatement of its waste and nuisance, which, in the interest of rivers, we desire to see. This arises from the enormous quantity of the sewer water and the small area of land on which it is used. At Lochend and Craigentinny on the north and east of Edinburgh, about 230 acres receive the whole drainage of 80,000 people, being at the rate of 350 people per acre. At Grange on the south side of the city, 16 acres get the drainage of a comparatively small number. At Dalry, on the west, 60 acres or thereabouts receive a very large quantity of filthy sewage, which they are unable perfectly to clean; and there are one or two plots similarly treated on the road to Leith. Here, however, altogether are only 400 acres, whereas the population whose drainage they receive must largely exceed 100,000 and it is not therefore surprising that the drainage water leaves the land by no means perfectly cleansed.

The *Foul Burn* which waters the Craigentinny meadows passes first through Lochend farm, where about 20 acres of permanent grass and eight acres of Italian ryegrass receive as much of it as the tenant chooses to apply. The quantity is, probably, often as much as 10,000 or 15,000 tons per acre during the growing season, besides an indefinite quantity during winter; and of course a very small proportion of the filth which it brings down from Edinburgh is deposited here. The stream flows on in almost undiminished foulness to the meadows lower down. In addition to the 20 acres of permanent grass land there are 12 acres arable at Lochend (of which eight acres are every year in first and second year's Italian ryegrass) commanded by a self-acting pumping apparatus. A water-wheel, driven by the stream, works a four-fold pump, delivering, when in perfect order, about 1,000 cubic feet per hour, a quantity which, as it works night and day during eight months of the year, corresponds to nearly 20,000 tons, or, even assuming that only half duty is accomplished, to 10,000 tons per acre. In either case it is plain that an enormous quantity is applied—much beyond the needs of the largest possible crop of grass.

PART I. REMEDIES.

Sewage irrigation at Edinburgh.

The grass of Lochend meadows has averaged, during nine of the spring sales at which it is disposed of by auction, 27*l.* 12*s.* 2*d.* per statute acre. During the past year the highest price attained was 41*l.* 17*s.* 6*d.* per acre; and from that down to 19*l.* an acre has been realized. The Italian ryegrass on the same farm has varied in price from 32*l.* an acre for the first year's cuttings to 25*l.* an acre for the second year's cuttings.

Leaving Lochend the *Foul Burn* pursues its course to the sea on the Portobello side of Leith; but it has for many years been diverted, right and left, to a considerable distance from the original watercourse, and a fan-shaped farm of more than 200 acres, widening out as it gets near the coast, has been thus laid out for irrigation at a cost of about 5,000*l.* This Craigentinny farm includes within its limits land of excellent natural fertility, but it terminates at its lower end in a wide belt of sheer sea sand, which though now equal in its annual produce to any of the originally superior plots, old men still remember as a barren shore. There is here too a portion of higher land of excellent natural quality watered by a pump, in this instance driven by steam power. The area this year watered thus is eight acres, and as the engine is driven only 300 hours during the six or eight dressings which this land annually receives, the pump, delivering from 60 to 80 tons an hour, does not distribute more than 3,000 tons per acre annually, a quantity which at 1*d.* per ton, if ordinary sewage be taken to be worth so much, many ordinary agricultural crops would easily repay. These eight acres of Italian ryegrass have been sold during the past year at from 25*l.* to 36*l.* an acre,—prices equal to those obtained at Lochend where four times the quantity of sewage is applied. It would seem therefore, that the enormous surplusage of foul water used at the latter place fails to be of any agricultural service.

In the lower Craigentinny meadows 190 acres receive probably nine-tenths of the *Foul Burn*, and, a night and day waterman being constantly employed in its distribution, it flows constantly over one plot after another; a single dressing of five or six hours being given between the several cuttings of grass to each of the 250 plots, or thereabouts, into which the whole area is divided. The summer's grass of these beds, varying from two to five roods each, is sold by auction to the Leith and Edinburgh cowkeepers every spring, and the maximum value reached last year was 36*l.* 15*s.* per statute acre. The quantity of grass for which such prices are obtained is believed to vary from 50 to 70 tons per acre. And as the means are perfected of distributing the sewage more evenly, and as the subsoil drainage of the land improves, the quantity and price are both increasing year by year. No exhaustion is apparent anywhere. The sewage brings down more than the plants require of every necessary constituent of their food, so that even the poor sea sand is as fertile as the rest, and the land is getting richer year by year, notwithstanding the enormous crops it yields. Taking the average price of the whole 240 acres to be 24*l.* an acre, we have a total annual produce of 5,760*l.* a year extracted by the land and grass from the drainage of 80,000 people, or 1*s.* 5*d.* from each person annually—certainly not $\frac{1}{2}$*d.* a ton over the enormous quantity of sewage which is here applied.

But the area is not sufficient to take up the whole of the filth brought down by the water. A much larger extent of crop could be obtained from the use of it if there were any land convenient on which it could be applied, or if there were a sufficient demand for the produce of it. The Edinburgh experience, therefore, must be quoted not as a successful example of sewage cleansed by irrigation, but rather as an instance of the largest produce raised by means of it from a limited area of land.

2. Lodge Farm, near Barking.—We turn now to an example of another kind where the supply of sewage is limited and where the object has been, from this limited supply, by means of an ample extent of land, to obtain the largest annual produce. Neither at Edinburgh nor at the farm near Barking in the occupation of the Metropolis

PART I. REMEDIES.

Sewage irrigation at Barking.

Sewage Company has the sanitary result or the purity of the water been the object aimed at. In the latter case, however, it has incidentally been secured. The object having been to obtain by agricultural use the largest return from the sewage used, it became necessary to make it as clean as possible before letting it go. At Lodge Farm near Barking the Metropolis Sewage Company in 1866 took about 200 acres, for the most part a light gravelly soil, (an analysis of which is given at page 67), for the purpose of illustrating thereon the value of North London Sewage of which they hold the concession for a term of years. The land has been accordingly laid out in beds varying from 50 to 150 feet in width with a central carrier down the middle of each, and having a slope from this carrier on either side, down which the sewage trickles to a midway furrow. The carriers are, as nearly as the general slope of the land allows, horizontal; the slope on either side varying from 1 in 20 to 1 in 60. The sewage is pumped from the outfall on the Thames near Barking through a 15-inch pipe to a reservoir on the highest part of the farm, and from that it is conducted in open ditches to the ridge-line carriers of these lands. These carriers, being stopped at intervals by the spade of the waterman, overflow; and the sewage, passing over and through the soil to the furrows, is by them conveyed to the lower slopes of the farm, over which it is distributed until it either sinks altogether into the land or flows finally off the surface at the foot of the farm. The soil is too pervious and has too hollow and open a subsoil to permit the water to travel far upon the surface, so that after 50 yards at most of surface flow it sinks to reappear only at the mouth of the main drain of the farm; which, nearly dry in ordinary weather, pours a full flow within an hour or two of the sewage being applied to the fields. Samples of water taken here represent therefore properly enough the effect of soil and plant upon the London sewage under such circumstances as the Lodge farm supplies. The following table gives the composition of successive series of samples taken (1) at the carrier, (2) after 50 or 60 yards of surface flow, (3) after a further surface flow; and (*a*) at the foot of the farm where the main drain pours it into a stream.

RAW AND EFFLUENT SEWAGE, LODGE FARM, BARKING.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Date and Number of Sample.	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Suspended Matters.		
							Mineral.	Organic.	Total.
* 1. April 22, 1868 - -	112·50	12·182	3·664	4·000	0	6·958	—	—	—
* 2. „ „ - -	90·55	4·331	1·872	2·250	·026	3·751	—	—	—
* 3. „ „ - -	91·75	2·768	·624	2·500	·032	2·715	—	—	—
* *a*. „ „ - -	79·25	1·366	·329	·800	2·955	3·943	—	—	—
1. June 23rd, 1869 - -	65·30	2·596	1·715	4·000	0	5·009	18·48	27·80	46·28
2. „ „ - -	74·30	2·028	1·285	2·437	·693	3·985	3·06	3·40	6·46
a. „ „ - -	79·50	·887	·236	·425	2·535	3·121	trace.	trace.	trace.

Comparing 1, 2, 3, with (*a*) in the first, and 1, 2, with (*a*) in the second of these examples, we observe the cleansing effect of land and soil in two separate instances, in both of which about 2,000 tons of sewage passed in the course of nine or ten hours over five or six acres of land; but in neither of them had the sample received more than an hour's treatment from soil and plant together. The soil of the farm is indeed too hollow and porous to allow the most to be made of the manure. Sinking away even in the channels which carry it from the reservoir, much of the sewage is wasted before it reaches the plant; and the remainder which trickles over the surface of the grass remains there too short a time for the entire extraction of the fertilizing matter which it conveys.

It will be seen, however, that the effluent waters marked (*a*) in the two series of trials were to a great extent purified.

Turning now to the produce of the sewage, here considered not as a nuisance but as a valuable manure, it appears that 300,430 tons were, in 1867, used over 56 acres of land, and 2,480 tons of Italian ryegrass were cut off that area. Of the sewage, however, no

* In this series of samples the suspended matters were not separated, but the liquids, just as collected, were submitted to analysis.

PART I. REMEDIES.

Sewage irrigation at Barking.

doubt a great deal was lost in the channels and on the land in first starting the process; and, as regards the grass, we are informed that a large proportion was killed by the unusual frost of January 1867, only 13 acres, in fact, of the whole extent having been in full bearing; and these yielded 62 tons of grass per acre. It appears, therefore, upon the whole experience, that for every 100 tons of sewage applied one ton of grass per acre was obtained over and above the natural produce of the soil and climate. In 1868 and 1869 experiments over a considerable extent of land have been made with other crops than grass, to which alone, or to equally succulent growths, so dilute a manure as sewage appears at first sight to be adapted. A field of 13 acres of poor gravel that was in wheat in 1867, yielding then about $3\frac{1}{2}$ quarters per acre, was sown in 1868 in the following manner:—$4\frac{3}{4}$ acres with wheat early in November, $2\frac{1}{4}$ acres with winter oats, 4 acres with rye, and 2 acres were planted with cabbages in October, which were taken off in March, and mangold sown in their place. The wheat was twice flooded with sewage, in March and in April, 450 to 500 tons to the acre being applied in the two dressings. The crop produced $5\frac{1}{2}$ quarters, and three loads of straw to the acre. The winter oats were three times flooded in March and in April, over the whole, and over a part in June, receiving in all about 500 tons to the acre. These oats yielded eight quarters of corn, with three loads of straw per acre. The rye was flooded twice, in March and in Aprii, in all with about 450 to 500 tons per acre; it was cut in July, and thrashed in the field, yielding six quarters, with three loads of straw.

If it be urged that in such an unusually dry season as 1868, good results would necessarily follow irrigation with town sewage, it must be remembered that although these crops no doubt benefited in common with those of the whole country, by the lengthened fine weather, the soil is a dry burning gravel, and no sewage was applied to either wheat or rye after the month of April, up to which time there was the ordinary amount of wet weather, without any unusual heat. The same field has been again in wheat and oats and barley and the experience of 1869 with a cold May and June equally with that of the hot and dry season of the previous year bears ample testimony to the power of sewage upon this soil as a manure for corn crops. The wheat has yielded 4 quarters per acre, the winter oats no less than 11 quarters per acre, the barley ripening unkindly only $4\frac{1}{2}$ quarters per acre; but it must be remembered in all these cases that the field, naturally a poor gravelly soil, was then yielding its third successive grain crop. Most satisfactory results also continue to be reported last year* from Lodge Farm in the cultivation of potatoes, cabbages, beet, mangold-wurzel, and other green crops. The Lodge farm experience, confining it to its growth of grass, may be said to represent a return of 5*s*. annually from every individual contributing to the sewage used upon it. Supposing the water supply to be over 30 gallons a head, each person will make 50 tons of sewage annually, corresponding to the production of 10 cwt. of grass, worth 10*s*. a ton.

The experience here, combined with the tabular statement, page 76, of the analyses of the clear effluent water, pouring from the farm into the neighbouring brook, is sufficiently encouraging for those who are interested in the cleanliness of both town and river.

We turn now to a large number of instances of irrigation where the object has been not only to make a profit but to abate a nuisance. Such are the cases of Aldershot, Banbury, Bedford, Croydon, Norwood, Rugby, Warwick, and Worthing.

3. Aldershot Farm.—The case of Aldershot may be placed first upon the list, because here land has been taken for irrigation, not by the authorities, but by a tenant who, bound no doubt to cleanse the sewage of the camp, yet has for his principal object the extraction of a profit from its use, so that he comes more nearly under the same class with the example last named. Mr. Blackburn here receives the drainage of the North and South camps, *i.e.* of a population which is fairly represented by a constant number of 7,000 adults. During winter the drainage of this population, amounting to about 700 tons a day throughout the year, is poured in succession over the several fields of the farm, 80 acres in all, one half being in one and two years old Italian ryegrass, and the other half growing crops of potatoes, mangel-wurzel, cabbages, &c. During the summer the crops upon the arable half take but little of the drainage of the camp, and it is then poured almost exclusively over the Italian ryegrass land. The soil is the poor sand of the Aldershot waste (consisting of almost pure silica), prepared at considerable expense by levelling and deep grubbing, so as both to provide a uniform slope over which the water may flow evenly, and to remove the ferruginous "pan" which everywhere underlies the soil and would hinder the even distribution of fertilizing matter downwards. A few deep drains serve to draw off the water which sinks beneath the surface.

* Notes upon the Sewage Cultivation of Lodge Farm, Barking, by the Hon. H. W. Petre—(Effingham Wilson, Royal Exchange).

PART I. REMEDIES.

Sewage irrigation at Aldershot.

The first set of samples A. taken in the afternoon of July 16th 1869 were;—(1) from the reservoir into which the camp drainage flows;—(2) from the lower carrier or surface drain of a plot of about an acre in extent over a width of 50 yards of which it had slowly trickled amidst a growing crop of ryegrass; and—(3) from the mouth of a drain, the only effluent water from the farm. The sewage was unusually offensive at the time, and the effluent water was apparently clear. The difference of composition indicated by the analyses shows that while the water (1) just poured on had, in its first passage over a surface already richly manured, apparently dissolved and carried with it some of the stuff left by a previous dressing, so that after its 50 yards of passage the sample (2) exhibited in its composition an even larger quantity of filthy matter in solution, yet in the end, and after passing through the land, the organic nitrogen and ammonia as shown in sample 3 had to a large extent disappeared.

RAW AND EFFLUENT SEWAGE.—ALDERSHOT FARM.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

—		Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
A.	1. July 16/69	46·6	5·878	2·052	0	9·025	9·484	9·45	6·72	14·28	21·00
	2. „ -	47·4	7·936	3·053	0	8·267	9·861	9·00	1·76	6·84	8·60
	3. „ -	18·6	·665	·132	1·152	·486	1·684	3·55	·68	·66	1·34
B.	1. May 1/68	93·40	16·335	2·694	·0	13·054	13·444	—	5·30	17·90	23·20
	2. „ -	39·00	·504	·129	1·312	·622	1·953	—	·38	·02	·40

The set of samples marked B. in the above table were taken on May 1st 1868. No. 1 was raw sewage as it passed upon the land, and No. 2 was effluent water from the drain; they indicate an immense reduction in the quantity of all the dissolved polluting materials in sewage by the process of irrigation. The organic carbon was reduced from 16·3 to ·5; and the organic nitrogen from 2·7 to ·1 in 100,000 parts. The above figures show, however, that the whole of this amelioration must not be attributed to the purifying action of the soil and crop, for the solid matters in solution in both series, and the chlorine in series A., point unmistakeably to the admixture of the effluent water with about double its volume of unpolluted spring or subsoil water. All that can be safely inferred from the above analytical results is, that in the series A. the organic impurities, soluble and insoluble, were reduced to less than one-fifth, and in series B. to one-eighteenth—the original sewage in the latter case being much stronger than in the former. Even after this deduction has been made from the observed effect, the result is a very satisfactory one.

In this case the extreme natural poverty of the soil does not seem to have been a hindrance to the efficiency of the process of cleansing by irrigation. The farm, well managed, is covered with a capital plant of vigorous growth, to be fed by the filthy water, which accordingly is greatly purified by the process. Mr. Blackburn lets portions of his land to neighbouring cowkeepers, at 20*l.* an acre; and here the grass, cut in regular rotation, was in the heat of July, when everything was withered and burned up around it, a perfect oasis of luxuriant green, yielding annually its four or five crops of eight to ten tons apiece per acre. The Aldershot farm appears the more satisfactory as an example of the sewage nuisance abated, at the same time that its filthy contents are converted into valuable produce, from the circumstance that a previous attempt to deal with it by subsidence and filtration tanks had been a complete failure.

Supposing 40 acres here to yield 20*l.* an acre, and other 40 acres to owe one-half of their crops, or 10*l.* an acre, to the winter sewaging, we have here a return of 1,200*l.* from the waste of 7,000 adults, or 3*s.* 4*d.* per head per annum.

4. Carlisle.—The sewage of Carlisle finds its way, for the most part, into the *Eden* through the main sewer beneath the alluvial pasture land bordering the river. It is delivered in the middle of the river channel through a submerged iron pipe. On the town side of the meadow a pumping station has been erected by Mr. McDougal, to whom the land (about 100 acres) is let; and a quantity is thus lifted, deodorized by treatment with carbolic acid, and distributed over the land by means of light portable iron troughs. These are shifted from place to place by the man in charge, and in this way

PART I. REMEDIES.

Sewage irrigation at Carlisle and Penrith.

the sewage pours on at one place after another, distributing itself with more or less regularity according to the natural surface of the land which has not been levelled, —flowing here, ponding there, soaking everywhere. There is an obvious increase in this way to the natural fertility of the land; and a larger quantity of stock is kept upon it than it would naturally maintain. There is no surface drainage from the land to the river, and our sample for analysis was taken by digging a hole three feet deep close to where the sewage had been lying on the previous day, and taking the water to which we at length came.

RAW AND PURIFIED SEWAGE.—CARLISLE.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 23, 1868 - -	44·9	2·673	·505	1·912	0	2·080	—	5·24	4·64	9·88
Water from hole dug in irrigated meadow, Sept. 23, 1868.	28·8	·591	·204	·025	0	·225	3·18	0	0	0

As there is properly speaking no effluent water from this meadow, the whole of the sewage applied being absorbed by the sandy soil and there being no drain outlet, the result is not quite so trustworthy as in other cases; nevertheless we may fairly conclude from it that the soakage from the irrigated land into the neighbouring river is effectually purified.

5. Penrith.—Here the drainage of a town of 8,000 people, only partly provided with water-closets, is received on 80 acres of good meadow land near the *Eamont.* A little more has been done here than at Carlisle to distribute the water by means of permanent carriers; but the treatment is otherwise the same, and the result is very similar. A very large stock of cattle and sheep is kept upon the land to graze down the abundant growth of grass which is obtained.

RAW AND EFFLUENT SEWAGE.—PENRITH.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Raw sewage, Sept. 24, 1868 - -	53·5	5·111	1·899	10·395	0	10·460	—	5·88	11·88	17·76
Effluent water from drain as it enters the *Eamont*, Sept. 24, 1868.	21·9	·320	·108	·001	0	·109	2·68	0	0	0

Here, as at Carlisle, the whole of the sewage is absorbed into a porous sandy soil, but the drain passing beneath the irrigated land and alluded to in the table, pours out a considerable and clear stream into the *Eamont*, and from this the sample of effluent water whose analysis is given was taken. The comparatively small proportions of solid matters in solution, and especially of chlorine in the effluent water, point to the admixture of unpolluted subsoil water with the true effluent sewage, and the figures in the above table indicate that no less than three volumes of this pure subsoil water mingled with one volume of real effluent sewage. But even after making this deduction from the purifying effect of the irrigation the result is still satisfactory. The whole of the suspended impurity was removed whilst a reduction of the organic matter in solution was effected to the extent of 75 per cent. of organic carbon and 77·2 per cent. of organic nitrogen.

6. Rugby. At Rugby, a town of more than 8,000 inhabitants, the Board of Health have taken a lease of 65 acres of land for a term of 31 years, at a rental which, with rates and taxes, amounts to 4*l.* 10*s.* per acre; and, confident in the powers of their somewhat gravelly soil (lying upon a clay subsoil) to cleanse their town drainage, and to convert it into valuable produce, they have laid out nearly 5,000*l.* on the works required for the

PART I. REMEDIES.

Sewage irrigation at Rugby and Banbury.

distribution of the sewage water over it. An intercepting sewer takes the drainage of all the upper part of the town by natural gravitation to the top of the farm; and, by a deep and costly tunnel drain, the waste of all the lower part of the town is made to flow (along with the tail water of the upper fields) over about 16 acres of the lower part of the farm.

The quantity of sewage at command is about 900 tons a day, or nearly 4,000 tons per annum for every acre of the farm. The land has been in hand for only one year, and much of it was sown with Italian ryegrass for the first time in the spring of 1869, so that the best results can hardly have been yet realized. The third and fourth cuttings (both heavy crops) were, however, ready in the following month of July, and a sale was being obtained for the grass at 8*s.* a ton upon the land. A considerable portion had been let at 10*l.* an acre; and the 16 acres at the lower end of the farm had supported throughout the spring and summer 54 head of cattle, consuming at least four tons of its grass produce daily; and a considerable extent of the crop on these 16 acres had been made into hay. In illustration of the cleansing power of land and plant at Rugby, three samples taken about mid-day, July 13, have been analysed; No. 1 was raw sewage taken from the hydrant as it poured over the top of the farm; No. 2 was the same sewage taken at the foot of $1\frac{1}{3}$ acre of land in Italian ryegrass over which it had passed 150 yards down the slope. Thence it flowed along a surface channel about 300 yards to another acre of Italian ryegrass; and No. 3 was taken at the foot of this grass plot about 80 yards from the carrier which supplied it. The following table gives the results:—

RAW AND EFFLUENT SEWAGE.—RUGBY.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Rugby Samples.	Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 13/69 -	52·60	5·505	2·322	·000	7·276	8·314	8·25	3·48	8·96	12·44
2. „ -	55·70	2·547	·506	·000	2·772	2·789	10·20	·72	·28	1·00
3. „ -	68·20	1·526	.164	·000	·420	·510	10·50	·88	·36	1·24

Here then is a case in which the nuisance of the sewage is entirely abated, and so much produce realized as to make it probable that the remedy, which has been here an expensive one, will yet prove profitable.

The following account of the experience of 1869 at this place has been communicated to us by Mr. T. M. Wratislaw, Clerk of the Local Board of Health:—

"The gross produce of the sewage farm, for the year ending 31st December, has been 544*l.* 16*s.* 8*d.* The total expenses, so far as the payments (including wages for the year) have been made, stand at 458*l.* 8*s.* 5*d.*, and I do not apprehend much addition."

"I am not aware of the actual number of persons contributing to the sewage utilized, but should estimate 7,800."

7. Banbury. A population of about 11,000 people here drain into tanks, from which, through a 12-inch pipe, the sewage is driven by steam power a mile or more to the upper end of a farm of 136 acres, a lease of which has been taken for 21 years, at a rent of 4*l.* 10*s.* per acre. The quantity thus applied amounts to about 300,000 gallons a day, or about 4,000 tons per acre per annum over that part of the farm which is under irrigation. The sewage settles to some extent in the tanks from which the pump lifts it, and both mud and scum are here taken from it, and mixed with the street sweepings and other scavenging refuse of the town; and 2,000 tons of this compost were sold last year, for which a sum of about 100*l.* was received at the depôt, the material being loaded by the purchaser into barges on the canal close by. The liquid part, delivered on the highest part of the farm, having about 17 feet of fall before it reaches the river *Cherwell*, flows twice or thrice over successive fields before it is finally dismissed, and the extreme filthiness of the river formerly complained of is now satisfactorily abated.

The following samples illustrate the cleansing process which the sewage thus undergoes. The series A. was taken at our visit to Banbury on October 17th, 1868; No. 1 being the sewage which had accumulated in the pumping well from 10 a.m. to 2 p.m., and No. 2 the effluent water as it left the meadows at 1 p.m. The series B. was collected on July 14th, 1869. No. 1 was taken at 10 a.m. and at noon, being raw sewage taken partly

PART I. REMEDIES.

Sewage irrigation at Banbury.

from the upper carrier on the farm and partly from the pump well. No. 2 was the water after it had passed over 200 yards in length, and four acres in extent of a field of Italian ryegrass, at the rate of, probably, 70 tons an hour. No. 3 was taken after this tail water had travelled half a mile in an open carrier, and then distributed itself over a flat meadow of permanent grass land. It was passing from the underground drain of the field in question, and represents the sewage as it reached the river. The farm is for the most part a very stiff soil, and the greater part of it is still in old grass land, and neither circumstance is favourable to its efficiency; the former because the soil tends to crack in dry weather, thus giving the sewage direct access to underground drains, and thence to the river before it has been properly acted upon by the soil; and the latter because the surface of the land not being specially and evenly laid out for irrigation, the water tends to collect in shallow ponds or puddles, to the injury of the produce, without being itself materially cleansed. The accounts given of the produce of the land are satisfactory, and it is believed that the farm will soon repay rent, and costs, and loan, so that the nuisance hitherto created by the town will be ultimately abated without any serious permanent charge upon the inhabitants.

The produce of Italian ryegrass and of the meadow land is sold by auction as the successive cuttings are ready for the scythe; and prices varying from 3*l.* to 5*l.* an acre have been obtained per cutting. The following are the results of our analyses:—

RAW AND EFFLUENT SEWAGE.—BANBURY.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Banbury Samples.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
A. 1. Oct. 17/68 -	111·5	6·246	2·764	·000	13·590	13·956	—	3·90	8·62	12·52
A. 2. - - -	70·9	2·241	·549	·000	2·282	2·428	13·25	·52	·84	1·36
B. 1. July 14/69	92·4	8·269	2·386	·000	6·702	7·905	8·75	9·56	20·12	29·68
B. 2. - - -	66.5	2·670	1·127	·000	3·112	3·690	6.75	1·68	3·84	5·52
B. 3. - - -	51·8	1·008	·207	·668	·725	1·472	5·50	·94	·80	1·74

The Banbury sewage, owing to a deficient water supply, is sometimes much above the average strength, and consequently its efficient cleansing is then a more difficult operation; nevertheless the above results are by no means unsatisfactory; and they are improving, both as regards the cleanness of the effluent water and the returns from the use of it.

The following account of receipts and expenses, in respect of the sewage farm here, for the year ending Lady Day 1869, has been supplied to us by Mr. T. Pain, the Town Clerk.

Receipts.

	£	s.	d.
Amount realized from sale of rye grass - - - - -	561	16	6
„ „ mowing grass - - - - -	347	18	2
„ „ oats - - - - -	198	0	0
„ „ aftermath - - - - -	166	11	8
Right of shooting over farm, and sundries - - - - -	6	1	6
	1,280	7	10

Payments.

	£	s.	d.	£	s.	d.
Mr. Tomline, a year's rent less property tax -	605	3	1			
Rates and taxes for the year - - - -	57	4	7			
Coals for engine - - - - -	111	16	0			
Labour expended in cultivation of farm - -	216	2	0			
Seeds, implements, &c. - - - - -	82	0	6			
Manager's salary - - - - - -	45	0	0			
Auctioneer's expenses of sale, including commission -	73	6	11			
				1,190	13	1
Profit on farm - -				89	14	9
Instalment of principal and interest in respect of loan of 4,000*l.* borrowed to carry out the irrigation work - - - - -				250	0	0

PART I. REMEDIES.

Sewage irrigation at Warwick and Worthing.

The produce of the summer of 1869, when we were over the farm, bid fair to at least maintain the satisfactory character of the account on the previous page.

8. Warwick, a town of 11,000 inhabitants, occupying 2,400 houses of which upwards of 2,000 are connected with the sewers, has lately poured its sewage over a clay-land farm of 100 acres about a mile away. The quantity thus pumped, and which formerly fouled the *Avon*, amounts to about 600,000 gallons a day, double the water supply of the town, or nearly 1,000,000 tons a year, corresponding to 10,000 tons per acre annually. A large quantity of very dilute drainage water thus flows over a very stiff and therefore less appropriate soil. What the result is, as regards its cleansing powers, appears from the following analyses:—No. 1 is a sample of raw sewage taken from the receiving tank by the pump at 4 p.m. on July 14th, 1869. No. 2 is the sewage after flowing over seven acres of recently cut Italian ryegrass taken at the foot of a field of red clay soil down which it had flowed probably 200 yards at the rate of 80 or 100 tons an hour. No. 3 is the same water after a second cleansing over three acres of Italian ryegrass in a field of similar soil. The results here may be taken to represent the powers of plant growth and of mere surface action of clay soil, for none of the water apparently had sunk into the land or been absorbed. Here the filth in about 150 tons of dilute sewage had been satisfactorily reduced by probably two hours irrigation treatment, under what must be pronounced unfavourable circumstances. Moreover the sewage, and consequently the residual impurities had obviously undergone concentration by evaporation, as is seen from the continuous increase of chlorine in the successive samples.

RAW AND EFFLUENT SEWAGE.—WARWICK.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

—	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 14/69 -	66·90	5·133	1·680	·000	2·439	3·689	6·30	2·64	3·36	6·00
2. - - -	69·70	2·727	·575	·000	1·705	1·979	7·70	3·30	·78	4·08
3. - - -	66·10	1·454	·175	·137	·839	1·003	8·15	Trace.	Trace.	Trace.

The farm has been in hand for two years. Pumping commenced only in the autumn of 1868, and it was not continuously carried on until the following year. This, together with the difficulty which the low and flat part of the farm presents to the proper drainage from it of so large a quantity of water, has hitherto delayed the satisfactory financial result which is looked for. Nevertheless the nuisance is sufficiently abated, and large crops of Italian ryegrass have been obtained, for which a ready sale at 10*s.* and 12*s.* a ton upon the ground has latterly been obtained. The farm must, we understand, pay at least 1,600*l.* a year to replace the costs which the town has already incurred and still bears in respect of rent, pumping, and works.

9. Worthing, containing about 8,000 inhabitants, has hitherto fouled a stream running into the sea two miles to the eastward of it. The town drainage now runs to a tank from which it may flow as heretofore, and still does run during the night, so that a good deal of very offensive filth even now lodges in the bed of the stream. During the day it is pumped and flows upon the land of the Worthing Land Improvement Company, who have about 100 acres on which to receive it. The soil is a good free loam perfectly well adapted for their purpose, and the natural slopes are quite sufficient for the easy distribution of the water. There are on the lower part of the farm upwards of 40 acres of an alluvial flat of natural grass on which the effluent drainage of the higher arable land is received before it leaves the farm. Mr. W. Hugh Dennett, Solicitor to the Worthing Land Improvement Company, has communicated to us the following account of the gross receipts and working expenses of the sewage farm for the year 1869:—

	£	s.	d.
Receipts - - - - -	1,807	4	9
Expenses - - - - -	1,045	6	9
Balance -	761	18	0

PART I. REMEDIES.

Sewage irrigation at Worthing and Bedford.

In the above expenditure is included a sum of 51*l.* 13*s.* 11*d.* for a "Level" rate, made for the protection of various lands from the encroachments of the sea, which is a special and not an ordinary parochial rate. There is also included a sum of 50*l.* for the rent of 8½ acres of the land referred to and comprised in the area stated below. A steam engine on the farm was used for about three months at a cost of about 25*l.*

The population of Worthing is about 7,600.

The engineer reports that the average volume of sewage pumped each day of 24 hours to the farm is about 480,000 gallons (of which about 130,000 gallons are spring or surface water). In addition to this, about 80,000 gallons of water per day flow into the *Teville* stream.

The extent over which the sewage flows is about 83 acres.

The whole farm consists of about 96 acres, a portion of which is not sewaged; 42 acres are pasture land.

I cannot say that the pollution has altogether ceased, because although it is stated that the 80,000 gallons of sewage flowing into the stream per day is top water, yet it flows from the sewage well, and must be necessarily polluted with sewage. However, the actual pumping of the sewage into the stream ceased some months ago, and the communication has been removed. The Local Board of Health have also cleansed the stream, and there is reason to believe that all the sewage pumped goes upon the land, though materially diluted by spring and surface water.

Our samples of the Worthing sewage were taken on July 15th, 1869, about 3 p.m., (1) from the head carrier, (2) from a carrier 150 yards lower down at the foot of a field of Italian ryegrass, over three or four acres of which the sewage was passing at about the rate of 60 tons an hour, and (3) from the effluent stream at the foot of the farm after it had further spread over two or three acres of the flat alluvial grass plot by the river. The following results were obtained on analysis:—

RAW AND EFFLUENT SEWAGE.—WORTHING.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

—	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
1. July 15/69 -	57·6	2·312	2·021	·000	3·717	5·082	10·75	1·86	4·74	6·60
2. - -	58·8	1·164	·226	1·105	·801	1·991	11·40	Trace.	Trace.	Trace.
3. - -	59·8	1·324	·334	·248	·591	1·069	11·00	„	„	„

The sewage, which was somewhat weak at the time of our visit, was sufficiently cleansed by passing over the first plot; indeed it was cleaner than another sample from the effluent stream which was probably carrying into the river the purified water from the stronger morning sewage. Close proximity to the sea affects the proportion of common salt in the Worthing sewage. The proportion of chlorine in all the samples is much higher than the strength of the sewage would lead us to anticipate. Some of the streets are watered with sea water.

10. Bedford. At Bedford, which contains about 15,000 inhabitants, large sums have been recently laid out under the direction of Mr. John Lawson, C.E., on both its water supply and its drainage system. The sewers here receive not only the fouled water supply of the town, together with a certain proportion of the rainfall on its houses and yards, but an immense quantity of land-water from the gravel site on which the town is built. Thus, though the water supply does not much exceed 150,000 gallons daily, the quantity of drainage which reaches the pumping station, about a mile below the town, is as much as 500,000 or 600,000 gallons daily. Each of the two 12 horse-power engines here stationed is, however, capable of lifting 2,000 gallons a minute to a height of 20 feet, so that either of them can master the ordinary dry weather sewage of the place.

During the night the comparatively pure water which then drains away is stored in the outfall sewer and tank at the pumping station. In the daytime it is delivered by an 18-inch iron pipe to the irrigated land 400 or 500 yards off, flowing thence into a small circular tank and afterwards, by two 15-inch pipes, along either side of the nearly flat land which has been laid out in transverse beds for its reception. These beds are about 70 feet wide on the side, with a fall of 8 or 10 inches from the central carrier to the midway furrow. The carriers are either 5-inch pipe tiles with open longitudinal slit, or 8-inch half round tiles; and a fall of about 1 in from 300 to 800 is given to them.

PART I. REMEDIES.

Sewage irrigation at Bedford.

The beds were sown in 1868 with Italian ryegrass, and have yielded heavy crops. Up to the middle of July three crops had been cut off 20 acres, besides one crop off 15 acres sown in 1869, and the sales amounted to nearly 330*l*. A much larger area of land is about to be taken in hand for irrigation purposes by the Corporation. The extent at present rented is about 50 acres, but a farm of about 200 acres will ultimately be under their management. The cost of pumping, which amounts to 4*l*. per acre of the land now irrigated, will then be reduced to a rentcharge of about 20*s*. an acre, which will be more easily repaid. And as the houses become more generally connected with the sewers, both the need of the greater area, and the produce derived from so large a supply of fertilizing matter, will increase. At present, as the following analyses show, the sewage is very weak, but the cleansing process is satisfactory. The samples of raw sewage (1, in the following table) were taken from the above-mentioned tank upon the farm; the effluent water (2) was taken from a ditch, which is dry except when the sewage is pouring on the land, but which was then flowing rapidly, being supplied from the subsoil drainage of the field which was being irrigated.

Samples were taken by us on three occasions. Series A. was collected on Sept. 10th, 1868, series B. on Oct. 10th, 1868, and series C. on July 24th, 1869.

RAW AND EFFLUENT SEWAGE.—BEDFORD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Times of Collection.		Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
A.	1., 4.45 P.M. -	74·8	2·732	·668	·000	2·700	2·891	-	13·26	13·14	26·40
	2., 5.0 „ -	76·8	·575	·163	·398	·023	·580	7·15	0	0	0
B.	1., 12.30 „ -	79·4	1·877	1·304	·000	4·300	4·845	—	5·58	5·50	11·08
	2., 1.30 „ -	78·3	·742	·381	·600	·010	·989	7·25	0	0	0
C.	1., 4.50 „ -	76·1	2·256	1·301	·000	3·100	3·854	10·90	8·16	13·68	21·84
	2., 5.30 „ -	81·7	·558	·034	·505	·095	·617	8·17	0	0	0

The undertaking here is thus shown to be sufficient as a sanitary agency, and its ultimate profitableness appears probable from the character of the crops we saw growing on the land. The Italian ryegrass must have weighed 12 to 14 tons per acre. The mangold-wurzel and kohl-rabi were tolerably promising. The prices obtained by auction for the former crop were improving at the successive sales, as the prejudice against sewage grown cattle food was dying out. The difficulties connected with the even distribution of the liquid will also diminish every year as the settlement of the moved land enables the necessary corrections of the surface to be made, so as to ensure a more uniform flow of water over it. The following report for 1869 has been furnished by Mr. John Lawson, C.E.:—

The land leased by the Corporation from the Duke of Bedford contains 54a. 3r. 7p. Of this area 47 acres have been irrigated by sewage.

Two fields, containing about 22 acres, were sown with Italian ryegrass in 1868, and the produce sold from this land in the year 1869 was about 420*l*.

Of the remaining portion of the land irrigated 15a. 2r. were sown with Italian ryegrass in the spring of 1869, and the remainder with mangold-wurtzel and other root crops. The sales from this bortion amount to about 227*l*. 10*s*. 4*d*., making a total of 647*l*. 10*s*. 4*d*.

	£	s.	d.	£	s.	d.
Produce in the year 1869 as sold by auction - - -				647	10	4
Rent, 55 acres at 4*l*. 10*s*. - - - -	247	10	0			
Auctioneers commission - - - -	33	8	6			
Printing - - - - -	22	9	0			
Seeds and plants - - - -	33	19	0			
Labour, including salary of manager - - -	213	4	0			
Taxes - - - - -	17	14	8			
Sundry expenses - - - -	11	19	0			
				580	4	2
				£67	6	2

PART I. REMEDIES.

Sewage irrigation at Norwood.

11. Norwood. The history of the facts connected with sewage irrigation at Norwood and at Croydon has been sufficiently prolonged to make it now thoroughly trustworthy and instructive. At the former place about 30 acres of low-lying clay land, with sufficient slope for natural surface drainage, have been well laid out for irrigation by Mr. Baldwin Latham, C.E. The drainage of about 4,000 people is received into a subsidence tank at the upper end, and thence flows along surface carriers, arranged both nearly in contour and down the slope. The fall in these carriers varies from 1 in 100 to 1 in 1,000, and the water stopped at intervals in their course flows over their edges, and so finds its way over the surface of the land. Plots varying in size from one to three acres are irrigated at once, according to the abundance of the supply, which, especially in summer time, when it is most wanted, is barely sufficient for the proper irrigation of the land. Nevertheless, very good crops of Italian ryegrass are cut five or six times a year; and a ready sale is obtained for the produce, at prices varying from 9*d*. to 1*s*. 3*d*. per rod, or 6*l*. to 10*l*. per acre, and the Croydon Board of Health have in this way obtained a revenue of 22*l*. per acre during nine months of 1868, and 25*l*. per acre in 1869, which, spread over the population to whose drainage it is due, amounts to about 3*s*. 9*d*. per head per annum. Mr. Baldwin Latham has furnished the following satisfactory report of the past year's experience:—

	£	s.	d.	£	s.	d.
The total amount received for the produce in the year was - -				741	0	6
The expenditure has been as follows:—						
Rent after deducting income tax - - - - -	292	16	3			
Wages for cutting produce, attending to the distribution of the sewage, re-digging and otherwise preparing the land for crops -	196	1	3			
Seed - - - - - - - -	17	2	6			
Taxes, rates, and tithes - - - - - -	63	15	3			
Printing - - - - - - -	2	3	0			
Sundry bills - - - - - - -	20	16	6			
				592	14	9
Balance - - -				£148	5	9

"The area under irrigation is 30 acres. Previous to the Local Board becoming the tenants of the land, the rent paid was 18*s*. per acre. The adjoining agricultural land is let at less than 1*l*. per acre rent. The average population draining to this area during the last year has been about 4,000. During the last month or two we have made provision to bring in a much larger area to this outfall, and in order to make provision for the increased population the Board has taken a sufficient area of land adjoining the present irrigation works at a rent of 10*l*. per acre. This will nearly double the existing area under sewage. It may also be interesting to the Commissioners to know that when the existing works at South Norwood were completed they were let to a tenant for three years, at a rent of 200*l*. per annum. The Board at this time paid the cost of distributing the sewage, so that as long as the works were let, there was a clear loss to the Board of 180*l*. per annum, but since they have taken them into their own hands a profit has accrued as will be seen from the foregoing figures."

A series of samples of raw sewage and effluent water has been taken from this land, giving the following results:—

RAW AND EFFLUENT SEWAGE.—NORWOOD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Date of Sample.		Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Nitrogen in Nitrites and Nitrates.	Ammonia.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
									Mineral.	Organic.	Total.
February 25, 1869 -	Head -	91·70	3·235	·699	·000	2·030	2·371	8·60	3·68	6·36	10·04
	Tail -	73·20	1·577	·391	·423	·988	1·628	5·70	Trace.	Trace.	Trace.
March 12, 1869 -	Head -	117·80	5·407	2·294	·000	8·970	9·681	8·87	4·08	14·96	19·04
	Tail -	83·10	1·294	·184	·381	·965	1·360	8·87	Trace.	Trace.	Trace.
March 25, 1869 -	Head -	75·30	3·275	1·765	·000	7·097	7·610	8·50	5·88	8·36	14·24
	Tail -	97·80	1·061	·189	·462	·342	·933	7·50	Trace.	Trace.	Trace.

The relative cleansing which sewage undergoes by employment for irrigation at different seasons of the year has not yet received any sufficient elucidation. The

PART I. REMEDIES.

Sewage irrigation at Norwood.

proximity of Norwood and Croydon to London afforded a favourable opportunity of submitting the effluent water from the two sewage farms to frequent investigation at all seasons of the year. Arrangements were, therefore, made for the periodical collection of samples for an entire year by our own laboratory man, in order to ascertain how far the efficient cleansing of sewage by this method is affected by the vigour or otherwise of vegetation, and especially whether the process could be relied upon during the winter months when plant life is in a comparatively dormant condition.

The following table contains the results of our periodical analyses of the effluent water from the sewage farm at Norwood:—

EFFLUENT WATER.—IRRIGATED MEADOWS, NORWOOD.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.		
								Temporary.	Permanent.	Total.
Average composition of the sewage before irrigation.	**94·9**	**3·972**	**1·586**	**6·032**	**·000**	**6·554**	**8·66**	—	—	—
Effluent water, September 24, 1868 -	81·7	1·621	·214	·013	·843	1·068	9·73	18·64	14·26	32·90
" October 8, " -	95·3	1·516	·189	·006	·587	·781	9·93	15·84	22·14	37·98
" " 22, " -	88·4	1·372	—	1·080	·710	—	9·93	17·68	16·70	34·38
" November 19, " -	78·0	1·473	·285	1·366	·167	1·577	9·73	11·80	22·90	34·70
" December 3, " -	79·6	1·258	·323	1·052	·694	1·883	8·54	4·18	27·74	31·92
" " 17, " -	103·0	1·187	·120	1·254	·796	1·948	8·74	8·18	30·45	38·63
" " 31, " -	77·8	1·291	·098	·497	1·450	1·957	6·75	9·30	25·56	34·86
" January 14, 1869 -	86·5	1·221	—	·721	·287	—	7·84	15·97	21·35	37·32
" " 21, " after two nights' frost.	94·3	1·173	·265	·720	·088	·946	8·44	19·31	18·99	38·30
Effluent water, January 25, 1869, after seven nights' frost.	100·3	1·431	·419	1·095	·072	1·393	10·13	24·23	16·37	40·60
Effluent water, January 28, " -	77·3	1·280	·406	1·195	·240	1·630	7·55	18·99	17·02	36·01
" February 11, " -	83·8	1·130	·133	·300	·549	·929	6·80	20·30	19·97	40·27
" " 25, " -	73·2	1·577	·391	·988	·423	1·628	5·70	16·86	17·19	34·05
" March 12, " -	83·1	1·294	·107	·965	·381	1·283	—	—	—	46·95
" " 25, " -	97·8	1·061	·189	·342	·462	·933	7·50	16·54	20·93	37·47
" April 8, " -	81·6	1·376	·321	·885	·547	1·596	8·00	19·68	17·16	36·84
" " 22, " -	102·5	1·495	·260	·842	·081	1·034	8·80	19·32	20·34	39·66
" May 6, " -	84·3	1·483	·410	1·131	·026	1·367	7·75	15·36	22·11	37·47
" " 20, " -	83·0	1·602	·354	·730	·498	1·453	7·50	14·03	19·67	33·70
" June 3, " -	97·1	1·683	·250	·415	·167	·759	9·64	17·80	20·92	38·72
" " 17, " -	79·8	1·360	·221	·894	·000	·957	8·50	17·95	16·69	34·64
" July 1, " -	95·1	1·577	·271	·905	·950	1·966	10·50	24·23	16·06	40·29
" " 15, " -	94·0	2·160	·274	·408	·705	1·315	13·10	23·63	11·95	35·58
" " 29, " -	93·6	1·889	·210	·135	·354	·675	10·20	20·77	17·01	37·78
" August 12, " -	93·8	2·095	·339	·130	·608	1·054	11·80	20·91	14·36	35·27
" " 26, " -	74·3	1·605	·370	·673	·000	·924	11·40	17·27	18·63	35·90
" September 9, " -	89·2	2·085	·300	·300	·403	·950	10·90	19·91	16·93	36·84
" " 24, " -	87·0	2·034	·517	1·128	1·390	2·836	10·60	17·50	16·37	33·87

These results, extending over an entire year, show that the effluent sewage was, except in a few instances, so far cleansed, even upon this heavy clay soil, as to be admissible into running water without nuisance. Two of these instances are instructive, since they occurred consecutively during and immediately after seven nights' frost, viz., in the samples collected on January 25th and January 28th, 1869. The frost was by no means severe, yet the organic nitrogen rose from ·098 to ·419 per 100,000 parts of effluent water, showing that the removal of offensive nitrogenous organic matter was partially arrested, and indicating that during a severe winter the purification of sewage upon a non-absorptive clay soil may be seriously interfered with. It is fortunate, however, that the admission of putrescible organic matter into streams during frosty weather is far less objectionable than it is when the temperature is higher, since the organic matter does not render the water offensive so long as a low temperature is maintained.

It is more difficult to account for the emission of exceptionally impure water from the Norwood farm at other periods of the year, viz., on December 3rd, 1868, and February 25th, April 8th, May 6th and 20th, August 12th and 26th, and September 24th, 1869, but it probably arose, in some cases at least, from unpurified sewage gaining access to the drains through cracks in the soil.

PART I. REMEDIES.

The hardness of the effluent water was not excessive, although it exceeded considerably that of the water supplied to Norwood. It never contained more than traces of suspended matters.

Sewage irrigation at Croydon.

12. Croydon. At the Beddington meadows below Croydon, 260 acres of an open soil upon a gravelly subsoil have for the last seven years received the drainage water of from 30,000 to 40,000 people. The water supply of Croydon and the copious land drainage of the place together yield a quantity of sewage equal to at least 3,000,000, sometimes exceeding 5,000,000 gallons daily. This passes through tanks where great pains were formerly taken to remove the solid and floating filth which it carried down, but less attention is now paid to this preliminary process, and the stream flows on very nearly as it leaves the town to the meadows in the occupation of Mr. Marriage, who, paying the rent at which the Board of Health have hired or bought the land, pays also a profit rent of 1*l.* per acre per annum for the use of the sewage. The success of sewage irrigation here as a deodorizing and cleansing process is complete, as the analyses show. There is never any lack of water, the soil is open, and has just slope enough to render easy the distribution of the liquid over it and through it, and there is sufficient fall between the top and bottom of the farm to allow the tail water of the upper fields to be spread a second time over fields below before it drains finally away. Very heavy crops of Italian ryegrass have been grown here. As much as 14 to 16 tons per acre are cut early in the month of May; and four or five cuttings a year are obtained, averaging from 8 to 10 tons each per acre. Mr. Marriage has also successfully used dressings of sewage in the cultivation of mangold wurzel; and when wheat has been grown after sewaged grass, he has irrigated the field with advantage, even so late as the month of July, when the crop has appeared to be flagging and apparently suffering during a drought. Water-cresses, too have proved here an excellent crop for sewaging, not only from the profit derived from them, but from their cleansing powers upon the dirty liquid. The greater part of the land here irrigated is, however, in grass. That being the only crop which can be continuously watered with advantage, it is necessary to retain the greater part of the farm in grass in order that the enormous quantity of dirty water here passing over the land may be changed from field to field often enough, and cleansed sufficiently before it leaves the land. Latterly, much of the land has been laid down to permanent grasses, which are better adapted for ordinary grazing purposes, and a large herd of feeding cattle have been successfully grazed upon these lands; being moved from field to field as the water drains off them. This was, however, we presume, a temporary arrangement intended to diminish the tenant's costs as the expiry of his lease approaches, and not intended as an example of the best method of converting the fertilizing matter of sewage into valuable produce.

The following results of analysis illustrate the effect of irrigation when carried out upon the porous gravelly soil of the Beddington meadows. It will be seen that the sewage as it flows upon the land possesses scarcely half the strength of average London sewage. The effluent water, even in the month of December, was satisfactorily cleansed and contained but mere traces of suspended matters.

RAW AND EFFLUENT SEWAGE.—CROYDON.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Suspended Matters.		
								Mineral.	Organic.	Total.
Sewage as it flowed upon land, Dec. 23, 1869	48·0	2·076	·749	2·684	0	2·959	4·39	1·96	6·64	8·60
Effluent water, Dec. 23, 1869 - -	52·3	·795	·072	·265	1·164	1·454	3·70	Trace.	Trace.	Trace.
Sewage as it flowed upon land, Dec. 30, 1869	48·0	2·882	1·269	2·700	0	3·493	4·30	3·80	10·80	14·60
Effluent water, Dec. 30, 1869 - -	45·0	·772	·076	·530	·678	1·190	2·95	Trace.	Trace.	Trace.

The following table contains the results of our periodical analyses of the effluent water from these meadows, extending over an entire year:—

PART I.
REMEDIES.

Sewage irrigation at Croydon.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description and Date of Collection.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Average composition of the sewage before irrigation.	**45·7**	**2·508**	**1·576**	**3·006**	**·000**	**3·527**	**4·23**	—	—	—
Effluent water, September 24, 1868 -	37·8	·723	·119	·006	·115	·239	2·73	21·03	5·93	26·96
" October 8, " -	37·9	·605	·120	·005	·382	·506	2·58	21·06	6·52	27·58
" " 22, " -	49·0	·644	·069	·008	·353	·429	3·18	19·10	7·70	26·80
" November 5, " -	39·9	·801	—	·248	·651	—	2·98	20·05	7·69	27·74
" December 3, " -	40·2	·766	·239	·534	·289	·968	3·77	22·57	7·55	30·12
" " 31, " -	48·7	·632	·124	·130	1·271	1·502	3·47	17·50	14·42	31·92
" January 14, " -	44·7	·604	·186	·166	·941	1·264	3·08	20·82	11·92	32·74
" " 21, " after 2 nights' frost.	46·0	·620	·242	·466	·210	·836	3·13	21·13	9·32	30·45
Effluent water, January 25, 1869, after 7 nights' frost.	45·1	·562	·235	·275	·686	1·147	2·58	18·50	10·67	29·17
Effluent water, January 28, 1869 -	34·5	·614	·093	·165	·425	·654	2·88	21·96	7·84	29·80
" February 11, " -	38·4	·979	·138	·125	·091	·332	2·70	20·24	10·21	30·45
" " 25, " -	39·9	·541	·089	·098	·776	·946	2·60	13·58	17·19	30·77
" March 12, " -	37·3	·545	·097	·246	·538	·838	2·30	—	—	27·58
" " 25, " -	38·8	·427	·077	·090	·596	·747	2·40	19·64	8·47	28·11
" April 8, " -	36·2	·637	·122	·150	·396	·642	2·50	19·61	7·90	27·51
" " 22, " -	39·1	·702	·129	·124	·241	·472	2·24	20·42	6·49	26·91
" May 6, " -	37·1	·758	·083	·032	·245	·354	2·45	21·98	4·93	26·91
" " 20, " -	37·1	·644	·080	·020	·284	·380	2·15	21·04	6·77	27·81
" June 3, " -	33·9	·531	·127	·062	·183	·361	2·40	18·40	7·90	26·30
" " 17, " -	29·1	·291	·082	·042	·000	·117	2·18	18·54	7·76	26·30
" July 1, " -	32·1	·761	·036	·050	·301	·378	2·28	20·05	5·36	25·41
" " 15, " -	38·1	·605	·124	·008	·201	·332	2·60	21·08	4·93	26·01
" " 29, " -	36·9	·628	·077	·090	·000	·151	2·60	20·93	7·48	28·41
" August 12, " -	39·1	·582	·385	·278	·325	·939	2·69	20·14	6·77	26·91
" " 26, " -	30·8	·362	·054	·018	·000	·069	2·80	17·89	6·92	24·81
" September 9, " -	32·7	·591	·105	·038	·147	·283	2·50	23·78	6·15	29·93
" " 24, " -	35·5	·606	·105	·068	·147	·308	2·44	15·23	5·21	20·44

These numerous analyses show that the sewage of Croydon is much more efficiently purified than that of Norwood. Only on one occasion (August 12th, 1869) during the entire year was the effluent water discharged in a somewhat unsatisfactory condition. On all other occasions the organic carbon and nitrogen were present in proportions considerably below those necessary to render the effluent water an offensive addition to a stream at any season of the year. Suspended matters were never present, except in minute quantity. It must be noticed, however, that during the continuance of the seven nights' frost in January 1869, the purification here, as at Norwood, became markedly impaired, the organic nitrogen increasing from ·186 part in 100,000, at which it stood before the frost, to ·242 part, whilst the assimilation of ammonia by the vegetation was also retarded, as is seen from the increased quantity of ammonia in the effluent water. Unfortunately, the winter of 1868–69 was too mild to permit of this point being satisfactorily tested, and it will therefore be desirable to resume these experiments should there be a longer continuance of frost during the winter of 1869–70. In order to show more clearly the condition of the effluent water from the Norwood and Beddington meadows at different seasons of the year, the following table has been prepared:—

INFLUENCE of SEASON upon the PURIFICATION of SEWAGE by IRRIGATION.
RESULTS of ANALYSIS expressed in Parts per 100,000.

Average composition of effluent Sewage Water.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.
Spring:							
Norwood - -	88·1	1·500	·303	·816	·220	1·194	8·37
Croydon - -	35·4	·594	·104	·072	·225	·388	2·32
Summer:							
Norwood - -	88·6	1·883	·312	·462	·657	1·361	11·03
Croydon - -	35·4	·607	·126	·069	·155	·300	2·57
Autumn:							
Norwood - -	87·0	1·349	·203	·835	·734	1·629	8·94
Croydon - -	43·1	·690	·138	·185	·589	·792	3·20
Winter:							
Norwood - -	87·0	1·271	·273	·876	·313	1·255	7·71
Croydon - -	40·6	·612	·145	·204	·533	·846	2·72
After seven days' frost:							
Norwood - -	88·8	1·356	·413	1·145	·156	1·534	8.84
Croydon - -	45·6	·591	·239	·371	·448	.992	2.88

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REMEDIES.

Sewage irrigation at Woking.

It will be seen from the above table that the total solid matters in solution are remarkably uniform at all seasons; but in estimating the degree of purification effected at different seasons on the two farms, it is necessary to bear in mind the relative strength of the sewage employed in each season, since the purity of the effluent water is considerably affected by the proportion of polluting ingredients in the original sewage; in other words by the strength of that sewage. The strength of sewage is approximately given by the proportion of chlorine which it contains. Estimated by this standard the sewage of Norwood was strongest in summer, whilst the organic elements in the effluent water were also present in largest proportion during the same season. In winter, when the sewage was weakest, the effluent water was purest. At the Croydon farm, on the other hand, the sewage was strongest in autumn and winter, and the effluent water was also less pure in those seasons. In summer, when the sewage was weaker, the effluent water was also purer, whilst in spring, with a still more dilute sewage, the water leaving the farm attained its highest degree of purity. It follows therefore that the cleansing of sewage is, in the absence of actual frost, less dependent upon season than upon the quality of the sewage itself. It is, however, far otherwise as regards the inorganic (and consequently non-polluting) fertilizing constituents,—ammonia, nitrates, and nitrites. These compounds are, as might be expected, removed with greater avidity by vegetation in spring and summer than in autumn and winter. This is clearly seen from the following table, which shows the amount of nitrogen in these three forms left in 100,000 parts of the effluent waters in each of the four seasons, especially if the varying strength of the sewage above mentioned be taken into consideration:—

NITROGEN as NITRATES, NITRITES, and AMMONIA IN EFFLUENT SEWAGE.

——	Spring.	Summer.	Autumn.	Winter.
Norwood - - - -	·892	1·026	1·422	1·011
Croydon - - - -	·284	·212	·741	·701

13. Woking.—We refer, in conclusion, to an experiment in sewage irrigation on the slopes of poor sandy soil below the invalid prison at Woking. A population of more than 1,000 adults there receive a water-supply of upwards of 20 gallons a head, equal to about one ton daily to every 10 persons. The whole drainage of the place passes through a tank capable of holding about 1,500 cubic feet or 40 tons of water; and thence it has hitherto flowed almost entirely to waste, being used, however, in an unsystematic way to fertilize the grass fields at the foot of the hill. Two acres upon the slope in four consecutive plots apiece were laid out in the spring of 1869, so that a tank full could at any time be poured upon the upper or any other plot of the series, the tail water being directed on any other plot of the series lower down. The four plots of one acre were sown with Italian ryegrass in March, and three crops averaging more than 12 tons each were cut during the following summer, the plant having been repeatedly sewaged during the intervals. The other acre lying in fallow was sewaged in the same way, and samples of the effluent water have occasionally been taken both from plots growing ryegrass and from plots without a crop, in the hope that we should ascertain the increased power of a surface covered with a growing crop as compared with one which depended solely on the soil as a filter. The second acre has subsequently been planted with cabbages, potatoes, and mangold wurzel, and these crops have received sewage when the plants required it. The difficulty of applying the results obtained here to the circumstances of any other case arises from the extreme hollowness and porosity of the Woking soil. A dressing of 40 tons of sewage, poured in three-quarters of an hour from the upper carrier of one of these quarter-acre plots, is, notwithstanding the steepness of the slope, almost all absorbed before it reaches the foot of the plot. It is only when the land is saturated with rain-water, and thus loses its power of absorption, that the sewage-water poured on at top, and conducted over the four plots in succession of the acre then being treated, will reach the bottom of the field. In the interests of the crop it has been therefore necessary to irrigate each plot in succession with raw sewage. The plan has generally been to give each acre so much sewage in the week as to make the result correspond to the allotment of an acre to every 100 persons throughout the year; and in the further prosecution of the experiment here, when the soil shall have become more clogged with root fibre and with sediment, it is hoped that the effect of the whole acre upon a specified quantity of sewage may be realized and observed. The experiment has also to be extended to other places in order that we may learn from it, if possible, the maximum powers of various soils in cleansing sewage, getting results of the same definiteness in regard to irrigation, as our laboratory experiments

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Effect of sewage irrigation on health.

have already given us with reference to filtration. Our results at Woking are still incomplete, and must be reserved till the issue of a later report; but it may be stated as regards the fertilizing power of sewage water thus applied, that Italian ryegrass sown in March on poor Woking sand, yielded between July and October three crops of grass, averaging more than 12 tons per acre each; and that on plots of similar soil the heaviest and most luxuriant growth of savoys, kale, and cabbage has taken place. A bed on which 20 tons of Woking peat had been laid one foot deep and watered in like manner, yielded as abundantly as the rest; and the result is sufficiently encouraging to justify the prosecution of the experiment on a larger scale, and on peat of a less questionable character, in order to ascertain, in the interests of the great Lancashire towns, whether sewage upon a true bog peat will feed succulent vegetable growth as successfully as it is found to do on all other kinds of soil.

INFLUENCE OF SEWAGE IRRIGATION ON HEALTH.

We do not recommend irrigation for the abatement of the town sewage nuisance without having made ample inquiry into any risk to health which may be incurred by the establishment of sewage meadows in the neighbourhood of towns. Such inquiries have been made at Edinburgh, Croydon, Norwood, and Barking, where irrigation has been carried on long enough and, near Edinburgh at least, in a sufficiently careless manner to have certainly developed whatever elements of mischief may be inherent in the practice. Nowhere have we found instances of ill-health that are properly attributable to malaria or other causes due to irrigation. At Edinburgh we were informed by Dr. Littlejohn that, though as medical officer of health to the city, he looked with prejudice and displeasure on the existence of sewage meadows in its suburbs, he had not been able to connect the ill-health of certain localities in Edinburgh with the Craigentinny meadows as its cause. Professor Christison too, President of the Royal Society of Edinburgh, speaking of these meadows, in an address at the meeting of the Association for the Encouragement of Social Science at Edinburgh, in October 1863, said, (Vol. II., *Minutes of Evidence*, part 4).

"I have recently been making careful inquiry respecting this famous and somewhat unsavoury institution; many years ago my own prejudices were all against the meadows; I have been compelled to surrender them. I am satisfied neither typhus nor enteric fever, nor dysentery, nor cholera, is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood. About 25 years ago it was stated that the cavalry soldiers at Piershill barracks, which are situated very near them, were unusually liable to the zymotic diseases caused or promoted by foul emanations, and also that meat could not be kept in the officers' larder on account of the absorption of foulness and quickly following decay. Either, however, there was some mistake committed through prepossession, or the meadows are now worked on a better system, but at all events I have the assurance of Mr. Lockwood, surgeon of the Scots Greys, that during their late occupation of Piershill barracks for two years, the messman of the regiment never observed the meat to be injured, nor did he himself observe among the men anything but remarkable freedom from diseases at large. I think it right, in reference to the late introduction of the Craigentinny system of irrigation into the vicinity of other large towns, that these precise facts should be known."

Dr. Christison writes, 4th February 1870, "I have nothing either to add to or subtract from the above quotation from my Social Science address in 1863."

Dr. Ligertwood, surgeon to the 8th Hussars stationed at these barracks, in 1868, says:—

"During the four months the regiment has been quartered at Piershill the men have been very healthy, and so have the women and children. Between the barracks and the sea there are upwards of 200 acres of land under irrigation from town sewage; these sewage fields do not apparently exercise any unfavourable influence on the health of the troops, or perhaps I should say, that my opinion is, that *in spite of these*, the health of the troops at Piershill is good, the site of the barracks being open and well exposed to the sea breeze counteracts any evil influences from proximity to such fields. These fields are certainly a source of nuisance to those living in barracks from the offensive emanations given off from the open ditches conveying the sewage, and also from injudicious flushing of the fields, the stench in barracks is sometimes quite sickening. All this might, however, be remedied by the sewage being conveyed to the fields in covered ditches or pipes, and outlets placed on the pipes in the fields at proper intervals for irrigating.

"During the years 1865, 66, and 67 the 4th Hussars were quartered at Piershill; I was surgeon in charge; the health of the regiment was remarkably good; during a portion of this time the cholera was epidemic at Leith and Edinburgh (not severe), but not a case occurred at Piershill barracks."

In reference to Barking we may add that during 1866, when the cholera was prevalent in some parts of North London, the North London sewage was constantly poured over the irrigated fields of Lodge Farm, but no case of cholera happened at the farm or near it. The only serious illness that has happened on the farm since it has been in the hands of the Metropolis Sewage Company was a case of scarlet fever in a newly built cottage, which attacked a labourer's family immediately on their coming into residence. But it

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Effect of sewage irrigation on health.

was satisfactorily proved that the infection had been received by the family before their arrival, and it did not afterwards spread.

At Norwood Dr. Alfred Creswell gave evidence before the former Rivers Pollution Commission (First Report, River Thames), tending rather to implicate the irrigation meadows there as the cause of malarious fever. The following, however, is an extract from a letter dated December 21, 1869, in which he states his subsequent experience:—

"My evidence went to prove that the irrigation fields *as a marsh* produced malarious diseases, and in this case intermittent fever, amongst the children living in the vicinity. At this period the works were badly managed, and the fluid allowed to remain on the field too long.

"I have resided in the neighbourhood ever since, and have the largest practice in it, especially attending the families of those who work on the fields, who also belong to clubs which I attend. Many of my patients' houses are within 150 yards of the sewage fields. Among others, there is a large girls' school standing between the fields and those houses where this illness existed in 1865–6. In this school, in which there are more than 30 inmates, there has not been a single case of illness from preventible diseases; and my last quarter's account was 5*s*. 6*d*. I have been able in no case to trace any illness to these fields. As for effluvia I will not say there does not exist any, but it is so seldom perceptible that a house built within 200 or 300 yards would command the same rent as if half a mile off.

"My investigations and independent observations during the last three years have made me an advocate for this method of utilizing sewage matter. And as an instance of how perfectly the watery portion is purified, I can state that the water flowing over these fields, and thence conducted to a neighbouring brook, is frequently drank by persons who are ignorant of its source. It is clear, pellucid, and tasteless. I repeat, therefore, that after watching the working of these fields, my opinion is, that when this system of sewage irrigation is *well managed*, the health of the inhabitants in the immediate vicinity is in no way influenced by it. I may mention that ours is a deep clay soil, and that I have no experience of light or sandy soils."

And at Beddington, near Croydon, it has been sufficiently established, whatever may be the amount of occasional nuisance owing to foul ditches, or perhaps to the ponding of foul water in hollows on the land, that no attack of disease has been consequent upon the process of irrigation there. The evidence of Dr. Alfred Carpenter is conclusive on this point. The following is an extract from his paper on "Some points in the physiological "and medical aspect of sewage irrigation" read before the Social Science Meeting at Bristol, Oct. 2, 1869:—

"The visitor to Beddington will see a number of villas, which have been occupied for some years, with irrigated fields both in front and rear, whilst not a trace of enthetic disease has appeared in any of them, though I think the Beddington farm is capable of much improvement. At Norwood the population is much greater and much nearer to the fields, probably 400 persons living within 200 or 300 yards from the farm. Previously to its establishment in that district fever abounded; since then that disease has all but disappeared, and the mortality of the district has steadily declined. The death-rate for Norwood population, about 5,000, for the last six years, according to Dr. Westall's mortality tables, is as follows, viz.:—

1863	18·76	
1864	18·89	
1865	18·17	Sewage farm established.
1866	15·34	
1867	14·21	
1868	12·07	

"I do not mean to assert that the low mortality in Norwood is due to the establishment of the sewage farm, neither do I expect that low rate to be maintained; but I contend that if miasms were produced by sewage farms, then the mortality would have increased after the establishment, and that preventible diseases would have more abounded than before the event. We find the contrary to be the fact.

"From the above table it will be seen that the establishment of the sewage farm in 1865 was immediately followed by a decrease in mortality, which would not have been the case if miasms had been promoted by their formation. Then, again, the Beddington farm of nearly 300 acres is within 500 yards of a populous portion of our town, and within 900 yards of the centre of the place; it lies to the westward of the town, and yet I can safely say that a continuance of west wind is always accompanied by a diminished amount of ordinary sickness in the place, and our ordinary mortality is generally below 20 per 1,000. At Norwood, moreover, a public footpath passes through the fields, which is frequented by hundreds of persons for recreation and amusement, especially on a Sunday. The persons so using the footpath have been frequently surprised when they have been told that their walks for pleasure have been taken through the sewage farm of the Croydon Local Board of Health. The path is much more frequented than other footpaths in the neighbourhood, which would not be the case if the fields were the nuisance they are supposed to be."

We are therefore justified in recommending irrigation as a safe as well as profitable and efficient method of cleansing town sewage. Both safety and efficiency, however, of course, depend upon the proper performance of the work. The profits of the process also hinge on this.

It is plain that the results of irrigation in the several instances to which attention has thus been directed in the foregoing pages, are satisfactory or otherwise, according to the

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Irrigation as a South Lancashire remedy.

degree of skill with which the work has been directed. The cleansing power of land and plant depends upon the uniformity with which the sewage water is distributed over and through them,* the quantity of surface over which it can be made continuously to flow, and the length of time during which their influence can be brought to bear upon it. When sewage water is poured over clay land which cracks in dry weather to the depth of the underground drains, it escapes in such weather from the field in an imperfectly purified condition. When the water is allowed to pour over an uneven surface, and does not flow regularly and constantly over the land, the plants growing on the water-logged patches are stunted and starved instead of being fed and fostered, and thus lose their powers both of cleansing sewage and of yielding produce. But wherever, as at Warwick and Norwood on a clay soil, and at Barking, Croydon, and Bedford on more porous soils, the sewage is spread uniformly over a considerable surface down which it trickles slowly, and thus constantly feeds a plant of grass or any other of a succulent and rapid growth, then the results are satisfactory; the filth is taken out of the sewage and transformed into valuable and saleable produce.

We have only to add that there seems to us ample opportunity for realizing such a result in the neighbourhood of most of the towns in South Lancashire and Cheshire, which we have visited. At Liverpool a company has been formed for pumping and conducting the contents of two of the northern sewers of that town, nine miles outwards to the light sandy soils north of the town. And at Walton and West Derby, two of the townships of Liverpool, nothing can be more favourable than the natural circumstances for the utilization of their sewage in a similar way. Even at Manchester and Salford, where probably 50,000 tons a day of sewage run to waste, so that the filthy condition of the Irwell strikes a stranger with astonishment, the difficulties in the way of sewage irrigation are not insuperable. There is at Throstlenest weir, below the town, a fall of water, which, as Mr. Alderman James Fletcher, of Salford, pointed out to us, might be made the source of all the power required to pump more than 50,000 tons to any height that would be needed to command the surface of the land; and 6 to 14 miles below Manchester there is grass land of comparatively poor quality with a very scanty population on it, and moss land in abundance, on which this sewage could be utilized without creating any nuisance. At Warrington water power of a similar kind is available and might be similarly used. At Bolton, where the water supply of 80,000 people is converted into sewage, thus rendering the river *Croal* an intolerable nuisance, the Corporation are considering the plan of pumping all their drainage to a height of about 200 feet, whence it would command several thousand acres of land available for irrigation above the town, so that the water, after irrigation there, should come back to them cleansed and useful for all the ordinary purposes which it is capable of serving after its filth has been given up as fertilizing matter to the soil to which it properly belongs. At Macclesfield something of a similar kind is contemplated; and there, whether the sewage be sent back to the uplands or allowed to flow over the river side meadows below the town, no great difficulty exists in the way of sewage irrigation. At Blackburn, where filtration subsidence tanks and the lime process have done literally nothing in the way of abating the nuisance, the Corporation are considering the possibility of carrying their sewage some miles down the river side, so that by natural gravitation it shall flow over the large extent of grass land perfectly well adapted for it between Blackburn and Walton-le-Dale. At Chorley, sewage irrigation has already commenced. A farm has been taken for the purpose, where the operations, incomplete when we visited the place, will no doubt more and more succeed as the management gradually overcomes the preliminary difficulties of uneven surfaces and unsettled carriers. Other towns, in both the *Ribble* and the *Mersey* basins, might also be named where circumstances are ripening for the adoption of irrigation as the only practicable method of abating an enormous evil. The nuisance is becoming injurious, expensive and intolerable, as population increases. Attempts to abate it, by such plans, other than irrigation, as have hitherto been thought of, have everywhere proved failures; and almost every corporate body on whom the responsibility of the evil rests, is being driven to the consideration or adoption of irrigation as the only available and certain remedy.

But an important question here presents itself,—how far can sewage be conveyed in open conduits without a serious loss of its most valuable constituent,—ammonia? Upon the answer to this question, would depend in many cases the practicability, or otherwise, of conveying the fertilizing liquid to tracts of waste land, lying at considerable distances

* We may refer here to Mr. Morgan's "Notes on the distribution of Sewage," Metchim, Parliament Street, a pamphlet in which the secretary of the Metropolis Sewage Company states in detail his experience at Lodge Farm, Barking, on this important department of sewage farming.

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Loss of ammonia in sewage by exposure.

from towns. Sewage is rich in carbonate of ammonia, a salt which in its pure or concentrated state, rapidly volatilizes into the surrounding air, but, being exceedingly soluble, is again readily washed out of the air by water. Thus carbonate of ammonia may be said to be attracted both by air and water, and it is difficult, in the case of sewage exposed to the air, to predict which of these attractions will prove the stronger, or rather what will be the resultant of their combined action, as regards the retention or dissipation of the dissolved carbonate of ammonia. We therefore submitted this problem to the test of experimental investigation.

Carbonate of ammonia was dissolved in water in such proportion as to constitute a solution containing as much of this salt as is present in London sewage of full strength. This solution was then exposed to a strong draught of air rushing over its surface through a partially opened window. To vary the conditions of the experiment, part of the solution was placed in a glass cylinder, 7·8 inches in diameter, in which it stood 12·5 inches deep, whilst the remainder was put into a shallow circular dish where it formed a layer only 2 inches deep, exposing to the air a surface 11·8 inches in diameter. These vessels were kept in the strong draught day and night for a period of 16 days, and the proportion of ammonia in each was determined at frequent intervals. The following tables exhibit the results of these experiments:—

TABLE I.

LOSS of AMMONIA by EXPOSURE to the AIR of a SOLUTION of CARBONATE of AMMONIA in a layer 12·5 inches deep.

Date.	Temperature of Liquid.	Ammonia in 100,000 parts of Solution.
1869.		
May 4th, 4·45 P.M.	10·5° C.	9·75
„ 5th, 10·30 A.M.	11·0 „	9·75
„ 5th, 4·30 P.M.	13·5 „	9·75
„ 6th, 5·0 P.M.	15·0 „	9·50
„ 7th, 5·0 P.M.	16·5 „	9·50
„ 8th, 10·30 A.M.	14·0 „	9·00
„ 10th, 10·30 A.M.	14·8 „	9·00
„ 11th, 10·30 A.M.	14·2 „	8·70
„ 12th, 4·30 P.M.	16·0 „	8·50
„ 14th, 5·15 P.M.	13·0 „	8·50
„ 17th, 11·0 A.M.	12·5 „	8·50
„ 20th, 10·30 A.M.	13·2 „	8·25

TABLE II.

LOSS of AMMONIA by EXPOSURE to the AIR of a SOLUTION of CARBONATE of AMMONIA in a layer 2 inches deep.

Date.	Temperature of Liquid.	Ammonia in 100,000 parts of Solution.
1869.		
May 4th, 4·45 P.M.	9·9° C.	9·25
„ 5th, 10·30 A.M.	10·8 „	9·25
„ 5th, 4·30 P.M.	13·0 „	9·25
„ 6th, 10·30 A.M.	13·3 „	9·00
„ 7th, 11·0 A.M.	16·8 „	8·50
„ 7th, 5·0 P.M.	15·3 „	8·00
„ 8th, 11·0 A.M.	13·9 „	7·50
„ 10th, 10·45 A.M.	15·3 „	6·75
„ 10th, 4·45 P.M.	16·8 „	5·75
„ 11th, 11·0 A.M.	13·8 „	5·75
„ 12th, 11·0 A.M.	15·0 „	5·50
„ 13th, 11·0 A.M.	14·0 „	5·50
„ 14th, 5·15 P.M.	11·3 „	5·00
„ 17th, 11·15 A.M.	12·5 „	4·63
„ 20th, 11·15 A.M.	14·0 „	4·50

It is evident from an inspection of the above numbers that an appreciable loss of carbonate of ammonia from sewage by evaporation during even a very long flow need not be feared, since, even under the most favourable conditions for evaporation involved in the experiments given in Table II. the loss in the first twenty-four hours was absolutely inappreciable.

Nevertheless as a small quantity of the water evaporated, the remaining liquid, although containing sensibly the same proportional amount of ammonia, must of necessity have contained a slightly smaller absolute quantity. Even after the lapse of three days the proportional loss amounted to little over 13 per cent. At the rate of only one mile per hour sewage would during this time have travelled 72 miles. But it must not be forgotten that the loss of carbonate of ammonia depends upon the relation of exposed surface to the bulk of its solution, as is evident from a comparison of the above tables;

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Irrigation: Summary of results.

for whilst a stratum two inches thick lost over 13 per cent. in three days, a layer six times as thick or 12·5 inches deep lost only 2½ per cent., or about ⅕th as much. A sewage stream would probably rarely be less than one foot deep and therefore the appreciable loss of fertilizing effect from the evaporation of carbonate of ammonia during its flow along a conduit, of any length likely to be constructed, need not be feared.

There is however another mode in which a serious loss of this kind may occur. When sewage becomes putrid the ammonia which it contains diminishes in quantity, and it is possible and even probable that where putridity supervenes a considerable loss of ammonia may occur. We have not yet had sufficient opportunities for the investigation of the changes which occur during the putrefaction of foul waters generally and of sewage in particular, but the subject is one which merits and will receive our careful attention. We may however here state that, so far as our observations have proceeded, there is no fear of any such loss occurring in sewage of not more than 24 hours age, even in the warmest summer weather.

In concluding this description of our observations and experiments upon the purification of sewage, we append the following condensed and tabulated summary of all the results obtained in our investigation of the different processes above enumerated, for the treatment of the foul liquid.

SUMMARY OF EXPERIMENTS ON THE PURIFICATION OF SEWAGE.

Name of Process.	Per-centage of Soluble Organic Pollution removed.		Per-centage of Suspended Organic Pollution removed.
	Organic Carbon.	Organic Nitrogen.	
Chemical Processes.			
Lime process:			
Best result	36·1	65·8	96·8
Worst „*	23·4	10·4	59·6
Average „	27·7	43·7	80·6
Sillar's A.B.C. process:			
Best result	34·8	58·9	96·0
Worst „	25·8	50·1	87·4
Average „	32·1	54·3	92·0
Lime and chloride of Iron	50·1	37·1	99·8
Sulphate of alumina	3·8	48·0	79·0
Holden's Process. Sulphate of iron, lime, and coal dust:			
Best result	43·2	0	100
Worst „	3·4	0	100
Average „	28·3	0	100
Upward Filtration.			
Through sand at rate of 3·6 gallons per cubic yard per 24 hours:			
Best result	50·7	65·5	100
Worst „	·6	12·4	100
Average „	26·3	43·7	100
Downward Filtration.			
Through sand at rate of 5·6 gallons per cubic yard per 24 hours:			
Best result	84·9	96·9	100
Worst „	81·1	94·5	100
Average „	83·3	95·6	100
Through sand and chalk at rate of 5·6 gallons per cubic yard per 24 hours:			
Best result	88·2	96·8	100
Worst „	84·3	95·9	100
Average „	86·7	96·3	100
Through Beddington soil at rate of 7·6 gallons per cubic yard per 24 hours:			
Best result	88·5	97·5	100
Worst „	87·6	96·9	100
Average „	88·0	97·2	100
Through Hambrook soil at rate of 6·2 gallons per cubic yard per 24 hours:			
Best result	80·4	92·9	100
Worst „	73·5	90·5	100
Average „	77·0	91·7	100
Through Barking soil at rate of 3·8 gallons per cubic yard per 24 hours:			
Best result	50·3	91·9	100
Worst „	0	57·4	100
Average „	32·8	78·7	100
Through Dursley soil at rate of 9·9 gallons per cubic yard per 24 hours:			
Best result	87·6	95·4	100
Worst „	84·2	92·8	100
Average „	86·3	93·9	100
Ditto at rate of 12·4 gallons per cubic yard per 24 hours:			
Best result	84·7	94·8	100
Worst „	64·8	82·2	100
Average „	76·9	88·3	100

* This result was obtained at Blackburn where the process is carried out in a most imperfect manner.

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Summary of results.

Name of Process.	Per-centage of Soluble Organic Pollution removed.		Per-centage of Suspended Organic Pollution removed.
	Organic Carbon.	Organic Nitrogen.	
Through Leyland peat at rate of 4 gallons per cubic yard per 24 hours:			
Best result	65·5	92·6	100
Worst „	47·7	49·0	100
Average „	51·1	59·1	100
Irrigation.			
On fallow land at Chorley (adhesive loam)	62·3	70·2	100
*At Edinburgh** (both sand and clay)	45·3	81·1	84·9
At Barking (gravelly soil)	65·8	86·2	100
At Aldershot: (light sand)			
Best result	91·8	87·3	99·7
Worst „	69·9	82·9	87·7
Average „	80·9	85·1	93·7
At Carlisle (light loam)	77·9	59·8	100
At Penrith „ „	75·0	77·2	100
At Rugby (adhesive soil)	72·3	92·9	96·0
At Banbury: (principally clay)			
Best result	87·8	91·3	96·0
Worst „	64·1	80·1	90·3
Average „	76·0	85·7	93·2
At Warwick (stiff clay)	71·7	89·6	100
At Worthing (loam)	42·7	83·5	100
At Bedford: (light gravelly soil)			
Best result	78·9	97·4	100
Worst „	60·5	70·8	100
Average „	71·6	81·3	100
At Norwood: (clay)			
Best result	76·1	92·0	100
Worst „	51·3	44·1	100
Average „	65·0	75·1	100
At Croydon: (gravelly soil)			
Best result	73·2	93·2	100
Worst „	61·7	90·4	100
Average „	67·4	91·8	100

The above results are still further condensed in the following table:—

Name of Process.	Average Per-centage of *dissolved* Organic Pollution removed.		Average Per-centage of *Suspended* Organic Pollution removed.
	Organic Carbon.	Organic Nitrogen.	
Chemical Processes.			
Best result	50·1	65·8	100
Worst „	3·4	0	59·6
Average „	**28·4**	**36·6**	**89·8**
Upward Filtration.			
Best result	50·7	65·5	100
Worst „	·6	12·4	100
Average „	**26·3**	**43·7**	**100**
Downward intermittent Filtration.			
Best result	88·5	97·5	100
Worst „	32·8	43·7	100
Average „	**72·8**	**87·6**	**100**
Irrigation.			
Best result	91·8	97·4	100
Worst „	42·7	44·1	84·9
Average „	**68·6**	**81·7**	**97·7**

An inspection of these results shows that all the classes of processes are to a great extent successful in removing polluting organic matter *in suspension;* for if we exclude the sample of sewage treated by lime at Blackburn, where, as we have remarked, the process is carried out in a very careless manner, there are but few instances in which the result is not satisfactory. As might be expected, the filtration processes are in this respect the best; irrigation ranks next, whilst chemical processes are somewhat less

* At Edinburgh the cleansing of the sewage does not receive even a secondary consideration, and the operations are carried out in the most slovenly manner. Hence the comparatively imperfect purification here recorded.

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efficient for the removal of suspended organic matters. But the getting rid of suspended matters is a simple problem compared with the removal of organic matters *in solution*. It is here that the different processes experience the most severe trial, and it is on the application of this test that the great superiority of downward intermittent filtration and of irrigation over upward filtration and the chemical methods of treatment becomes strikingly apparent. Thus, in round numbers it may be said that, on the average, the processes of downward intermittent filtration and irrigation, remove from the soluble constituents of sewage (as measured by organic carbon and nitrogen) twice as much polluting matter as that got rid of by the processes of chemical treatment and of upward filtration. Looking only to purity of effluent water it would be difficult to decide between downward intermittent filtration on the one hand and irrigation on the other, but there are obvious reasons why the latter must, in all but very rare and exceptional instances, be preferred on economical grounds. Intermittent filtration is a costly process with no possibility of any return, whilst irrigation, although it may in the first instance require a larger outlay of capital, affords a hopeful prospect of a return for the capital invested.

III. PURIFICATION OF LIQUID REFUSE FROM MANUFACTORIES.—At the outset of our investigation, the purification of the liquid refuse from manufactories presented much more formidable difficulties than that of sewage. The wide differences in the character of these waste products, and in some cases their vast volume and comparative worthlessness, render their treatment a much more complicated problem. As our inquiries proceeded, however, and as personal observation made us better and more intimately acquainted with the several manufacturing operations, we had the satisfaction of finding that difficulties, which at first appeared to be insuperable, gradually showed themselves amenable to chemical and mechanical remedies which are not only practicable on the score of expense, but in some cases offer a fair prospect of considerable profit to the manufacturer. Of the many polluting liquids which now poison the rivers of the *Mersey* and *Ribble* basins, we feel ourselves justified in stating that there is not one which cannot be either kept out of the streams altogether, or so far purified before admission as to deprive it of its noxious character, and this not only without unduly interfering with manufacturing operations, but even in some instances with a distinct profit to the manufacturer; and even in those cases where a certain amount of expense must be incurred in unremunerative operations, the use of the purified stream will more than recompense this expenditure.

The annual saving to the manufacturers whose works are situated upon rivers, by such a cleansing of the water as we contemplate, may be inferred from the answers returned to the following question belonging to a series addressed to cotton and woollen manufacturers, calico and silk printers, dyers and bleachers, Vol. II., *Minutes of Evidence*, part 2:—"If " the river or stream from which you might derive your supply of water were rendered clear " and colourless, what would be the direct money value to you?"—In answer to this question the Strines Printing Company say, "If the water of the river were rendered clear " and colourless the benefit to us would be very great." Messrs. Heywood, Higginbottom, Smith, & Co., paper manufacturers, "If the river were rendered clear and colourless it " would be impossible to estimate its value to us." Messrs. George Cheetham & Sons, cotton and merino yarn spinners, "If the river was freed from sewage, dyeing and " bleaching refuse, the water would be of the value of 50*l.* per annum to us." The Water Street Mill Company, cotton spinners, Stalybridge, "If the river were rendered " clear and colourless, it would be of inestimable value to us." Messrs. Wells, Taylor, & Edwardson, alkali makers, Widnes, "If the stream was rendered clear and colourless " it would be now worth 100*l.* per year to us, but more as our works increase." Messrs. Longworthy, Brothers, & Co., cotton manufacturers, spinners, printers, and dyers, Salford, " If the river were rendered clear and colourless so that we could obtain the whole of our " supply from thence, it would be worth to us 200*l.* per annum." Mr. James Barrett, bleacher and finisher, Pendleton, near Manchester, "If the river were clear and colourless " it would be of the money value to me of 50*l.* per annum." Messrs. Robertson and Stansby, paper manufacturers, Salford, "If the river were clear and colourless we should " be able to make a much better class of paper." Messrs. Joshua Scholfield & Sons, dyers and finishers, Manchester, "If the stream were clear and colourless it would be of " the money value to us of 500*l.* a year." Messrs. Walker, Norris, & Son, smallware manufacturers, Manchester, "If the river were clear and colourless it would be of the " money value to us of 50*l.* per annum." Messrs. George Wright & Sons, general dyers and cleaners, Chorlton-on-Medlock, "If the river from which we might derive our supply " were clear and colourless it would be worth 200*l.* a year to us." Messrs. Hoyle and Sons, calico printers, Manchester, "If the river from which we might derive our supply of " water were clear and colourless it would be of the money value to us of 1,000*l.* a year." Messrs. Wood & Wright, calico printers, Medlock Vale, near Manchester, "If the river " were clear and colourless it would be a great saving of expense to us in providing and " working settling lodges and filters." Messrs. Johnson & Son, dyers and finishers, Manchester, "If the river from which we might derive our supply were clear and colourless, " it would be worth to us in money value 45*l.* a year." Messrs. John Andrew & Co., dyers, printers, and bleachers, "Arrangements for water supply being made, and considering the expense of alterations, the money value to us if the river from which we " might derive our supply were rendered clear and colourless would be comparatively " trifling." John Lancaster, junior, bleacher, dyer, and finisher, Manchester, "If the " river (*Irk*) from which I might derive supply were rendered clear and colourless it " would be of the money value to me of 125*l.* yearly." Messrs. Dickinson & Co., silk and cotton dyers and printers, "If the river were clear and colourless so that we could " use the water, it would be a money value to us of 100*l.* per annum." Mr. John Buckley, bleacher, Prestwich, near Manchester, "Twenty years ago I could use the river water " without filtering, but have been obliged to make two filters since, which cost 50*l.* a year " to keep in repair." Messrs. John Emmett & Co., paper makers, Bolton-le-Moors, "If " the river from which we might derive our supply be rendered clear and colourless the " gain to us would be considerable." Messrs. Chadwick, Brothers, manufacturers, bleachers, and dyers, "If the river were clear and colourless, from which we might " derive our supply, it would be of the money value to us of 1,000*l.* per annum." Messrs. E. Buckley & Co., bleachers, dyers, and finishers, Bury, "If the river were rendered " clear and colourless it would be of considerable money value to us." Messrs. Olive, Brothers, and Partington, paper manufacturers, "If we had not formed settling reservoirs " a clear stream would have been worth to us 180*l.* a year." Mr. Edward Mucklow, garancine manufacturer, Bury, "If the river were rendered clear and colourless it would " be worth in money value to me from 150*l.* to 200*l.* per annum." Mr. James R. Crompton, paper manufacturer, Bury, "If the river from which I might derive supply were " rendered clear and colourless it would be of money value to me of from 400*l.* to 500*l.* " per year." Messrs. Mugliston, Whittaker, & Co., bleachers and finishers, "If the river " were clear and colourless it would be of money value to us of from 400*l.* to 500*l.* a " year." Messrs. T. R. Bridson & Sons, bleachers, Little Lever, near Bolton-le-Moors, "If the river (*Croal*) from whence we might derive our supply, were rendered clear and " colourless it would be of money value to us of not less than 500*l.* a year." Messrs. T. R. Bridson & Sons, bleachers, Bolton-le-Moors, "If the river (*Irwell*) from which we might " derive our supply were clear and colourless it would be of money value to us of at least " 800*l.* a year." Mr. John J. Rolden, cotton spinner, Macclesfield, "It would save great " wear and tear of engines and boilers if the river were rendered clear and colourless, and " it would be of money value to us, but we are not prepared to give an amount." Messrs. Thomas Clarkson & Co., chintz furniture printers, Higher Walton, near Preston, "If the " river were clear and colourless it would undoubtedly be of considerable money value to " us, but we cannot state the amount." Messrs. John Wilkinson & Co., calico printers and dyers, Oakenshaw, "If the river were rendered clear and colourless it would be of " the money value to us of 150*l.* a year." The Pillingfield Mill Co., cotton spinners, Burnley, "If the river were clear and colourless it would be of money value to us of from " 30*l.* to 40*l.* a year." Messrs. John Baines & Son, cotton spinners, Burnley, "If the " river were clear and colourless it would be of money value to us of from 100*l.* to 125*l.* " a year." Mr. John Fish, cotton spinner and manufacturer, Blackburn, "If the water " were clear and colourless it would be of the money value to us of from 20*l.* to 30*l.* per " annum." Messrs. C. and J. Potter & Co., paper manufacturers, "If the river were " rendered clear and colourless it would be of the money value to us of 500*l.* a year." Messrs. Thomas and Joseph Eccles, power loom cloth manufacturers, Over Darwen, "If " the river were clear it would be of the money value to us of 40*l.* a year." Mr. Thomas Gillibrand, cotton manufacturer, Over Darwen, says, "It would be of great advantage to " me if the river were clear and colourless, but I cannot state the money value." Messrs. Eccles, Shorrock, Brothers, & Co., cotton spinners, Over Darwen, "If the river were clear " it would perhaps be of the money value to us of from 50*l.* to 100*l.* a year." Mr. William Thomas Ashton, cotton manufacturer, Over Darwen, "If the river were clear and colour- " less it would be of the money value to me of 20*l.* a year." Mr. Nathaniel Walsh, cotton spinner, Over Darwen, "If the river were rendered clear and colourless it would be of the " money value to me of from 100*l.* to 150*l.* a year." Messrs. McNaughton and Thom, calico printers, Chorley, "If the river were rendered pure it would certainly be worth at " least 3,000*l.* a year to us." Mr. James Gidlow, cotton spinner, Ince, near Wigan, "If " the brook were perfectly clear it would be worth 100*l.* a year to me."

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The 200 firms who have returned answers to our inquiries constitute but a small fraction of the total number of manufacturers in these basins; moreover, only 39 have replied to this question, and of these only 30 have given a money value to the advantage which the cleansing of the rivers would confer upon them; nevertheless the annual money value of this advantage so returned by but little over one-seventh of the manufacturers who have sent replies, is no less than 10,207*l.*; and there is reason to believe that in most cases the estimates given are exceedingly moderate.

In describing the remedies with which we have become acquainted, for the various forms of liquid manufacturing refuse which contribute to the pollution of the rivers under consideration, it will be convenient to classify them under the heads already employed.

1. Polluting liquids from calico-print, dye, and bleach works.— Every form of pollution arising from the operations carried on in these works can be satisfactorily remedied by subsidence or filtration. We have seen these operations performed with perfect success upon water of the foulest description; indeed water so polluted, and even with the further addition of sewage, is constantly so purified in most calico-print works which have not the good fortune to be situated near the source of a stream. The process is everywhere in operation, and in this way the water of a river is often purified over and over again in its passage down to the sea. Unfortunately, however, the riparian owners other than manufacturers, and the public generally, derive no advantage from these purifying processes, the clarified water existing only within the premises of the manufacturer. In order to give the general public the advantage of these repeated cleansings, in other words, to keep the river pure, it is only necessary to carry the purifying process one stage higher up the stream. It is, in fact, only necessary in most cases that the fortunate manufacturer at the top of the stream should adopt them, and restore to the river the water in the clear and colourless condition in which he receives it; then each successive printer can devote his present subsidence and filtration plant to the cleansing of the polluted water which leaves his works. Instead of operating upon the filthy water of the river, and restoring it as dirty as before, he would receive it clean and return it clean, and thus the dirty water would exist only upon the premises of the pollutor, whilst the river would flow on clean and unpolluted, the present condition of things being reversed.

We collected several samples of water before and after these processes of purification, and the results of the analysis of these samples given in the following table show how well the purification was effected:—

WASTE WATER:—EFFECTS OF FILTRATION AND SUBSIDENCE.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
The *Roch*, at Messrs. Wrigley's paper mills - - - - -	43·30	4·518	·288	·512	·230	·940	8·83	7·57	16·40	2·82	3·18	6·0
Ditto, after treatment with lime, subsidence and filtration - - -	30·10	·368	·010	·020	1·710	1·736	1·72	9·25	10·97	0	0	0
The *Tame*, after about 16 days subsidence in Messrs. Bradshaw and Hammond's reservoirs - - -	18·28	·617	·060	·077	·000	·123	1·13	7·05	8·18	trace	trace	trace

In the purification of the water of the *Roch* for Messrs. Wrigley & Sons' paper manufactory, the water is first mixed with slaked lime in the proportion of from 5 to 7 grains of lime per gallon; it is then admitted into capacious subsidence tanks, the largest having an area of one acre; thence it passes on to the sand filters, of which there are nine, each 40 yards by 9 yards. These filters deliver 600 gallons per minute of splendidly bright water. The deposition tanks are cleaned out twice a year; a process which occupies only 4 hours; the sludge is thrown into the river. The filters require cleaning once a fortnight, two men half a day suffice for each filter. The two samples of impure and purified water in the above table are not strictly comparable, as they were both taken on the same day, and the impure water occupies several days in passing through the purifying apparatus. The effluent water is considerably superior to the water of the *Thames* as delivered to consumers in London,—a result which could hardly have been anticipated, considering the very foul condition of the *Roch* at this part of its course.

At Messrs. Hammond's, the foul and turbid water of the *Tame* is admitted through a

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sluice into a series of reservoirs having a total area of 6 acres, in addition to which about one mile of the river is ponded up by a weir so as to form a preliminary reservoir of subsidence. The reservoirs themselves contain about 15½ millons of gallons, one million of which is used daily.

In order to test the efficacy of filtration for the purification of the foulest liquids produced upon the premises of the calico printer, Messrs. Hammond and Co., in compliance with our request, forwarded to us a cask containing the following mixture of waste liquors:—" One-third of lime washing water from bleach house, one-third of waste " soap water, and one-third of waste dye-washing water." This liquor, after being submitted to analysis, was allowed to filter downwards intermittently through the cylinder containing Hambrook soil, mentioned at page 66, at the rate of 4·2 gallons per cubic yard per 24 hours. The effluent water was submitted to chemical examination weekly, and the following results were obtained:—

DOWNWARD FILTRATION of WASTE LIQUOR from CALICO PRINTWORKS through HAMBROOK SOIL.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Arsenic.
Liquor filtered through paper - -	256·8	35·149	2·158	·185	0	2·310	·160
Ditto after filtration through Hambrook soil, August 9, 1869.	77·1	1·606	·372	·686	0	·937	·006
Ditto, August 16, 1869 - - -	103·8	2·459	·328	·540	0	·773	·000
Ditto, August 23, 1869 - - -	244·7	3·340	·555	·500	0	·967	·000
Ditto, August 30, 1869 - - -	438·2	4·771	·549	·650	0	1·084	·000
Ditto, September 6, 1869 - - -	606·7	5·591	·589	·586	0	1·072	·000
Ditto, September 13, 1869 - - -	642·5	6·221	·664	·435	0	1·022	·000
Ditto, September 20, 1869 - - -	657·6	6·938	·812	·294	0	1·054	—

These results show to what a great extent this very foul liquid was purified by simple filtration through five feet of porous earth. More especially was this the case whilst the liquid was fresh, the organic carbon being at first reduced to about $\frac{1}{35}$th of its original amount, and the organic nitrogen to less than $\frac{1}{5}$th, and this by the same earth which had already been employed for four months in the purification of very large quantities of London sewage. By keeping, the unfiltered liquor gradually became acid, vast numbers of maggots were at one time developed on or near the surface of the soil and, as the acidity increased, the destruction of organic matter became less perfect, whilst the solid matter in solution became much augmented by the action of the acid liquor upon the calcareous portion of the soil. At no time, however, did the effluent water become offensive on standing for a week in a warm room. These experiments also show that simple filtration of this kind is sufficient to remove arsenic from these waste liquors. Although the original liquid contained a considerable proportion of this poisonous element, no trace of it could be found in the effluent water after the filter had been in operation a fortnight.

In looking to the quality of the effluent water in the above experiments, it must be borne in mind that the original liquid was the foulest which could be obtained—a reference to the analytical table on page 31, shows that it was about eight times more polluted by organic matters in solution than the average of the discharges from calico printworks which we have examined. Moreover, the above experiments indicate that better results would be obtained if the foul water were operated upon fresh, as would be the case at the factory.

It is interesting to notice the striking difference in the *modus operandi* of the Hambrook soil upon the *animal* organic matter of sewage on the one hand, page 66, and upon the *vegetable* organic matter of dye water on the other. In the case of the former a large proportion of nitrogen appears as nitrates and nitrites in the effluent water, whilst in the latter case not even a trace of these compounds is produced by filtration through the same soil and under precisely the same conditions. These experiments add one more item to the already overwhelming evidence that nitrates and nitrites are produced by the oxidation of animal but not of vegetable matter.

The process of purification most suitable for each calico printer must obviously depend upon his position on the stream, the space at his disposal, and other circumstances. Situated upon a large tidal estuary, it would only be necessary to keep solid matters out of the river; if his works be situated above the estuary, and there be land at a reasonable price available for the purpose, he would probably prefer subsidence in

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a series of reservoirs for the purification of the whole of his polluted water, as being cheaper than filtration; whilst where land is more valuable, filtration might be the most economical method of treatment. In many cases the plan carried out at the Levenshulme Printworks near Manchester might be adopted with advantage. Here, owing to scarcity of water, the less polluted portions of it used in washing, &c. are pumped back again into subsidence reservoirs, where sufficient purification is effected to render the water, after admixture with a certain proportion of unpolluted water, sufficiently pure for all the purposes of the manufactory except use in the dye becks, in which, however, but a very small proportion of the total water used is required. At present the other and fouler portions of water are turned into the stream. It is evident that by the adoption of a plan of this kind the manufacturer would require thoroughly to cleanse only a very small fraction of the total amount of polluting liquid which he produces. By keeping apart for purification and transmission into the stream, the contents of the dye, dung, and soap vats, the rest of the water would, according to the experience of Messrs. Aitken Brothers at Levenshulme Printworks, be readily rendered available for repeated use after a slight subsidence and admixture with an amount of fresh water corresponding to that which had been supplied to the dye, dung, and soap vats.

At the time of our visit to the Levenshulme Printworks in May 1869, the effluent water which was passing from the subsidence reservoirs to the manufactory, possessed the following composition:—

Purified Effluent Water.—Levenshulme.

Results of Analysis expressed in Parts per 100,000.

Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Arsenic.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
39·75	1·051	·115	·021	0	·136	4·28	·160	3·30	15·75	19·05	·92	·97	1·89

As this water was used at the Levenshulme Printworks for all purposes except for the dye becks, it is obvious that water of no very high degree of purity may be successfully employed for many of the operations of a calico printwork.

We have also tried for the purification of these liquors the press invented by Mr. Needham, and described in the Third Report of the former Rivers Pollution Commissioners, Vol. I., p. xxv. Another sample of the waste liquor above mentioned from Messrs. Hammond and Co.'s Printworks was mixed with $\frac{3}{10,000}$ths of its volume of a strong solution of perchloride of iron (containing ·54 gram. of perchloride in three cubic centimetres), slight excess of lime was then added and the liquor pumped through the press. The following table contains the results of the analysis of the liquid before and after filtration:—

Treatment of Waste Water from Printworks, by Needham's Press.

Results of Analysis expressed in Parts per 100,000.

Description.	Total Solid Matters in solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Arsenic (Metallic).	Chlorine.
Waste water before treatment, with perchloride of iron and lime, and before filtration, October 25, 1869.	163·0	51·303	2·861	·235	0	3·054	·004	6·30
Ditto, after treatment and filtration.	208·5	44·569	3·537	·445	0	3·902	·004	—

These numbers show that, however efficient in other cases, Needham's press promises but little assistance to the calico printer, even when supplemented with perchloride of iron and lime. The treated liquor exhibits, it is true, a diminution in organic carbon; but this improvement is more than counterbalanced by the solution of nitrogenous suspended matter to such an extent as actually to increase considerably the proportion of organic nitrogen in solution. The addition of lime in excess rendered the liquid alkaline, and the solution of nitrogenous organic matter appears to be favoured by alkalinity. On this account a better result would probably be obtained by an acid method of treatment, similar to that pursued in the sewage works at Stroud, where sulphated clay or crude sulphate of alumina is used for the clarification and purification of sewage. There is, however, but little hope that even this modification of the process would render the worst kinds of waste water from printworks sufficiently pure to be admissible into rivers.

Part I. Remedies.

Pollution by chemical works.

2. Pollution by Chemical Works.

—We have already stated that the pollution of streams by chemical works is due almost entirely to matters in solution. The polluting liquids consist of,—

1. The drainage from soda waste - - - - - } From alkali works.
2. Dilute muriatic acid - - - - - - }
3. Chloride of manganese mixed with some perchloride of iron and chloride of arsenic - - - - - }
4. Crude solution of glycerin containing common salt, from soap works.
5. Coloured arsenical liquids from aniline colour works.

Our visits to numerous alkali works in these river basins and elsewhere have shown us that the chief pollutions arising from such works admit of simple, efficient, and even profitable remedies.

At the Netham Chemical Works, Bristol, the polluting effect of alkali waste is entirely obviated by treating the waste, as soon as it is produced, according to Mond's process for the recovery of sulphur; whilst the drainage from the old heaps of waste—the accumulation of years—is carefully intercepted and made to yield by the same process about 3 per cent. of its weight of sulphur. We were informed that at an expense of from 40*s.* to 50*s.*, a ton of sulphur was thus recovered which met with a ready sale at 6*l.* Ten tons of sulphur are thus extracted weekly at the Netham Chemical Works (Vol. II., *Minutes of Evidence*, Q. 1702). The process is also being successfully carried out at Messrs. Tennant's large works in Glasgow, and also at two factories at Widnes. It might be expected that a process promising so considerable a profit would be eagerly taken up by alkali manufacturers without any pressure from legislative enactments; experience, however, scarcely warrants this hope; the absolute yearly profits, although by no means inconsiderable, would form but a small item in the balance sheet of a chemical factory, and in the smaller works especially, would probably be regarded as unworthy the additional trouble and anxiety, which a new process always occasions in factories where the operations are of a strictly routine character. It was, in fact, only after threatened actions for nuisance that the process was adopted in the works just mentioned.

In a conference with a deputation of alkali manufacturers (see Vol. II., *Minutes of Evidence*, part 3, Q. 3048–3100) the latter expressed to us their fears that any prohibition of the flow of the drainage from alkali waste into streams would place them at the mercy of Mr. Mond, the patentee of the process to which we have above alluded. We do not share these fears, because Mr. Mond's process, although perhaps the most profitable, is by no means the only one by which the noxious qualities of alkali waste can be got rid of. Amongst several other methods which have been proposed for this purpose we may mention one which has been in successful operation for some time in France. This process also possesses the advantage of dealing at the same time with another of the polluting liquids above mentioned—the chloride of manganese liquor from the chlorine stills. Mr. J. Lothian Bell, of Newcastle, one of the best known alkali manufacturers in this country, thus speaks of the method, after a visit to the alkali works at Dieuze, near Nancy, where the alkali waste and manganese liquor are treated according to this plan. He says,*

"This process has been in operation at Dieuze for some months, and at the present moment by its means about one and a half tons of sulphur are being recovered daily. It will be seen that no new material is required, the only ingredients being the two waste products from the manufactory itself. The apparatus employed is of a most simple character, consisting almost entirely of tanks, on which the expense for maintenance will be a mere trifle; in fact, the whole cost is one of labour, which, at the Dieuze works, amounts to something like 40*s.* per ton on the sulphur obtained."

As the sulphur extracted is worth at least 6*l.* per ton, it is evident that the relief of our rivers from this horrible pollution will be attended with considerable profit to the manufacturers themselves, even if it be effected by this alternative process. Indeed, Mr. Bell goes on to say:—

"Supposing 40 per cent. of the sulphur used in this kingdom to be thus recovered, the annual saving this process is capable of effecting will amount to a considerable sum. I may add, that these operations have been carefully examined by some of the leading men of science of France, both in

* "Chemical News," 27 September 1867.

PART I. REMEDIES.

their practical and scientific relations, and that in their recent adjudication of prizes at the International Exhibition at Paris, the inventors (Messrs. M. W. Hofmann and Paul Bouquet) had a gold medal awarded for the service they are considered to have rendered to the industry of their country."

Pollution by chemical works.

We cannot, therefore, see how the interference of the Legislature, in preventing the admission of the drainage of alkali waste into rivers can inflict any serious hardship upon chemical manufacturers.

The second source of pollution from alkali works is the dilute muriatic acid containing arsenic which results from the condensation, under the Alkali Act, of that portion of the acid which was, previous to the passing of that act, allowed to escape as gas into the atmosphere.

The remedy here is sufficiently simple and is indeed, to a considerable extent, involved in the application of Mond's process for dealing with alkali waste, since this process necessitates the employment of large quantities of dilute muriatic acid. There is considerable difference of opinion amongst the witnesses who have given evidence before us as to the amount of acid required for Mond's method; but, as very dilute acid can be used, we have no doubt that all the muriatic acid produced could be profitably employed either in the manufacture of bleaching powder or in the extraction of sulphur from alkali waste. In either case the pollution of water by muriatic acid would cease. There is another obvious method by which this form of pollution can be prevented, but as it is one involving outlay and no return, it is not likely to be generally adopted. It consists in neutralizing the dilute muriatic acid by causing it to flow through a conduit or tank containing fragments of chalk or limestone, a material which is always largely employed in the so-called black-ash process, which is essential to the alkali manufacture. One ton of real muriatic acid requires nearly $1\frac{1}{2}$ tons of chalk or limestone to neutralize it. In large works, like those of Messrs. Crossfield, Brothers, and Co., of St. Helens, about 330 tons of chalk or limestone would be annually required to neutralize the whole of their waste acid. At 5*s.* per ton the cost of materials would be 82*l.* 10*s.*, an outlay which, considering the value of unpolluted water, can scarcely be deemed excessive, if an extensive alkali work, decomposing 10,450 tons of common salt, and burning 45,000 tons of coal annually, should choose to employ this unremunerative method of abating a great nuisance.

The pollution of water by the chloride of manganese liquor from the chlorine stills can be avoided in any one of the three following ways:—

1. By the conversion of the chloride of manganese and iron which it contains into chloride of calcium, a transformation which can be effected by the addition of milk of lime to the waste liquor. The chloride of calcium thus produced may be admitted into running water without causing pollution.

2. By the use of this liquor in Hofmann and Bouquet's method for the recovery of sulphur from alkali waste, the chloride of manganese being converted in this process into chloride of calcium.

3. By Weldon's process (Vol. II., *Minutes of Evidence*, part 4) for the recovery of the manganese from the waste liquor of chlorine stills. We have seen this method in operation upon a large scale at the works of Messrs. Gamble & Co., St. Helens. The patentee states that—

"The quantity of native peroxide of manganese necessary to liberate the quantity of chlorine required for the manufacture of a ton of bleaching powder ordinarily costs between 4*l.* and 5*l.* My process substitutes for this cost for native peroxide of manganese a cost for the operations I have above described of not quite 1*l.* per ton of bleaching powder. Moreover, the solution of native peroxide of manganese is so difficult to effect, except by the aid of a large excess of acid, that for every ton of bleaching powder made by means of native peroxide of manganese there has ordinarily to be employed the acid from between 70 cwt. and 75 cwt. of salt; but the compounds produced by my process dissolve so readily that a ton of bleaching powder can be made by means of them from the acid from only 40 cwt. of salt. The difference between these two quantities of acid is absolutely wasted in the ordinary process of manufacturing chlorine."

In this process the chloride of manganese becomes transformed into chloride of calcium, which, is admissible into rivers with no other ill effect than that of rendering the water harder. The specimen of effluent chloride of calcium, which we tested, was free from arsenic.

As the last two processes promise a considerable profit to the manufacturer, they would, doubtless, be adopted in preference to the first, which is a profitless operation.

The waste liquor from soap works containing glycerin and common salt might be discharged into sewage without detriment to the employment of the latter for irrigation, but a considerable demand for glycerin has lately arisen in France for the sweetening of beer, and large quantities are, we believe, exported from this country for that purpose. Glycerin is incapable of becoming acid, and is therefore much better adapted than cane or grape sugar for the sweetening of malt liquors. By availing themselves of this material the brewers

PART I. REMEDIES.

can afford to convert into alcohol the whole of the sugar contained in wort, the necessary sweetness being afterwards given to the fermented liquor by the addition of glycerin. Beers thus treated are said to be incapable of turning sour. The pure glycerin obtained in the manufacture of stearic candles is used for this purpose. The crude glycerin of soap works would be far too impure, but it might, probably, be readily purified by distillation; it is at all events very desirable that an effort should be made to utilize the large quantities of this valuable material, which are now thrown away by the soap manufacturer. Pure glycerin figures in price lists at 1*s.* 4*d.* per lb., whilst from Messrs. Gossage & Co.'s soap works alone five tons of this material are weekly run into the estuary of the Mersey.

Pollution by tanneries, paper mills, woollen works, and silk works.

The waste liquors discharged from colour works, and which frequently contain arsenic, may be effectually purified by admixture with small proportions of lime and perchloride or sulphate of iron, and subsequent filtration, through sand. In this way both the coloring matters and the arsenic are retained upon the filter. As the volume of these liquids is small, their treatment cannot inflict any appreciable hardship upon the manufacturer. Dr. Martius, chemical manufacturer of Berlin, informs us that in Prussia the aniline colour manufacturers are compelled to evaporate down these liquids and to preserve the residue under sheds, so as to preclude the access of arsenic to the neighbouring streams.

3. Pollution by Tanneries.—The waste liquors from tanneries may for all practical purposes be regarded as concentrated sewage, possessing from five to ten times the manure value of the latter. These liquors would, therefore, form an acceptable contribution to the contents of town sewers, when the sewage is applied to irrigation. If this were impracticable, owing to the tannery being situated in the country, there could be no difficulty in disposing of these valuable liquids upon the neighbouring land. Or, lastly, they might be sufficiently purified, to be admissible into streams, by downward and intermittent filtration through sand or porous soil, as described at pages 63–70.

4. Pollution by Paper Mills.—We have already mentioned that the two chief foul liquors discharged from paper mills are the water in which filthy rags have been washed, and the soda liquor in which esparto grass has been boiled. The rag liquor can be readily purified by filtration through sand, or by the use of Needham's press. Indeed, as employed in the large paper works of Messrs. Cowan and Co., on the North Esk, near Edinburgh, the latter apparatus effects the saving of a considerable quantity of pulp which would be otherwise lost by discharge into the stream. In the same works we have also seen the turbid water from the pulping engines and paper machines clarified to a considerable extent by subsidence in reservoirs. The strong esparto liquors are boiled down to dryness and ignited in suitable furnaces for the recovery of the soda ash which they contain, the weaker liquors being used in the steam boilers instead of river water until they are sufficiently concentrated to be mixed with the strong liquors. In this way a large proportion of the soda used is recovered, which recoups the manufacturer for the boiling down and furnace operations.

A third source of pollution from paper mills is the discharge of waste bleaching liquor containing chloride of lime. This discharge is, however, quite unnecessary, and is never permitted to take place in well conducted mills; it is, in fact, a slovenly waste of valuable material, and its prohibition could, therefore, entail no hardship upon the manufacturer.

5. Pollution by Woollen Works.—The remedies to be applied to polluting liquids arising from the scouring, washing, and dyeing of wool, will be fully discussed in our Report upon the rivers *Aire* and *Calder*, where these operations are extensively carried on. We will only remark here that several of these liquids will form valuable additions to town sewage when the latter is used for irrigation; whilst the purification of the remainder will present no greater difficulties than those which are encountered in the clarification of similar polluted liquids discharged from calico-print and dye works.

6. Pollution by Silk Works.—The polluting liquids discharged from silk works do not differ essentially from those issuing from calico and woollen works, but the degree of pollution is considerably less in the former, whilst the volume of liquid to be treated is comparatively insignificant. The grease ought to be extracted from the soap-suds, and then the residual liquid mixed with the contents of the dye vats would be sufficiently purified by the addition of almost infinitesimal proportions of lime and perchloride of iron, and subsequent filtration through sand or soil, on the intermittent plan described at pages 63–70.

Part II. Water Supply.

PART II.—THE WATER SUPPLY IN THE MERSEY AND RIBBLE BASINS.

Existing quantity.

The instructions issued for our guidance with reference to "the great question of the water supply," were based upon the letter of Charles Neate, Esq., M.P. to the Right Hon. Sir George Grey, Bart., G.C.B., Secretary of State, dated June 27, 1865.

In this letter Mr. Neate stated that the effect of drainage, even to the extent to which it had been already carried out for agricultural purposes, was a subject of serious alarm to many people, and that he considered it to be a 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 number of springs have failed altogether or do fail in the summer.

Very soon after we commenced our inquiries into the character and amount of the supply of water in Lancashire, the conviction was forced upon us that the supply has become in some cases inadequate to the demand, not so much from the action of the causes alluded to by Mr. Neate, as from the rapid accumulation of population upon a narrow tract of country, and from the consequent increasing amount of the demand for water to be used by them in their factories as well as in their dwelling-houses. We have thus been constrained to take a more general view of the question of the supply of water as affecting the health and comfort of the population of the *Mersey* and *Ribble* basins than that sketched out in our instructions; and, as stated at the commencement of our report, we have directed our inquiries more to the determination of the means by which the largest *regular* supply of water can be secured, than to the investigation of the effect of particular causes upon the level of springs, as to which the evidence is almost certain to be of the loosest and most conjectural character.

QUANTITY OF THE EXISTING WATER SUPPLY.

The actual amount of water poured into the sea, at the points which we have already named as the heads of the two estuaries into which these rivers run, cannot be stated with accuracy; neither indeed is it necessary for our purpose that we should attempt to arrive at more than an approximation. This, however, can be done by taking the amount of the rainfall, and assuming, after a fair allowance for the quantity carried off by evaporation or by the action of vegetation, that the remainder finds its way into the different rivers and streams which form the natural outlets for the drainage.

The result of observations collected by Mr. G. J. Symons on the amount of the rainfall within the district during seven years from 1862 to 1868 inclusive is shown in the following table:—

RAINFALL IN SOUTH LANCASHIRE.

Year.	Number of Stations.	Total Rainfall.	Mean.
1862	36	1493·39	41·48
1863	38	1732·91	45·60
1864	56	1808·84	32·30
1865	46	1482·84	32·23
1866	72	3441·58	47·37
1867	76	2845·78	37·73
1868	79	2866·90	36·29
			273·00
		Average annual rainfall	39·0

The average rainfall is thus 39 inches, the maximum in any one year being 47·37 inches, and the minimum 32·23 inches.

This amount, however, is the total rainfall; we have yet to estimate the proportion of it which finds its way into the watercourses. It is evident that this must vary very much according to the slope of the ground, the quality of the surface, the nature of the soil and subsoil, and the character of the climate. The following facts show how very wide the limits are within which this proportion ranges, and how little any general rule, applicable to all areas of drainage, can be depended on. From a very explicit account

Part II. Water Supply.

published by Mr. Alexander Ramsay, manager of the Edinburgh Water Company,* it appears that in a wet year (1863), at Edinburgh, with a rainfall of 39·3 inches over their gathering ground, a quantity corresponding to no less than 34·185 inches was measured as received in their water tanks, and either delivered for town or mill supply or allowed to pass over the waste weir. Here accordingly only 13 per cent., barely one-eighth of the rainfall, was lost by evaporation and absorption, no less than seven-eighths being available. This, however, was in the case of a mountain valley with steep grassy sides, in a year when "the rains were frequent and heavy and very considerably above the "average." And Mr. Ramsay goes on to state, of the following dry year (1864), with reference, however, not to the whole year but only to the six summer months, that the rainfall being only 10·89 inches during the six months commencing with April, the loss by evaporation and absorption amounted to 7·489 inches of rain over the gathering ground, or a loss of 69·44 per cent.

For inland navigation.

In the *Thames* valley it is found that out of an annual rainfall of 27 inches, two-thirds or 18 inches go off by evaporation or absorption, and only one-third passes away by drainage;† and in the basin of the Lee, with an average rainfall of 25 inches, only one-fourth, six inches or thereabouts, can be depended upon as drainage.‡

It may be added here that a very similar experience obtains at Sydney in Australia, where with a rainfall of 50 inches, it has been found that not more than 12 inches make their appearance at the outfall; and a similar result was obtained in the very different climate of India; a series of observations having been made in the Madras Presidency for the purpose of ascertaining the proportion of the rainfall which there passes down the river channels.

Returning, however, to our own country, and to the wetter climate of Lancashire, something nearer to the Edinburgh experience reappears; and from the evidence of the Consulting Engineer of the Manchester Waterworks it would seem that the proportion which comes into the reservoirs there is considerably more than two-thirds of the rainfall upon their gathering grounds.§ From the evidence of the late Mr. Duncan, Engineer to the Liverpool Waterworks, it appears that at Rivington, which furnishes two-thirds of the Liverpool water-supply, about three-fourths of the rainfall enters the reservoir in ordinary seasons, the proportion being somewhat smaller in the drier years.‖ But it is plain from the evidence recently given before the Royal Commission on the water supply of London that the data on which estimates of this kind must be founded, where no actual observations have been made, are still very imperfectly determined. And any estimate of the drainage water of a large district like the *Mersey* basin, characterized by every variety of soil and slope, and even climate, must be more or less a mere conjecture. Taking into consideration, however, the very considerable margin of steep upland pasture by which the *Mersey* and *Ribble* basins are surrounded, and the larger rainfall of the whole district,—nearly double that of the southern counties—it is, we think, certain that a much larger proportion than one-third here escapes evaporation, and finds its way into the river courses of these watersheds. And we are probably not far wrong if we assume that an average season may be credited, according to the figures of Mr. G. J. Symons just quoted, with a rainfall of 39 inches, of which 20 inches, or 448,000 gallons per acre, find their way to the sea through the *Mersey* and *Ribble* estuaries.

This quantity of water, whatever the exact amount may be, has to supply a variety of demands, including (*a*) the needs of inland navigation within the district, (*b*) the wants of the population for all domestic purposes, and (*c*) the provision for manufacturing purposes.

(*a*.) **Supply for Inland Navigation.**—The rainfall has first to furnish water for a large extent of inland navigation. The country is intersected with canals leading up the different valleys from points on the coast or on the estuaries. These, before the introduction of railways, were the main lines of traffic for minerals and for other raw as well as manufactured produce; and although a large proportion of this traffic has been transferred to the railroads there is still a great deal left for the canals.

* Transactions of the Royal Scottish Society of Arts, vol. vii.

† *See* Evidence of Mr. J. T. Harrison, C.E., before the Royal Commission on Water Supply (Minutes of Evidence, p. 104).

‡ *See* Evidence of Mr. N. Beardmore, C.E., before the Royal Commission on Water Supply (Minutes of Evidence, p. 203).

§ *See* Evidence of Mr. J. F. Bateman, C.E., F.R.S., before the Royal Commission on Water Supply (Minutes of Evidence, p. 4).

‖ *See* Evidence of Mr. T. Duncan, C.E., before the Royal Commission on Water Supply (Minutes of Evidence, pp. 123–124).

PART II. WATER SUPPLY.

For domestic use.

The quantity of water withdrawn from the rivers for the maintenance of this internal navigation is very large, being represented by the number of locks full of water used to pass vessels up or down the canal; not to speak of unavoidable leakage and possible loss by evaporation. The following returns have been received from the different canal companies, and profess to be an approximation sufficiently close to indicate the extent of their demand upon the rainfall, (Vol. II., *Minutes of Evidence*, part 4):—

		Gallons.
The Rochdale Canal consumes annually	-	1,682,000,000
The Ashton Canal do.	-	2,385,000,000
The Peak Forest Canal do.	-	1,770,000,000
The Bridgewater Canal	-	3,077,000,000
Gallons	-	8,914,000,000

This is equivalent, according to the estimate above, to the average supply from about 20,000 acres.

In addition to these the Leeds and Liverpool canal, running for 70 or 80 miles through the valleys of the *Mersey* and the *Ribble*, and absorbing at times, as we saw at Wigan, the whole of the water of the *Douglas*, must use a very large quantity; we have not, however, been able to obtain from the authorities in this case any account of the quantity of water which they collect, either in reservoirs for the special use of the canal at its higher levels, or from the rivers and streams which it crosses. Some of the water taken into this canal is applied to manufacturing purposes, being returned again into the canal; but as a general rule the water of canals is taken out of the different valleys, and is but little used for other than the purposes of navigation before being passed into the sea at the outlet locks.

(*b.*) **The Water Supply for the Population.**—The next demand made upon the rainfall is for the supply of the personal wants of the population.

The quantity required is variously estimated; but 20 gallons per head is generally affirmed to be the amount supplied by the different water companies or municipalities. This is admitted to be sufficient; not only supplying the fair demand for all ordinary purposes, but allowing a large amount for waste. Indeed, we are informed from Manchester that 20 gallons a head suffice for the use of a large number of mills, as well as all the houses; and that one-third of the quantity supplied at this rate to a population of 600,000, goes to manufactories within the district. Looking, however, to the fact that throughout Lancashire water-closets are the exception, it may be well to make an allowance for the waste likely to be caused when they shall come generally into use, and to put the amount per head at 25 gallons daily, or about 9,000 gallons for each individual per annum. That, then, is the quantity per head for which provision has everywhere to be made. Hamlets, scattered houses and villages, obtain their supply either from natural springs, or from wells. In the cases of some of the larger towns also, and notably in Liverpool and in the large towns on both shores of the *Mersey* as far as Warrington, a large part of the supply is derived from wells, and is thus recovered, as it were, from that proportion of the rainfall which disappears by absorption. In the coal districts, however, and in the saliferous portion of the new red sandstone district, wells do not often furnish drinkable water, and then the dependance falls on rivulets and streams, which, when taken near their sources where they contain only the drainage water of upland pastures, afford a perfectly satisfactory supply. Lower down, they necessarily contain the drainage of houses, villages, and cultivated fields, and their water cannot then be taken without risk, for no process, has been yet devised of cleansing surface water once contaminated with sewage so as to make it safe for drinking. It is therefore advisable to adopt as generally as possible the mode of collecting into reservoirs for household purposes the water from the high lands along the edge of the great valleys, or from such other collecting grounds as may be most convenient. And it may be well to consider the principles which should determine the area of these gathering grounds, and the size of the reservoirs needed to meet the demands of the population.

Ample provision must indeed be made for a very large addition to the number of the existing population, as the tables given in the former part of this Report show that the number of people on the coal fields of Lancashire has been doubled twice since the beginning of this century, and the rate of increase is still very rapid.

The inadequacy of the supply is indeed already occasionally manifest. It was in some places obvious enough in the summer of 1868, when, owing to an unbroken drought during the months of May, June, and July, the quantity of water passing down the rivers

PART II. WATER SUPPLY.

For domestic use.

was very trifling; and the amount stored up in reservoirs for the use of the population in the large towns proved to be insufficient.

That this was no extraordinary or improbable event appears at once on studying the meteorological statistics of the district. We have examined the records of the amount of the rainfall for several years; and we submit the following abstract of the rainfall in the years from 1861 to 1868 inclusive, on the line of the Manchester, Sheffield, and Lincolnshire Railway, for which we have to thank Mr. Robert Heathcott, the Company's canal superintendent, as being, in the monthly form of it, well adapted to show not only the actual quantity of rain over a somewhat extensive area, but also its distribution in time as well as over surface; and it will be seen from this that droughts such as that experienced in 1868 are by no means rare.

ABSTRACT of the MONTHLY STATEMENT of the RAINFALL in the Years from 1861 to 1868 inclusive on the Line of the Manchester, Sheffield, and Lincolnshire Railway.

Height above Sea in Feet.	Jan.	Feb.	March.	April.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1861.													
100 and under - -	·57	2·28	1·55	1·08	·93	2·90	3·64	·41	1·81	1·05	3·11	1·24	20·42
100 to 500 - - -	·61	3·21	4·95	1·58	1·05	2·53	4·04	1·82	3·45	1·33	3·72	1·82	30·31
Above 500 - - -	·60	3·28	6·62	1·44	1·28	2·87	4·60	2·62	4·65	1·56	4·72	2·77	37·01
1862.													
100 and under - -	1·16	·82	2·72	1·34	1·95	1·77	1·84	1·66	3·77	1·91	0·85	1·42	21·21
100 to 500 - - -	1·97	·73	3·75	2·43	4·29	2·83	3·42	2·44	4·46	4·64	1·12	2·31	34·39
Above 500 - - -	3·03	1·05	4·62	3·02	4·62	4·77	4·98	3·08	4·28	5·72	1·48	3·71	43·76
1863.													
100 and under - -	2·51	·29	·89	·73	·57	2·26	1·36	2·75	2·58	2·61	2·16	1·25	19·96
100 to 500 - - -	5·36	1·10	0·91	1·43	1·61	4·72	1·68	4·58	5·17	5·67	2·97	3·07	38·27
Above 500 - - -	6·42	1·35	1·35	1·83	2·65	4·59	2·43	5·28	5·78	6·91	3·98	3·88	46·45
1864.													
100 and under - -	·74	1·31	1·39	·81	1·73	1·60	·51	1·82	1·73	1·92	2·46	1·58	17·60
100 to 500 - - -	1·27	2·99	2·36	1·70	2·56	2·05	1·18	1·98	3·47	2·68	3·23	1·83	27·30
Above 500 - - -	1·77	2·77	2·51	1·35	3·12	3·21	1·71	2·81	3·77	3·23	5·18	2·54	34·00
1865.													
100 and under - -	1·43	1·47	1·20	·69	2·96	1·32	2·12	3·64	·19	4·42	2·19	·69	22·32
100 to 500 - - -	2·55	2·19	1·10	1·40	3·02	1·09	2·87	3·87	0·39	5·35	2·60	0·78	27·21
Above 500 - - -	3·08	2·72	0·86	1·68	3·23	0·92	5·39	4·62	0·44	6·93	4·41	1·38	37·66
1866.													
100 and under - -	1·30	1·92	1·24	1·21	1·21	3·17	2·75	2·73	3·16	2·32	2·45	1·46	24·92
100 to 500 - - -	3·17	3·17	1·68	0·88	1·30	4·20	3·70	4·08	5·47	2·74	4·32	3·47	38·18
Above 500 - - -	4·98	4·73	2·39	1·61	2·11	5·44	4·59	5·80	6·47	3·03	6·78	4·78	52·68
1867.													
100 and under - -	2·07	1·12	1·86	2·42	2·03	1·69	2·55	2·31	1·70	1·83	1·04	1·72	22·34
100 to 500 - - -	3·01	2·73	1·91	4·11	2·31	2·02	4·15	2·60	2·35	3·23	1·33	2·77	32·52
Above 500 - - -	4·09	4·29	2·16	6·19	2·17	2·23	5·67	2·66	3·31	4·62	1·82	4·52	43·73
1868.													
100 and under - -	1·56	1·48	1·24	1·63	0·71	0·56	0·42	3·36	2·18	2·19	1·36	5·46	22·15
100 to 500 - - -	2·46	2·17	3·27	1·85	1·17	0·37	0·22	2·54	2·15	3·79	2·02	7·83	29·84
Above 500 - - -	3·66	3·08	5·46	3·16	1·56	0·34	0·54	3·68	2·87	5·61	3·06	9·72	42·74
Mean of 8 years:—													
100 and under - -	1·42	1·33	1·51	1·24	1·51	1·91	1·90	2·33	2·14	2·28	1·95	1·85	21·37
100 to 500 - -	2·55	2·28	2·49	1·92	2·15	2·47	2·65	2·99	2·74	3·68	2·66	2·98	31·56
Above 500 - -	3·45	2·90	3·24	2·53	2·59	3·04	3·74	3·82	3·94	4·70	3·93	4·16	42·04
Maximum of 8 years:—													
100 and under - -	2·51	2·28	2·72	2·42	2·96	3·17	3·64	3·64	3·77	4·40	3·11	5·46	24·92
100 to 500 - -	5·36	3·21	4·95	4·11	4·29	4·72	4·15	4·58	5·47	5·67	4·32	7·83	38·27
Above 500 - -	6·42	4·73	6·62	6·19	4·62	4·62	5·67	5·80	6·47	6·91	6·78	9·72	52·68
Minimum of 8 years:—													
100 and under - -	·57	·29	·89	·69	·57	0·56	0·42	0·41	0·19	1·05	0·85	0·69	17·60
100 to 500 - -	·61	·73	·91	·88	1·05	0·37	0·22	1·82	0·39	1·33	1·12	0·78	27·21
Above 500 - -	·60	1·05	·86	1·35	1·28	0·34	0·54	2·62	0·44	1·56	1·48	1·38	34·0

The above figures show that in the months of May, June, and July 1868 the fall of rain was respectively ·71, ·56, ·42 inches, making a total in the three months of 1·69 inches; while in the year 1863, during the months of February, March, April, and May, the fall was ·29, ·89, ·73, ·57 inches, making a total in four months of 2·48 inches, the mean monthly fall in the former case being ·56 inches, and in the latter ·62 inches. In either case evaporation and absorption must have carried off by far the larger amount of that scanty supply, and the population must have been left for three months in one case, and for four months in the other, dependent altogether on the amount stored up in

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reservoirs; while the manufacturers who looked to a regular supply of water, whether for power or trade purposes, must have been subjected to loss and inconvenience.

It is true that the drought in 1863, recorded in the above table, showed itself more at the Lincolnshire end of the railway than in Lancashire; but a reference to the rainfall along the whole line during the four spring months of 1863, will show a monthly average fall of but 1·22 inches, while that of the three summer months of 1868 gives a monthly average of ·65 inches. Our object however in directing attention to these tabular returns is not so much to give an idea of the amount of the supply of water, as to show the necessity of disregarding averages, or even annual amounts of rainfall, and of looking to the actual period of drought as alone measuring the possible extent of the evil against which precaution must be taken.

For instance, in Mr. G. J. Symons' table, quoted on page 104, it appears that the two years 1863 and 1868, which we have taken as illustrative of the action of prolonged drought, do not indicate a falling off in the supply of the whole year. On the contrary, in 1863 the total quantity of rain was greater than in any year except the abnormal one of 1866, and that in 1868 was within less than half an inch of the mean of the eight years including 1866. It is thus the monthly rainfall which is irregular, and it is the returns of this to which we must look in order to determine the quantity of water for which storage must be provided. The supply is variable, and much greater in winter than in summer, while the demand is nearly regular but somewhat greater in summer than in winter, and means must therefore be found of keeping the excess in store to an extent sufficient to meet every possible contingency.

In 1861 during six summer months, and in 1863 during four spring months the rainfall was very deficient; and looking at the table we should judge that the droughts in those years must have been more severely felt than the drought of 1868, when the autumn rains were tolerably abundant. It is plain, however, from these figures, that provision must be made for at least a half year's storage.

This is indeed, upon the average, already done. In the following table it will be seen that most of the larger water companies—those of Manchester, Liverpool, and Oldham, for example,—store as much as from 240,000 to 320,000 gallons per acre of their gathering ground. We shall immediately find that the whole annual issue to their customers is in the case of these companies, not more than from 260,000 to 370,000 gallons per acre per annum, and if we add to these figures one half more for compensation water in order to ascertain the total delivery per acre in the year, we shall find that their storage capacity corresponds to seven or eight months of the whole year's delivery. And adding together the performances of all the waterworks, as declared in the two following tables, it will be found that while the issue from 50,893 acres of gathering ground is 36,600,000 gallons daily to consumers—or, adding the compensation for the mills to the amount, 55,000,000 gallons daily, or about 20,000,000,000 gallons per annum on the whole; the actual storage capacity possessed by these works amounts to 10,750,000,000 gallons, or fully half the year's demand.

Name of Waterworks.	Population. (1861.)	Area of Gathering Ground.	Contents of Reservoirs.	Storage per Acre.
		Acres.	Gallons.	Gallons.
Dukinfield	15,024	280	48,000,000	343,000
Ashton-under-Lyne	34,894	1,890	450,000,000	185,000
Liverpool	443,938	10,000	3,268,000,000	326,000
St. Helens	40,000	300	8,100,000	27,000
Manchester	441,136	19,000	4,582,000,000	241,000
Bolton	70,396	3,165	935,000,000	120,000
Bury	30,000	1,800	312,500,000	173,000
Rochdale	38,164	700	147,900,000	211,000
Oldham	72,334	2,700	742,000,000	275,000
Macclesfield	36,115	2,000	177,500,000	88,700
Nantwich	6,225	600	14,000,000	230,000
Preston	82,985	2,878	264,700,000	127,000
Oswaldtwistle	9,246	240	82,400,000	343,000
Accrington	17,688	600	110,000,000	183,000
Burnley	28,793	1,090	68,000,000	62,000
Over Darwen	16,492	504	116,000,000	92,000
Chorley	15,013	1,000	72,000,000	72,000
Wigan	37,658	2,200	237,000,000	108,000
Total and average	1,436,101	50,947	11,535,100,000	225,000

The towns supplied from these upland reservoirs are generally situated low down on the stream, often, indeed, in an altogether different valley; and the water, caught and passed through pipes for the use of their inhabitants, is thus withdrawn from the natural channels down which it would have found its way to the sea, and is hence placed beyond the

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control of the people living on the banks of these streams. Manchester, for instance, has its gathering ground at the head of the *Etherow*, a tributary of the *Mersey*; the water is carried in pipes for 14 miles into the valley of the *Irwell*, and passes through the *Irwell* into the outfall of that river: and Liverpool, though it derives a portion of its supply from wells sunk into the new red sandstone, has its principal source of supply at Rivington, some 25 miles distant, where, from a gathering ground of 10,000 acres, the water of several small brooks, tributaries of the *Douglas*, the *Darwen*, and the *Yarrow*, is collected and transferred into the valley of the *Mersey*.

When sanctioning such transferences of water from one valley to another, or permitting the collection of the head waters of a stream into a reservoir, the Legislature has been in the habit of requiring a portion, generally one-third of the whole, to be reserved and passed down the ordinary channels of the river as "compensation water" for the use of the inhabitants and manufacturers on the stream. When, however, the supply runs short in dry seasons, the domestic demand for the town below, which is imperative, has to be met by impounding this compensation water; and although the injustice, so far as the interest of the manufacturer has been interfered with, is then met by a money payment, yet the effect is to compel the people, an increasing population, on the banks of the original stream, who have a natural right to the use of all the water it contains, to content themselves at such time with much less than one-third, if not to go without altogether.

Considering, however, the difficulties connected with the enormous water supply needed in South Lancashire, it is impossible not to admire the resolution, enterprize, and success with which they have been encountered. The following table includes the particulars of evidence on this subject which have been supplied to us by the corporations and water companies in the *Mersey* and *Ribble* basins. We learn from it that of a population which must now exceed 3,000,000 within the watersheds of these rivers, more than 1,500,000 (taking the census of 1861, which is subsequent to the date of most of the waterworks) have taxed themselves 4*l.* a head for the construction of works which now provide with water a population of nearly 2,000,000 (estimated at the somewhat low rate of five persons per house) who are willing to pay rates averaging about 1*s.* in the pound upon the rental of their houses for the cost of it. The table gives the names of the several corporations or companies, the number of houses supplied, and the total capital invested by each, the estimated population each supplies, and the cost in every case per head of the town populations by whom in the first case it was incurred. There is also given in other columns the extent of gathering ground taken in those cases where gravitation works exist, and the annual quantity of the supply per acre derived from it.

STATISTICS of WATER SUPPLY in the MERSEY and RIBBLE BASINS.

Name of Waterworks.	To whom belonging.	Water is supplied to			Cost of Waterworks.		Extent of Gathering Ground.	Total daily Delivery of Water from Gathering Ground.	Annual Delivery of Water per Acre.
		Houses.	Factories.	People, estimated at Five per House.	Total.	Per Head of Population in 1861.			
		No.	No.	No.	£	£ s.	Acres.	Gallons.	Gallons.
Hyde	Mr. Mottram	2,830	?	14,150	?	—	—	?	?
Dukinfield	Board of Health	3,000	10	15,000	23,280	1 10	280	90,000	117,000
Staleybridge	Corporation	4,000	10	20,000	141,700	5 13	280	100,000	130,000
Ashton-under-Lyne.	Do.	10,000	65	50,000	115,000	3 6	1,890	600,000	116,000
Liverpool	Do.	99,284	775	496,420	2,000,000	4 10	10,000	10,000,000	365,000
St. Helens	Do.	6,138	70	30,690	40,443	1 2	300	60,000	73,000
Wallasey	Board of Health	1,828	10	9,140	40,901	3 19	—	—	—
Birkenhead	Commissioners	7,600	20	38,000	320,000	8 9	—	—	—
Tranmere	Board of Health	2,350	14	11,750	38,250	4 0	—	—	—
Manchester	Corporation	108,419	9,416	542,095	1,780,000	4 0	19,000	13,500,000	260,000
Bolton	Do.	20,000	396	100,000	381,629	5 4	3,165	2,125,000	245,000
Bury	Private company	9,700	232	48,500	142,137	4 7	1,800	1,000,000	216,000
Bacup	Do. do.	1,753	36	8,765	16,000	0 19	350	150,000	128,000
Heywood	Do. do.	5,200	30	26,000	71,811	4 11	1,260	100,000	30,000
Rochdale	Corporation	13,000	?	65,000	157,000	4 0	700	750,000	290,000
Oldham	Do.	20,000	400	100,000	229,000	3 3	2,700	2,750,000	370,000
Macclesfield	Do.	8,637	56	43,185	50,000	1 8	2,000	1,000,000	182,000
Southport	Private company	3,000	?	15,000	70,000	7 0	—	—	—
Preston	Corporation	17,000	250	85,000	234,000	2 16	2,878	2,200,000	275,000
Burnley	Do.	7,100	200	35,500	76,735	2 11	1,090	800,000	268,000
Chorley	Liverpool Corporation	3,000	50	15,000	40,000	2 13	1,000	500,000	182,000
Wigan	Corporation	6,700	?	33,500	172,000	4 11	2,200	700,000	116,000
Over Darwen	Private company	2,960	32	14,800	?	?	?	?	?
On the whole		363,499	12,072	1,817,495	6,139,886	4 0	50,893	36,425,000	267,000

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It will be seen from the last two columns of this table that the annual quantity issued by the several works which are dependent on gravitation, varies between somewhat less than 100,000, and rather more than 300,000 gallons per acre of the gathering ground. Almost all these gathering grounds are on the upland pastures along the high moorland margin of the river basin, and these variations can hardly be put down to any variation in the proportional quantity of water which the gathering grounds would yield if the whole supply from them were stored, but rather to the fact that the demand for water has more nearly approached the limits of this supply, and has thus necessitated a more careful storage, in some cases than in others. The actual issue from a total of 50,893 acres of gathering ground averages 260,000 gallons per acre per annum. But in those instances —Liverpool and Oldham, for example,—where necessity has compelled careful storage, it has amounted to 365,000 gallons annually per acre. One-third of the available water has to be delivered into the natural channel, and we should therefore infer from this a delivery altogether of 547,500 gallons per acre, to which must be added an indefinite quantity which inevitably goes to waste during excessive rainfalls and in floods.

This conclusion must, however, be received with some reservation, because in many cases where the natural supply has been barely sufficient, some of the " compensation water " has been bought up from those to whom it had been allotted, and is passed into the storage reservoirs of the companies for use by their customers. In order, therefore, to ascertain the whole delivery per acre from these gathering grounds, the quantity actually issued must not always be increased by so much as one-half more on account of compensation water. This result of our inquiry, however, is not inconsistent with the estimate which we have already made of 448,000 gallons per acre over the whole watershed, as the quantity which finds its way by the river channels to the sea.

Certainly, 365,000 gallons per acre per annum, exclusive of what is due as compensation, is a very moderate estimate of the quantity which is available from all the upland districts in these basins. It follows, therefore, that every upland acre will supply 50 people with water; and the 3,000,000 here congregated require, therefore, but 60,000 acres of gathering ground, a mere fraction of the 700 square miles within this district, which, as will be seen on the sketch map of the Mersey and Ribble basins facing page 1, lie above the level of 500 feet above the sea.

(*c.*) **The Water Supply for Manufacturing Purposes.**—The third demand upon the available water supply of the district is made by the different manufacturing establishments within it. These are, as a general rule, situated on the rivers and streams, or in the immediate vicinity of them; in fact, their requirements are in many cases so large that they could not be worked elsewhere, and it would be impossible, without serious damage to them, to permit any diminution of the existing minimum supply which these streams bring to them.

The quality as well as the quantity of the supply has to be considered. As regards the former, how great a value the manufacturers themselves have put upon a restoration of the rivers to their naturally clean condition has been already represented at pp. 96, 97, where, from the evidence of thirty manufacturing firms, it appears that to them alone, a restoration of the river to its original degree of purity would be worth more than 10,000*l.* a year. The condition of things which is thus found to be so desirable in the trade interests of the district, will be realized so soon as the various forms of wrong doing, of which its rivers have hitherto been the victims, shall have ceased. These various abuses have been already described, and methods of correcting them pointed out in this Report; and we will here only further remark that when this desirable consummation shall have been achieved, the present large demand of factories upon the domestic supply of this district will, to a great extent, be discontinued. Thus the efficient cleansing of the river waters of South Lancashire will at once set free for domestic use a large portion of that water which now goes to the supply of factories, and which, in the case of the Manchester Waterworks, amounts to one-third of the whole annual issue.

As regards the quantity of river water available for manufacturers, this is a subject which it might seem useless to discuss, for it is necessarily dependent on the rainfall, which is practically beyond the scope of any artificial influence. Although, however, the total available quantity is beyond our interference, it is certainly possible to regulate the distribution of it, which is naturally irregular. The supply may be for two or three months so scanty as to compel the manufacturer to restrict his operations, while at other times floods pour down which are always more injurious than useful; for, though they carry away the filth and rubbish which has been collected in the river channel and thus act as scavengers, yet, on the other hand, even if they commit no direct damage, they generate the habit of slovenliness and indifference to the existence of these nuisances, which is eventually productive of loss to all upon the river side, whether manufacturers or not. Whether, therefore, the work be left wholly to private enterprize, or be in any way assisted by contributions from the general property within the river basin, it is certainly extremely desirable, now that the manufacturing industry of so large a district has reached such a high state of development, that steps be taken to store up, as far as may be possible, both ordinary winter and extraordinary flood waters on the higher grounds, and thus to take out for use in drought some portion of that surplus flow which in its excesses is now entirely useless, and in its maxima becomes destructive. Mr. Thomas Greenwood, formerly resident surveyor of the Glossop Dale estate, to which the *Etherow* is generally the boundary for 17 miles, states in a published letter on the floods in the River *Irwell,** that the water power of that stream used to be very uncertain and irregular, the water-wheels being often stopped either from scarcity of water or excess of water, but since the formation of the reservoirs in the upper part of that valley by the Manchester Corporation, the state of things is entirely changed, the flow of "compen- " sation water " from the waterworks is generally uniform and regular, and injurious floods are prevented. At the time when the storm water of November 1866 was making such ravages in the *Irwell* valley, it was computed that the water then being stored in the reservoir at the head of the *Etherow* would, if it had not been thus impounded, have sufficed to raise the flood line in the river at Wellington bridge, Stockport, six feet above the height it reached during that storm. Mr. Greenwood strongly urges the general formation of reservoirs in the upper valleys of all the affluents of the *Irwell,* for the use of manufacturers in both flood and drought; and he very appropriately quotes his experience on the *Etherow,* as strongly recommending the proposal. The storage of river water is indeed to a small extent already done in detail by manufacturers, who endeavour by storage reservoirs to guard against the possibility of a short supply, even if only for a single day. That which is done on a small scale might be done with more general advantage on a greater scale; and we entirely agree with Mr. Greenwood that it would be for the great benefit of the manufacturer, and for the comfort and convenience of the population generally, if steps were taken to establish reservoirs for the retention of flood water at convenient points in the course of the streams which serve to drain the basins of the *Mersey* and *Ribble.* When that is done it will be possible to bring the daily supply of the different streams more nearly to an average condition; the injurious action of floods will to some extent be lessened, and on the other hand droughts such as that of 1868, so far as the river bed is concerned, will never be productive of the same amount of injury as at present, for there will always be in hand an artificial supply to eke out the natural deficiency.

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Quality.

QUALITY OF THE EXISTING WATER SUPPLY.

In our visits to the various towns in the *Mersey*, *Irwell*, and *Ribble* basins we have devoted a considerable amount of time and labour to the investigation of the quality of the water supplied to the inhabitants for domestic purposes, and that subject will therefore claim the remainder of this second division of our Report. We have in many cases inspected the gathering grounds, in most the storage and service reservoirs, and in all 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, taken by ourselves. Some of these waters were supplied to communities for domestic purposes, as for instance those derived from numerous deep wells in and around Liverpool, which are largely employed to supplement the product of the gathering ground upon Rivington Pike; 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, such as the carboniferous limestone, millstone grit, oolite, &c., whenever the chemical examination of such samples promised to throw important light upon the effect upon water, of storage in large lakes, or of percolation through particular strata. By continuing these observations in other districts which we are directed to visit, a great body of information will be collected in

* Floods in the River Irwell. Letter to the Mayor and Corporation of Manchester.—W. Livesley, Church Street, Manchester, 1868.

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accordance with the instructions conveyed to us in consequence of Mr. Neate's letter, and thus we trust the resources of the country as regards water supply will be better known and understood than has hitherto been the case.

An investigation as exhaustive as possible of this subject appeared to us of the greater importance, first, because the volume of water soiled by manufacturing refuse and sewage is becoming every year greater; and second, because 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 observations and experiments described in the former part of this Report prove conclusively that the so-called self-purifying power of streams contaminated with sewage is fallacious, the process being one of such extreme slowness that no river, in this country at least, is long enough to secure even any approach to such a purification as would render the use of the water as a beverage reasonably free from danger.

It is not proposed in this Report to enter fully into this department of our inquiries, but we shall confine ourselves to a statement of the results of analysis and the special remarks and recommendations which they suggest as applicable to the basins of the *Mersey* and *Ribble*, reserving for a later Report considerations of a more general character, which we shall be in a better position to advance when we have acquired a like intimate acquaintance with the potable waters of other districts.

With but very few exceptions, the towns visited are supplied, on the constant system, with water of excellent quality. In many cases it is brought from considerable distances and at a cost which shows that the local authorities, once impressed with the extreme importance of having a supply of this first necessary of life of such a quality as to be above all suspicion of excremental pollution, carried out their object in a most liberal spirit. In many cases they have purchased the rights of private companies, and taking the works into their own hands, have greatly improved both the quantity and quality of the supply. The very liberal expenditure for this purpose per head of population is given in detail at page 109.

Chemical Analysis of Potable Waters.—In the chemical examination of water intended for domestic purposes, the most important facts which it is desirable to know are, first, the amount of organic matter present in the water at the time of analysis; second, the quality of this organic matter,—whether it be of animal or vegetable origin; third, the previous history of the water as regards animal contamination; and fourth, the amount of hardening or soap-destroying materials which the water contains. The analytical methods by which these facts are determined do not differ essentially from those employed by us in the examination of the waters of polluted rivers described at page 14; and it is only necessary here to supplement that description by a few remarks on the nature of the evidence which discloses the history of water as regards previous animal contamination, a subject of but little significance (as stated at page 14) with reference to pollution popularly so called, but one of the utmost importance when the use of the water as a beverage is contemplated. We have already stated (page 14) that there is no process known by which the total weight of organic matter in water can be ascertained; but by the determination of its two chief elements,—carbon and nitrogen,—the relative quantities of organic substances in different waters are approximately indicated, whilst the relative proportion of these elements, in each sample, frequently gives a clue as to whether the organic matter be of animal or vegetable origin. With more certainty, however, can the quality of the organic matter be judged of by the previous history of the water recorded in the mineral ingredients which it contains. It has been proved above that the organic matters of an animal origin contained in water, such as those derived from sewage, the contents of privies and cesspools, or farmyard manure, undergo oxidation in 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 äerated 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 contained in most streams, frequently remain dissolved in the water for a long time, and constitute a record of the sewage or other analogous contamination to which it has been subjected since its last descent to the earth as rain. Such previous sewage or animal contamination is conveniently expressed in so many parts of average filtered London sewage as would, if thus completely oxidized, yield a like amount of nitrogen in the form of nitrites, nitrates, and ammonia. For this purpose average filtered London sewage has

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been assumed to contain 10 parts of combined nitrogen in 100,000 parts. Our own numerous analyses of London sewage given above show that this assumption is greatly in excess of the truth, 7·06 parts only of combined nitrogen being the average amount contained in solution in metropolitan sewage according to the table given at page 29. As the standard thus assumed, however, has now been in use for several years, and as it is obviously 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 will doubtless undergo still further diminution when the water supply to the poorer districts of the metropolis becomes more commensurate with their wants.

In thus tracing the history of water through the nitrates and ammonia which it holds in solution, it is necessary to bear in mind that rain water itself contains these substances, although in very minute quantities. The average of 23 recent analyses of rain water kindly collected for us at Rothamsted, by Dr. J. H. Gilbert, F.R.S., gives the amount of nitrogen in these forms = ·038 part in 100,000 parts of water, which does not differ materially from the number ·032 derived from previous analytical observations upon rain water, and used for some years past as the constant to be deducted from the nitrogen in these forms found in potable waters. After this number has been subtracted the remainder, if any, represents the nitrogen derived from oxidized animal matters with which the water has 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 amount of combined nitrogen is 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 2,940 lbs. of average London sewage. This evidence of the amount of animal organic matter previously in the water is liable to be weakened or even altogether destroyed by several influences to which water is sometimes subjected; thus we look in vain for the full evidence of anterior animal pollution in the effluent water from fields irrigated with sewage, because the growing plants have removed a considerable proportion of ammonia and nitrates from the liquid as it flows over their rootlets. In like manner the aquatic vegetation of rivers, lakes, and reservoirs also slowly removes these compounds from the water and to that extent destroys the evidence of animal contamination. Nitrates are also rapidly destroyed when the organic matter of the water containing them enters into putrefaction, a condition which often occurs in streams or reservoirs containing much polluting organic matter. It also 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, being cut off from a supply of oxygen from the air, accomplishes its oxidation at the expense of the nitrates, and thus destroys them. Owing probably to this cause, the evidence of previous animal contamination is not met with in some deep chalk wells in which it might be expected to occur. The gases dissolved in the water of these wells are always found to be nearly, if not quite devoid of oxygen.

The previous animal contamination of water, as deduced from chemical analysis, must therefore always be regarded as a minimum quantity; it does not represent 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 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 they are in themselves innocuous; but from the risk lest some portion of the noxious constituents of the original animal matters should have escaped that decomposition, which has resolved the remainder into innocuous mineral compounds. And the danger is the more to be feared because it is quite impossible by chemical analysis, or indeed by any other process of investigation short of administration of the water to human beings, to discover whether or not such noxious substances are still left in the water. We cannot but regard this risk as considerable, whatever may be the nature of the noxious ingredient in excrementitious matters, but if we are to accept the theory which is now prevalent amongst many physiologists who have closely studied the subject of the spread of epidemic and infectious diseases, that these diseases are propagated by minute zymotic germs, the danger becomes much augmented on account of the great resistance which such organic and living germs oppose to the oxidizing agencies which gradually decompose and destroy dead organic

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matter. That this is no imaginary danger is evident from the numerous outbreaks of typhoid fever and cholera which have been distinctly traced to the drinking of water previously polluted by excrementitious matters, but in which chemical analysis failed to detect any noxious ingredient. Thus Dr. R. Thorne Thorne, the medical officer deputed by Your Majesty's Privy Council to examine into the case of an outbreak of typhoid fever in the year 1867, in the village of Terling, reports, Tenth Report of Medical Officer of the Privy Council, 1867, that the outbreak was caused by the drinking of water from certain wells; chemical analysis, however, did not discover any noxious substance in the water, but the analytical results gave for three of the wells a previous sewage or animal contamination as follows:—

	Previous sewage or animal contamination in 100,000 parts of water.
Middleditch Well - - - - - - -	24,850
Lines Well - - - - - - -	9,160
Terling Place Pump - - - - - -	10,980

In September, 1867, an outbreak of typhoid fever occurred at Guildford, and Dr. Buchanan, an inspector of the Medical Department of the Privy Council Office was sent to investigate the cause. He reported that a new well had been sunk to supply the higher part of the town, and that water from this well was supplied to about 330 houses for one day only, the 17th August. On the 28th of August there were several cases of typhoid fever in these houses, although they are all situated in the highest and healthiest district in the town. The number daily increased and there were in all about 500 cases and 21 deaths. With three exceptions, all the persons attacked in August and September had drank the water exceptionally supplied for one day only,—as just stated. It was subsequently found that a sewer ran within 10 feet of the well, and that the sewage leaked through the joints of the brickwork and saturated the soil just above the spring which supplied the well.

The water was afterwards analyzed, and no ingredient was found that could be pronounced noxious, the results, however, showed that each 100,000 lbs. of it had been previously polluted with a quantity of animal matter equivalent to that found in 7,330 lbs. of average London sewage.

Similar outbreaks of typhoid fever in many other places have been ascribed, by the medical officers deputed to investigate them, to the excremental pollution of drinking water. In every case analysis showed large anterior animal pollution, but in no instance was any deleterious substance found in the water; indeed, it is obviously impossible for the chemist to detect the fatal ingredient, until the physiologist has discovered what ingredient it is, in excremental matters, which, at certain times, produces such disastrous results. On this account, the chemical examination even of the actual excrements of typhoid patients has hitherto failed to detect anything to which positive injury to health could be ascribed, and it is therefore obviously impossible that any such constituent can be found, after the excrements have been diffused through many thousand times their bulk of water. In his evidence before the Royal Commission on Water Supply, Mr. Simon, F.R.S., the Medical Officer of Your Majesty's 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 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. 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

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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 Lea. The contamination was sewage. Speaking broadly for the whole metropolis, 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.

"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.

"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."

Speaking of the influence of the degree of sewage contamination of water upon the propagation of epidemic cholera, Dr. Farr, 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, shows 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 from cholera to the extent of 8 in 10,000. Of every

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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. In Lambeth, which was supplied partly by the Lambeth and partly by the Southwark Company, the deaths from cholera, which were 1618 in 1849, fell to 904 in 1854. In 26,000 houses supplied by the Lambeth Company, the deaths were 294, whilst in 40,000 houses, supplied by the Southwark Company, 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 with each other; 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.

Although the water of the *Thames* has been submitted to analysis by different chemists on many hundred occasions, no constituent which could be pronounced noxious has been detected, but the history of the water traced in the inorganic constituents above referred to always reveals, that which is indeed well known to be the fact, its previous contamination with sewage or animal matters.

In his evidence before the Royal Commission on Water Supply, 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 communicating 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 reagents.

"But under the microscope have you the means of detecting?—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 class 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 lady's 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 effected 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, seem to show that the outbreak of the fever is owing to the impregnation of the water with sewage."

Further and abundant evidence to the same effect might be adduced, but we have confined ourselves to that of Medical Officers in Your Majesty's service whose special duty it is to inquire into the causes of epidemic disease. This evidence, taken in connection with our own investigations, appears to us conclusively to prove, first, that there is at certain times in human excreta some material capable of producing disease of a very fatal character in the human subject; second, that this morbific matter can be detected only by its specific action upon the human subject, and cannot be distinguished, either by chemical or microscopical analysis, even in the concentrated excreta, much less in water

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Character in Mersey and Ribble basins.

mixed with the excreta; third, that inasmuch as the organic matters of sewage are oxidized and destroyed with extreme slowness in running water, there is great probability that the morbific matter will escape destruction and be conveyed to great distances in rivers and streams; fourth, that owing to the rapid oxidation and destruction of the organic matter of sewage during filtration through porous soils, the passage of this morbific matter into deep wells carefully preserved from the admission of surface water, is but little to be feared.

These conclusions supply the interpretation which we desire to have put upon the evidence of previous sewage or animal contamination afforded by the chemical analysis of potable waters, viz.:—that this evidence implies very much more danger in river water than in deep seated spring, or deep well water. It must not be forgotten, however, that no matter what may be the exact amount of risk attending the use of previously contaminated waters from these respective sources, that risk is increased in direct proportion to the amount of such previous contamination. On this ground, water even from a very deep well should be rejected for domestic purposes if its analysis shows that it has been in contact with a large amount of animal matter. It is, of course, impossible to give any definite proportion of previous contamination of this nature beyond which deep well water should be considered dangerous, and short of which it should be deemed perfectly safe; but we think that such water might be regarded as reasonably safe if it did not exhibit chemical evidence that 100,000 parts of it had been in contact with more animal matter than that contained in 5,000 parts of average London sewage, or, in other words, if it did not exhibit more than 5,000 parts of previous sewage or animal contamination in 100,000 parts.

With regard to a river water, the detection of any amount of previous animal contamination ought to raise the suspicion that it is not safe for domestic supply, but as it is obvious that such evidence of previous contamination may be afforded by the water of deep seated springs supplying the river, the water ought not to be condemned if the proportion of previous contamination be small, until an inspection of the stream has shown that sewage or animal matter does actually gain access to it.

Potable Waters in the Mersey and Ribble basins.—We now proceed to give the results of our analyses of, and inquiries into the potable waters supplied to the towns in the *Mersey* and *Ribble* basins.

Liverpool.—This town 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 25 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:—

* For a minute description of these works see Vol. II. (*Minutes of Evidence*), part 4.

† These wells appear, however, to be still occasionally used, for in a pamphlet by Mr. Charles H. Beloe, Chairman of the Liverpool Water Committee, just published, it is stated that, "the following stations are " rarely or ever used for supplying the town with water, *except during protracted droughts*, 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."

(Handbook of the Liverpool Waterworks, by Charles H. Beloe. London, printed by Spottiswoode & Co., Parliament Street, Westminster.)

PART II. WATER SUPPLY. — Liverpool.

COMPOSITION OF POTABLE WATERS SUPPLIED TO LIVERPOOL.

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 or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Temperature—C.	Distance from Town Hall in a direct line.	Depth of Well and Bore-holes.	Yield in Gallons per Day.
												°	Yards.	Feet.	
Bevington Bush Well, May 21, 1868. Closed.	86·70	·135	·038	·005	8·678	8·721	86,510	12·61	11·52	23·99	35·51	—	1460	149	—
Soho Well, May 21, 1868. Closed.	59·98	·066	·024	·001	2·195	2·220	21,640	7·51	3·90	16·23	20·13	—	1540	123	—
Bootle Extension Well, May 21, 1868.	34·40	·091	·027	·001	·418	·446	3,870	3·18	0	13·71	12·62	10·4	5350	312	1,600,000
Green Lane Well, May 21, 1868.	26·40	·020	·020	·000	·416	·436	3,840	2·68	4·01	9·55	13·56	11·0	5060	370	3,000,000
Dudlow Lane Well, May 21, 1868.	19·64	·004	·000	·003	·679	·681	6,500	2·61	·46	6·50	6·96	—	6820	245	700,000
Windsor Well, May 21, 1868.	32·00	·076	·033	·000	·411	·444	3,790	2·87	2·12	12·75	14·87	11·2	3230	453	900,000
Water Street Well, May 21, 1868.	51·42	·018	·013	·001	1·975	1·989	19,440	7·94	1·62	11·62	13·24	16·0*	2340	156	300,000
Kensington service reservoir, containing a 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	·46	5·73	6·19	13·0	—	—	—
Rivington Pike water, unfiltered, as it passed on to filter beds, June 4, 1869.	8·48	·243	·031	·004	·000	·034	0	1·53	·13	3·59	3·72	—	—	—	—
Ditto, as issuing from sand filters, June 4, 1869.	9·66	·210	·029	·002	·000	·031	0	1·53	·25	3·72	3·97	—	—	—	15,500,000

* The condensing water of the pumping engine is allowed to mix with the supply, and hence this comparatively high temperature.

The analytical numbers are to be read thus:—100,000 lbs. of the water of Bevington Bush well contained 86·7 lbs. of total solid impurity; the organic matter constituting a portion of this impurity contained ·135 lb. of carbon and ·038 lb. of nitrogen. The above quantity of water also contained ·005 lb. of ammonia, and 8·678 lbs. of nitrogen in the form of nitrates and nitrites, whilst the total amount of *combined* nitrogen in every form was 8·721 lbs. After its descent to the earth as rain 100,000 lbs. of the water had been contaminated with refuse animal matter equivalent to that contained in 86,510 lbs. of average London sewage. By gradual oxidation, this animal contamination had been (so far as analysis can show) converted into innocuous inorganic compounds (see p. 112) before the water was submitted to investigation. The above quantity of water also contained 12·61 lbs. of chlorine. Finally, 100,000 lbs. of the water contained 35·51 lbs. of carbonate of lime or their equivalent of other hardening ingredients (total hardness); of these 11·52 lbs. would be got rid of by boiling the water for half an hour (temporary hardness), whilst 23·99 lbs. would still remain in solution (permanent hardness). The numbers in the analytical table can be converted into grains per imperial gallon by multiplying them by seven and then moving the decimal point one place to the left.

All the substances mentioned in the above table were in solution, and the column headed "total solid impurity" corresponds to those in the former part of our Report headed "total solid matters in solution." These solid matters usually consist chiefly of mineral salts of lime, magnesia, and soda, which, being innocuous or nearly so, cannot, when present in but moderate quantity, be regarded as polluting agents. When they occur in water destined for domestic purposes, however, these substances are justly described as impurities, because in the first place they are entirely useless for all the purposes to which potable water is applied, and secondly they act injuriously in several of those processes, rendering the water hard and consequently unfit for washing and cleansing operations. The latter consideration becomes more cogent when it is remembered how large a proportion of the water supply of a town is used for washing.

PART II. WATER SUPPLY. — Liverpool.

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 the oxidized products of animal refuse. They are in this respect but little superior to the much shallower wells of London as is seen from the following comparison:—

	Previous sewage or animal contamination.
Liverpool deep wells.	
Bevington Bush well	86,510
Soho well	21,640
Water Street well	19,440
London shallow wells.	
Pump in Aldgate	38,080
" Minories	57,060
" Leadenhall Market	57,370
" St. Nicholas Olave churchyard	75,640
" 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 connection between the supply of this water and the outbreak of cholera in Liverpool in that year, see Vol. II. (*Minutes of Evidence*), part 3, Q. 1873. It is satisfactory to know that these wells are now permanently closed (see, however, foot note p. 117); and that the Water Street well, which is but little better as regards anterior animal contamination, will also soon be abandoned. It is to be feared, however, that, as the suburbs of the town extend, the other wells will also become similarly affected.

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 oxidized and purified by percolation through a porous and well aerated soil, that but very minute quantities of organic matter (represented in the above analyses by organic carbon and organic nitrogen) have escaped decomposition. They 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 becomes 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 oxidized 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 this well was not completed, and the water was, therefore, probably not in a normal condition. It ought to be examined again when the works are finished.

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
Windsor Well	1	:	2·30
Water Street Well	1	:	1·38
Rivington Pike Water	1	:	7·24

PART II.
WATER SUPPLY.
Manchester.

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 filter 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 just 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 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, and a new source of supply is, therefore, only a question of time.

Manchester.—This city is bountifully supplied on the constant system with water of excellent quality from gathering grounds situated about 20 miles distant upon the slopes of the Derbyshire and Cheshire hills near Woodhead. During the long drought of 1868 there was some scarcity, but two additional impounding reservoirs, capable of containing 734,000,000 gallons, have since been added to the works. The position of the gathering ground and reservoirs is such as to preclude the possibility of excremental pollution, and consequently the water is not filtered before delivery. Nevertheless, even in the case of a water of such undoubted purity, we would recommend filtration, since 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 Manchester Corporation also supply Salford and some other neighbouring towns with the same water. An analysis of a sample which we collected at the Manchester Town Hall on the 19th June 1868, gave the following numbers :—

100,000 parts of the water contained,—

Total solid impurity - - - - -	6·20	parts.
Organic carbon - - - - - -	·183	„
Organic nitrogen - - - - - -	·009	„
Ammonia - - - - - - -	·006	„
Nitrogen, as nitrates and nitrites - - -	·025	„
Total combined nitrogen - - - - -	·039	„
Previous sewage or animal contamination - - -	0	„
Chlorine - - - - - - -	1·12	„
Temporary hardness - - - - -	·14	„
Permanent „ - - - - -	3·59	„
Total „ - - - - -	3·73	„

PART II.
WATER SUPPLY.
Other towns.

Other Towns.—The following table contains the results of our analyses of water supplied to other towns in the Mersey and Ribble basins :—

POTABLE WATERS of the MERSEY and RIBBLE BASINS.

Results of Analysis expressed in Parts per 100,000.

Description.	System of Supply.	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			Remarks.
										Temporary.	Permanent.	Total.	
MERSEY BASIN.													
Birkenhead. Spring Hill Waterworks. Deep well, May 16, 1868.	Constant	18·80	·041	·038	·000	·366	·404	3340	3·40	·15	9·71	9·86	Clear.
Flaybrick Hill. Deep well, May 16, 1868.	Constant	14·20	·047	·015	·000	·175	·190	1430	3·48	·83	4·90	5·73	Clear.
Wallasey water supply. Deep well, May 16, 1868.	Constant	37·80	·030	·008	·002	·278	·288	2480	3·18	1·22	7·87	9·09	Clear.
Wirral Water Co.'s deep well, May 16, 1868.	Constant	27·80	·249	·034	·001	·376	·411	3450	3·53	5·57	8·48	14·05	Clear.
Tranmere water supply. Deep well, May 22, 1868.	Constant	22·14	·000	·000	·004	·274	·278	2450	2·88	2·81	8·48	11·29	Clear.
Runcorn public fountain, May 18, 1868.	—	60·80	·118	·011	·000	·382	·394	3510	7·00	8·10	17·24	25·34	Clear.
St. Helen's new waterworks. Deep wells, May 23, 1868.	Constant during day.	21·66	·000	·000	·000	·436	·442	4040	1·94	5·95	6·80	12·75	Clear.
Warrington. Proposed supply from Spa spring, Winwick, May 25, 1868.	—	24·34	·027	·002	·000	·310	·312	2780	1·64	7·92	10·17	18·09	
Northwich. From Wade brook, May 27, 1868.	Constant	27·96	·633	·049	·000	·064	·113	320	2·43	2·43	11·62	14·05	Turbid.
Macclesfield. Gathering ground, June 16, 1868.	Constant	10·10	·188	·005	·020	·030	·051	146	1·11	4·58	4·82	9·40	Slightly turbid.
Congleton. Town pump at Star Inn. Shallow well, May 29, 1868.	—	38·00	·177	·044	·002	1·076	1·122	10,456	3·18	3·99	13·08	17·07	
Bolton. Gathering grounds. Entwistle reservoir, June 22, 1868.		9·37	·297	·018	·024	·010	·048	0	1·19	·15	4·97	5·12	Slightly turbid.
Bolton. Sweetlove's reservoir, June 24, 1868.	Constant	7·74	·333	·047	·015	·029	·088	94	1·14	·70	2·82	3·52	
Bolton, Heaton reservoir, June 24, 1868.		11·84	·355	·024	·018	·044	·083	269	1·39	·31	5·73	6·04	
Rochdale. Buckley Wood reservoir, June 26, 1868.	Constant	8·82	·134	·000	·014	·000	·012	0	1·09	0	5·12	5·12	
Rochdale. Spring near Churchyard, June 26, 1868.	—	37·04	·070	·046	·001	1·813	1·860	17,818	2·98	·50	13·88	14·38	Clear.
Bury and Radcliffe. Gathering ground, June 24, 1868.	Constant	11·00	·229	·000	·032	·066	·092	598	1·22	·46	4·97	5·43	Turbid.
Oldham. Gathering ground, July 22, 1868.	Constant	12·80	·166	·014	·004	·011	·028	0	1·29	·92	6·04	6·96	
Oldham. Nook pump. Shallow well, May 8, 1869.	—	29·86	·068	·019	·006	1·037	1·061	10,100	1·77	0	11·5	11·5	Clear.
Ashton-under-Lyne. Gathering ground, July 24, 1868.	Constant	24·14	·200	·031	·010	·028	·067	45	1·89	3·24	10·97	14·21	Very turbid.
Water from bore-hole in Dinting Vale Printworks, July 28, 1868.	—	26·32	·092	·020	·003	·019	·042	0	·89	9·81	5·90	15·71	Clear.
Stockport. Disley gathering ground, July 27, 1868.	Usually constant.	14·18	·204	·019	·007	·015	·040	0	1·29	0	8·29	8·29	Slightly turbid.
RIBBLE BASIN.													
Accrington. Supply from coal pit, June 11, 1869.	Constant	33·42	·045	·017	·000	·012	·029	0	1·40	7·70	2·18	9·88	
Preston. Gathering ground, July 31, 1868.	Constant	12·44	·236	·031	·006	·000	·036	0	1·59	3·67	5·27	8·94	Slightly turbid.
Leyland. Shallow well -	—	54·40	·325	·056	·003	2·466	2·524	24,360	—	—	—	17·5	Clear.
Blackburn. Gathering ground, August 5, 1868.	Constant	11·80	·249	·021	·000	·010	·031	0	1·14	·15	5·78	5·93	Slightly turbid.
Stream from Little Harwood. Abandoned coal-pit, 70 yards deep, near Blackburn, Aug. 5, 1868.	—	36·96	·117	·055	·002	·029	·086	0	1·29	9·20	1·16	10·36	Clear.
Chorley. Gathering ground, March 9, 1869.	Constant	11·66	·401	·019	·001	·000	·020	0	1·56	0	5·41	5·41	Clear.
Wigan. Gathering ground, August 7, 1868.	Constant	24·78	·350	·048	·007	·071	·125	450	1·79	3·49	8·58	12·07	Clear.
Over Darwen. From streams, August 10, 1868.	Constant	10·98	·272	·068	·001	·029	·098	0	1·39	0	6·22	6·22	
Intermittent spring from mountain limestone at Giggleswick, June 14, 1869.	—	20·98	·011	·007	·000	·040	·047	80	·98	10·88	5·50	16·38	Clear.

PART II. WATER SUPPLY.

Various towns.

The towns on the Cheshire shore of the estuary of the *Mersey*, Birkenhead, Wallasey, and Tranmere, are all supplied with excellent water from deep wells in the New Red Sandstone. With the exception of the water from the Wirral Water Company's well, all these samples contain remarkably small amounts of organic matter; indeed a most minute analysis failed to detect any trace of organic matter in the water supplied to Tranmere. In all cases the evidence of previous animal contamination falls considerably within the limits (5,000 parts in 100,000) which we regard as reasonably safe in deep well waters (see page 117). The hardness of all the samples is also moderate.

At the time of our visit to Runcorn a deep well was being sunk into the same rock for the supply of the town, but the works were not advanced sufficiently to render the taking of a fair sample of the water possible. The inhabitants were still dependent for water chiefly upon a public fountain fed from a neighbouring spring, the quality of which, though not unimpeachable, is by no means very bad.

At St. Helen's the new works, consisting of deep wells in the New Red Sandstone, were in full operation, yielding a water in which analysis failed to detect a trace of organic matter. The hardness was also moderate.

Warrington was about to be supplied with water of nearly equal excellence from borings into the same rock near a natural spring at Winwick.

Owing to the large saline deposits in the basin, it is difficult to procure good potable water in the valley of the *Weaver*. Northwich has gone to the *Wade* Brook, about one mile distant, for its supply. The water is not of good quality, although it is filtered through gravel, sand, and charcoal, 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; 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.

Macclesfield is supplied with good and moderately soft water, chiefly from a gathering ground of 2,000 acres at Langley, but partly from Rulow, Swine Park, and Round Fountain. The water is filtered before delivery. There is some though very slight evidence of previous animal contamination, which ought to be traced to its source.

Congleton has no regular water supply, but is dependent upon pumps drawing from shallow wells; 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. Congleton is a town with, at the last census, a population of 12,344, and is a municipality. It is not creditable to the authorities that this town should still derive its supply of water from such dangerous sources.

Bolton is supplied with water from gathering grounds (chiefly moorlands) lying between four and five miles north-west of the borough. At the time of our visit a new reservoir had just been constructed in the townships of Turton and Entwistle capable of containing 555,000,000 gallons. The water collected in this reservoir was of excellent quality, soft, and containing no evidence of anterior pollution. That collected in Sweetlove's and Heaton reservoirs, though fairly good, is inferior to the Entwistle water; it also exhibits traces of anterior animal pollution. All these waters contain a remarkably high proportion of ammonia. They are not filtered before delivery.

Rochdale derives its chief water supply from catchwater drains and springs on Brown Wardle Common; the storage reservoirs being all situated within two miles of the borough boundary. Their united capacity is nearly 150,000,000 gallons. The water is very soft, contains but a small amount 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. 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.—See Vol. II. *Minutes of Evidence*, part 3, Q. 681.

At Bacup about half the population obtain their water from springs, wells, and small reservoirs, while the remainder look for the supply of their wants to the Rosendale Waterworks Company which was established in 1853. This company has a gathering ground of 350 acres, and two reservoirs to receive the water from it; one, which can contain 14,000,000 gallons, is reserved for domestic purposes; the other will contain 8,000,000 gallons, and 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 one half of the town, failed during three months in 1868 to supply any water from the large reservoir appropriated to 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 wants 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.

PART II. WATER SUPPLY.

Various towns.

The towns of Bury and Radcliffe are supplied by a private company with unfiltered water from some of the upper sources of the *Irwell*, taken in the hills above the populous towns and villages and stored in reservoirs. The company has established five reservoirs, which receive the drainage from 1,800 acres. The total contents of these reservoirs is put at 312,000,000 gallons; but, as six cubic feet per second for 12 hours per diem must be sent down as compensation water, this, which amounts in the course of the year to about 600,000,000 gallons, swallows up a very large proportion of the water flowing from the gathering ground; and in case of a drought a large deduction would have to be made from the compensation water, in order to enable the company to supply the ordinary wants of the population, for which here as elsewhere, about 20 gallons per individual are required daily. In 1868 the reservoirs were exhausted, and the water company had to purchase a supply of water for seven weeks from another company to enable it to meet the demands made upon it. 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. Harper of Bury:—"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 at once prevented. The analysis (page 121) shows 598 parts of previous sewage or animal contamination, in 100,000 parts of the water as delivered at Messrs. Harper and Dodd's office in Bury.

Oldham is supplied from the sources of the rivers *Irwell* and *Medlock*. The water is stored in impounding reservoirs, situate at Strinesdale, about two miles east of the town, and at Piethorne about four miles east of Rochdale. The quality is excellent; it is soft, contains but little organic matter, and exhibits no traces of previous animal contamination. It is not filtered before delivery. 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 the New Red Sandstone, 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. The analysis, in the above table, of the sample taken at the time of our visit, shows 10,100 parts of previous sewage or animal contamination. In his evidence Mr. Thomas Platt, surgeon of Oldham, states that scarlatina has prevailed in the neighbourhood of this well (Vol. II. *Minutes of Evidence*, part 3, Q. 917). The use of potable water derived from such a source cannot but be attended with great risk.

Ashton-under-Lyne is supplied from waterworks belonging to the Corporation, chiefly from a reservoir situated about two miles from the town, supplemented by water pumped from a coal-pit within the borough. 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 contained, as shown above, but a moderate amount of organic matter, and exhibited but very faint traces of previous animal contamination. It was, however, rather hard, owing, doubtless, to the admixture of the coal-pit water, which was to be discontinued as soon as new and extensive works then in progress were completed.

Stockport is stated, in answer to questions (Vol. II. *Minutes of Evidence*, part 3), to be but badly supplied with water by a private company, partly from wells, partly from the Manchester waterworks, and partly from a reservoir in Lyme Park, near Disley. That portion which is supplied from the Manchester Works and from Lyme Park is, however, of excellent quality, as shown by our analyses. In their replies to our questions the Corporation state that the quality "entirely depends upon where it comes from; if

Part II. Water Supply.

Various sources.

" from the river, it is bad; if from the pumps, it is very hard and unserviceable; if " from Manchester waterworks, good; and if from Lyme reservoir, good." 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 (Vol. II. *Minutes of Evidence*, part 3, Q. 1031). The water, which we saw supplied 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 (Vol. II. *Minutes of Evidence*, part 1, and part 3, Q. 951).

Accrington is supplied with unfiltered water by a private company, from springs, streams, and reservoirs fed by a gathering ground of 600 acres. A part of the town receives water pumped from a coal mine. From evidence given before us (Vol. II. *Minutes of Evidence*, part 3, Q. 2741), this latter water appears to be regarded as of suspicious quality. Analysis, 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.

Preston receives its water from gathering grounds on Longridge Fell. The storage reservoirs are situated at distances of from three to eight miles from the town. 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*. 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.

The village of Leyland is a fair type of many others in the districts which we 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 excrements 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 of 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.

The town of Blackburn is supplied on the constant system by a private company with soft water of excellent quality, containing no traces of previous animal contamination. The proportion of organic matter is moderate, and its composition indicates a vegetable origin.

Chorley receives its water supply on the constant system from a reservoir on Rivington Pike belonging to the Liverpool Corporation Waterworks. The water is filtered, and

Part II. Water Supply.

Various sources.

its quality is unimpeachable; in fact, it is very similar to that of the water supplied to Liverpool from the same and neighbouring gathering grounds.

Wigan derives its supply from a stream four miles north of the town; and the works belong to the Corporation. The water is supplied on the constant system, is filtered through sand before delivery, and is kept in darkness after filtration. The quality of the water is not quite equal to that of most other Lancashire towns. The proportion of organic elements is rather high, and there is marked evidence of previous animal contamination which, as the water is derived from a stream, should be traced to its source (see page 117). The source, indeed, is indicated by Mr. J. Law Hunter, C. E., as being manure amongst which is a "*very little*" *privy stuff* (see Vol. II., *Minutes of Evidence*, Part 3, Q. 2410–2414). 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.

Over Darwen receives a constant supply from a private company of good but unfiltered water from streams. The reservoir is situate about a mile from the town. The water is soft and free from any indications of previous animal contamination.

Potable Waters from other Sources.—The following table contains the results of our analyses of various samples of waters from sources external to the *Mersey* and *Ribble* basins. For reasons already given at page 112, we defer our comments upon these samples to a future opportunity.

Potable Waters from other Sources.

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 or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
Aldershot Camp. Water supplied from gathering ground, May 1, 1868.	6·14	·417	·048	·001	·000	·049	0	1·241	·95	3·23	4·18	Slightly turbid.
Northampton. Deep oolite wells, May 11, 1868.	57·76	·168	·024	·003	·000	·026	0	5·153	8·64	1·69	10·33	Clear.
Rugby. River *Avon* and land Drainage, May 12, 1868.	26·24	·123	·037	·002	·382	·421	3512	2·04	6·80	9·09	15·89	Clear.
Leicester. Gathering ground -	23·70	·506	·020	·001	·001	·022	0	—	—	—	13·40	Clear.
Water overflowing from borehole in chalk at New Wimbledon, July 7, 1868.	33·38	·063	·038	·004	·047	·088	182	2·38	6·28	6·96	13·24	Clear.
Worthing. Old deep well in chalk.	36·70	·162	·000	·000	·426	·426	3940	—	—	—	23·80	Clear.
Worthing. New deep well in chalk, July 17, 1868.	32·44	·007	·000	·002	·420	·421	3910	3·08	16·36	8·33	24·69	Clear.
Bedford. Water supply from shallow well in upper oolite, Oct. 10, 1868.	72·46	·133	·021	·001	·034	·056	30	4·27	29·31	11·46	40·77	Clear.
Bedford. River *Ouse* as it flows past the Waterworks, Oct. 10, 1868.	47·90	·620	·088	·004	1·005	1·096	9760	2·68	13·47	15·06	28·53	Turbid.
Bedford. Mineral spring a few yards from water-supply reservoir, October 10, 1868.	74·20	·137	·028	·002	·004	·034	0	4·07	29·84	12·23	42·07	Arsenic ·002. Clear.
Bedford. The pillory pump, October 10, 1868.	140·74	·325	·088	·000	2·497	2·585	24,650	15·29	29·11	25·40	54·51	Clear.
Lancaster. Gathering ground on Bleasdale Fells, October 1868.	4·58	·129	·022	·001	·000	·023	0	·99	0	·87	·87	Clear.
Newcastle-on-Tyne. Supply from Whittle Dean, Sept. 16, 1868.	23·40	·237	·062	·000	·000	·062	0	1·59	5·81	8·14	13·95	Clear.
Sunderland. Supply from deep wells in dolomite, September 16, 1868.	44·18	·035	·030	·000	·416	·446	3840	4·17	·79	13·95	14·74	Calcium 5·888. Magnesium 3·956. Clear.
Norwich. Water supply from "Broads," September 18, 1868.	28·18	·227	·055	·000	·000	·055	0	2·63	19·07	4·61	23·68	
Norwich. Artesian well 400 feet deep, Carron works, September 17, 1868.	38·14	·074	·027	·000	1·001	1·028	9690	2·58	23·27	6·37	29·64	Clear.
Norwich. Artesian well 150 feet deep, Times paper mill, Taverham, September 18, 1868.	27·30	·059	·024	·000	·428	·452	3960	2·73	14·44	5·04	19·48	Clear.
Edinburgh. Water supply from *Crawley Burn*, Sept. 22, 1868.	11·28	·187	·031	·001	·000	·032	0	1·04	·74	5·34	6·08	
Edinburgh. Water supply from *Comiston Water*, September 22, 1868.	22·58	·085	·017	·001	·744	·762	7124	1·89	2·81	7·55	10·36	
Edinburgh. Water supply from *Swanston Water*, September 22, 1868.	12·70	·378	·059	·001	·000	·060	0	1·39	0	6·22	6·22	

PART II. WATER SUPPLY.

Various sources.

Description.	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.
Edinburgh. Water supply from *Colinton Water*, September 22, 1868.	14·10	·203	·042	·000	·000	·042	0	·89	4·41	4·76	9·17	
Carlisle. Water supply from river *Eden*, September 23, 1868.	13·10	·233	·037	·001	·000	·038	0	·99	3·54	5·19	8·73	
Grassmere Lake, Westmoreland, September 28, 1868.	4·18	·235	·050	·001	·000	·051	0	·79	0	2·70	2·70	Clear.
Rydal Lake, Westmoreland, September 28, 1868.	4·44	·254	·043	·002	·000	·045	0	·69	·67	2.43	3·10	Clear.
Windermere Lake, Westmoreland, September 28, 1868.	5·78	·299	·076	·002	·018	·096	0	·99	1·61	2·43	4·04	Slightly turbid.
Buttermere Lake, Cumberland, September 29, 1868.	3·56	·127	·040	·004	·000	·043	0	·89	0	1·01	1·01	Clear.
Crummock Lake, Cumberland, September 29, 1868.	4·06	·183	·055	·007	·000	·061	0	·89	0	1·30	1·30	Clear.
Derwentwater Lake, Cumberland, September 29, 1868.	6·56	·218	·043	·001	·000	·044	0	1·29	0	1·74	1·74	Clear.
Bassenthwaite Lake, Cumberland, September 29, 1868.	4·64	·154	·037	·000	·000	·037	0	1·29	·80	2·03	2·83	Very slightly turbid.
Cockermouth. Water supply from the river *Cocker*, before filtration, September 28, 1868.	4·62	·069	·022	·001	·000	·023	0	1·09	·13	2·02	2·15	Very slightly turbid.
Maryport. Water supply from river *Derwent*, September 28, 1868.	6·00	·210	·041	·004	·000	·044	0	1·09	·40	2·97	3·37	Very slightly turbid.
Whitehaven. Water supply from Ennerdale Lake, September 28, 1868.	2·16	·042	·017	·000	·000	·017	0	·99	0	1·45	1·45	Clear.
Keswick. Water supply from Skiddaw, September 29, 1868.	4·34	·132	·024	·001	·000	·025	0	1·09	1·34	2·03	3·37	Very slightly turbid.
Banbury. Water supply from river *Cherwell*, October 17, 1868.	36·60	·382	·054	·003	·230	·287	2010	2·09	13·63	10·52	24·15	
Tring. Chiltern Water Company's deep chalk well, November 6, 1868.	28·60	·036	·010	·001	·094	·105	630	1·39	22·96	3·37	26·33	Very slightly turbid.
Ditto after softening by Clark's process, November 6, 1868.	8·18	·041	·008	·001	·094	·103	630	1·19	0	3·23	3·23	Clear.
Woking Prison. Basingstoke Canal near, November 7, 1868.	12·00	·457	·109	·004	·000	·112	0	1·79	1·03	6·37	7·40	Slightly turbid.
Woking Prison. Deep well, November 7, 1868.	31·66	·224	·026	·004	·064	·093	350	3·57	4·86	7·84	12·70	Clear.
Woking Prison. American pump near, November 7, 1868.	23·18	·228	·098	·004	·000	·101	0	2·48	7·54	5·63	13·17	Slightly turbid.
Broadmoor Criminal Lunatic Asylum. Water supply filtered through animal charcoal, November 10, 1868.	11·16	·295	·044	·001	·138	·182	1063	1·69	0	4·04	4·04	Slightly turbid.
Bristol. Water supply,* February 8, 1869.	28·66	·160	·017	·001	·203	·221	1720	1·30	18·53	5·93	24·46	Slightly turbid.
Bristol. Spring in All Saints' Lane,† February 8, 1869.	127·28	·186	·030	·001	4·712	4·743	46,810	7·10	32·22	34·70	66·92	Clear.
London. Artesian well, Trafalgar Square, May 6, 1869.	83·40	·150	·012	·070	·000	·070	260	16·55	2·97	2·95	5·92	Clear.
London. Artesian well, Royal Mint, May 31, 1869.	83·96	·195	·025	·060	·000	·074	170	13·92	7·74	9·74	17·48	Clear.
London. Artesian well, Barclay's Brewery, July 9, 1869.	73·30	·085	·008	·060	·000	·057	170	14·08	4·51	2·82	7·33	Clear.
Dublin. Water supply from river Varty, April 14, 1869.	6·34	·238	·024	·001	·000	·025	0	1·24	0	2·97	2·97	
Dublin. Cartan's pump, near Newgate,‡ April 14, 1869.	81·62	·089	·034	·000	2·865	2·899	28,330	8·30	—	—	41·38	
Deal. Water supply, as delivered, July 24, 1869.	33·20	·029	·013	·000	·698	·711	6660	2·85	19·96	6·35	26·31	Very turbid.
Deal. Water supply from deep chalk well, July 24, 1869.	33·24	·032	·022	·000	·702	·724	6700	2·80	20·39	5·92	26·31	Clear.
Deal. Deep chalk well at Hill's Brewery, affected by tide, July 22, 1869.	202·14	·139	·137	·065	1·976	2·167	19,980	71·82	31·03	16·22	47·25	
Switzerland. The *Rhine* above Schaffhausen, September 6, 1869.	15·80	·108	·012	·003	·000	·015	0	·20	3·99	6·77	10·76	Slightly turbid.
Switzerland. Lake of Zug, at foot, September 5, 1869.	13·20	·149	·026	·000	trace	·026	0	·27	3·96	5·07	9·03	Clear.
Switzerland. Lake of Zürich, at foot, September 7, 1869.	14·30	·092	·009	·002	·000	·011	0	·17	5·81	4·80	10·61	Clear.

* The Company supplying this water decline to give any information as to its source.
† Much used in the neighbourhood, and by the small trading vessels that lie on the "Welsh Back."
‡ Much used in the neighbourhood.

GENERAL SUMMARY.

GENERAL SUMMARY.

Descriptive.

Before humbly stating to Your Majesty the conclusions to which our inquiries have led us, we submit the following summary of the facts on which they are based.

The condition of the rivers and streams in the Mersey and Ribble basins has been fully illustrated in the foregoing pages by numerous analyses of their waters, of the mud accumulated in their channels, and of the various polluting liquids which are poured into them, our object having been to furnish in every instance an exact definition of the various impure materials which here make up the sum total of river contamination. The fact, long since obvious enough to the senses, that the running waters of this district, many of which 30 or 40 years ago were beautifully clear, have now become intolerably foul, is thus both conclusively established and quantitatively explained. The difference in their condition now, as compared with then, obviously arises from the immense population which, during the interval, has gathered on the river banks, and from the great number of factories in which that population is employed. The drainage from the former has contributed many times the quantity of filthy organic matter which is present in the running waters of an ordinarily populated district: the drainage from the latter has changed the pure water of almost every rivulet into an offensive muddy stream. Mansion, cottage, mill,—all contribute to the nuisance; and whether it be the river-side "tip" for the house and garden rubbish of a riparian landowner's mansion, or the waste furnace ashes from a manufactory—whether the drainage from the water-closets of country houses, or that from the vats of dye works and other factories—the result upon the whole is that the river channels become the recipients and carriers of every kind of waste material, solid as well as liquid. In passing through the towns, the stream receives a volume of sewage equal to twenty gallons daily per head of the population; and this, where hundreds of thousands live together, as in Manchester and Salford, is obviously a horrible aggravation of its already filthy plight.

The responsibility for this state of things necessarily varies in degree, but, in kind, it is uniform and general. It rests most on those whose waste happens to be bulkiest and most offensive, but everyone is guilty. The landowner, complaining bitterly of the nuisance made by the towns and mills, which have, however, on the whole greatly increased the value of his property, is himself an offender to the extent of his opportunity; just as the corporate authority and the millowner whom he blames. The manufacturer, who declares with justice that the river water is injured for his purposes by the sewage of towns above him, rarely hesitates to let the excrements of his workpeople drain into the stream, and thus make it still worse for those below him. Even the villagers add their contribution to the nuisance; their privies are placed over a running brook, or are drained into it; household liquid refuse of every kind finds its way into the nearest watercourse; and solid rubbish from the cottages and gardens is shot over the banks of the river to be washed away by floods. In fact, while all complain of the effect of this habitual carelessness upon their own comfort and convenience, all are equally indifferent to the comfort and convenience of others.

The injury and nuisance are as universal as the recklessness to which they are owing. The resident landowner, in some cases literally driven from his house by the stench, is generally loudest in complaint; and being able to enforce his rights at law, his complaint receives attention; but others, sharing less than he in the compensating circumstances of the case, bear the injury in silence. Not only landed proprietors, but farmers, inhabitants of small villages, and labourers living in the vicinity of the stream which is used and abused by manufacturers and towns, are equally deprived of the use of both clean water and pure air.

The manufacturers who are obviously offenders, are also sufferers; and while professing to fear the effect upon the general interests of the district which the enforcement of expensive remedies might produce, they are ready to admit that it is hard to imagine a greater injury to local interests than that which is inflicted by the miserable condition in which the rivers are everywhere found.

Remedies, if not excessively costly, will thus be generally welcomed. Nothing more than mere enactment, *if efficiently administered*, will be required to ensure that for the future the river-channel shall not be encumbered with solid refuse materials. But, except in rare cases, the influx of liquid polluting materials cannot be checked, and hence some mode of cleansing them must be adopted. It was this conviction which

General Summary.

Remedies.

induced us carefully to investigate various methods of purifying foul waters; and we have found that there is nothing which need hinder either towns or manufacturers from adopting the necessary processes. As to the expense, the towns have, in the use of their sewage upon land, not only the certainty of an effectual removal of its filth, but the possibility of profitably converting into food that which is now a nuisance and a source of harm: the manufacturers also in many special instances have found that the attempt to purify their foul waste products has proved not only successful but profitable.

Both towns and manufacturers, moreover, have the means of rendering the organic impurities dissolved in their waste waters so far harmless, by slowly passing them through well aerated filter beds, as to admit of their being again useful for manufacturing purposes. It has been shown by the experiments carried out in our laboratory, that a properly conducted system of intermittent filtration will cleanse town sewage sufficiently to enable it to be used for all but domestic purposes. At the same time, however, it has been clearly proved that in order to secure the efficiency of this process it needs to be conducted on a much larger and more expensive scale than has hitherto been thought necessary. An acre of filtering material, six feet deep, used intermittently, will cleanse the drainage water of only 3,300 people at most. The result, however, is a true oxidation, and thus an entire transformation of nearly the whole of the organic matter in the sewage, so that from a remedial point of view it is successful; but, as sewage possesses a high agricultural value, this method of treatment would be very wasteful, and only to be recommended on a small scale, or where circumstances render any other process extremely difficult or expensive. Moreover, it is not unlikely that the operation, involving as it does the exposure of large and offensive filtering beds to the air, would be itself attended with much serious nuisance. The previous treatment of the sewage by one of the chemical processes already described would, however, obviate this liability to nuisance, whilst it would probably reduce by one half the size of the filter necessary for cleansing a given volume of sewage. Such a combination of a chemical method with *intermittent* filtration offers the most hopeful process, both as regards economy and efficiency, in cases where irrigation is impracticable. In all practicable cases, however, we strongly recommend the adoption of irrigation in preference to filtration, for when irrigation is carefully and properly conducted, not only is the polluted water rendered inoffensive, but a return of profit is derived from its employment. Every experiment which has hitherto been made goes to show that sewage can be most beneficially employed as a manure, and that it is thus also most perfectly cleansed. The drainage of more than one hundred people can be purified sufficiently by application, in this way, to one acre of land; but it is certain that much valuable though non-polluting matter is still left in the sewage when it leaves the land, and that such effluent sewage might be applied again to crops in a similar manner with very great advantage, and with additional benefit to the water itself. It is thus highly probable that the sewage of 100 people—amounting, with a water supply of 20 gallons per head daily, to about 3,500 tons a year, would, if evenly distributed, be sufficient for the manuring of several acres; and it would thus be possible to distribute the cost of pumping, wherever it has to be incurred, over a larger area of land. It is a most important feature of this plan of treating town sewage, that although wherever irrigation is carelessly conducted a certain amount of unpleasantness is inevitable, yet, no injury to health follows the adoption of the plan. No locality can be named in which typhus, enteric fever, dysentery, or other zymotic disease generally attributable to foul emanations, has been traceable to irrigation with town sewage (see page 90). On every ground, therefore, irrigation may be confidently recommended as a safe and trustworthy remedy for the nuisance with which towns have to deal.

Manufacturers are in a somewhat different position. Even they, however, will generally find the land the best recipient of their waste products. The spent liquors from tan-yards may thus be completely turned to agricultural use. Some of the foul liquids from wool washing will also be a serviceable addition to sewage used in irrigation. As to other polluting materials,—those from calico-print and silk works, for example,—which plants cannot assimilate, manufacturers will have to resort to subsidence or filtration; and individual cases will doubtless be met with in which want of available land will impose serious difficulties in the way of efficient purification; it is therefore proper to add that, in any enactment on the subject, ample time should be allowed to those who are earnestly endeavouring to abate any nuisance with which they are chargeable.

The water supply for domestic purposes in the Mersey and Ribble basins is almost invariably distributed on the constant system; it is generally of excellent quality, but occasionally insufficient in quantity. In many cases it is brought to towns from considerable distances, and often at great cost to the local authorities, who, as a rule, have long since bought up the rights of private companies and taken the works into their own hands. This has been of great advantage to the towns, as regards the cost, quantity, and quality of the supply, and its application to the watering of streets, to the flushing of sewers, and to other sanitary uses.

General Summary.

Water supply.

A very large proportion of the water used for domestic purposes is derived from gathering grounds, the remainder being pumped chiefly from deep wells in the new red sandstone. The water from the first-named source is very soft, nearly always free even from suspicion of excremental pollution, and well suited both for washing and drinking. It is generally supplied, unfiltered, from large reservoirs of subsidence; but its appearance and palatability would, in most if not in all cases, be markedly improved if it were submitted to sand filtration immediately before delivery to consumers. Private filtration, which is rarely performed satisfactorily even in the houses of the wealthy, and is not attempted in the cottages of the poor, would thus be rendered unnecessary.

The deep well water is always harder than that from the gathering grounds, but still considerably softer than much of the water used in the southern counties. When the well is at a distance from thickly inhabited places, the quality of the water is generally excellent, but as the population around it increases, the water gradually becomes mixed with a larger and increasing proportion of excremental soakage, and at length, for sanitary considerations, the well is abandoned for a new one, sunk at a greater distance from human habitations.

The water supply for manufacturing purposes may be described as wretched in the last degree, being often deficient in quantity and generally polluted with all kinds of filth. Compelled, however, in most cases to use it, the manufacturer has to incur considerable cost in its purification; and even then, owing chiefly to the discharge of sewage into the rivers, it is but ill adapted for many of the processes employed in the staple industries of the district. The excessive foulness of the streams from which the manufacturer ought to derive his supply, not unfrequently compels him to purchase water destined for domestic purposes, and thus encroachments are made upon that precious fraction of the rainfall which, being carefully preserved from the possibility of excremental pollution, ought to be exclusively reserved for domestic use, at least until this vital want of the population is bountifully supplied.

The cleansing of the rivers, so far as to render them available for manufacturing purposes, would, therefore, be of great money value to the manufacturers of this district. According to statements which we have received in answer to our inquiries from 39 firms who are carrying on different branches of trade in the basins of the Mersey and Ribble, the annual money value of the advantage which would accrue, to this minute fraction of the total number, would amount to no less than 10,157*l.*; and one calico-printing firm estimates that the gain to it would be 3,000*l.* per annum.

The water required for canal navigation makes a considerable demand upon the upland rainfall of the district. It is at present but slightly used by manufacturers before being passed through locks into tidal estuaries. This is owing, doubtless, in part at least, to the unpleasant consequences of admitting polluted liquids into the comparatively stagnant water of canals. But if the purification of polluted water be enforced, it may fairly be expected of the canal proprietors, in return for the heavy contributions which they levy upon the upland rainfall (See Vol. II., *Minutes of Evidence*, part 4), that they should allow the canal water to be used by manufacturers on the condition that it be returned properly purified, at the same level from which it was taken.

CONCLUSIONS.

We have now given a detailed description of the rivers and running waters in the *Mersey* and *Ribble* basins. We have considered the various influences to which river water is subjected; and have particularly investigated the pollutions by town sewage and by manufacturing refuse, which it has suffered in these districts. We have, moreover, discussed the various remedies which are within our reach for all the evils thus described; and have considered the questions relating both to the supply of water and to the purification of the same, with which corporate bodies have to deal There yet remains the task of suggesting an authority or agency, by which the evils thus

CONCLUSIONS. described may be remedied, by which the works necessary to correct them may be facilitated or directed, and by which offences against the purity of rivers may be punished and prevented. Before, however, entering on the discussion of this subject two considerations require attention—the first (A) relating to the definition of offences with which the authority will have to deal;—the second (B) relating to the limits of the area within which it should exercise jurisdiction.

(A.) In order, on the one hand, to guard the manufacturer against any arbitrary interference of this authority, and, on the other, to secure an efficient and uniform check upon the pollution of rivers by liquid refuse throughout the country, it will be necessary to prescribe definite standards of purity below which no liquid shall be admissible into any river or stream.

The following standards have been framed with a due regard to the extent to which the cleansing of foul liquids can be effected without the imposition of undue restrictions upon the manufacturer, and without "serious injury to such processes and manufactures" as are carried on in the *Mersey* and *Ribble* basins. We do not recommend the adoption of these standards as workable and practical without having ascertained their applicability to the very numerous samples of polluting liquids which have been analysed in our laboratory since April 1868. We believe that as science progresses improved methods of purifying polluting liquids will be discovered, and that eventually standards of purity considerably higher than those given below may, if necessary, be enforced; but, as the manufacturer is not necessarily an original discoverer, it would obviously be unfair to throw upon him the onus of inventing new and improved processes for producing higher degrees of purification than those easily attainable by methods already known.

Having in view, then, at present only the chief sources of pollution in the basins of the *Mersey* and *Ribble*, and the methods of cleansing now available, we suggest that the following liquids be deemed polluting and inadmissible into any stream:—

(*a*.) Any liquid containing, *in suspension*, more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b*.) Any liquid containing, *in solution*, more than 2 parts by weight of organic carbon, or ·3 part by weight of organic nitrogen in 100,000 parts by weight.

(*c*.) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d*.) Any liquid which contains, *in solution*, in 100,000 parts by weight, more than two parts by weight of any metal except calcium, magnesium, potassium, and sodium.

(*e*.) Any liquid which, in 100,000 parts by weight, contains, *whether in solution or suspension*, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

(*f*.) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

(*g*.) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h*.) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i*.) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

We would here add that whatever authority may be constituted for the future protection of rivers it should not only be required to direct the observance of any enactment based upon the above standards, being at the same time empowered to enforce the adoption of remedies for proved nuisances wherever the offender is negligent; but it should also be enabled to stay proceedings, on the part of those suffering from the nuisance, when satisfied that the offender is honestly trying to abate it. We do not desire that any complaint founded on the existence of a nuisance arising from any of the above offences should be finally silenced, or that any just claim for damages founded on it should be absolutely barred by the mere fact that a scheme for the abatement of the nuisance had received official sanction. But we believe it will be for the general interest that such a sanction should, for the time, exonerate from legal liability those, whether corporate bodies or individual offenders, who are carrying into operation any scheme thus sanctioned.

(B.) As to the area within which the proposed authority shall exercise jurisdiction over these offences, it must in the first place be observed, that as they are offences against the purity of river water, the superintendence of all the natural drainage channels, whether they be running streams or river tideways, must extend throughout the whole basin.

There are doubtless many instances in which nuisances arising from polluted water exist upon a tidal river channel, and even on the coast line of an estuary. Such a nuisance, for example, is alleged by the inhabitants of Waterloo and Seaforth as being created by the sewage of the neighbouring town of Liverpool, notwithstanding that the tide runs to and fro in its channel there at the rate of four or five knots. (See Vol. II., *Minutes of Evidence*, part 3.) We do not, however, propose to give the river authority active jurisdiction excepting in the case of the river channels proper. It is difficult to define an estuary so as to draw a line between it and the river channels over which official superintendence is required; and it may be necessary, therefore, in the case of every separate river basin, to name arbitrarily the point beyond which the river authority shall not actively extend. Runcorn Gap is the natural division in the *Mersey* basin between the river and its estuary. While, therefore, we desire that the offences we have specified should be entirely forbidden and prevented in the *Mersey* channel and its tributaries, as far as Runcorn Gap, as well as along all the streams entering the estuary below that point, we do not propose to make the authority responsible for the suppression of nuisances arising from polluting liquids discharged at any point along the coast line of the estuary itself. It may be well to facilitate any remedy against offenders, now possessed by sufferers from such nuisances on the estuary, by giving to the authority which will superintend the rivers of the *Mersey* basin power, on receiving complaints, to adjudicate upon nuisances in such places. But we do not propose that it should be the duty of the river authority, unappealed to and unprompted, to inspect the estuaries as it will inspect the rivers.

A further remark upon the area within which river conservancy is required is suggested by the fact that as our inquiries for the purposes of this report have been limited to the condition of the rivers and streams in the *Mersey* and *Ribble* basins, so it may be considered that we are premature in pronouncing upon those kinds and degrees of pollution which are to be declared offences under a River Conservancy Act, which shall have jurisdiction throughout the whole country. We are commanded by Your Majesty to examine the condition of other river basins, and to report upon the river pollutions due to the special industries of other places. We have probably yet to learn many important particulars regarding the pollutions due to the woollen manufacture, to ironwork, mining, metallurgy, and other industries not especially characteristic of the *Mersey* basin; and it is no doubt possible that further information may induce us to modify some of the above definitions of offence, so far at least as to name exceptions, which it may be necessary to allow in the case of industries which we have not yet examined. We do not, however, anticipate that these exceptions will be numerous or important. Our inquiries have indeed been hitherto confined to the manufacturing districts of Lancashire and Cheshire, but some of the chief causes which have converted the rivers and streams of these districts into common sewers are active in all other densely populated places; and this Report on the *Mersey* and *Ribble* basin, so far at least as the towns are concerned, is virtually descriptive of the nuisances arising out of the congregation of people together everywhere. As regards town sewage, therefore, and in respect also to the pollutions from alkali and chemical works, from calico-print, silk, bleach, and dye works, from paper manufactories, and tanneries, the facts collected during our inspection of these basins are, we believe, quite sufficient to justify a definition of the offences which ought everywhere to be forbidden.

The constitution of the authority to which allusion has been made in the above conclusions has now to be suggested. Notwithstanding, however, our perfect unanimity on all other matters, we have been unable to agree completely upon this point, and we are, therefore, obliged to submit our opinions separately.

All which we humbly certify to Your Majesty under our hands and seals.

(Signed) W. DENISON, Major-General. (L.S.)
E. FRANKLAND. (L.S.)
JOHN CHALMERS MORTON. (L.S.)

S. J. SMITH, *Secretary*,
16th February 1870.

CONSTITUTION OF THE RIVER CONSERVANCY BOARD.

Separate Conclusions and Recommendations by Major-General Sir William Denison, K.C.B.

CONSTITUTION OF RIVER CONSERVANCY BOARD. — *Sir W. Denison, K.C.B.*

1. The Common Law of the country affirms the right of every owner of land to make use of the water of the river or streams passing through or by his property, but it prohibits the employment of the water in such a manner as will render it unfit for the use of those lower down the stream. This Common Law right, as will be seen by the evidence submitted in this Report, exists now but in name; the cost of enforcing it by legal process is so excessive as, practically, to leave complainants without redress.

We have in the former part of this Report pointed out, to those who have been in the habit of abusing the privilege conceded to them by the Law, methods by which they might make use of the water without inflicting any injury on their neighbours. I now propose to provide for those who may be injured by such abuse a simple and cheap mode of obtaining a guarantee against such wrong for the future.

The wrong complained of must necessarily be at first of a purely local character,—neighbour complains of the conduct of neighbour. It would therefore be advisable, both for the sake of economy and rapidity of obtaining redress, that the authority appointed to adjudicate should be close at hand. The area of the jurisdiction of these courts of first instance should be narrow; and, as cases may arise for adjudication wherever there can be any interference with, or interruption to the drainage of the country, it would be advisable to divide the whole area of the watershed of the rivers and streams into blocks of convenient size, and to place each of these in the hands of competent local authorities.

I propose, for many obvious reasons, to adhere to existing known and recognized divisions; to accept the parish as the unit, and to hold the parish officers responsible for the state of the rivers and streams passing through or by it. When several parishes have been grouped together under the authority of a corporate body, or a local board of health, this corporation or board should be responsible for the whole area placed under its jurisdiction, and hold each parish responsible for the condition of the streams passing through it.

It may perhaps be thought that when the whole area of the watershed of a river and its affluents is thus divided, and placed in the hands of authorities to whom power is given to decide upon the various questions relating to the supply of water and the purification of the same, there would be a sufficient guarantee that the work would be properly carried out; but the evidence we have had of the total disregard of mere legal enactments which tend to fetter the actions of masses of people, of the constant evasions of obligations imposed by law, of the inefficiency of the law, even when means have been found to bring it into action, to enforce the adoption of any special remedy for the evils complained of, has satisfied me that it will be necessary to call into action an authority superior to all those local municipalities, embracing in its scope the whole area of the watershed sub-divided among these bodies, and to confer upon such authority powers differing both in kind and degree from that exercised by ordinary municipalities or conservancies.

2. I am disposed to recommend that these authorities should have a local organization, as their powers will be exercised over a limited area, and for purely local objects. Such an organization, while it would harmonize with the principles upon which the municipal system is constituted, might, at the same time, be made sufficiently responsible to the general government to enable the latter to check or prevent any abuse of the power entrusted to the local authorities, or to notice and reprove, and even *punish* all negligence or unfairness in its mode of action. The members, therefore, of these bodies should be resident within the limits of their jurisdiction; they should not receive any salary for the performance of the duties they may be called upon to perform, as these are purely social and municipal; while, in order to secure to the government a proper amount of control over them, it should have the power of defining the area over which the body should exercise its jurisdiction, of determining the qualification of the members and of summarily displacing any or all of these, should there be fair grounds to impute to them an abuse of the power placed in their hands. It may be a matter for consideration whether in the case of Lancashire, *one* authority might not exercise this jurisdiction over the whole of the basins of the Mersey and the Ribble; there are already several questions connected with the supply of water, which, if separate authorities were established over the valleys of the *Mersey*, the *Irwell*, and the *Ribble*, would render reference to each a matter of necessity, and it would be desirable to avoid the risk of possible collisions of interest or opinion between these authorities.

CONSTITUTION OF RIVER CONSERVANCY BOARD. — *Sir W. Denison, K.C.B.*

The power to be intrusted to this local authority would be so extensive as to require an organization placing it beyond the suspicion of subserviency to local influence; it should consist of *few* members, (not more than three,) for responsibility becomes but a name when it is shared among many, and these few should have such rank and position as would give weight to their decisions.

Subject to these conditions, it might be as well, at all events in Lancashire, that the members of the local body should be elected; that the different parishes should nominate a body of electors, and that to these should be entrusted the task of selecting the members of the local authority, subject (perhaps) to the approval of the Government. The power which will have to be entrusted to this local authority, and the duties it will have to perform, should partake of both a legislative and an administrative character. When I say *legislative*, I mean that it should not only have power to frame regulations or bye laws, and to enforce their observance, but that it should also have authority given to it to deal with the questions of the supply of water, and the purification of the rivers and streams, to an extent which would render from henceforward any applications to Parliament upon such matters, whether by individuals or corporate bodies, altogether unnecessary. The administrative power of this body would be confined within narrower limits, that is, it would act more as a referee than as the initiator of schemes; still, however, it should have power, when complaint is made of neglect on the part of the parishes or corporations, to direct the initiation of schemes, and to enforce the adoption of that which, when it is brought officially before it, is considered to be best suited to the circumstances of the case.

There is one point as to which the local authorities have expressed themselves strongly. Our predecessors, in their Report upon the rivers *Aire* and *Calder*, have said that the West Riding manufacturers have expressly objected to any legislative enactment which should not be enforced upon the textile trade in other districts. A similar objection has been made to us by the manufacturers in Lancashire. I am of opinion that this objection is well founded, and that restrictions upon any trade or manufacture should apply to such, wherever it may be practised, throughout the United Kingdom.

These recommendations, though forming part of our Report upon the basins of the rivers Mersey and Ribble, are, in point of fact, applicable to all parts of the country, and I wish them to be considered as bearing upon the questions of the purification of sewage and the supply of water throughout England and Wales. There are of course special evils arising out of different processes of manufactures, or of mining, with which it will be our duty to deal in other districts, but the principles upon which these recommendations are based will be equally applicable to the agricultural, the manufacturing, and the mining districts, though there will necessarily be some slight modifications in the instructions under which the local authorities may have to act.

With reference to the recommendations with which Dr. Edward Frankland and Mr. John Chalmers Morton have concluded their separate Report, I am quite willing to adopt the whole of them, with the simple substitution, in numbers three, six, and seven, of the term *local* for *central* board.

All which I humbly certify to Your Majesty under my hand and seal.

W. DENISON, Major-General. (L.S.)

CONSTITUTION OF THE RIVER CONSERVANCY BOARD.

Separate Conclusions and Recommendations by Dr. Edward Frankland and Mr. John Chalmers Morton.

CONCLUSIONS.

Constitution of River Conservancy Board. — *Dr. Frankland and Mr. J. C. Morton.*

1. Inasmuch as there exist at present no local bodies competent to deal with questions connected with efficient river conservancy, capable of detecting pollutions, and enforcing remedies,—it will be necessary to call into action an authority possessing greater capacities and powers than those of the existing corporate bodies or local boards of health.

2. The duties which this authority should discharge, and for which it must be qualified, would be of two distinct kinds. Under one division they would be essentially those of a river police, employed in the detection of offences, and in obtaining the conviction of offenders, and would resemble those discharged by Dr. R. Angus Smith, Your Majesty's Inspector under the Alkali Act. Under the other division they would include the investigation of and decision upon various works connected with rivers, proposed by either towns or individuals, such as schemes for water supply and for the defecation, filtration, or utilization of sewage and other polluting liquids.

3. It is of the first importance in carrying out any legislative enactment in connection with river pollution, that all river basins be uniformly dealt with. This has again and again been urged upon us by the representatives of the staple manufactures in the *Mersey* and *Ribble* basins. They state,—and we think with reason,—that it would be most unfair, for example, to the calico printers of Lancashire to have a law stringently enforced against them, while in another river basin their competitors in trade were being treated with comparative leniency and indulgence. But we believe that no such unanimity of action could be secured if, in each river basin, a board of conservators were left to pursue a separate and isolated policy; for although all these boards would ostensibly carry out the same legislative enactments, they would certainly differ in the energy with which they enforced the law against offenders.

4. Moreover, such boards would be incompetent, of their own knowledge, to deal with many questions which would be continually arising for their decision. They could not determine the degrees of foulness of liquids flowing from manufactories; they could not ascertain with accuracy the extent to which any given stream is polluted; they could not apportion the blame of its pollution amongst the delinquent towns or manufacturers upon the stream; nor could they determine the efficiency or otherwise of the different processes adopted by manufacturers for the purification of polluted water; they could not ascertain the quality of the effluent water from irrigated fields and from precipitating tanks in which sewage may have been treated by chemical agents, nor would their judgment be any guarantee of the quality of water derivable from various sources which may be proposed for the supply of towns. Local conservancy boards could obtain information on these points only from persons capable of investigating them.

The usual mode in which such information is sought for under these circumstances is to take the evidence of two or more experts employed by the opposing parties. The result is almost invariably eminently unsatisfactory; for the experts, from the very nature of the case, are made to approach the investigation of the subject from anything but an impartial point of view. The circumstances favourable to the interests of their respective clients are brought prominently to their notice, whilst those of an opposite character are often carefully concealed. Thus the two sets of experts usually come to opposite conclusions, and instead of helping the tribunal, before whom they appear, to form a sound judgment, they only increase its embarrassment; and the usual result is either that the court, rejecting altogether the conflicting scientific or professional evidence, arrives at what it considers to be a common-sense conclusion, or, by some ingenious but fallacious process, contrives to twist the discordant statements sufficiently into harmony to afford some justification for conclusions thus apparently based upon them. We cannot too strongly condemn this method of endeavouring to arrive at truth on matters involving scientific and professional knowledge. It has become a crying evil in our law courts and before parliamentary committees where such matters are only incidentally the subject of inquiry; but it would be much more mischievous if adopted in a court where the chief business would be the determination of disputed points connected with the pollution of rivers, the qualities of water intended for domestic purposes, and other matters in which scientific and professional knowledge are constantly and essentially involved. It would, in our opinion, infallibly introduce so much uncertainty into the decisions of the constituted authority as seriously to interfere with those important branches of industry which require the use of running water.

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5. We are of opinion, that for the proper discharge of its duties, under both of the divisions to which we have referred (Sec. 2) the authority to be constituted should be central—in the one case because its agents, the inspectors who would act as a river police, ought to be entirely independent of local influences—in both cases because it is necessary, in view of the existing rivalry of trade interests in the various river basins of the country that a uniform administration of justice be in operation throughout them all. The former Rivers Pollution Commission arrived at the same conclusion. In their Third Report on the rivers *Aire* and *Calder*, p. liv., they say, "One conclusion, there-" fore, forces itself upon anyone who honestly deliberates upon the existing state of " things, in regard to the rivers we have visited with a view to its permanent improve-" ment. A stronger power than has hitherto been available must be brought to bear " if the present abuse and pollution of streams is to be arrested, and *Government* " *supervision and inspection* must enforce and strengthen the action of local autho-" rities." And again, at p. lv., "Our experience of the weakness inherent in unaided " and uncontrolled local authorities as at present constituted, convinces us that *a central* " *board appointed by a State department* is necessary to the efficient protection of " running waters."

6. It is plain that so far as the future prevention of offence is concerned, this being the first division of the duty to be laid upon the proposed authority, no special local organization is required. The offender is in every case an individual before the law,—either a corporate body (which can be sued through its clerk), or an individual literally,—and the evidence of the inspector will prove any offence which the law shall define, and justify the infliction of the penalty which it may enact.

7. As regards the second division, on the other hand, of the duties devolving on the central authority, the co-operation of the Local Corporations is required for the efficient discharge of them. It appears to us, indeed, that if guided and assisted by a properly qualified central court the present Local Boards would be quite competent to meet all local difficulties and to supply all local wants. They already have the power of self-taxation, within their districts, for all necessary works; and, so far as the immediate necessities of the population are concerned, the existing local authorities with a central court to appeal to, and, if the law shall so enact, obey, are all the organization which the case requires. A central authority would not extinguish, it would hardly interfere with the Corporations and Local Boards at present existing in the river basins. It would indeed, we believe, materially promote the energy of local action by removing the obstacles which at present hamper it, and by giving a prompt and cheap decision to the questions which it has to solve.

8. It is obvious that an authority properly qualified and empowered, by which offences against rivers may for the future be prevented, and by which towns and local boards upon their banks may be guided in connection with both the subjects which have been committed to our consideration, viz., river pollution on the one hand, and water supply upon the other, will possess great public serviceableness. We do not forget, however, that though these are two important branches of the subject of river economy, they are not the whole of it. Even when all who live near the river shall have ceased to foul it, and when the whole riparian population shall have at their command a full provision of all that the river can supply, there will yet remain a great department of river improvement demanding attention with which the central authority having no powers of taxation, and the local corporate authorities having limited jurisdiction and limited areas of taxation are incompetent to deal. The improvement of the river course beyond the limits of the local authorities will ultimately be called for. The removal, from its channel, of obstructions which prevent the rapid escape of flood water is desirable in the interests of all dwellers on its banks. The construction of reservoirs in the upper reaches of the river is desirable in the interests of manufacturers. The straightening and deepening of its channel for the purposes of navigation is calculated to promote the general industry of the district. For river improvements, in these and other ways, within the whole area of the basin, it may be necessary to extend the boundaries within which Corporations or Local Boards now exercise authority, so as to divide among them the whole district within the river basin, and thus leave no part of the main stream or its affluents uncared for by local authority. And in order that this department of river conservancy may be carried out in the general interests of the whole river basin and

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not here and there on the plan which mere local interests might direct; in order too, that the costs of such work as is resolved upon may be apportioned with just reference to the several advantages and responsibilities of riparian landowners, manufacturers, and inhabitants, it may be desirable to create a principal conservancy board for each great river basin to be elected by the several interests concerned, to whom representations on this department of general river improvement may be made, and with whom will rest the responsibility of directing the execution and defraying the cost of any work to be done after it shall have received the sanction of the central authority.

9. There is, undoubtedly, a large field of useful work in every important river basin for a conservancy board of this kind; and it is certain that whenever the necessity of the various river improvements which it would direct and superintend shall have become urgent, a representative body of the kind we have suggested will be necessary, having power in connection with the local and corporate authorities within the river basin to levy rates for defraying the cost of whatever operations it may direct. But we are convinced that the thing of immediate and imperative importance in connection with river improvement in the *Mersey* and *Ribble* basins is simply the prevention of the existing wrong doing. And for the prohibition and punishment of river offences here and elsewhere with uniform and energetic justice, it appears to us that a central and duly qualified authority or board is absolutely necessary.

10. It hardly falls within the scope of our instructions to inquire whether there may not be other questions affecting both rivers, and localities or populations near them, of which such a central authority or board would be competent to take charge; or whether there may not be sub-departments of Your Majesty's Government already in existence accustomed to deal with conflicting and divergent interests in property, competent to direct engineering and other public works, practised in superintending the conduct of local affairs, and equal to the task of dealing even with those questions of pure science which efficient river conservancy involves, to whom the duties of such a central board as has been suggested, might be committed. It appears to us sufficient for the present to point out in general terms the necessity for such a board in order to the proper administration of river conservancy.

RECOMMENDATIONS.

In accordance with the foregoing Report and conclusions we humbly submit to Your Majesty the following recommendations:—

1. That the casting of any solid matters of whatever kind into rivers and running waters, or the placing of solid refuse in such positions on the banks of rivers as to render it liable to be washed away by floods, be absolutely prohibited under adequate penalties: and that any Act passed for this purpose be made to take effect immediately.

2. That the discharge of any polluting liquids, such as those defined in the conclusions to this Report, into any river or stream from any sewer or other outlet, reservoir, tank, or vat, be prohibited under adequate penalties: but that after the passing of any Act prohibiting the admission of polluting liquids into running water, a reasonable time be allowed to corporations, local boards, manufacturers, and others, for the execution of the necessary works for purification.

3. That all rivers and streams in England be placed under the superintendence of a central authority or board, to be composed of not more than three persons, who shall be duly qualified to deal with all questions connected with the pollution of water and with water supply.

4. That it be the duty of this board to see that all enactments relating to the use or abuse of running water be duly enforced: and that for this purpose power be given to it to inspect manufactories, reservoirs, sewerage, and other similar works; and to cause to be constructed, at the expense of the owners of the same, whether corporate or private, any necessary purifying apparatus, in case the said owners neglect or refuse to provide such apparatus for themselves.

5. That, subject to proper regulations to prevent abuse, additional powers be given to corporations, local boards, manufacturers, and others, to take land compulsorily, under "Provisional Order," for the purpose of cleansing sewage or other foul liquids, either by irrigation, filtration, or otherwise, and to obtain, if required, easements for the construction of culverts and outfalls for drainage through private property, making compensation only for damage actually done, reserving, however, to the owner the right at any time afterwards, if he could show further damage, to have further compensation.

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6. That it be the duty of the central board to exercise a surveillance over both the quality and quantity of the water supply of towns; to carefully guard domestic supply from contamination; or, if it be already contaminated, to ascertain the source or sources of injury, and to cause the same to be removed.

7. That it be the duty of this central board to investigate all schemes for water supply; and also all proposals for public works connected with river conservancy, whether initiated by local authorities or by any principal conservancy board of a river basin either now in existence or to be hereafter constituted; and to report thereon to one of Your Majesty's Principal Secretaries of State.

All which we humbly certify to Your Majesty under our hands and seals.

E. FRANKLAND. (L.S.)
JOHN CHALMERS MORTON. (L.S.)

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