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SECOND REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1868 TO INQUIRE INTO

THE BEST MEANS OF PREVENTING THE POLLUTION OF RIVERS.

THE A.B.C. PROCESS OF TREATING SEWAGE.

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

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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 authorised and appointed, and do by these Presents authorise and appoint you, the said Sir William Thomas Denison, Edward Frankland, and John Chalmers Morton, to be Our Commissioners for the purposes aforesaid.

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

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

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

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

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

By Her Majesty's Command.

(Signed) GATHORNE HARDY.

INSTRUCTIONS to the COMMISSIONERS.

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

SIR,

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

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

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

SIR,

Whitehall, 29th April 1868.

I AM 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 the COMMISSIONERS.

Whitehall, 30th May 1865.

GENTLEMEN,

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

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

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

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

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

INSTRUCTIONS to the COMMISSIONERS.

GENTLEMEN, Whitehall, 7th July 1865.

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

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

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

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

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

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

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

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

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

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

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

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

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

COMMISSION (SCOTLAND).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Sealed at Edinburgh, the third day of December, in the year One thousand eight hundred and sixty-nine.
(Signed) John H. Dunn,
Substitute Keeper of the Seal.
80*l.* Scots.

Additional Instructions to the Commissioners.

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

Sir,

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

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

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

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

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

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

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

Sir,

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

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

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

REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY,

THE public interest is at present deeply involved in the determination of an efficient remedy for the sewage nuisance, to which so large an amount of river pollution is due; many large towns are under injunction from the Court of Chancery to abate this nuisance; and the so-called "A. B. C." patent method of dealing with it has been so confidently advocated, that it has clearly been our duty to submit this process to careful investigation. We have now, therefore, humbly to submit to Your Majesty the following report upon it, together with the conclusions regarding it to which our inquiries, observations, and analyses have led us.

We have already given some account of this process for the purification of sewage in our first report (Report on the *Mersey* and *Ribble* basins, Vol. I., pp. 53–57), where two trials of it were described at which we had been present, our object having been both to test its efficacy as a method of cleansing the drainage water of a town, and to ascertain the manure value of the material which it extracts. On both of these occasions the patentees contended that the results of the experiments were inconclusive, an accident having interfered with their accuracy at Leicester, and the weather having been wet and unfavourable at Leamington. Although we could not admit that these experiments were in any way vitiated by the circumstances referred to, we nevertheless expressed our willingness to re-visit the works at the latter place, for a further examination of the method at a time when it could be seen in operation under more ordinary and favourable conditions.

This intention was carried out on the 10th and 11th of May last, when, the weather having been dry for some weeks, the sewage (being then merely the fouled water supply of the town) might be supposed to be of the strength and quantity for which the works were adapted. We collected on this occasion a series of samples both of the sewage as it arrived at the works and of the effluent liquid as it left them, and from a subsequent analysis of those samples we are now able to report confidently on the character and results of this process.

Our attention was first called to the "A. B. C." plan for sewage defœcation in June 1868 by Mr. G. W. Wigner, whose report on a trial of it about that time at Tottenham will be found in the Appendix (No. 1.) It appeared to us desirable that we should have an opportunity of witnessing its capabilities upon a more considerable scale, and accordingly at our request (see Appendix, 3—15) the Mayor and Corporation of Leicester very kindly put their large sewage works and tanks at the disposal of the patentees for a trial of it in comparison with the lime process, which had been carried out there for several years. This experiment extended over three days, July 30 and 31 and August 1, 1868. As already stated, we have since, on two occasions, inspected the works at Leamington, where the "A. B. C." process has been in operation for more than 12 months; and finally, on the 27th ult., we visited works recently established for the same purpose at Hastings.

We proceed in the first place to describe the results of our investigation at Leicester, quoting for this purpose much of what has been already published in our report on the *Mersey* and *Ribble* basins.

I. *Experiments at Leicester.*

The sewage works at Leicester devised by Mr. Wicksteed for carrying out his lime process were admirably adapted for the experiments conducted in our presence. They were indeed, in our opinion, decidedly superior for that purpose to those in which the "A. B. C." method of treatment is now carried on at Leamington. The sewage as it arrives at these works is twice violently agitated by machinery after the chemicals have been added to it, and it then passes on to large reservoirs of subsidence in which a copious deposit of mud takes place, while the supernatant liquid flows off in a comparatively clear condition.

At the time of our visit we were informed by the patentees that their complete specification had not yet been filed, and that consequently they were compelled to keep their process secret; we had, therefore, no opportunity of ascertaining either the nature or the proportions of the chemicals used, consequently our observations were confined to the quality of the raw sewage, the effluent liquid, and the mud (raw manure) extracted from the precipitating tanks. We could not, however, help noticing that alum, animal charcoal, and perchloride of iron were among the materials employed.

The following is a copy of the specification which was subsequently filed in the Great Seal Patent Office:—

"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."

The samples of raw and effluent sewage were collected during the course of our experiments at Leicester in the following manner:—

On the first day a sample of the sewage as it arrived at the deodorizing works was taken at 1.30 p.m., whilst at 5.40 p.m. and 6.10 p.m. samples of the effluent liquid, after treatment, were collected; 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 9 p.m. (See Appendix No. 16). 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 our laboratory.

Submitted to analysis these samples yielded the following results:—

TREATMENT OF LEICESTER SEWAGE BY THE "A. B. C." PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.						Suspended Matters.		
	Solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Mineral.	Organic	Total.
July 30th, 1868.									
Raw sewage, 1.30 p.m.	111·0	3·745	·722	1·650	·021	2·102	28·78	28·78	57·56
Effluent liquid, 6.10 p.m.	117·0	2·778	·297	2·000	·000	1·944	2·30	3·82	6·12
July 31st, 1868.									
Raw sewage, 10 a.m. to 9 p.m.	112·0	3·536	·747	1·800	0	2·229	18·50	29·58	48·08
Effluent liquid, 4 p.m. to 9 p.m.	125·0	2·305	·373	2·500	0	2·432	1·22	3·14	4·36
August 1st, 1868.									
Raw sewage, 10 a.m. to 5 p.m.	108·0	2·752	·103	2·250	0	1·956	22·18	37·70	59·88
Effluent liquid, 10 a.m. to 5 p.m.	119·0	2·039	·296	2·500	0	2·355	1·26	1·50	2·76

Before proceeding to interpret the results of our 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 left on evaporation," 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 previous visit to Leicester (May 13th, 1868), shows that the sewage of this town is much below the average strength, and that it does not seem to vary in strength between very wide limits.

	May 13th.	July 30th.	July 31st.	Aug. 1st.
Total solid matters in solution left on evaporating 100,000 lbs. of sewage	107·5 lbs.	111·0 lbs.	112·0 lbs.	108 lbs.
Total combined nitrogen dissolved in 100,000 lbs. of sewage	2·524 "	2·102 "	2·229 "	1·956 "

But although the strength of the sewage separated from suspended matter 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:—

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

The purification of sewage may be conveniently considered under two heads: 1st, clarification, or the removal of suspended matters, so as to make the resulting liquid more or less clear and transparent; and 2nd, removal of matters in solution. The suspended matters contained in sewage are well known to undergo rapid putrefaction and to become very offensive, consequently their removal, either by filtration or chemical treatment, is in itself an important amelioration of sewage. But the liquid so clarified contains in solution much nitrogenous organic matter, which, in warm weather, becomes putrid, even when mixed with a considerable volume of river water.

In regard to clarification, the experiments at Leicester were not entirely satisfactory, the effluent liquid being at all times obviously turbid, and on each of the three days the organic portion of the matters in suspension exceeded the proportion which in our first report (Report on the *Mersey* and *Ribble* basins, Vol. I., p. 130) we suggested should cause a liquid to be deemed polluting and inadmissible into any stream, viz.:—"Any liquid containing in suspension more than one part by weight of dry organic "matter in 100,000 parts by weight of the liquid." Thus the effluent sewage at Leicester still contained the following quantities (dry) of organic matter in suspension, during the continuance of the experiment:—

Suspended Organic Matter (dry) in 100,000 parts of effluent Liquid.

1st day	3·82 parts.
2nd „	3·14 „
3rd „	1·50 „

Of the soluble constituents of sewage, the most important are those given in the accompanying analytical results under the heads "Total Solid Matters in solution left on evaporation," "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 process. The numbers all refer as usual to 100,000 lbs. of sewage.

EFFECT OF THE "A. B. C." PROCESS ON THE SOLUBLE CONSTITUENTS OF SEWAGE.

At Leicester, July 30—Aug. 1, 1868.	Total Solid Matters in Solution.	Organic Carbon.	Organic Nitrogen.	
	Added.	Removed.	Removed.	Added.
	Lbs.	Lbs.	Lbs.	Lbs.
1st day	6·0	·967	·425	—
2nd „	13·0	1·231	·374	—
3rd „	11·0	·713	—	·193

The numbers show that, as applied at Leicester, the process markedly augmented the total solid matters in solution. This is obviously due to the fact that considerable quantities of dissolved chemicals are added which are not afterwards precipitated. It is also possible that 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 matters which is greater than the amount originally present in the sewage.

The process had the effect of diminishing the organic carbon on each of the three days during which the experiments were continued.

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 chiefly 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 the process signally fails in accomplishing such an amount of purification as would render 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 matter of the raw sewage was greater than that precipitated from solution by the chemical reagents added. Leaving out of consideration this result, which must be regarded as abnormal, the following table shows the amelioration effected on the first two days:—

	Per-centage of Organic Nitrogen removed.
1st day	58·86
2nd day	50·07

It may be stated therefore in round numbers that, as regards putrescible organic matter, the application of the process at Leicester during our visit would render it possible to double the amount of purified sewage admitted into the 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 shows that the effluent sewage after treatment invariably contained more ammonia than the raw sewage; thus on the first day 100,000 lbs. of sewage contained 1·65 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: alum is used in the process, and as nearly all alum now manufactured is ammonia-alum, containing 3·7 per cent. of ammonia, it is probable that this is the chief if not the only source of the additional quantity of ammonia. Treated according to the specification, 100,000 lbs. of the sewage would receive, in the 10 lbs. of alum added to it, ·375 lb. of ammonia; but if the proportion of chemicals used ranged up to double that prescribed by the specification, as was the case at Leamington, then 100,000 lbs. of sewage might receive in the alum added to it ·75 lb. of ammonia, which almost exactly corresponds with the maximum increase of ammonia (·7 lb. in 100,000 lbs. of effluent liquid) observed in the above experiments. The action of the chemical re-agents upon the nitrogenous organic matters contained in the raw sewage, partly in suspension and partly in solution, is also possibly another source of the increased quantity of ammonia.

Such an addition to the amount of dissolved ammonia has little 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 that the ammonia in solution in the raw sewage—the most valuable manure constituent—is not precipitated. Indeed it will be seen from an inspection of the analytical table that on the second and third day the "total combined nitrogen" (which represents very nearly the manure value) was actually greater in the effluent liquid than in the raw sewage. In other words, the results of the second and third days' experiments showed that, as regards dissolved constituents, the effluent liquid was a more valuable manure than the raw sewage. This fact is very significant, as bearing upon the manufacture of manure by the "A. B. C." process, when it is remembered that $\frac{7}{8}$ths of the manure value of sewage resides in the soluble constituents. (See Report on the *Mersey* and *Ribble* basins, Vol. I., p. 27.)

Notwithstanding the loss of actual or potential ammonia in this process for sewage defœcation, the method of treatment still yields a solid manure of greater value than that obtained by the treatment of sewage with lime; a circumstance which is explained, to a great extent, by the mud from the new process being acid, whilst the lime mud is alkaline, so that in drying, the latter loses ammonia, whilst the former, especially if still further acidified, cannot suffer this loss.

We collected a sample of the mud as it was being raised from the subsidence tanks. It was first dried in the sun, with free exposure to the air, so as to imitate, as nearly as may be, the process of drying such manure usually employed on the large scale, and it was then submitted to analysis. The following results, expressed in per-centage numbers, were obtained:—

Mineral matters	54·772
Organic and other volatile matters	45·228
Carbon	24·994
Phosphoric acid	·496
Total nitrogen	1·943
Ammonia	·185
Total nitrogen calculated as ammonia	2·36

The theoretical value of the manure, as estimated from the above chemical composition, is 1*l*. 13*s*. 0$\frac{3}{4}$*d*. per ton.*

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

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

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 Leicester

* In order to arrive at this result the following prices were fixed upon the several ingredients: ammonia, 59*l*. per ton, and superphosphate of lime, 32*l*. per ton; if calculated at the rate of 56*l*. a ton for the ammonia and 15*l*. per ton for soluble phosphate, the manure appears to be worth only 1*l*. 8*s*. 9*d*. per ton.

† Report on the Main Drainage of the Metropolis, by Hofmann and Witt, 1857, page 19.

mud is actually sold for 1*s*. per ton, although its indicated value is from 15*s*. to 17*s*. Indeed, without fortification with sulphate of ammonia, nitrate of soda, or superphosphate of lime, such manures are scarcely saleable.

II. *Experiments at Leamington.*

In March 1869 the patentees undertook to apply their "A. B. C." process to the sewage of Leamington pending the execution of the necessary works for the conveyance of the sewage to a farm on the estate of the Earl of Warwick, where it is to be used for irrigation. At the request of the patentees, and by previous arrangement with them, we visited these works on December 11, 1869.

Here we found that the chemical or "A. B. C." method of treatment had been supplemented by a subsequent process of continuous filtration through animal charcoal, sand, and gravel; but it was soon apparent that the filters could not pass anything like the whole volume of sewage which had been submitted to chemical treatment. 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. As the supplementary process of filtration has since been abandoned, the failure of this part of the operations is not of importance, more especially as it forms no part of the "A. B. C." method of treatment.

The experiments were commenced at 9 a.m. by making the "A. B. C." mixture, composed as follows:—

	cwt.	qrs.	lbs.
Alum - - - - - - - -	1	2	0
Sulphate of alumina - - - - - -	0	3	7
Clay - - - - - - - -	8	0	0
Animal charcoal - - - - - -	0	2	0
Clay and blood, containing 5½ pints of blood - - -	0	1	12
A mixture of potash, carbonate of potash, and carbonate of soda	0	0	6
Previously manufactured manure - - - -	0	0	14
Strong solution of perchloride of iron - - - - -			1 pint.

This mixture was put into a large cauldron where it was thoroughly incorporated with river water, and afterwards kept continuously agitated by means of a "rouser" worked by steam power. The horizontal shaft communicating motion to this rouser worked a small chain pump by which a regulated supply of the mixture was delivered into a neighbouring circular tank, in which it was mixed and violently agitated with the raw sewage. From this vessel the sewage flowed into a series of subsidence tanks beneath the floor of the building, where a large proportion of the suspended matters was deposited; thence the defœcated sewage flowed into other subsidence tanks in the open air, and from these on to the filter beds above mentioned.

On the occasion of our second visit to these works, (May 10th and 11th, 1870) we became aware for the first time that, between the two sets of subsidence tanks there is a penstock which feeds a water-wheel from the river *Leam*, the outlet for the wheel race being through the second set of subsidence tanks; and we were informed by Mr. W. C. Sillar that this water-wheel is used instead of the steam-engine during the night. The whole of this water-power plant being placed underground, and being approachable only by means of a trap-door and ladder, we were not cognizant of its existence until it was pointed out to us by Mr. W. C. Sillar on the occasion of our second visit to the works. On that occasion we found that the penstock was not water-tight; there was also a hole in the side of the sluice only partially stopped by a wooden plug; so that even when the wheel was not working, a considerable stream of unpolluted water from the river *Leam* was mingling with the effluent sewage before it reached the place where our samples were taken. The effect of this water-power arrangement would obviously be to fill the second set of subsidence tanks and the filter beds every night with the large volume of river water required to work the water-wheel, mixed with the weak night sewage; whilst during the day the effluent sewage would be constantly diluted by the leakage of unpolluted river water through the penstock. We mention these circumstances here because they throw light upon the analytical results which unmistakably disclose an admixture of unpolluted water with the sewage during its passage through the sewage works,

We took half-hourly samples of raw sewage from 9 a.m. to 3 p.m., and of effluent liquid from 10 a.m. to 4 p.m. Submitted to analysis these samples yielded the following results:—

EFFECT OF THE "A. B. C." PROCESS ON LEAMINGTON SEWAGE.

RESULTS of ANALYSIS, expressed in Parts per 100,000.

At Leamington, Dec. 11, 1869.	Dissolved Matters.							Suspended Matters.		
	Total solid Matters left on evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
Raw sewage - - - -	83·5	4·355	2·890	5·971	0	7·807	11·00	96·24	56·28	152·52
Ditto after the "A. B. C." treatment, but before filtration.	94·3	2·803	1·334	4·660	0	5·172	9·50	6·68	4·12	10·80

An inspection of the numbers contained in the column headed chlorine shows that the sewage has undergone dilution with some liquid containing a smaller proportion of that element, for we find that the application of the "A. B. C." process to sewage, using some of the mixture actually employed at Leamington, does not appreciably affect the proportion of chlorine. A knowledge of the water-power arrangements above described leaves no doubt that the liquid which thus flowed into the sewage and reduced the proportion of chlorine from 11 to 9·5 parts in 100,000 was the water of the *Leam*, which, according to our analysis, contains 3·48 parts of chlorine in 100,000 parts. Before we can ascertain, therefore, from the analytical numbers the purifying effect of the A. B. C. process in the above experiment, it is necessary to ascertain the proportion of *Leam* water which commingled with the sewage between the two points where the samples of raw sewage and effluent liquid were taken. A simple calculation based upon the proportions of chlorine in the raw sewage, effluent liquid, and river *Leam* water shows that the sewage had become mixed with almost exactly one-fourth of its own volume of river water. The formula

$$x=\frac{a-c}{c-b},$$

in which a, b, and c represent the amount of chlorine in 100,000 parts of sewage, river water, and effluent water respectively, and x the required volume of the river water which has thus commingled with each volume of the original sewage, gives the proportion ·249 of river water to 1 of sewage.

Applying this correction and assuming the composition of the river water to be the same as that found by analysis on May 10th, 1870 (see page 14), we obtain the following numbers illustrative of the nett effect of the "A. B. C." process on this occasion—1st, on the total solid matters left on evaporation; 2nd, on the elements of organic matter—organic carbon, and organic nitrogen; 3rd, on the total combined nitrogen; and 4th, on the organic matters in suspension.

NETT EFFECT OF THE "A. B. C." PROCESS ON LEAMINGTON SEWAGE.

RESULTS of ANALYSIS, expressed in Parts per 100,000.

At Leamington, Dec. 11, 1869.	Dissolved Matters.				Suspended Organic Matters.
	Total solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Total combined Nitrogen.	
Raw sewage - - - - -	83·5	4·355	2·890	7·807	56·28
Ditto after treatment by the "A. B. C." process -	99·2	3·379	1·652	6·392	5·15

These results show that the sewage operated upon at Leamington was much stronger than that experimented with at Leicester, for whilst the former contained on the average of the first two days in 100,000 parts only 3·641 parts of organic carbon, ·735 part of organic nitrogen, and 2·166 parts of total combined nitrogen, 100,000 parts of the latter held in solution 4·355 parts of organic carbon, 2·89 parts of organic nitrogen, and 7·807 parts of total combined nitrogen, being about equal in strength to average London sewage, 100,000 parts of which, as we have already shown (First Report on *Mersey* and *Ribble* basins, Vol. I., p. 63) contain in solution 4·386 parts of organic carbon, 2·484 parts of organic nitrogen, and 7·06 parts of total combined nitrogen. It was therefore to be expected that the proportional amelioration obtained by the application of the "A. B. C." process at Leicester would not be maintained in the application of the same method to Leamington sewage, and a comparison of the Leamington with the Leicester results from this point of view shows that as regards the soluble polluting matters of sewage, this anticipation is realised.

COMPARISON OF RESULTS OF "A. B. C." TREATMENT AT LEICESTER AND LEAMINGTON.

Results.	of Organic Carbon removed.	Organic Nitrogen removed.
At Leicester - -	30·3	54·47
At Leamington (average)	22·4	42·84

After this comparison it is almost needless to add that as the effluent liquid at Leicester was not admissible into running water, the liquid flowing from the works at Leamington was much less so.

Considering it desirable to test the process under more favourable conditions as regards weather, on the 10th of May 1870, after a long continued drought, we paid a second visit to the works at Leamington, on this occasion without giving any previous notice of our intention. We were courteously received by the Messrs. Sillar, who expressed their gratification that we had come without giving them warning, as we should thus have the opportunity of seeing the process in its ordinary course of work, and in the finest weather. In addition to the usual staff of workmen, we found in charge of the laboratory Mr. Graham an analytical chemist, with an assistant. We found the yards around the buildings covered with the sewage mud, which had been spread abroad to dry, in order to get it into saleable condition as manure. The smell was extremely offensive, and the process, as it was then being carried out, would be pronounced a nuisance whenever conducted in or near a town. (See Appendices, Nos. 32 and 33.) The nuisance arose on the present occasion, we were told, partly from the need of quickly drying a large accidental accumulation of the material; but, whether conducted out of doors or under shelter, on a large scale or on a small scale, this method of dealing with the raw manure extracted from raw sewage is attended with the evolution of much offensive smell: to abate this nuisance Mr. W. C. Sillar informed us that they had recently used chloride of lime.

It was arranged that every part of the cleansing process should be carefully watched, and submitted to rigorous investigation; the ingredients of the "A. B. C." mixture were to be weighed out, and put into the mixing cauldrons only in our presence, and the workmen were to be superintended during the night by the Messrs. Sillar and ourselves conjointly. To enable us to carry out these arrangements satisfactorily we took down with us two of the chemical assistants in our laboratory. Our party therefore consisted of six; and this staff was divided into three sections, the first having the duty of collecting the half-hourly samples of raw sewage above the works; the second the superintendence of the weighing and manipulation of the chemicals; and the third the collection of half-hourly samples of effluent liquid as it fell into the *Leam*. It was arranged with the entire acquiescence of Messrs. Sillar that during the experiments the process should follow exactly its usual course, so far as day operations were concerned, but that at night, in order to prevent the admission into the subsidence tanks, conduits, and filter beds of the great volume of river water which is then necessary to work the water-wheel, the night sewage was to be allowed to flow through the works untreated. We expressed our willingness to pursue the alternative course,* that is, to let the night sewage be treated with small quantities of the "A. B. C." mixture by means of the water-wheel, and then to allow it to mix with river water as usual in the tanks, samples being taken at regular intervals as during the day; but the Messrs. Sillar entirely agreed with us that the plan actually adopted would be on the whole the best, if sufficient time were allowed in the morning for the clearing out of the untreated sewage before the sampling was commenced. It is well known that night sewage is exceedingly weak; thus the sewage of Preston (see First Report, *Mersey* and *Ribble* basins, Vol. I., page 28), contained in 100,000 parts on the average of 24 hours, 3·776 parts of organic carbon, 1·449 parts of organic nitrogen, and 24·08 parts of suspended organic matters, whilst a sample collected at midnight contained only 1·751 part of organic carbon, ·512 part of organic nitrogen, and 4·46 parts of suspended organic matters. It can scarcely be doubted therefore that the untreated sewage flowing through the works during the night contained less polluting matter than the treated sewage discharged during the day, and the sequel shows that the samples collected during the morning of the following day exhibit the "A. B. C." process to greater advantage than those collected at any other period. At no time during the experiments did the Messrs. Sillar or any other person express to us the desirability of using any other chemicals than those actually employed; but Mr. W. Sillar informed us that small quantities of other substances were occasionally added to the "A. B. C." mixture. He stated, however, that he considered them neither necessary nor useful. (See Appendix, No. 22, "1st," and No. 23, "2nd."

* See Appendix No. 23 (paragraph 5).

Our investigation commenced at 11 a.m. on the 10th May, at which time a sample of raw sewage was taken about 200 yards above the works. At the same time a mixing tank commenced to discharge the "A. B. C." liquid into the sewage. This tank contained :—

	cwt.	qrs.	lbs.
Ammonia alum - - - - - - -	3	0	0
Clay (moist) - - - - - - -	6	0	0
Animal charcoal - - - - - -	0	0	15
Vegetable charcoal - - - - - -	0	0	20
Epsom salts - - - - - - -	0	0	20
Blood in a pailful of clay-magma - - - -	0	0	4

River water about, as we were informed, 1,135 gallons.

By rough trials we found that this mixture was discharged into the sewage at the rate of about 210 gallons per hour; in reality, however, the discharge must either have been more rapid or the contents of the vessel smaller in volume, since this tank was exhausted in 4 hours 40 minutes, which gives an hourly discharge of nearly 244 gallons, assuming the tank to have contained 1,135 gallons; or if the hourly discharge were really 210 gallons, the above quantities of "A. B. C." materials must have been added to only 980 gallons of river water. Our own analysis of a sample of liquid taken from this tank indicates that 1,027 gallons of river water had been used.

Mr. W. C. Sillar informed us that the filters became choked soon after our last visit and had not been in operation since; but a sluice allowed a considerable proportion of the unfiltered effluent sewage to flow beneath the filter beds, and this, emerging at the tail-race of the filters, would cause an uninstructed observer to think that the liquid issuing into the *Leam* had undergone filtration. It is but justice to the Messrs. Sillar to state that, neither with regard to this arrangement nor the admixture of river water with the sewage at the wheel-race, was any information kept back from us on this occasion; both these circumstances having been communicated to us unasked at the commencement of our operations.

At 12 noon a sample of effluent sewage was taken as it flowed over a dam from the top of the filter beds into the *Leam*. At this time its odour was slightly offensive. Along the filter beds masses of black putrid mud buoyed up by gas occasionally rose to the surface and floated into the river. In collecting our samples of effluent sewage, however, care was taken not to include any of this material. We were informed both on this and on our previous visit that the sewage requires about an hour to pass through the works to the outfall, and upon this statement our plan of sampling was founded. We find, however, on comparing the dimensions* of the settling tanks, culverts, and filters, and the depth of sewage flowing through them above the deposited mud, with the hourly gaugings of the flow made for us during these experiments by Mr. Robert Davidson, the Surveyor to the Leamington Local Board of Health (see Appendix, No. 28), that the sewage at the average dry-weather day rate of flow requires more than 7 hours to fill the culverts, subsidence tanks, and filter beds between the mixing vessel and the outfall. It is, perhaps, not right to assume that when these reservoirs are already filled the whole quantity thus collected is successively displaced by successive volumes of the sewage as it passes through the works; but it is certain, that, owing to the room thus provided for its collection and retention, instead of being only one, it must be several hours (at least five or six in the case of ordinary dry-weather flow) before any particular volume of sewage just arrived at the works shall make its exit at the outfall. Even during the maximum wet-weather flow of the 11th May it would have taken more than two hours to fill those tanks and reservoirs. A similar calculation shows that—excluding the indoor tanks in which the "A. B. C." mud is deposited for subsequent removal as manure, and referring only to the outdoor subsidence tanks, filter beds, and culverts—after these have been filled with the mixture of weak night sewage and river water ordinarily transmitted through

* Kindly supplied to us by Mr. W. C. Sillar.

them during the night, it will take more than 5½ hours dry-weather flow of sewage to clear them out. These figures show that the effluent liquid flowing into the river during the greater part of the day is in reality a mixture of the treated weak sewage of the early morning mixed with a large volume of clean river water from the wheel-race above described; and this circumstance explains the comparative purity of the effluent sewage collected at noon on May 10th; for Mr. W. C. Sillar states in his letter to his brother directors, dated May 17, 1870 (see Appendix, No. 23), that on the morning of our visit the water-wheel had been at work for two days and a half, and had not been replaced by the steam engine until 7 a.m. It also proves how fallacious the results of the analysis of single pairs of samples may be; and it shows that the analysis of samples taken between 8 a.m. and 1 p.m., when the raw sewage is strong and the effluent water weak, will give results favourable to the cleansing powers of the "A. B. C." process, whilst those collected between 1 and 7 p.m., when the raw sewage is weaker but the effluent liquid strong, will, as a rule, lead to conclusions unfavourable to the process.

On the first day, May 10th, half-hourly samples of raw sewage were taken from 11.30 a.m. till 7 p.m.; these samples were mixed together in a large glass carboy, and at the end of the day an average sample was taken for analysis from the carboy. A similar series of samples of effluent sewage was taken in the same way from 12.30 till 7.30 p.m., when the treatment of the sewage was discontinued for the night.

At 1 p.m. the second mixing tank was charged, to be in readiness when the first was worked out. It received the same charge as the first, but delivered its contents at a slower rate, extending over 5 hours 20 minutes, of which 3 hours and 50 minutes were on the 10th, and 1 hour 30 minutes on the 11th of May.

On the morning of the 11th the machinery and mixing apparatus were set to work under our supervision at 5 o'clock. At 6.30 the second or slowfeed tank of "A. B. C." mixture was exhausted, and the discharge from the first or fast-feed tank, which had been charged as before over-night, was set running, but at 8.30 a.m. the second or slow-feed tank was again substituted for it, having been recharged in the interim. At 11 a.m. the fast tank was once more substituted for the slow one, in order, as alleged, to meet the condition of stronger sewage at this time of the day. The sampling of raw sewage as before was commenced at 7 a.m., and that of effluent liquid at 8 a.m., 3 hours after the addition of the "A. B. C." mixture had begun. Slight rain fell during the morning, but, as will be seen from the gaugings, the flow of sewage was not perceptibly affected thereby until noon. At this time the rain became heavier, and we deemed it expedient to take separate average samples during the afternoon. The morning average sample of raw sewage, therefore, extended from 7 a.m. till 12.30 p.m., and that of effluent sewage from 8 a.m. till 1.30 p.m. The afternoon average sample of raw sewage extended from 1 p.m. till 6 p.m., and that of the effluent liquid from 2 till 7 p.m. Finally, a separate sample of raw sewage was taken at 6 p.m., and of effluent liquid at 7 p.m., when the experiments terminated.

At 1 p.m. ½ cwt. of alum and half a pailful of the blood and clay mixture were added to the slowfeed tank, and at the same time *both* tanks were set to discharge the "A. B. C." mixture, as the raw sewage now obviously came down in larger volume. At 3.15 the fast-feed tank was re-charged with the following ingredients:—

	cwt.	qrs.	lbs.
Alum - - - - - -	4	0	0
Clay - - - - - -	6	0	0
Epsom salts - - - - - -	0	0	20
Animal charcoal - - - - - -	0	0	15
Vegetable charcoal - - - - - -	0	0	20
Blood diffused in a pailful of clay magma - - -	0	0	5

At 4 p.m. the slow-feed tank was exhausted, and the fast-feed tank set in action, and continued until the close of the experiments at 7 p.m. The maximum flow of sewage occurred at 6 p.m. (see Appendix, No. 25), when it amounted to 95,595 gallons per hour, but we presume that even this maximum cannot be said to be seriously in excess of the volume with which the works are capable of dealing, as Mr. G. W. Wigner states (Appendix, No. 19) that 1,500 gallons per minute (or 90,000 gallons per hour) can be treated with ease at these works.

The proportion of "A. B. C." mixture to sewage used in these experiments was as follows:—

On the first day 1,834 lbs. of solid mixture were added to 43,192 cubic feet, or 252,352 gallons, which is at the rate of rather less than 7·3 lbs. to 1,000 gallons of sewage. This is nearly double the proportion prescribed by the specification; moreover the proportion of alum, the most active ingredient in the above instance, is 30·5 per cent., while the proportion in the specification is only 23·2 per cent.

In the morning and till 1 p.m. of the second day 1,714 lbs. of the solid "A. B. C." mixture were added to 214,252½ gallons of sewage, being at the rate of almost exactly 8 lbs. of the mixture to each 1,000 gallons of sewage.

In the afternoon of the same day, owing to the increased volume of sewage, both tanks were, as already mentioned, set to discharge "A. B. C." mixture, and between 1 p.m. and 7 p.m. 1,816 lbs. of the solid mixture were added to 404,861 gallons of sewage, being at the rate of 4·5 lbs. of the mixture to each 1,000 gallons of sewage, a proportion still in excess of that prescribed in the specification. Moreover, the proportion of alum in the afternoon mixture was still further increased by one-third; 4 cwt. instead of 3 having been added to each tank of mixture. An increase of one-fourth was also made to the blood put into the "A. B. C." mixing tanks.

On our return to town the samples collected as above described were submitted to analysis, and yielded the following results:—

TREATMENT OF LEAMINGTON SEWAGE BY THE "A. B. C." PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.			Remarks at time Samples were collected.
	Total solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.	
Raw sewage above works at 10.55 a.m., May 10/70.	125·8	6·027	2·814	9·910	0	10·975	17·00	17·48	33·20	50·68	
Effluent sewage below works at 11.55 a.m., May 10/70.	84·4	1·326	·502	1·110	·149	1·565	6·10	1·21	1·14	2·35	Slightly offensive to smell.
Raw sewage above works, half-hourly samples, 11.30 a.m. to 7 p.m., May 10/70.	125·7	6·657	1·949	9·990	0	10·176	15·30	17·68	33·12	50·80	
Effluent sewage below works, half-hourly samples, 12.30 a.m. to 7.30 p.m., May 10/70.	106·2	3·458	1·088	5·808	0	5·871	9·69	2·08	2·52	4·60	Offensive to smell.
Raw sewage above works, half-hourly samples, 7 a.m. to 12.30 p.m., May 11/70.	110·5	4·833	2·494	7·945	0	9·037	13·00	18·48	28·36	46·84	
Effluent sewage below works, half-hourly samples, 8 a.m. to 1.30 p.m., May 11/70.	96·9	2·203	1·250	3·092	0	3·796	9·22	1·40	3·06	4·46	Offensive to smell.
Raw sewage above works, half-hourly samples, 1 p.m. to 6 p.m., May 11/70.	112·0	4·867	2·185	6·917	0	7·881	12·60	62·24	53·32	115·56	
Effluent sewage below works, half-hourly samples, 2 p.m. to 7 p.m., May 11/70.	113·0	4·029	1·899	8·025	0	8·508	12·20	3·68	5·52	9·20	Very offensive to smell.
Raw sewage above works, half-hourly samples, at 6 p.m., May 11/70.	89·5	3·426	1·962	2·854	0	4·312	10·30	111·40	86·08	197·48	
Effluent sewage below works, half-hourly samples, at 7 p.m., May 11/70.	106·3	3·578	2·203	3·652	0	5·211	10·25	5·08	5·00	10·08	Very offensive to smell.

In the interpretation of these results it is necessary to take into consideration, as before, the proportion of clean river water which mingled with the sewage between the points at which our samples were taken, owing to the working of the waterwheel, and to the leakage at the water-wheel penstock. Applying the formula already given to the numbers in the column headed chlorine, and bearing in mind that 100,000 parts of the water of the *Leam* contain 3·48 parts of chlorine, we find that 100 volumes of true effluent sewage had thus become mixed with the following volumes of river water:—

	Volumes of river water added.
Effluent sewage at 11.55 a.m. May 10/70 - - - - - -	416
Effluent sewage, average of half-hourly samples from 12.30 a.m. to 7.30 p.m., May 10/70 - - - - - - - -	90·3
Effluent sewage, average of half-hourly samples from 8 a.m. to 1.30 p.m., May 11/70 - - - - - - - -	65·9
Effluent sewage, 2 to 7 p.m., May 11/70 - - - - - -	Inappreciable.
Effluent sewage, 7 p.m., May 11/70 - - - - - -	Inappreciable.

The admixture of a very large volume of river *Leam* water with the effluent sewage, when the sample was taken at 11.55 a.m. on May 10th, as thus determined by the diminution of chlorine, is strikingly confirmed by the presence of nitrates in the effluent liquid. The Leamington sewage contains no nitrates, neither does the "A. B. C." process produce nitrates; on the other hand, 100,000 parts of the water of the *Leam* contain ·178 part of nitrogen in the form of nitrates; consequently, if 416 parts of *Leam* water were mixed with 100 parts of Leamington sewage, the mixed liquid ought to contain ·143 part of nitrogen as nitrates; our analysis given at page 11 shows ·149 part of nitrogen as nitrates in 100,000 parts of the effluent liquid, a proportion which indicates a slightly larger admixture of *Leam* water than that deduced from the chlorine determinations. Nitrates may thus be used for the determination of the *minimum* proportion of river water which has mixed with sewage. They cannot, however, be safely employed as an indication of the *maximum* proportion, because, as we have already shown (First Report on *Mersey* and *Ribble* basins, Vol. I., p. 113), the admixture of a large volume of sewage with river water containing nitrates rapidly decomposes and destroys all trace of the latter. For instance, the water supply of Leamington contains ·191 part of nitrogen as nitrates, no trace of which, however, is to be found in the Leamington sewage. In like manner the nitrates of the *Leam* water were not present in any of the subsequent samples of effluent liquid, because these contained much larger proportions of sewage.

During the whole course of the experiments we saw the stream of river water from the wheel-race mingling with the treated sewage. That this leakage was inappreciable by the chlorine test in the afternoon samples of the second day is doubtless due chiefly to two causes, viz.:—1st, to the greatly increased volume of sewage during the rain; and 2nd, to the diminished strength of the raw sewage as compared with the original strength of the treated sewage, owing to the length of time required by the latter to pass through the tanks and conduits to the outfall where the samples of effluent liquid were taken—the strength of watercloset sewage exhibiting a continual diminution during the afternoon. For the same reason the other analytical results yielded by these last samples of effluent liquid show an unfavourable comparison with the companion samples of raw sewage; more especially is this the case with the final pair of samples in which the effluent liquid is, as regards dissolved matters, in all items, except chlorine, actually somewhat stronger than the raw sewage with which it is compared in the above table.

We may therefore dismiss from consideration the first and last pair as comparative samples, observing however that the effluent liquid even in the case of the first pair, notwithstanding its dilution with more than four times its volume of river water, was still polluting and inadmissible into running water.

It will therefore only be necessary to correct for admixture of river water in the average samples of effluent sewage collected on the 10th inst., and on the morning of the 11th. Thus corrected, the results of the analysis of these samples are compared in the following table with those yielded by the corresponding samples of raw sewage:—

NETT RESULTS OF TREATMENT OF LEAMINGTON SEWAGE BY THE "A. B. C." PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.		
	Total solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
Raw sewage, half-hourly samples, 11.30 a.m. to 7 p.m., May 10/70.	125·7	6·657	1·949	9·990	0	10·176	15·30	17·68	33·12	50·80
Effluent sewage, half-hourly samples, 12.30 p.m. to 7.30 p.m., May 10/70.	134·6	6·130	1·929	11·017	0	11·002	15·30	3·96	4·80	8·76
Raw sewage, half-hourly samples, 7 a.m. to 12.30 p.m., May 11/70.	110·5	4·833	2·494	7·945	0	9·037	13·00	18·48	28·36	46·84
Effluent sewage, half-hourly samples, 8 a.m. to 1.30 p.m., May 11/70.	111·5	3·325	2·033	5·103	0	6·235	13·00	2·32	5·08	7·40

It is evident that a certain amount of possible fallacy attaches to the corrected numbers in the last table owing to the varying relations of chlorine to the other constituents of sewage of varying strength, and to the want of complete correspondence, as already described, of the samples of raw sewage with those of effluent liquid; we deemed it therefore expedient to try the "A. B. C." process in our own laboratory upon sewage of known composition under circumstances excluding any possible alteration of composition, except that due to the action of the "A. B. C." chemicals. For this purpose we brought back with us from the works at Leamington a sample of the "A. B. C." liquid actually used in the above experiments; this was mixed with fresh London sewage in the proportion of one volume of the liquid to 100 volumes of sewage, that being about the proportion used in the experiments on the 10th May. The mixture was violently agitated for 5 minutes and then allowed to subside for two hours in a deep glass cylinder. A sample of the supernatant liquid was then removed for analysis, the results of which, together with those of the sewage operated upon, are contained in the following table:—

TREATMENT OF LONDON SEWAGE BY THE "A. B. C." PROCESS.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.		
	Total solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
London sewage collected May 23, 1870.	67·3	3·614	1·886	5·418	0	6·348	10·23	10·30	18·00	28·30
Ditto after treatment by A. B. C. process.	80·5	2·257	1·878	6·086	0	6·890	10·20	traces.	traces.	traces.

These results are very instructive; they are free from the sources of fallacy attending the trials at Leamington; and, moreover, this laboratory experiment, being quite as likely to yield results favourable to the process as any operations on the large scale, even with the most perfect plant, may be regarded as exhibiting the true amount of amelioration which can be obtained by this process even with the employment of double the proportion of chemicals prescribed by the specification.

We learn then from the above results:—

1st. That of the dissolved matters those left on evaporation were increased in weight by nearly one-half the amount of soluble ingredients added to the sewage; for the "A. B. C." mixture making up 100,000 parts with the sewage to which it was added contained, according to our analysis, 27·8 parts of soluble matters left on evaporation, whilst the increase of soluble matters left on evaporation, shown in the above table, amounts to 13·2 parts.

2nd. That the organic carbon in the dissolved matters was diminished to the extent of 37·5 per cent.

3rd. That the organic nitrogen in the dissolved matters underwent no alteration; consequently, the organic matters precipitated from solution by the "A. B. C." mixture were non-nitrogenous, and therefore valueless as manure.

4th. That the proportion of ammonia was augmented, because more was added in the "A. B. C." mixture than was precipitated by the action of that mixture upon the sewage. 100,000 parts of the "A. B. C." mixture gave on analysis 132·1 parts of ammonia; there was consequently added to each 100,000 parts of sewage in the "A. B. C." mixture, 1·32 part of ammonia, whilst the augmentation of ammonia shown in the above table is ·668 part.

5th. That no nitrates were formed in the operation.

6th. That the total combined nitrogen was augmented by the ammonia added in the "A. B. C." mixture; consequently, as regards soluble constituents, the effluent liquid possessed a greater manure value than the raw sewage, the increase in value being due to the ammonia in the chemicals employed.

7th. That the proportion of chlorine remained unaltered.

8th. That the matters in suspension, both mineral and organic, were almost completely removed, although the defœcated sewage remained perceptibly turbid.

Reverting to the samples collected on May 10th and 11th, the analytical results yielded by these samples show that the "A. B. C." process, as carried out at Leamington, effects but a very slight purification of the sewage of that town. Even the suspended organic matters were present in the effluent liquid in four or five times the proportion suggested in our First Report (Report on the *Mersey* and *Ribble* basins, Vol. I., p. 90) as the maximum admissible into a river; the soluble polluting matters were removed to but a slight extent even during the dry weather operations, when double the proportion of "A. B. C." mixture prescribed by the specification was employed; whilst during a slight fall of rain (·286 inch) in the afternoon of the 11th May, the effluent liquid discharged into the *Leam* contained almost exactly as much soluble polluting matter as the raw sewage, although it had been treated with a proportion of "A. B. C." mixture one-eighth greater than that prescribed by the specification. On no occasion, even when mixed with more than four times its volume of clean river water, was the effluent sewage other than a polluting liquid, offensive to the senses even at the moment of discharge, and always quite unfit to be admitted into running water.

It is proper also to remark here that in order to ascertain the state of the river *Leam*, we examined it carefully both above and below the sewage works. Above the works the water was somewhat turbid, but on the whole like that of an unpolluted river; no sewer fungus nor any indications of putrescence were observed. At 6 p.m. on the 10th May we rowed down the stream from the works to the junction with the *Avon*. At this time a large volume of water was flowing over the weir opposite the works, although for some hours in the middle of the day but little water passed this weir. Even to the eye the water below the sewer outfall was in a marked degree inferior in purity to that above the weir. Masses of putrid mud, like those we had observed in the filter tanks, were floating here and there on the surface, buoyed up by the gases generated during putrescence. The water, though offensive to the eye, was not so to the sense of smell. Everywhere there was a thick stratum of very black mud at the bottom of the river, which when stirred with the oar emitted large quantities of very offensive gases. The temperature of the water was 14·6° C. (58·3° F.). About 150 yards below the sewage outfall we found a boom placed across the river to intercept floating matters. Sewer fungus was growing abundantly on submerged objects near the banks, and we observed that it markedly increased in quantity as we approached the works on our return up the river. About one-third of a mile below the works the Messrs. Sillar pointed out to us a place on the left bank where they believed a sewer from Milverton emptied itself into the river beneath the surface. We could not perceive either an outlet or any flow of sewage here (see also Appendix, No. 34, Q. 48, 49); nevertheless in collecting a sample of the *Leam* after admixture with the treated Leamington sewage, we took the water from the river at a point above this suspected outlet.

The results of the analysis of this sample, and of one collected immediately afterwards above the weir at the sewage works, are contained in the following table:—

EFFECT OF LEAMINGTON SEWAGE TREATED BY THE "A. B. C." PROCESS UPON THE LEAM.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Hardness.		
	Total solid Matters left on Evaporation.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage Contamination.	Chlorine.	Temporary.	Permanent.	Total.
The *Leam* above the sewage works, May 10/70.	74·8	·499	·061	·040	·178	·272	1,790	3·48	15·55	12·51	28·06
The *Leam* below the sewage works, May 10/70.	81·0	·575	·102	·370	·179	·586	4,520	3·70	16·40	15·28	31·68

Calculated from the increase of ammonia exhibited in the above table by the *Leam* below the sewage works, we should infer that one volume of the average *nett* effluent sewage of the 10th May had become mingled with 32·3 volumes of river water in the *Leam*. The ammonia of sewage does indeed gradually disappear when discharged into the water of any running stream in which plants are growing, or in which the water is in a state of putrefaction; but neither of these conditions obtained in the *Leam* on the occasion of our visit, and this calculation founded on the ascertained proportion of ammonia present in its water, is therefore probably trustworthy. The river is undoubtedly now being polluted both by suspended and dissolved matters in the effluent sewage, but owing to the comparatively large volume of clean water, the degree of pollution by dissolved organic matters is only small, the organic

nitrogen being increased by little more than 60 per cent. The more serious pollution is doubtless caused by suspended organic matters, which are gradually deposited in the bed of this very sluggish stream; but it is impossible to estimate how much of the present abominable condition of the bed of the river is due to previous mal-practice, and how much to the admission, during thirteen months, of sewage treated by the "A. B. C." process.

We have now to consider this process as a manure-producing operation, because if it be true that a valuable manure can be thus extracted from sewage, it might be advantageous to prefix this method of treatment to some other method capable of purifying the effluent liquid; thus it might be advantageous to make it preliminary to irrigation, since, as we have shown, the effluent liquid still retains the whole of the valuable soluble constituents and has lost only matters in suspension. It is true that the field for profitable enterprise is here greatly narrowed by the circumstance that only about one-eighth of the manure value of raw sewage attaches to the suspended matters, still, taking into consideration the enormous annual value of the sewage now for the most part wasted in this country, it might be worth while to extract even this small fraction if it could be obtained in a sufficiently portable and concentrated form.

The chemical analysis of the precipitated mud which, under the guidance of the Messrs. Sillar, we extracted for this purpose from one of the subsidence tanks on the 10th of May, does not afford any encouragement to such an enterprise. This mud acidified with dilute sulphuric acid to prevent loss of ammonia, and dried in the air, contained the following ingredients:—

Organic matter containing 18·15 parts of carbon and 1·55 part of nitrogen	34·27
Ammonia	·16
Phosphoric acid	1·98
Clay and other useless mineral matters	56·13
Water	7·46
	100·00

Total nitrogen calculated as ammonia = 2·05 per cent.

In the preparation of the manure at Leamington, the mud is pumped into centrifugal drying machines, which were not at work on the occasion of our recent visit. We were, however, informed that one-half or more of the water which the mud contains is thus driven off in a filthy black stream, which is sent back to the tank for repeated treatment. The comparatively dry soil is then taken out of the revolving cages and spread abroad to lose a further portion of its water; being ultimately sold in much the condition as to dryness of an ordinary commercial superphosphate, with probably from 10 to 15 per cent. of water still remaining in it. Notwithstanding the small proportion of fertilising matter which our analysis proves it to contain, the manure is said to have commanded a ready sale at 3*l*. 10*s*. per ton. We are bound, however, to say that the evidence hitherto obtained of its agricultural value is of the weakest kind. No agricultural experience of the manure resulting from the process was, indeed, possible in 1869, for we put altogether aside the possibility of determining the value of a fertiliser by its influence on autumn-sown catch crops, whose produce generally depends much more on the character of the weather than on the composition of any manure that has been applied to them; and the weather of 1870 has hitherto been such that spring top dressings of even the strongest artificial manures have been useless. The whole testimony is thus necessarily that of mere garden beds and flower pots, where enormous quantities *per acre* are almost certain to have been applied, so that they are entirely insufficient to justify an agricultural opinion.

In the absence of that test of the manure over acres of various crops during several seasons, which alone can enable a farmer to speak confidently of its value, we must fall back on the ascertained composition of the sample taken from the tank, and it offers the following comparison with such manures as a good bone superphosphate worth perhaps 90*s*. a ton (wholesale price), and Peruvian guano worth 13*l*. a ton.

Ingredients in 100 Parts.	"A. B. C." Manure.	Bone Superphosphate.	Peruvian Guano.
Combined nitrogen	1·695	·4	14
equal to ammonia	2·05	·5	17
Phosphoric acid equal to soluble phosphate of lime	3·26	26·0	7
Neutral phosphate of lime	—	10·0	22
Soda salts	—	—	} 8
Potash	—	—	

If on valuing these manures we take the ammonia to be worth 56*l.* a ton, the soluble phosphate to be worth 15*l.*, the neutral phosphate 5*l.* a ton, and the alkaline salts 1*l.* a ton—nearly the prices at which they are sold in imported manures—the super-phosphate comes out worth about 4*l.* 14*s.* per ton, which is more than its value in the whole-sale market; the guano comes out worth upwards of 12*l.* per ton, and the "A. B. C." manure appears to be worth about 32*s.* per ton. That is to say, 160 cwts. of the "A. B. C." manure would be worth as much as 20 cwts. of guano, or 55 cwts. of the superphosphate, supposing both to have been deposited upon and within the soil. It is plain, however, that this supposition cannot be realised without a much larger expenditure on the weaker manure for carriage and labour of distribution than in the case of guano or of superphosphate,—an expenditure which indeed very soon altogether destroys the commercial value of a manure as it diminishes in strength. The dried lime mud from the Leicester sewage works, for example, which, according to Dr. Voelcker's analysis is worth 15*s.* 5*d.* per ton, commands only 1*s.* per ton in the actual market. It is, therefore, certain that the theoretical value of the Leamington "A. B. C." manure will not be nearly realised when its price shall have been determined by the ordinary process of competition with other purchaseable fertilisers. On this point we refer to the testimony of Messrs. Lawes and Gilbert (Nos. 29, 30, Appendix), as still more conclusive of the comparative worthlessness of such manures as have their fertilising ingredients, like those of the "A. B. C." manure, mixed with a great mass of inert matter. No doubt a higher value may be obtained if the process of manufacturing a manure, of which the precipitated sewage mud is only one of the ingredients, shall be adopted, as it is at Stroud. Guano or superphosphate, nitrates or ammonia salts may be added to the "A. B. C." mud until the composition of the mixture shall make it worth the farmer's while to pay 3*l.* or even more per ton for it at the works, even though he should have to cart it several miles to his fields. But in that case it deserves the careful consideration of the agriculturist, whether, if he desires to use a fertiliser of diminished strength, he will not be better served by carrying only the pure guano, superphosphate, nitrate, or ammonia salt from the market to be mixed with a sufficient quantity of diluting material at home.

An artificial fortification of the comparatively worthless sewage mud thrown down by the "A. B. C." mixture is, however, occasionally practised. It will be seen in the Appendix (No. 34) that added crystals of sulphate of ammonia were found in the "A. B. C." manure at Leamington by Dr. W. A. Miller, F.R.S., and Dr. W. Odling, F.R.S., who visited the Leamington works on April 2nd, this year, under instructions from the Metropolitan Board of Works, to inquire especially into the value of the manure made there. As these gentlemen have as yet made no formal report upon the subject (*see* Appendix, Nos. 25, 26, and 31,) we called Dr. Odling before us, and his evidence is reported in full in Appendix, No. 34. It will be seen from those of his answers to our questions which are extracted below* that when a sample of the genuine manure was

* Extract from Dr. Odling's Evidence :—

"Did you also examine the manure which was being manufactured ?—Dr. Miller and I took a great number of different samples of manures, but we found that many of these samples contained large crystals of sulphate of ammonia. These are some of the crystals of sulphate of ammonia, which were found in one of the heaps in the drying shed (*producing the same*).

"The manure from which these crystals were removed was in the drying shed ?—Yes.

"Did you find any of these crystals in any other portions of the manure about the works ?—Yes, in several other portions.

"And you have proved them to be sulphate of ammonia ?—Yes ; I may say that it was then arranged that we should simply take a sample of the manure as it was going out in the cart, and that we should examine that alone.

"Have you examined it ?—We have.

"Can you furnish us with an analysis of it ?—I hand in the analysis. (*This will be found at the end of the evidence of the witness.*)

"What is your opinion as to the value per ton of that sample which you analysed ?—I might put it in this way, that it contains about $\frac{1}{24}$th part of the nitrogen which is contained in guano, and less than $\frac{1}{24}$th part of the amount of phosphate, so that, estimating it merely as regards those two constituents, it would have been $\frac{1}{24}$th part of the value of guano, making no deduction for the amount of dilution.

"Can you account for the presence of these crystals of sulphate of ammonia in the manure from any of the processes to which the sewage is subjected in the works ?—No. I may say that when these crystals were first discovered, the manager, Mr. Wigner, told us that he knew nothing about how they had come there, but that he supposed that they must have been swept up by accident. That was the original information which was offered. When we pointed out the large extent of the admixture and the number of different heaps, we were then told that it was sulphate of magnesia which had been added in order to assist the desiccation of the manure, and the fixation of the ammonia. After we had left the works we were told that the manager (Mr. W. G. Wigner) had intended to order sulphate of magnesia, but that he had accidentally written "sulphate of ammonia" instead of sulphate of magnesia.

examined, its ingredients indicated a value corresponding to about $\frac{1}{24}$th that of Peruvian guano, or 11*s.* 3*d.* per ton, which is considerably below the value based upon our analyses. These were indeed analyses of samples not of the manufactured manure, but of the raw sewage mud thrown down by the "A. B. C." mixture, and afterwards treated in the laboratory with greater care for the preservation of its volatile ingredients than is possible on the large scale of an ordinary manure manufactory. There can be no doubt, therefore, that our results are especially favourable to the character of the "A. B. C." manure.

It may be useful here to glance at the weight and value of the "native guano" produced from a given quantity of sewage and the expense of the chemicals required to produce it. Unfortunately our data for the calculation are not so complete as might be wished, since it was obviously impossible to investigate this part of the process so elaborately as the chemical part, without expending more time than we should have considered ourselves justified in devoting to this one object. The proportion of suspended and precipitable matters in the Leamington sewage doubtless varies from day to day, and even the actual weight of clay and chemicals added is, as already stated, altered according to the strength and volume of the sewage; nevertheless, taking as an example the 10th of May, a close approximation may be arrived at from the following data :—2,523,520 lbs. of sewage were treated during 8½ hours on that day; this sewage contained 1,262 lbs. of matters in suspension, of which about $\frac{5}{6}$ths or 1,052 lbs. were retained in the tanks. To this weight of sewage 1,834 lbs. of solid "A. B. C." mixture were added, containing 1,215 lbs. (or 925 lbs. when dried at 100° C.) of insoluble matters—clay and charcoal, and 619 lbs. (or 501 lbs. when also dried at 100° C. of soluble matters—ammonia, alum, Epsom salts, and blood. If no precipitation occurred the soluble matters thus added ought to increase the weight of the "solid matters left on evaporation" to the extent of 501 lbs. The analytical table at p. 12 shows, however, that the increase of weight of dissolved matters in 2,523,520 lbs. of effluent liquid as compared with the same volume of raw sewage was only 225 lbs., consequently 276 lbs. were precipitated. The following is therefore the weight of dry manure produced on May 10th :—

Suspended matters in sewage operated upon - -	1,052 lbs.
Insoluble matters added in "A. B. C." mixture - -	925 „
Soluble matters precipitated by action of "A. B. C." mixture - - - - - -	276 „
Total manure dried at 100° C. - - - -	2,253 „

But as the manure when merely air-dried for sale contained 7·46 per cent. of water, which would be expelled at 100° C. (*see* p. 15), it follows that the above weight of manure corresponds to 2,435 lbs., or 1 ton 1 cwt. 2 qrs. 27 lbs. of manure as sent to market.

The value of this weight of manure as indicated by its chemical composition is 1*l.* 14*s.* 9*d.*; but appraising it at the value which it will, according to Messrs. Lawes and Gilbert, fetch in the market, it is not worth one-third of this sum.

Now, besides labour, fuel, wear and tear, and interest upon plant, there was expended in the production of this manure,—

	£	s.	d.
577 lbs. ammonia alum at 7*l.* per ton - -	£1	16	1
34 lbs. Epsom salts at 20*s.* per ton - -	0	0	4
26½ lbs. animal charcoal at 6*l.* per ton - -	0	1	5
34 lbs. vegetable charcoal at 2*l.* per ton -	0	0	7
1,155 lbs. clay - - - -		—	
7 lbs. blood - - - - -		—	
	£1	18	5

"Upon that occasion was it one of your chief objects to ascertain the value of the manure made by this process ?—Yes, that was our chief object.

"Would the addition of sulphate of ammonia increase the value of the manure ?—It would increase its value to the extent to which ammonia salt was added.

"During your experiments, did you have the chemicals weighed which were added to the sewage ?—No."

Looked at from another point of view, the results of this day's working may be thus formulated:—

The manure value of the chemicals added was,—

21·3 lbs. of ammonia at 56*l.* per ton, in the ammonia alum	£0 10 8
21·3 lbs. of neutral phosphate at 5*l.* per ton, in the animal charcoal	0 0 11
	£0 11 7

Taking, therefore, the theoretical value of the manure, as above given, at 1*l.* 14*s.* 9*d.*, the nett result of the day's working was the recovery from the sewage of Leamington of manure constituents worth theoretically 1*l.* 3*s.* 2*d.* We shall certainly be understating rather than overstating the fact if we assume that in the 8½ hours *day* working not less than one half of the total 24 hours sewage matter of Leamington reached the works; but taking this estimate it follows that the 20,000 inhabitants of Leamington would yield annually by the "A. B. C." process manure of the theoretical value of 845*l.* 11*s.* 8*d.*, or 10*d.* per head per annum. It is plain, however, from the table on page 17, which omits many considerable items of expenditure, that notwithstanding the recovery of this value of manure ingredients from each individual, the process would involve an expense greatly exceeding the returns, even when thus calculated on this liberal theoretical estimate. The actual value of the recovered manure would, at 7*s.* a ton (*see* Appendix, No. 30), amount to 255*l.* 10*s.*, or 3½*d.* per head per annum; and the actual loss upon the process would therefore be so much the greater. This is an even less satisfactory result than is obtained by ordinary scavenging operations in the Lancashire towns (*see* First Report on the *Mersey* and *Ribble* basins, Vol. I., p. 26), where manure of the annual value of rather less than 5*d.* per head over a population of more than 1,000,000 is annually obtained.

As therefore the inevitable conclusion is unfavourable to the "A. B. C." process, in respect of its alleged power to hinder the pollution of rivers by town sewage, so also is it altogether unfavourable to the value of the manure which it manufactures. The one statement is, indeed, in some sense the complement of the other; for just in proportion to the largeness of the amount of the fertilising matter which escapes must be the comparative worthlessness of the small remainder which is retained.

Our visit to the works at Hastings, the greater part of which has been specially constructed for carrying out the "A. B. C." treatment of town sewage, added nothing to our knowledge of this process. We were informed that these works had been for some time in operation, and were ready for our inspection, but we found that they were not yet in the hands of the Hastings Sewage Manure Company; and the process was not in operation on our arrival. It appeared, however, on examination, that owing to the depth of the tanks and the position of the culverts and outfall, no such investigation of the process could be conducted there as had been carried out at Leamington. The effluent liquid is delivered into the sea at extreme low water, and it would have been difficult, if not impossible, to obtain the requisite samples.

CONCLUSIONS.

Our investigations into Sillar's or the "A. B. C." process of treating sewage, as carried out at Leicester and at Leamington, extending over nearly two years, have led us to the following conclusions:—

1. The process removes a large proportion of the *suspended* impurities from sewage, but on no occasion, when we have seen it in operation, has this removal been so complete as to render the effluent sewage admissible into running water.

2. The "A. B. C." process removes a very small proportion of the soluble polluting matters from sewage. After treatment by this process, the effluent sewage is very little better than that which is obtained by allowing raw sewage to settle in subsidence tanks.

3. The manure obtained by this process has a very low market value, and cannot repay the cost of manufacture.

4. The manipulations required for the extraction and drying of this manure are attended with a nauseous odour, especially in warm weather, and would occasion a serious nuisance if the works were situated in or near a town.

It would obviously be rash to set any bounds to the possibilities of chemistry. Substances may, perhaps, be hereafter discovered capable of combining with and rendering insoluble the filthy constituents of our town drainage; but we are compelled to admit that the present resources of this science hold out no hope that the foul matters dissolved in sewage will be precipitated and got rid of by the application of chemicals to the offensive liquid. The chemical affinities of these foul matters are so feeble, and the matters themselves are dissolved in such enormous volumes of water, that their precipitation is a problem of extreme difficulty.

In thus humbly submitting to Your Majesty these results of our investigation into the "A. B. C." method of treating sewage, we have endeavoured to confine ourselves to a positive statement of the case; but it would not be right to conclude without comparing them with those which have been obtained, where sewage has been submitted, not to the action of limited quantities of chemicals in a tank, but, by means of irrigation, to the action of a vast mass of soil, whose surface is covered with growing plants which it feeds, whose depth is penetrated by their hungry roots, and whose whole substance provides an immensely greater quantity of material efficient for sewage defœcation than can be supplied by any of the so-called chemical processes which have been or can be invented for this purpose.

If we except the laboratory experiments in the treatment of sewage by intermittent downward filtration described in our first report (Report on the *Mersey* and *Ribble* basins, Vol. I., pp. 63–70), no other method of sewage defœcation approaches irrigation in the uniform excellence of its results. It is no doubt very desirable, in the interest of those towns where sewage cannot be dealt with by irrigation, that an experiment in intermittent downward filtration should be conducted on what may be considered a working scale, when all those difficulties would arise which do not show themselves in a laboratory experiment, and when it would be proved whether the process can be conducted on the drainage water of, say, 20,000 people with the efficiency to which our laboratory experiments pointed, and without creating a nuisance. But the best result under that system would simply be the conversion of a polluting into a non-polluting stream. The injury done by town sewage would in that case disappear, but the agricultural value of it would be wholly lost. By using it in irrigation, on the other hand, the nuisance vanishes, while the fertilising influence is retained and utilised.

By the "A. B. C." process, again, it is plain from our investigations that neither of these results is attained. Considered as a method of merely cleansing sewage, it is compared with irrigation in the following table, where the composition of the effluent water at both Leicester and Leamington is contrasted with that of the effluent water from the sewaged fields at Norwood and at Croydon, the one a clayey soil, and the other gravelly and open.

PURIFICATION of SEWAGE by IRRIGATION.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Locality and Season.	1 Total solid Matters in Solution.	2 Organic Carbon.	3 Organic Nitrogen.	4 Ammonia.	5 Nitrogen as Nitrates and Nitrites.	6 Total combined Nitrogen.	7 Chlorine.
Norwood (raw sewage)	**94·9** *	**3·972**	**1·586**	**6·032**	**0**	**6·554**	**8·66**
Norwood:							
Spring (effluent water)	88·1	1·500	·303	·816	·220	1·194	8·37
Summer do.	88·6	1·883	·312	·462	·657	1·361	11·03
Autumn do.	87·0	1·349	·203	·835	·734	1·629	8·94
Winter do.	87·0	1·271	·273	·876	·313	1·255	7·71
After seven days' frost (effluent water).	88·8	1·356	·413	1·145	·156	1·534	8·84
Croydon (raw sewage).	**45·7**	**2·508**	**1·051***	**3·006**	**0**	**3·527**	**4·23**
Croydon:							
Spring (effluent water)	35·4	·594	·104	·072	·225	·388	2·32
Summer do.	35·4	·607	·126	·069	·155	·300	2·57
Autumn do.	43·1	·690	·138	·185	·589	·792	3·20
Winter do.	40·6	·612	·145	·204	·533	·846	2·72
After seven days' frost (effluent water).	45·6	·591	·239	·371	·448	·992	2·88

* The average quantity of organic nitrogen in 100,000 parts of the raw sewage of Croydon is erroneously stated as 1·576 in page 88, Vol. I. of our First Report (Report on the *Mersey* and *Ribble* basins), where the amount has been mis-calculated from analyses accurately given in a previous table, p. 29 of that report.

Purification of Sewage by "A. B. C." Treatment.

Results of Analysis expressed in Parts per 100,000.

Locality and Season.		1 Total solid Matters in Solution.	2 Organic Carbon.	3 Organic Nitrogen.	4 Ammonia.	5 Nitrogen as Nitrates and Nitrites.	6 Total combined Nitrogen.	7 Chlorine.
At Leicester: July 30, 31, 1868	**Raw sewage** -	**111·5**	**3·641**	**·735**	**1·725**	**·015**	**2·166**	—
	Effluent water -	121·0	2·541	·335	2·25	0	2·188	—
At Leamington: Dec. 11, 1869	**Raw sewage** -	**83·5**	**4·355**	**2·890**	**5·971**	**0**	**7·807**	**11·**
	Effluent water -	99·2	3·379	1·652	5·815	0	6·392	11·
At Leamington: May 10, 11, 1870	**Raw sewage** -	**118·1**	**5·745**	**2·221**	**8·967**	**0**	**9·606**	**14·15**
	Effluent water -	123·05	4·727	1·892	8·060	0	8·530	14·15

It is plain from the figures in these two tables, and especially from those in the 1st, 2nd, and 3rd columns, not only that the "A. B. C." method falls altogether below irrigation in its powers as a mode of sewage defœcation, but that it altogether fails—never in any instance approaching even in its maximum results those standards of purity below which we have recommended (Report on the *Mersey* and *Ribble* basins, Vol. I., p. 130,) that no water shall be discharged into running streams. And if this failure be charged upon any alleged unfairness in the conditions under which the experiments took place at Leicester and at Leamington, it must be pointed out in reply, that when the experiment was tried in the laboratory under circumstances which excluded all possible sources of error, the same result was still more unmistakeable; and the contrast of this failure with the uniform success of irrigation in sewage defœcation becomes still more remarkable (*see* pp. 13 and 19).

We have, in our previous report (Report on the *Mersey* and *Ribble* basins, Vol. I., p. 88), given the composition of thirty-one samples of effluent water taken at regular intervals throughout an entire year as it flowed from the irrigated meadows at Croydon; on only one occasion was the condition of the water unsatisfactory, and even then but slightly so. We also analysed this water twice during the severe frost last winter, when it might be expected that the purifying action both of soil and plant would be at its minimum; but even under these unfavourable circumstances the effluent water was perfectly satisfactory, being much within the standards of purity suggested in our first report. Only on two occasions were the authorities connected with the irrigation aware that samples were about to be taken. (*See* Mr. Rawson's letter, Appendix, No. 22.)

At Croydon, indeed, the conditions are very favourable for the cleansing of the foul liquid; the soil is very porous and the raw sewage weak; but at Norwood the conditions are unfavourable; the soil over the greater part of the farm is a stiff clay and the raw sewage strong; consequently, as might have been expected, the effluent water was not so completely purified as at Croydon. Yet even here, and in its worst condition, it was much superior to anything that has ever been achieved upon a working scale by any other means. Here also thirty samples were analysed, taken at regular intervals throughout a whole year, and, except on one occasion, without any previous notice to the manager.

On the other hand, we have never taken a sample of effluent sewage that had been subjected on a working scale to any other cleansing process, which was not still so highly charged with putrescible animal matters as to be utterly unfit for admission into running water.

Irrigation is the only process of cleansing sewage which has stood the test of experience, and unless it be extensively adopted, there is but little hope of any substantial improvement in our sewage-polluted rivers.

Considered merely as a method of utilising the valuable manuring substances which town sewage carries with it, the contrast between the "A. B. C." and irrigation processes is no less obvious. Thus the table (p. 19) shows (col. 6), that at Norwood (where the results are not complicated by the mixture of any unpolluted water with the effluent liquid) a proportion varying from less than three-quarters during autumn and winter to nearly five-sixths during the growing season, of the total combined nitrogen of the sewage was extracted and utilized during irrigation; while at Leamington the

proportion extracted by the "A. B. C." process, taking the average of the three experiments reported in the table (p. 20), was not one-eighth; and from the laboratory experiment it appeared that no influence whatever was exerted by the "A. B. C." process on the total combined nitrogen, which is the characteristic manure ingredient of sewage—the quantity in the original sewage being actually increased in the effluent water by a portion of that present in the added chemicals. In fact, the so-called "A. B. C." manure is little more than the original suspended solid matter of raw sewage, *plus* the insoluble materials added in the "A. B. C." mixture, nineteen-twentieths of these being merely clay. The suspended solid matters of sewage arrive at the works after being roughly driven through the sewers of a town—every 10 cwts. of them carried along in 1,000 tons of water,—and it is not possible to imagine that they retain in them on their arrival much that is soluble or valuable. They are then allowed to subside along with an equal quantity of clay; being indeed materially helped to subside by the added alum, which may also throw down a trifling proportion of the organic nitrogen dissolved in the sewage water; a proportion which, though insignificant considering the quantity it leaves untouched, may nevertheless be enough over the immense flow of sewage passing through the exit sewer of any considerable town to add 1 or 2 per cent. of nitrogen to the subsided mud. The result is a manure theoretically worth probably one half more than that resulting from the Leicester lime process, 20 tons of which, according to a chemical valuation, ought to be worth as much as 1 ton of Peruvian guano, but for which not more than one shilling per ton can be obtained from the farmers of the district.

Contrast this with the efficiency of irrigation as a utiliser of the manure ingredients of town sewage. All these ingredients are in this case taken to the land; and three-fourths of them in winter, four-fifths or five-sixths of them in summer are left there for the use of growing plants; the remainder being rendered unoffensive. These manure materials are thus carried, distributed, and buried; and thus, without the costly labour of the dung cart, manure distributor, or plough, they are brought to the very roots they are to feed; and the fertility they accordingly produce is unexampled otherwise in English agricultural experience. The process can be carried on without offence to any but those who go close to the tanks or channels; and it can be conducted, as the experience of many years at Edinburgh and Croydon proves (*see* Report on *Mersey* and *Ribble* basins, Vol. I., p. 90), without injury to health. We have therefore no hesitation in recommending irrigation as the only plan of dealing with the sewage difficulty at present known to us which at once abates a nuisance and turns to profitable account an otherwise valueless material.

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*,
4th July 1870.

APPENDIX.

No. 1.

Report by Mr. G. W. Wigner on experiments at Tottenham with Sillars' process of deodorizing sewage.

Grove Lane, Camberwell,
June 15, 1868.

Sir,

I beg to submit to the Rivers Pollution Commissioners the following report of experiments with Messrs. Sillars' process of deodorizing sewage tried at the Tottenham Sewage Works under my direction.

I have added analyses of the sewage itself, the supernatant water and the residue.

The first tank used held 5,000 gallons; the sewage was pumped into this at the rate of about 500 gallons per minute. The chemical agents used having been mixed with water to the consistency of cream were allowed to flow in at the same time. The amount of dry material used was 76 lbs., forming about 14 gallons of solution.

The tank was 10 feet in depth, and after settling for 18 minutes a sample of water was drawn from a tap one foot from the bottom of the tank. An analysis of this sample is at the end of this report marked No. 1.

It was very slightly turbid when first drawn, but speedily settled. It was almost free from smell and tasted only of salt.

The 4,600 gallons of water having been run off, the deposit was stirred, and the tank again filled with sewage. This occupied about 25 minutes in settling to the same level; the time required being probably increased by the want of a suitable agitator.

The water was decidedly clearer and freer from smell than the first sample. Only two pounds of chemical agents were added.

The supernatant liquor, 4,600 gallons, having been again run off, the tank was filled as before, agitation being kept up while filling (nine minutes) by two large stirrers; the changes were sooner effected, and in 20 minutes the sample analysis of which is marked No. 3 was drawn from the lower tap.

On the tank being filled for the fourth time it was found necessary to defer the conclusion of the experiments until the following day, and the liquid remained 16 hours. There was but little difference in the analysis of the water drawn at night and that allowed to settle until the morning.

The tank was filled for the fifth time and allowed to settle in exactly the same way.

The analysis of the supernatant water after half an hour is marked No. 5.

At this point of the experiments the settled residue, owing to an accident, ran out of the tank, and only a small sample could be obtained for analysis.

A larger quantity of the residue being required, a second set of experiments precisely similar were undertaken, and (excepting a small decrease in the quantity of silica and salt present in the sewage) with identical results.

The next experiment was with a large tank holding 36,000 gallons of sewage.

The necessary ingredients were mixed as before in two large tubs, and the sewage being allowed to flow by gravitation at the rate of about 1,000 gallons per minute into the tank, the liquor running from the tubs at the same time.

Owing to the absence of any mechanical agitator this experiment was not quite so successful; nevertheless, the greater part of the impurities were precipitated, as will be seen from the analysis of the water, which was dipped out after the sewage in the tank had been at rest for 20 minutes.

I have given at the end an analysis of the water supplied to Tottenham drawn on a previous day from a tap in the neighbourhood.

The analysis of sewage is of an average sample taken at intervals during the day.

The expense of this process I estimate at about 17*s.* 6*d.* per 100,000 gallons.

I consider that if proper agitators could have been used the results would have been still more satisfactory.

The solid residue will weigh *about* 6 cwt. from the 25,000 gallons.

Its value I consider sufficient to pay all expenses and leave a considerable profit.

The samples of water after standing for 10 days are perfectly free from smell.

I am, &c.
(Signed) G. W. Wigner.

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

Report by Mr. G. W. Wigner on experiments at Tottenham with Sillars' process of deodorizing sewage—cont.

Analyses of Sewage and Supernatant Water.

—	Mixed Sewage.	No. 1 Water.	No. 3 Water.	No. 5 Water.	Large Tank, 36,000 Gals.	Tottenham Water.
Total solid matter per gal. -	203·89	88·34	76·29	81·24	91·16	48·70
Combustible matter - -	109·20	13·31	13·16	17·40	18·50	11·31
Oxygen absorbed from permanganate.	8·761	1·512	1·515	1·617	1·720	1·260
Ammonia - - - -	3·97	·590	·602	·561	·587	—
Chloride of sodium - -	57·10	60·13	55·41	57·00	57·19	9·21
Sulphates of alkalies - -	4·22	10·91	6·62	6·08	9·08	2·41
Lime, silica, alumina, and iron.	26·00	1·83	·40	·33	1·67	11·06
Phosphoric acid - -	7·23	—	—	—	—	—
Various salts - - -	—	2·05	·63	·30	4·54	13·64
Loss - - - -	·14	·11	·07	·13	·18	1·07

Analysis of Sewage Residue.

Water - - - - -	4·45
Organic matter - - - - } Yielding ammonia 2·37 - - - }	20·05
Sulphate of lime - - - -	1·67
Phosphoric acid - - - -	5·33
Oxide iron - - - -	·11
Various salts - - - -	16·61
Silica - - - - -	51·71
Loss - - - - -	·07
	100·00

(Signed) G. W. Wigner.

No. 2.

Letter from Secretary to the Commission to Mr. G. W. Wigner.

2, Victoria Street, Westminster, S.W.,
June 20, 1868.

Sir,

I acknowledge the receipt of your Report of the experiment recently carried out at Tottenham on the sewage of that town by Messrs. Sillars' process, together with an analysis of the sewage before and after treatment, and of the supernatant water. I have brought the communication under the notice of Her Majesty's Commissioners for inquiring into the Pollution of Rivers, and am directed to inform you that a copy of that report has been sent to the Mayor of Leicester, with a suggestion on the part of the Commissioners that the Corporation should cause an experiment to be made with the process on the sewage of Leicester, and intimating that the Commissioners would arrange to be present.

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

G. W. Wigner, Esq.,
Grove Lane, Camberwell, London.

No. 3.

Letter from Secretary to the Commission to the Mayor of Leicester.

2, Victoria Street, Westminster, S.W.,
June 20, 1868.

Sir,

I am directed by Her Majesty's Commissioners for inquiring into the Pollution of Rivers to forward to your Worship a copy of a report from Mr. G. W. Wigner on an experiment recently carried out at Tottenham by a process of deodorizing sewage invented by Messrs. Sillar.

The arrangements at the sewage works at Leicester for carrying out an experiment on a large scale are more complete than elsewhere, and it has occurred to the Commissioners that it would be desirable to give Messrs. Sillar an opportunity of completely testing their process, which, if successful, would enable the Corporation to beneficially utilise the buildings and plant at present in use in working the lime process.

If the Corporation agree to this experiment being made, the Rivers Pollution Commissioners will arrange to be present to investigate the process.

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

The Worshipful the Mayor,
Leicester.

No. 4.

Letter from the Town Clerk of Leicester to the Secretary to the Commission.

Borough of Leicester, June 23, 1868.

Sir,

I am directed by the Mayor to acknowledge the receipt of your letter of the 20th inst. with its inclosure, and to inform you that the same shall be laid before the Sewage Committee on Friday evening. I will then write to you.

I am, &c.
(Signed) Samuel Stone,
Town Clerk.

The Secretary Rivers Pollution Commission,
2, Victoria Street, Westminster, S.W.

No. 5.

Letter from Secretary to the Commission to the Under-Secretary of State, Home Department.

2, Victoria Street, Westminster, S.W.,
July 2, 1868.

Sir,

I am directed by the Rivers Pollution Commissioners to acquaint you, for the information of Mr. Secretary Hardy, that Messrs. Sillar have brought under their notice a process of deodorizing sewage, and in the opinion of the Commissioners it is desirable that an experiment, on a large scale, should be made upon the process.

The Commissioners believe that such experiment may be fairly tried at the Sewage Works at Leicester, and I am directed to request that the Secretary of State will be pleased to cause an application to be made to the Mayor and Corporation of Leicester to carry out the experiment, with an intimation that the Commissioners will attend to investigate the process.

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

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

No. 6.

Letter from the Under-Secretary of State, Home Department, to the Secretary to the Commission.

Leicester, 10 July 1868.

Whitehall, July 11, 1868.

Sir,

I am directed by Mr. Secretary Hardy to inform you, with reference to your letter of the 2nd instant, that, in accordance with the suggestion of the Rivers Pollution Commissioners, he has communicated with the Mayor of Leicester relating to the proposal to experiment upon Messrs. Sillars' process of deodorizing sewage, and I am to transmit to you herewith, to be laid before the Commissioners, a copy of a letter which has been received from the Town Clerk of Leicester expressing the readiness of the Highway and Sewage Committee of the Corporation to afford the Commissioners every facility for making the proposed experiments, and requesting early intimation of the course proposed to be adopted in carrying them out.

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

The Secretary,
Rivers Pollution Commission,
2, Victoria Street, Westminster, S.W.

No. 7.

(Enclosure in No. 6.)

Letter from the Town Clerk of Leicester to the Under-Secretary of State, Home Department, enclosure in No. 6.

Leicester, July 10, 1868.

Sir,

I beg to inform you that I have laid your letter of the 6th instant before the Highway and Sewage Committee of the Corporation, and that the Committee will be glad to afford every facility for making experiments upon Messrs. Sillars' process of deodorizing sewage.

The Committee presume that the means of making the experiment will be supplied by the Rivers Pollution Commissioners, and carried out under the direction and in the presence of some of the members.

The Corporation will be glad to have an early intimation of the course proposed to be adopted, and of the time when Messrs. Sillar and the members of the Commission will attend in Leicester.

The Exhibition of the Royal Agricultural Society will commence on Thursday the 16th and close on the 21st instant.

I have, &c.
(Signed) Saml. Stone,
Town Clerk.

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

No. 8.

Letter from Secretary to the Commission to the Town Clerk of Leicester.

2, Victoria Street, Westminster, S.W.,
July 13, 1868.

Sir,

I am directed by the Rivers Pollution Commissioners to acquaint you that the Secretary of State has caused a copy of your letter addressed to him to be transmitted to the Commissioners.

The Commissioners are pleased to learn that the Highway and Sewerage Committee of the Corporation of Leicester are willing to afford every facility for making the experiment upon Messrs. Sillars' process for deodorizing sewage.

I have forwarded a copy of your communication to the Messrs. Sillar, and have requested them to arrange with you the mode of conducting the experiment, and when all the details are settled to notify to the Commissioners the time at which the experiment is to take place, when some or all of the members of the Commission will be present for the purpose of examining the process.

I may state that in the opinion of the Commissioners it would be desirable that the experiment should extend over several days, so that a fair average may be obtained.

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

The Town Clerk,
&c. &c. &c.
Leicester.

No. 9.

Letter from Mr. G. W. Wigner to the Secretary to the Commission.

Grove Lane, Camberwell,
July 16, 1868.

Sir,

I enclose copy of letter I have just sent to Town Clerk of Leicester proposing July 27th to 31st as the date of our experiment in that town on Messrs. Sillars' sewage process.

The first day would probably be occupied in getting the process fairly to work, but of course we will arrange the date to suit the convenience of the Rivers Pollution Commission.

I am, &c.
(Signed) G. W. Wigner.

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

No. 10.

Letter from Mr. G. W. Wigner to the Town Clerk of Leicester.

Grove Lane, Camberwell,
July 16, 1868.

Sir,

With reference to the experiments on Messrs. Sillars' process for deodorizing sewage, I have now to make you the following offer:—

We will undertake to purify one half of the Leicester sewage (say two million gallons per day) for four or five days, while the other half is purified in your usual way with lime.

If the Corporation will put the works (machinery and staff) at our disposal in their present state, we will pay all expenses of the experiments including the necessary materials and analyses of sewage water, residue, &c.; taking in return the manure which is made, we paying the expenses of removal of the same.

The object of this being to enable us to put the manure on the market in sufficient quantity to get a commercial and practical test of its value, the Corporation would, of course, be at liberty to have any quantity they required for similar uses.

The analyses already forwarded to you of the Tottenham experiments afford a sufficient proof that the quality of the effluent water will be such as not to cause any nuisance to the neighbourhood.

I have written the Royal Rivers Pollution Commission proposing July 27th to 31st as the date of the experiments.

If these arrangements are satisfactory to the Corporation I shall be glad of an early reply.

I am, &c.
(Signed) G. W. Wigner.

S. Stone, Esq.,
&c. &c.
Town Clerk, Leicester.

No. 11.

Letter from Mr. G. W. Wigner to the Secretary to the Commission.

Grove Lane, Camberwell,
(No date.)

Sir,

I have received a letter this morning from the Town Clerk of Leicester, assenting to all my arrangements as mentioned in my letter to him of the 16th July: I therefore only want the assent of the Commissioners to the proposed date, or if that is not suitable, to know what date will be convenient to them to attend in Leicester.

I have, &c.
(Signed) G. W. Wigner.

The Secretary,
Rivers Pollution Commission,
2, Victoria Street, Westminster, S.W.

No. 12.

Letter from the Secretary to the Commission to the Town Clerk of Leicester.

Palatine Hotel, Manchester, July 22.

Sir,

I am directed by the Rivers Pollution Commissioners to ascertain from you if the arrangements at Leicester are sufficiently advanced for the experiment to be made on Tuesday next, on the process of Messrs. Sillar for deodorizing sewage, and the time convenient to the Mayor, the Sewage Committee, yourself, and the Borough Surveyor, to meet the Commissioners at the Sewage Works.

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

S. Stone, Esq.,
&c. &c.
Town Clerk, Leicester.

No. 13.

Letter from the Town Clerk of Leicester to the Secretary to the Commission.

Leicester, July 23, 1868.

Sir,

I have just seen the Borough Surveyor, who agrees with me that Thursday next, the 30th instant, would be the most suitable day for witnessing the experiments, and if that day will be convenient to the Commissioners, at 12 o'clock, I would inform the agent of Messrs. Sillar, and request the presence of the Mayor, and some of the members of the Sewage Committee.

Mr. Wigner, the chemical agent of the patentees, will commence on Monday, and we think that it may require two or three days to have the works in a satisfactory condition for the experiments.

I am, &c.
(Signed) Saml. Stone,
Town Clerk.

S. J. Smith, Esq., Secretary,
Rivers Pollution Commission,
Palatine Hotel, Manchester.

No. 14.

Letter from Mr. G. W. Wigner to the Secretary to the Commission.

Grove Lane, Camberwell, S.,
July 24, 1868.

Sir,

The Town Clerk of Leicester has just forwarded me your letter, and states that he has recommended Thursday in preference to Tuesday. I hope to have all in order and the experiments in full operation by 12 o'clock on Tuesday, but either that day or Thursday, or both, will suit me. I therefore only want your reply on Monday to say when I am to be prepared to receive you.

I am, &c.
(Signed) G. W. Wigner.

S. J. Smith, Esq., Secretary,
Rivers Pollution Commission,
Palatine Hotel, Manchester.

No. 15.

Letter from the Secretary to the Commission to the Town Clerk of Leicester.

George Hotel, Stockport.
July 27, 1868.

Sir,

I acknowledge the receipt of your letter of the 23rd instant, and in reply have to inform you that the Rivers Pollution Commissioners will be in Leicester on the day and at the time you propose, viz., at noon on Thursday next, for the purpose of witnessing the experiments, with Messrs. Sillars' process, on the sewage of Leicester.

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

S. Stone, Esq.,
&c. &c.,
Town Clerk, Leicester.

No. 16.

Letter from Mr. G. W. Wigner to the Rivers Pollution Commissioners.

Sewage Works, Leicester,
August 1, 1868.

Gentlemen,

On Friday 31st July when the samples of sewage purified by Mr. Sillar's process were taken by Mr. Thorpe, on behalf of the Royal Commission, 137,000 gallons of raw sewage were through the breakage of a dam allowed to flow into the reservoir containing the purified sewage, and about 15,000 gallons of limed sewage also entered. The consequence of course is that the samples drawn that day cannot be considered as final tests of the value of that process. Those taken before 4 o'clock were by my request kept separate, as I consider them quite valueless. The subsequent ones probably contained a small admixture of sewage, but this source of contamination was entirely removed by the next morning.

I am, &c.
(Signed) G. W. Wigner.

The Rivers Pollution Commissioners,
&c. &c. &c.
2, Victoria Street, Westminster, S.W.

No. 17.

Letter from the Secretary to the Commission to Mr. G. W. Wigner.

1, Park Prospect, Westminster, S.W.,
December 8, 1869.

Sir,

I am directed by the Rivers Pollution Commissioners to inform you that Dr. Frankland and myself will visit the Sewage Works at Leamington at 3.15 p.m. to-morrow, for the purpose of making arrangement for a further investigation by the Commissioners (on Saturday the 11th inst.) of the "A. B. C. Sewage process," carried on at those Works.

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

G. W. Wigner, Esq., Managing Director,
Native Guano Company Limited
(A. B. C. Sewage Process),
62, Cornhill, E.C.

No. 18.

Letter from Mr. G. W. Wigner to the Secretary to the Commission.

62, Cornhill, London, E.C.,
December 8, 1869.

Sir,

I beg to acknowledge receipt of your communication, and shall be happy to meet Dr. Frankland and yourself at Leamington at 3.15 p.m. to-morrow.

I am, &c.
(Signed) G. W. Wigner,
Managing Director.

The Secretary, Rivers Pollution Commission,
1, Park Prospect, Westminster, S.W.

No. 19.

Letter from Mr. G. W. Wigner and Mr. C. Rawson, Managers of the "A.B.C. Sewage Process" Company, to the Rivers Pollution Commission.

1, St. Swithin's Lane, London, E.C.,
December 17, 1869.

Gentlemen,

In consequence of the heavy rain which fell on the occasion of your official visit to our works at Leamington on the 11th instant, we take the liberty of asking you to favour us with another visit under more favourable auspices, so that you may be able to report on the results of our "A. B. C. process" in fine as well as in wet weather.

You are doubtless aware that the tanks were constructed for the lime process, and adapted only to receive and treat an average supply of about 700 gallons per minute, allowing the effluent water to subside for $1\frac{1}{4}$ hours before running into the *Leam*. We find, however, that we can with ease treat twice this quantity, or 1,500 gallons. On the 11th the quantity of sewage rose to 5,700 gallons per minute, and the effluent water would thus only be about seven minutes in passing through the works, and leaving enough time for a proper admixture and settlement to take place. The consequence also of the heavy flood was to surcharge the sewers, and to bring down the decomposed deposit on their sides and top.

We have no fear but that the results of last Saturday will be found satisfactory under these inauspicious circumstances, but we should wish the Commissioners to satisfy themselves as to what our process can effect in more favourable weather.

It is on this account that we take the liberty of asking for another visit, feeling assured that you are only anxious to ascertain the real advantages of every system before reporting upon it.

We have, &c.
(Signed) G. W. Wigner,
Managing Director.
C. Rawson,
General Manager.

The Rivers Pollution Commissioners,
&c. &c. &c.
1, Park Prospect, Westminster, S.W.

No. 20.

Letter from Secretary to the Commission to Mr. G. W. Wigner and Mr. C. Rawson, Managers of the "A. B. C. Sewage Process" Company.

1, Park Prospect, Westminster, S.W.,
January 6, 1870.

Gentlemen,

Referring to your letter of the 17th December 1869 and subsequent interview with me, I am directed by Her Majesty's Commissioners, for inquiring into the Pollution of Rivers, to inform you that they will visit the works at Leamington again in more favourable weather to further examine the "A. B. C. process," but are unable at present to fix the date.

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

Mr. G. W. Wigner and Mr. Christopher Rawson,
&c. &c. &c.
1, St. Swithin's Lane, E.C.

No. 21.

Letter from Mr. C. Rawson, General Manager of the "A. B. C. Sewage Process" Company to the Secretary to the Commission.

1, St. Swithin's Lane, London, E.C.,
May 20, 1870.

Sir,

I am sure the Commissioners must have been so satisfied of the very unsatisfactory way in which our "A. B. C. process" was being worked at Leamington during their late visit, that neither you nor they will be surprised to hear that the board of this company have felt bound to lay all the particulars before the Home Secretary and to take his opinion whether the results, which must be arrived at by Dr. Frankland, can be considered as a fair and true criterion of the merits of our "A. B. C. process." I feel sure that the Commissioners will bear us out as to the facts stated, and that the process was not treated in a way to do itself justice.

1, St. Swithin's Lane, E.C., May 19, 1870. Sewage Works, Leamington, May 17, 1870.

I am directed by the board to send for the perusal of the Commissioners copy of the correspondence with the Home Office, and to express their regret that they have felt obliged to ask the favour of another visit after the works have been put into working order again and the old accumulations have been cleared off.

I am sure that the object of the Royal Commissioners is to ascertain the real merits of our process and how far it can be utilised for the good of the country, and that they would really wish to see the process working at its best, so as to satisfy themselves whether it can be really useful to the country. I hope, therefore, their next visit, if they determine on paying another to the works, will be when assured by us that the process is really being worked to the best advantage that these old works will admit of.

We should be glad if the Commissioners would also visit our new works at Hastings, but here, too, we must ask that sufficient notice be given of their intention, that every precaution be taken by our staff at the works to show the process to its best advantage.

I am, &c.
(Signed) C. Rawson,
General Manager.

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

No. 22.

(*Enclosure in No. 21.*)

Letter from the General Manager of the Company to the Right Hon. the Secretary of State, Home Department—enclosure in No. 21.

The Native Guano Company, Limited (A. B. C. Sewage Process),
1, St. Swithin's Lane, London, E.C., May 19, 1870.

SIR,

REFERRING to your letter of the 11th inst., received here on the following day, intimating that the Royal Rivers Pollution Commissioners were about to visit the works at Leamington, it is with much reluctance that the directors of this company have instructed me to enter their protest against the results of that visit on the 11th and 12th instant [*10th and 11th*], being considered a fair criterion of the merits of our "A. B. C. process."

I will simply state the grounds on which the board feel this protest necessary, leaving it to your judgment to decide as to whether the process has had a fair trial.

1st. Our private analysis of the effluent water samples, drawn by Dr. Frankland on that occasion, showed a result so different from, and so inferior to, the usual run of the effluent water that our board immediately wrote for an explanation from Mr. Sillar at the works. It appears by the copy of his report, attached hereto, that the formula then being used at Leamington was not that of the improved "A. B. C. process," important ingredients having been omitted. Of this omission Dr. Frankland was cognizant.

2nd. Dr. Frankland having expressed a wish that the water wheel should not work during the night, according to the invariable custom, the consequence was, that wholly untreated sewage, with all its contaminations, flowed through our tanks and canals, necessarily leaving a deposit therein of sewage slime which alone would seriously affect the effluent water for days afterwards.

On these two points the board found their present protest.

The present Leamington works (being adapted from the old lime process, and not specially constructed for the "A. B. C.") could hardly be expected on every occasion to do full justice to the process, but we certainly have a right to expect that on such an important occasion due notice should have been given, so that the works should be seen at their best instead of being visited, as on this occasion, under a combination of peculiarly unfavourable circumstances, as shown by Mr. Sillar's report.

As this is a question of great importance to the public, the board feel it their duty to submit this matter to your consideration, as to whether, under these circumstances, a fair and just test of our process can have been made.

It may be objected that we have been for some time inviting the visits of the public, and many deputations have certainly visited the works; but these came to see the process in operation, and were not of the important nature of a Royal Commission, on whose verdict so much depends, not alone for our private interest, but for the public good.

I am further instructed not to conclude this letter without bringing to your notice that no step has been taken on the part of any department of the Government to ascertain the value of the manure now made by the "A. B. C. process," the Royal Commissioners having, on each occasion of their visit, stated their duty was solely to take cognizance of the purity of the effluent water. It will not escape your notice that the national value of the process must depend on the valuable properties of the sewage retained in the manure.

Under these circumstances it is respectfully submitted to you that it would only be an act of justice to withhold the report of the Rivers Commissioners on their recent visit, until a further examination into the process has taken place. In a fortnight from this time the old accumulations will have been cleared off from the works, and the tanks and canals cleaned out, and otherwise returned to a state to show the real merits of the process.

I have, &c.
(Signed) C. RAWSON,
General Manager.

The Right Hon. H. A. Bruce, M.P.,
Secretary of State,
Home Department, Whitehall.

No. 23.

(Enclosure in No. 21.)

Report by Mr. W. C. Sillar to the Directors of the "A. B. C. Sewage Process" Company, enclosure in No. 21 and referred to in No. 22.

Sewage Works, Leamington,
May 17, 1870.

DEAR SIRS,

REFERRING to my report to you of the visit of the Royal Rivers Commissioners, I now beg to call your attention prominently to the following circumstances, as they may have a considerable bearing upon the state of the effluent water, of which samples were taken by them.

Of course, you are aware that since you determined to construct permanent works at Hastings and elsewhere, our engineering and chemical staff have been transferred from Leamington, and though, on receiving notice that we should retain Leamington for a further period, you engaged another chemist, that gentleman did not take up his appointment till last Thursday, or the day after the visit of the Commissioners. Consequently we were at the time of the visit, and for a month previously, without the chemical supervision requisite to do justice to the process.

As I do not pretend to more than a very limited chemical knowledge, I merely state the facts to you and leave you to draw your own inferences, merely premising that, as the Commissioners expressed their wish for the process to be worked "just "as we had been working it," I made no alterations whatever on the previous day's work which, as you will see further on, was not according to formula.

Report by Mr. W. C. Sillar to the Directors of the "A. B. C. Sewage Process" Company, enclosure in No. 21 and referred to in No. 22—*cont.*

1st. Preparing for our new *twelve months* occupancy of the works, orders were given to scale the boilers and repair the shaft of the mixing pit. This necessitated blowing out the fires on Saturday at 5 p.m. They cooled during Sunday. On Monday the scaling was done, so that we recommenced working the process at 7 a.m. on Tuesday, or four hours before the visit of the Commissioners. During these two days and a half, our machinery not being in duplicate, we worked the process by the water wheel, which you know but imperfectly clarifies the day sewage.

2nd. Our stock of the chemicals forming the new patent had been exhausted, and our new supplies which arrived on the 5th May were not opened, as I was waiting the arrival of our chemist, consequently neither in quantity nor kind were the materials in use those of our improved "A. B. C." process, and this fact was mentioned to Dr. Frankland.

3rd. We were occupied in clearing away accumulations of deposited manure previous to the recommencement of our new year's work, and consequently our settling tanks were overburdened with deposit; their contents being 160,000 gallons, of which 110,000 gallons were occupied by deposit, so that we had only 50,000 gallons available as settling room. This would seriously affect the character of our outfall. If we had notice of this visit we could have prepared for this, but the sudden manner in which it was made, conveyed to me the impression that the object was as much to see what we *were* doing as what we could do. Consequently no change in the programme was made.

4th. The barometer had been falling steadily for three days, and this you know generally causes a disengagement of any gas that may be contained in the deposit.

5th. During the night the water-wheel could not be worked, as Dr. Frankland particularly wished that no water other than sewage water should enter the culvert. Stopping the wheel gained this object, but it necessitated a flow of night sewage totally unpurified through our settling tank. You can judge whether this is detrimental to the process. I presume that if it had been so Dr. Frankland would not have committed the error of allowing me to sanction it, but to the best of my knowledge such a thing has never before been permitted since we took the works.

6th. Heavy rain set in on the second day, and so increased the flow through our tanks, that I should not be surprised if it washed out of them a considerable quantity of previously deposited and untreated sediment from the previous night work, and consequently deteriorated our outflow.

Lastly. Our filter being completely destroyed by the flood the last time the river rose, the samples drawn were from the further overflow, and totally unfiltered.

I therefore consider that on all these points a chemical opinion should be at once taken as to the various circumstances I have mentioned, in order to see if in any points the process was improperly worked.

I am, &c.
(Signed) W. C. SILLAR.

To the Directors of the Native
Guano Company, Limited.

No. 24.

Letter from the Secretary to the Commission to Mr. C. Rawson, Manager of the "A. B. C. Sewage Process" Company.

1, Park Prospect, Westminster, S.W.,
May 23, 1870.

SIR,

I ACKNOWLEDGE the receipt of your letter of the 20th instant, transmitting copy of a communication dated 1, St. Swithin's Lane, London, May 19th, 1870, and addressed by you to the Right Honourable the Secretary of State, Home Department, together with a copy of a Report, dated Sewage Works, Leamington, May 17th, 1870, addressed to the Directors of the Native Guano Company, Limited, by Mr. W. C. Sillar, referred to in the communication of the 19th May, and I have to acquaint you, for the information of the Directors of the Company you represent, that I brought the correspondence under the notice of the Commissioners at the meeting to-day.

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

C. Rawson, Esq., Manager,
Native Guano Company, Limited,
1, St. Swithin's Lane, E.C.

No. 25.

Letter from the Secretary to the Commission to the Clerk to the Metropolitan Board of Works.

Pressing.

Rivers Commission,
1, Park Prospect, Westminster, S.W.,
May 23, 1870.

SIR,

I AM directed by Her Majesty's Commissioners for inquiring into the pollution of rivers to forward to you for the information of Sir John Thwaites and the members of the Metropolitan Board of Works a copy of their report on the basins of the Mersey and Ribble, and especially to draw attention to pp. 53 to 58, the description and examination of the "A. B. C." process for the treatment of sewage by chemical agents, which process is, at the present time, carried on at Leamington by the Native Guano Company, Limited.

The Commissioners have investigated the process three times: first, at Leicester on July 30th, 31st, and August 1st, 1868; second, at Leamington on December 11th, 1869; and, third, at Leamington on the 10th and 11th of the present month.

The Commissioners were informed that Dr. W. A. Miller, F.R.S., Dr. W. Odling, F.R.S., and Professor Abel, F.R.S., under instruction from and on behalf of the Metropolitan Board of Works, had recently inspected the Works at Leamington, examined the process and the manure obtained by the treatment, and have reported thereon, and I am directed to request that you will be pleased to move your Board to

Letter from the Secretary to the Commission to the Clerk to the Metropolitan Board of Works—cont.

cause a copy of that Report to be forwarded to Her Majesty's Commissioners with as little delay as possible.

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

J. Pollard, Esq.,
&c. &c. &c.
Clerk to the Metropolitan Board of Works.

No. 26.

Letter from the Clerk to the Metropolitan Board of Works to the Secretary to the Commission.

Metropolitan Board of Works,
Spring Gardens, S.W.,
June 1, 1870.

Sir,

I have to request that you will kindly convey the thanks of the Board to the Commissioners for inquiring into the Pollution of Rivers for sending to the Board a copy of their report on the basins of the Mersey and Ribble, which contains a description and examination of the "A. B. C." process for the treatment of sewage by chemical agents.

With reference to the request of the Commissioners to be furnished with a copy of the report of Dr. Miller, Dr. Odling, and Professor Abel, on the process of the Native Guano Company at Leamington, I have to state that the Board have not yet received the report in question, but that as soon as they do so, they will have much pleasure in furnishing the Commissioners with a copy thereof.

I am, &c.
(Signed) John Pollard,
Clerk.

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

No. 27.

Letter from Mr. C. Rawson, General Manager of the "A. B. C. Sewage Process" Company to the Secretary to the Commission.

The Native Guano Company, Limited,
("A. B. C." Sewage Process),
1, St. Swithin's Lane, London, E.C.,
June 1, 1870.

Sir,

I have the pleasure to send herewith the plans of our Hastings Sewage Works which your Commissioners asked for during their late visit.

I am sorry to say they are still so behind with their work at Leamington that they will not have clean tanks before the 15th instant, and the works will not be in a fit state to be visited before that date.

I have, &c.
(Signed) C. Rawson,
General Manager.

S. J. Smith, Esq., Secretary to the
Royal Rivers Pollution Commissioners.

No. 28.

Gaugings of the Sewage of Leamington furnished to the Commission by Mr. Robert Davidson, C.E., Surveyor to the Local Board of Health.

LEAMINGTON.

Gaugings of Sewage flowing down Main Sewer on May 10th and 11th, 1870, taken at the first Manhole above Sewage Works.

1870.	Hour.	Height of Water in Gauge.	Cubic Feet per Hour.
May 10 - - -	12 noon - -	4 inches	4531·80
" - - -	1 p.m. - -	4 "	4531·80
" - - -	2 " - -	$3\frac{3}{4}$ "	4133·40
" - - -	3 " - -	$3\frac{1}{2}$ "	3735·60
" - - -	4 " - -	5 "	6332·40
" - - -	5 " - -	$4\frac{1}{2}$ "	5431·80
" - - -	6 " - -	4 "	4531·80
" - - -	7 " - -	$4\frac{1}{2}$ "	5431·80
"			
May 11 - - -	7 a.m. - -	3 "	2938·80
" - - -	8 " - -	3 "	2938·80
" - - -	9 " - -	$3\frac{1}{2}$ "	3735·60
" - - -	10 " - -	4 "	4531·80
" - - -	11 " - -	4 "	4531·80
" - - -	12 noon - -	5 "	6332·40
"			
- - -	1 p.m. - -	5 "	6332·40
" - - -	2 " - -	5 "	6332·40
" - - -	3 " - -	$5\frac{1}{4}$ "	6829·80
" - - -	4 " - -	7 "	10512·60
" - - -	5 " - -	7 "	10512·60
" - - -	6 " - -	9 "	15295·20
"			

(Signed) Robt. Davidson,
Surveyor to the Local Board of Health,
Leamington.

25th May 1870.

No. 29.

Letter from Dr Edward Frankland, F.R.S. to Dr. J. H. Gilbert, F.R.S.

Rivers Commission,
1, Park Prospect, Great Queen Street,
Westminster, S.W., June 9, 1870.

Sir,

Will you kindly give the Rivers Pollution Commissioners your opinion of the value of two samples of manure which yielded on analysis the following results:—

No. 1. Manure manufactured by A. B. C. process at Leicester.

Mineral matters - - - -	54·772
Organic and other volatile matters - - -	45·228
Carbon - - - - -	24·994
Phosphoric acid - - - - -	·496
Total nitrogen - - - - -	1·943
Ammonia - - - - -	·185
Total nitrogen calculated as ammonia - -	2·36

No. 2 Manure manufactured by the A. B. C. process at Leamington.

Organic matter containg 18·15 parts of carbon and 1·55 parts of nitrogen - - - -	34·27
Ammonia - - - - -	·16
Phosphoric acid - - - - -	1·98
Clay and other useless mineral matters - -	57·13
Water - - - - -	7·46
	100·00

Total nitrogen calculated as ammonia = 2·05 per cent.

I am, &c.
(Signed) E. Frankland.

J. H. Gilbert, Esq., F.R.S.

No. 30.

Letter from Dr. J. H. Gilbert, F.R.S., to the Rivers Pollution Commissioners.

Harpenden, St. Alban's,
June 14, 1870.

Gentlemen,

In reply to yours of June 9th, requesting my opinion of the value of two samples of manure made by the "A. B. C." process, No. 1, made at Leicester in 1868, No. 2, made at Leamington, May 1870, the statement of the analysis of which you annex, I beg to say that I have consulted Mr. Lawes on the subject, and our opinion is as follows:—

It appears that neither sample contains 2 per cent. of total nitrogen, the Leicester (1868) sample containing 1·94, and the Leamington (1870) sample only 1·69 per cent.; on the other hand, the Leicester (1868) sample contains scarcely 0·5 per cent. of phosphoric acid, whilst the Leamington (1870) sample contains nearly 2 per cent.

In any estimate of value these differences would so nearly balance one another that practically the same valuation may be considered as applicable to both. Further, experience has shown that when such small amounts of valuable are mixed with such a large proportion of valueless constituents in a manure, that which may be called the theoretical value according to composition is never realizable in practice on the large scale. Assuming such a manure to be produced in large quantities, our opinion is that it would certainly be worth more per ton than stable dung, provided the nitrogenous substance were in an easily decomposable condition, and its nitrogen readily available, and provided the phosphoric acid were also in a readily soluble condition; but if the nitrogen and phosphoric acid were not in such conditions, it may be a question whether the "A. B. C." deposited manure or stable dung would be the most valuable. The result would depend in a measure on the quantity of the respective manures in the market, the cost of carriage, and other local circumstances. Stable dung would, however, probably have the preference for market gardening.

In conclusion, it should be remarked that the amount of mixture in the sample "A." is not given, and that it is stated to be only about $7\frac{1}{2}$ per cent. in the sample "B." There can, however, be no doubt that it would average much more than this, and the valuable constituents would accordingly be still further diluted.

I am, &c.
(Signed) J. H. Gilbert.

To the Rivers Pollution Commission,
1, Park Prospect, Westminster, S.W.

No. 31.

Letter from the Clerk to the Metropolitan Board of Works to the Secretary to the Commission.

Metropolitan Board of Works,
Spring Gardens, S.W., 15th June 1870.

Sir,

Referring to my letter to you of the 1st instant, and to our interview of this day relative to the request of the Commissioners for inquiring into the Pollution of Rivers to be furnished with a copy of the report of Drs. Miller and Odling on the process of the Native Guano Company at Leamington, I beg to inform you that I have since seen the Chairman of the Board on the subject, and I find that no report has been presented by those gentlemen, and that as the Board have completed their evidence before the Committee on the Thames Navigation Bill and that Committee have

Letter from the Clerk to the Metropolitan Board of Works to the Secretary to the Commission—cont.

reported to the House, no such reports will now be made. The gentlemen referred to had simply a memorandum before the Committee, but this was very crude, and moreover of a confidential nature, I fear that I shall be unable to let you have a copy of it.

With regard to Dr. Keates I will write and request him to call upon you on the subject of the process before he proceeds to Leamington, and I shall be glad if you will give him any information in your power.

I shall also be glad to receive a copy of the Report of your Commission, when published, for which of course I shall be happy to pay.

I am, &c.

S. J. Smith, Esq., Secretary, (Signed) JOHN POLLARD,
Rivers Commission. Clerk to the Board.
1, Park Prospect, Westminster, S.W.

No. 32.

Letter from the Rev. Henry Pixell, M.A., to the Secretary to the Commission.

Milverton, Leamington,
16th June 1870.

SIR,

I and many of my neighbours solicit the protection of your Commission from a serious grievance, namely, the offensive smell from the Leamington Sewage Works. We have suffered much for the last twelve months but we have forborne to complain publicly till two months ago; many have been our complaints to the chairman of the Leamington Local Board of Health, still the nuisance is now if possible worse than ever, and I have not the least hesitation in asserting that the atmosphere in this neighbourhood is at times pestilential.

I am, &c.

S. J. Smith, Esq., Secretary, (Signed) HENRY PIXELL.
Rivers Pollution Commission,
1, Park Prospect, Westminster, S.W.

No. 33.

Letter from the Rev. Henry Pixell and other residents at Milverton to the Rivers Pollution Commissioners.

Milverton, Leamington,
20th June 1870.

GENTLEMEN,

IT is with reluctance we trouble you, but we feel compelled to use every endeavour in our power to obtain relief from the extreme annoyance and suffering we have endured for many months from the Leamington Sewage Works. It is difficult to describe in fitting terms the intolerable smell we have been subject to day and night for a long period. It is distressing to think that the air in a populous neighbourhood should be so contaminated, bringing, as we are apprehensive, disease and death to our very door.

Earnestly soliciting your attention to the matter.

We remain, &c.
(Signed) HENRY PIXELL.
E. LYNCH BLOSSE, Lt.-Colonel.
HUBERT LLOYD, Milverton Lawn.
H. BEAVER ROBERTS, D.L., Thorn Bank.
THOMAS CROW, Milverton Lodge, South.
ROBERT BAKER, Milverton Hill.
JOHN N. O. HALLORAN, Courtenay Villa, Milverton Hill.
WILLIAM MOORE, Knightcott House.
VINCENT R. CORBET, Riversdale.

To the Royal Rivers Pollution Commissioners,
1, Park Prospect, Westminster, S.W.

No. 34.

MINUTES OF EVIDENCE.

No. 1, Park Prospect, Westminster, S.W., Friday, 24th June 1870.

PRESENT:

MAJOR-GENERAL SIR WILLIAM DENISON, K.C.B., F.R.S., IN THE CHAIR.
DR. EDWARD FRANKLAND, F.R.S. | MR. JOHN CHALMERS MORTON.
MR. S. J. SMITH, *Secretary*.

DR. WILLIAM ODLING examined.

Dr. W. Odling.
14 June 1870.

1. (*Dr. Frankland.*) You are a Fellow of the College of Physicians, a Fellow of the Royal Society, and Professor of Chemistry at the Royal Institution?—I am.

2. I believe that you are acquainted with the A B C process of treating sewage?—Yes.

3. Where and when have you seen that process in operation?—I saw it in operation at Leamington on April the 2nd of this year.

4. Did you examine the effect which it had upon the quality of the sewage there?—I may say that I was conjoined in the inquiry with Dr. Miller, on behalf of the Metropolitan Board of Works, and we made an attempt to ascertain its effect upon the sewage, and we were very much struck by noticing the different quantities of common salt contained in the original sewage and in the effluent water. The average amount of chlorine in the original sewage was 11·3 grains in the gallon. The average amount of chlorine in the effluent water was 6·3 grains in the gallon.

5. Did you ascertain the cause of this reduction of the chlorine?—No; but we know that it is impossible by any chemical means to extract chlorine from the water, and we were satisfied that something was being concealed from us.

6. (*Mr. Morton.*) That is to say, that it cannot be extracted by any chemical means in practical use?—There are no chemical means, which are practicable on a large scale, for removing chloride of sodium from the sewage water, and certainly not the chemicals which are alleged to be employed in the A B C process.

7. (*Dr. Frankland.*) Have you since ascertained the reason why the chlorine was diminished?—Only from information that the water of the river Leam is let into the effluent water, which would amply account for it. I know of no other means by which it can be accounted for.

8. Have you gone into any calculation as to the effect which the admission of such a volume of river water would produce upon the quality of the effluent water, independently of any operation which might have been performed upon the sewage by the A B C process?—Even if we took the river water as free from chlorine it would be equivalent to diluting the original sewage with that bulk of river water; but supposing the river water to have contained about two grains of chlorine in a gallon, a much larger bulk of it must have mixed with the effluent sewage.

9. You of course took samples both of the raw sewage arriving at the works and of the sewage after treatment?—Yes, we took samples of what we thought was the sewage after treatment.

10. Was that sewage which you thought had been treated by merely a chemical process or by a chemical process plus the subsequent filtration?—It was plus the subsequent filtration.

11. Did you examine the filters, and are you at all acquainted with the material through which the sewage was filtered?—No.

12. Are you sure that the effluent sewage was at the time passing through the filters?—I am not sure of it. I only noticed that from the tail of the filter issued clear water.

13. Have you analysed samples of the water?—Yes.

14. You can furnish us with the results?—I hand in the analysis. (*This will be found at the end of the evidence of the witness.*)

15. Can you state to us now the general nature of those results, as showing the effect of the process upon the sewage?—The results are in the lower portion of the table.

16. Did you find that the effluent water contained less total residue than the original sewage?—Yes.

17. Have you made any laboratory experiment on the application of this process to sewage?—Yes, but chiefly with a view to the manure.

18. You do not know whether in operating upon a quantity of sewage the total solid residue is increased or diminished by the A B C process?—I am not sure that I have a note of that, but it must almost necessarily be increased.

19. Soluble matter is added?—Yes.

20. And the increase of course depends upon how much is precipitated?—Yes.

21. Was the effluent water of a quality which was fit to be admitted into the river?—I do not think that the river at that time, in April, was suffering much from the admission of the effluent water into it; but I very much doubt whether it would not suffer in hot weather.

22. Was there much water coming over the weir?—There was a good deal of water coming over the weir.

23. How was the effluent liquid as regards suspended matter?—It was clear; it was practically free from suspended matter.

24. Have you formed any opinion from these analytical results taken in connexion with the probable dilution of the sewage by the river water, as to what proportion of amelioration was effected by the process?—I should be inclined to think that the removal o matter in solution was exceedingly small; but owing to the admixture of the effluent sewage with an indefinite amount of river water it is difficult to speak positively.

25. Did the water which flowed into the river Leam emit any perceptible smell?—No.

26. Did you also examine the manure which was being manufactured?—Dr. Miller and I took a great number of different samples of manures, but we found that many of these samples contained large crystals of sulphate of ammonia. These are some of the crystals of sulphate of ammonia, which were found in one of the heaps in the drying shed (*producing the same*).

27. The manure from which these crystals were removed was in the drying shed?—Yes.

28. Did you find any of these crystals in any other portions of the manure about the works?—Yes, in several other portions.

29. And you have proved them to be sulphate of ammonia?—Yes; I may say that it was then arranged that we should simply take a sample of the manure as it was going out in the cart, and that we should examine that alone.

Dr. W. Odling.

24 June 1870.

30. Have you examined it ?—We have.

31. Can you furnish us with an analysis of it ?—I hand in the analysis. (*This will be found at the end of the evidence of the witness.*)

32. What is your opinion as to the value per ton of that sample which you analysed ?—I might put it in this way, that it contains about $\frac{1}{24}$th part of the nitrogen which is contained in guano, and less than $\frac{1}{24}$th part of the amount of phosphate, so that, estimating it merely as regards those two constituents, it would have been $\frac{1}{24}$th part of the value of guano, making no deduction for the amount of dilution.

33. Can you account for the presence of these crystals of sulphate of ammonia in the manure from any of the processes to which the sewage is subjected in the works ?—No. I may say that when these crystals were first discovered, the manager, Mr. Wigner, told us that he knew nothing about how they had come there, but that he supposed that they must have been swept up by accident. That was the original information which was offered. When we pointed out the large extent of the admixture and the number of different heaps, we were then told that it was sulphate of magnesia which had been added in order to assist the desiccation of the manure, and the fixation of the ammonia. After we had left the works we were told that the manager (Mr. G. W. Wigner) had intended to order sulphate of magnesia, but that he had accidentally written "sulphate of ammonia" instead of sulphate of magnesia.

34. Upon that occasion was it one of your chief objects to ascertain the value of the manure made by this process ?—Yes, that was our chief object.

35. Would the addition of sulphate of ammonia increase the value of the manure ?—It would increase its value to the extent to which ammonia salt was added.

36. During your experiments, did you have the chemicals weighed which were added to the sewage ?—No.

37. Did you gauge the sewage or effluent water ?—No.

38. Did you witness any of the experiments of drying manure in the hydro-extractors ?—Yes.

39. What was your opinion of that process ?—It seemed to me to be perfectly inefficient. We had very considerable difficulty in getting a sample from the extractor.

40. Did you find that what was left in the extractor was tolerably solid and consistent, or was any liquid left in it ?—It was tolerably consistent.

41. What length of time did it require to dry one extractor full of manure ?—I cannot say.

42. Did you notice whether there was any unpleasant smell or otherwise about the works ?—There was the general smell of sewage, but it was a cold day, and there was nothing very marked excepting at one particular time, that was when they were adding sulphuric acid to the portion of dried sewage in order to fix the ammonia; then there was sulphuretted hydrogen given off very perceptibly.

43. Would that be likely to cause a nuisance ?—That would depend upon the scale on which it was done. Upon the scale on which we saw it I should say no; the greater nuisance arose from the accumulation of sludge which had not been dried. It was giving off gas from its entire surface, and no doubt in hot weather it would be very offensive.

44. Did you notice the temperature at the time of your visit ?—Yes. I am not sure about the temperature of the air. I think that it was 36 degrees, but the temperature of these manure heaps was 45 degrees Fahrenheit.

45. It was a cold day ?—Yes.

46. Did you go down the river below the works ?—Yes; we went down the river.

47. What did you notice in the river ?—There was nothing very objectionable in the river until we got some considerable distance down to below Dr. Jephson's foot bridge; between that bridge and the chain which crosses the river above its junction with the Avon the condition of the stream was objectionable. There were patches of filth lying upon its surface.

48. Do you know whether in the neighbourhood of that bridge which you speak of any sewer enters the river ?—We were told that there was a sewer, but whether that is so or not I do not know.

49. Could you yourselves see that sewage was coming in there ?—No.

50. Did you make any examination of the plants growing in the water or on the margin of the river as to whether there was any sewer fungus upon them ?—There was sewer fungus upon them, especially by and below this bridge.

51. Looking at the whole result of the experiments, do you consider that this is a process to be recommended for the purification of town sewage ?—Certainly not. No doubt this method, like all other methods of precipitation, does keep out a considerable proportion of filth from the river, but there was a great deal of putrescible matter in the effluent liquid, and in comparing this mode of precipitation with others it did not seem to me that its alleged superiority had any foundation. As regards its superior defœcation of sewage, and the high value of the product yielded, I came to the conclusion that it was simply a juggle.

52. I think that you have examined into the treatment of the Northampton sewage ?—Yes; I am examining into it now.

53. Do you consider that the process which they use there is at all equal to the A B C process ?—Judging from the manner in which everything is conducted, it being perfectly above board and fairly done, it seems to me that the effect upon the sewage there is at least equal to that which is effected by the A B C process.

54. Does the river there retain its purity ?—The river there was looking pretty well. There had been apparently a very considerable growth of aquatic vegetation all the way down; but at the mill, two miles or so lower down, during the working of the wheel the stench was very great, notwithstanding the comparatively good appearance which the river presented. I have no doubt that in the hot weather, when this aquatic vegetation is less active, sewer fungus will appear again there.

55. Do you know of any chemical process of treating sewage which produces an effect at all equal to that of irrigation ?—I do not.

56. Taking into consideration all the processes which are known to us at the present time for dealing with sewage, which process would you prefer as a means of purifying the liquid before its admission into the river ?—Irrigation, undoubtedly.

57. (*Mr. Morton.*) In comparing the A B C manure with the guano, what standards of value did you use for the fertilising ingredients ?—I have taken no standards. The nitrogen in the A B C process is one twenty-fourth of the quantity in the guano, and the phosphate is about the same. Therefore it seems that judging from these two constituents, the value would be about one twenty-fourth.

58. As regards the samples of manure that were taken for analysis, are you certain that they too were not fortified by the addition of any material ?—The manure was so extremely poor that I should think that that was not the case.

The witness withdrew.

Adjourned.

Analyses referred to in Questions 14 and 31.

LEAMINGTON SEWAGE.

No. I.—Mean of Six Samples of Sewage, one taken hourly from 8.30 a.m. to 1.30 p.m. II.—Mean of Five Samples of Effluent Water from tail of filter, one taken hourly from 10.30 a.m. to 2.30 p.m.

—	Parts in 100·000.	
	No. I. Sewage.	No. II. Effluent Water.
Total residue	233·1	149·4
Ash (saline matter)	166·6	123·7
Chlorine	16·1	9·0
Sulphuric acid (SO_4)	17·7	32·0
Nitrogen of ammonia and organic matter	12·0	3·0

LEAMINGTON MANURE.

No. I.—Sample of Manure from Bag in Cart as going out for Sale; No. II.—Sample of Deposit collected from precipitated Sewage taken out of subsiding Tank on the Works; No. III.—Sample of Deposit yielded by an Experiment made in London by adding A B C Mixture to above Leamington Sewage.

—	No. I.	No. II.	No. III.
Moisture	27·54	24·80	24·80
Organic matter	10·90	18·98	33·00
Matter soluble in acid	15·48	11·48	19·32
Clay and sand	46·08	44·74	22·88
Nitrogen	0·68	0·86	1·72
Phosphoric acid (PO_4)	0·59	—	—

April 2nd, 1870.

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THIRD REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1868 TO INQUIRE INTO

THE BEST MEANS OF PREVENTING THE POLLUTION OF RIVERS.

POLLUTION ARISING FROM THE WOOLLEN MANUFACTURE, AND PROCESSES CONNECTED THEREWITH.

VOL. I.

REPORT, PLANS, AND FAC-SIMILES.

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

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

1871.

[C. 347.] *Price 2s.*

CONTENTS.

COMMISSION (ENGLAND).

VICTORIA R.

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

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

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

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

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

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

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

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

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

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

By Her Majesty's Command.

(Signed) GATHORNE HARDY.

INSTRUCTIONS to the COMMISSIONERS.

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

SIR,

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

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

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

Whitehall, 29th April 1868.

SIR,

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 the COMMISSIONERS.

Whitehall, 30th May 1865.

GENTLEMEN,

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

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

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

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

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

INSTRUCTIONS to the COMMISSIONERS.

Whitehall, 7th July 1865.

GENTLEMEN,

I AM directed by Secretary Sir George Grey to transmit to you an extract of a
5072 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 authorised to visit the River Tweed and its tributaries, and the River Clyde and its affluents, in that part of Our United Kingdom called Scotland, and also to visit such other rivers or parts of rivers in that part of Our said United Kingdom as We may from time to time be pleased to direct, by signifying Our Pleasure, under the hand of one of Our Principal Secretaries of State.

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

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

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

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

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

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

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

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

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

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

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

(Signed) John H. Dunn,
Substitute Keeper of the Seal.
80*l*. Scots.

Additional Instructions to the Commissioners.

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

Sir,

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

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

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

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

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

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

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

Sir,

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

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

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

THIRD REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY,

INTRODUCTION.

WE, Your Majesty's Commissioners appointed to inquire into the best means of preventing the pollution of rivers, have, in our Report upon the basins of the *Mersey* and *Ribble*, described the foul condition of those rivers and their affluents, and the causes which have acted so injuriously upon their waters. We have also given in that Report the results of our examination of the various remedial processes, whether of prevention or of purification, which had been brought under our notice; and in our second Report (1870)—on the " A, B, C " method of treating sewage—we have given the results of a further inquiry into a suggested mode of purifying sewage which has been tried upon a large scale at Leicester, Leamington, and Hastings.

The instructions originally issued to us limited our inquiries to the basins of certain rivers, which were considered to exhibit with sufficient accuracy and completeness the character and the amount of the injury inflicted by particular classes of manufactures upon the streams into which their refuse was passed. In the course of our investigation, however, into the state of the running waters in the basins of the *Mersey* and *Ribble*, the conviction was forced upon us that the information derived from an examination of the refuse of various manufacturing processes in any single district would not be sufficient to enable us to recommend rules applicable to analogous processes throughout the country at large.

We were, indeed, justified in reporting confidently regarding ordinary sewage, both as to its influence upon the running waters into which it is discharged, and as to the methods by which its polluting constituents may be transformed into innocuous compounds; for the character of town sewage and its effect upon rivers is substantially everywhere the same. There are also certain classes of manufactures, fully represented in the *Mersey* and *Ribble* basins, the various drainage waters of which have been so fully investigated, that we have been able to speak, in our report on those basins, of the river pollution which they create and of the remedies for it which ought everywhere to be enforced, with as much confidence as was possible in the case of town sewage. But there are other technical operations which have been examined and reported on by the first Rivers Pollution Commission as well as by ourselves, in which, though the staple dealt with is the same, the mode of treatment differs in different localities, so that the drainage from them is not everywhere the same; and it appeared probable, therefore, that one remedy or set of remedies would not be uniformly applicable. Hence, we deemed it advisable to suggest such an alteration of our instructions as would authorise us to prosecute inquiries into the effect of particular manufactures wherever we might think it important to do so. This suggestion was approved, and in a supplement to the instructions issued for our guidance, we are directed " to inquire into the specific pollution " caused by any particular manufacture, wherever located, in England or Scotland."

The Report therefore on the Woollen Manufacture which we now humbly submit to Your Majesty will be found to deal with the effects of this manufacture on rivers and streams generally—including not only the clothing districts of the West Riding of Yorkshire, but also those of Gloucestershire and Somersetshire, the flannel trade of Wales, the blanket manufactories of Witney and of Dewsbury, the worsted and rug factories of Kendal, and the carpet works of Kidderminster, Halifax, Rochdale, Durham, and Wilton.

In August 1867 our predecessors submitted to Your Majesty a report upon the rivers *Aire* and *Calder*, the principal seats of the woollen and worsted trades in the West Riding of Yorkshire. In it they described the topography, geology, and meteorology of Yorkshire, and gave a special account of the *Aire* and *Calder* basins, including a description of the obstructions and pollutions they had witnessed in the course of these rivers. An account of the various processes in which water is employed in these valleys was also given, along with an estimate of the nature and amount of the filth discharged in the course of the operations of the woollen and worsted manufacture.

Attention was also directed to methods by which the different matters contained in the waste water, rendering it unfit for use, might be precipitated or got rid of; some

INTRODUCTION.

of them being described as effective, others as only partially available, though admitting of improvement.

The report also contained a statement of the extent to which these rivers were polluted by refuse from tanyards and by the ochrey water from coal workings; and the opinion was expressed that both these causes of river pollution might be got rid of without injury to the industry of the district.

That we might properly appreciate the information gathered on this subject by our predecessors, and collect such further evidence as seemed necessary, we have examined the whole course of the *Aire* and *Calder* for ourselves, holding public meetings at all the principal towns in these valleys, inspecting the sewerage arrangements of both towns and factories, and taking samples for examination, not only of the various drainage waters which these rivers receive, but of the river water itself at different points in its course. We have held meetings and made inspections in this way at Skipton, Keighley, Bingley, Cullingworth, Saltaire, Bradford, Leeds, and Castleford upon the *Aire* and its tributaries; and at Todmorden, Halifax, Huddersfield, Dewsbury, Batley, and Wakefield on the *Calder* and its affluents.

We have also held public meetings, made inspections, and taken samples in all the other localities of the woollen manufacture in both England and Scotland; as at Trowbridge, Frome, and Bath, in Wiltshire and Somersetshire; at Stroud and Nailsworth in Gloucestershire; at Newtown, Montgomeryshire, a principal seat of the flannel manufacture; at Witney near Oxford, a seat of the blanket manufacture; at Kidderminster, Durham, and Wilton near Salisbury, seats of the carpet manufacture; at Kendal in Westmoreland, where worsted and rugs are made; also at Galashiels, Peebles, Jedburgh, Selkirk, Hawick, and Kilmarnock, Scottish towns chiefly occupied with the manufacture of various woollen fabrics, to which fuller reference will be made in our fourth Report,—on the rivers of Scotland. In all these places every assistance needed for the prosecution of our inquiry has been cordially rendered by nearly all the Local Authorities, and also by a large number of individual manufacturers and traders who have returned replies to our series of questions. To the information obtained orally, by inspection, and by the examination of samples, must be added the large mass of documentary evidence thus received, which will be found in Volume II. of this Report.

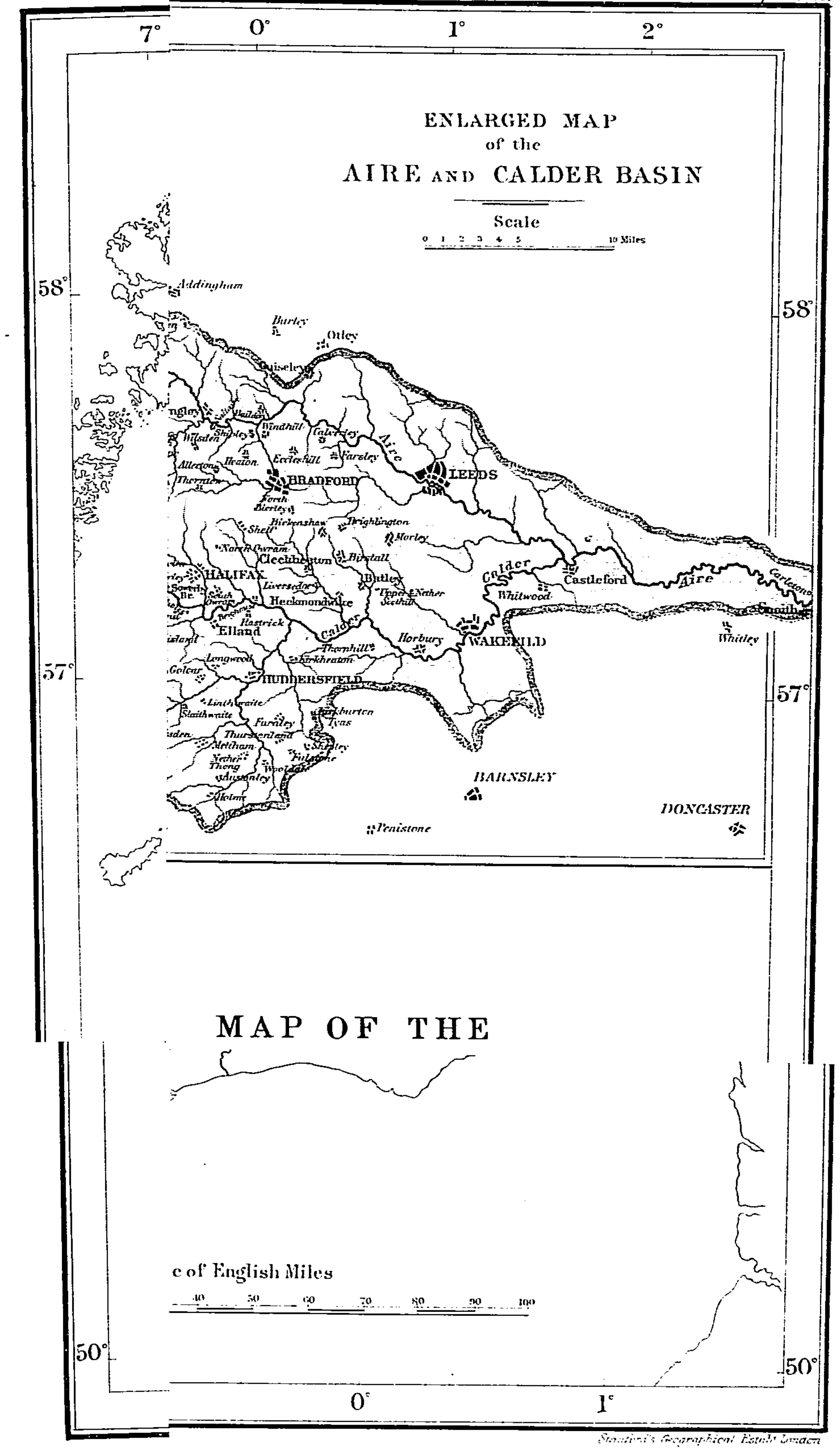
We have also kept in view the inquiry suggested by Mr. Charles Neate (see Letter to the Secretary of State, Home Department, p. vi.) into the water supply for domestic and manufacturing purposes in the districts and towns which we have visited. We have everywhere examined into the amount and quality of unpolluted water supplied to towns or likely to be rendered available for them. The results of this investigation and of the analysis of numerous samples of such water will be found in Part II. of this Report.

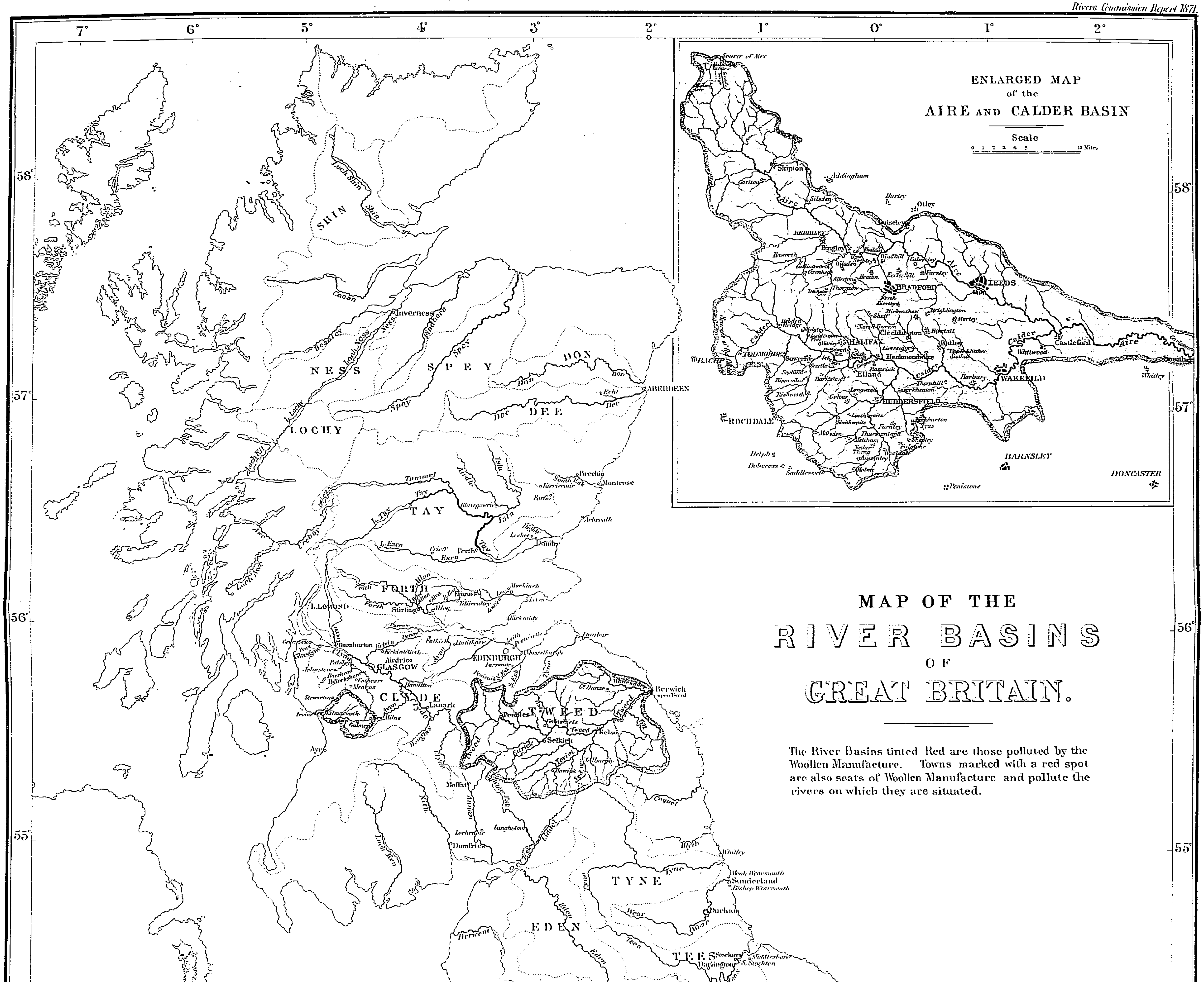
Our predecessors, at the conclusion of their report upon the *Aire* and *Calder*, after having given a sketch of the special conditions of the principal towns visited, and described the general state of the water supply of the district, and after having brought under notice the defects of the existing law relating to river pollution, showing its action to be slow, cumbrous, expensive, and ineffective, postponed the recommendations to which their inquiries in these valleys had led them, giving their reasons for this postponement in the following paragraph:—

"As we are now, in obedience to Your Majesty's Commission, about to visit rivers "specially polluted by other manufactures, and by mines, we respectfully reserve the "absolute recommendations which would appear to be in this place due from us, partly "in deference to the express objection on the part of the West Riding manufacturers "to any legislation which should not also be enforced upon the textile trade of other "districts, and partly in the hope and expectation that by postponement of final judgment "to experience of other pollutions and localities, our recommendations will be more "valuable, and more capable of general application to the improvement of the rivers of "England."

Having the advantage of the evidence collected in 1866, as well as of that obtained by ourselves since that date, both in Yorkshire and in other parts of England, and in Scotland, we are now in a position to lay before Your Majesty a completed report upon the river pollutions which are due to the woollen manufacture; including such a description of processes, localities, and samples as shall define the nuisance thus created; a discussion of such remedial or preventive measures as may help to abate the same; and such conclusions and recommendations as ought, in our opinion, to guide legislation on this subject.

Rivers Commission Report 1871.




MAP OF THE
RIVER BASINS
OF
GREAT BRITAIN.
The River Basins tinted Red are those polluted by the Woollen Manufacture. Towns marked with a red spot are also seats of Woollen Manufacture and pollute the rivers on which they are situated.
ENLARGED MAP of the
AIRE AND CALDER BASIN
Scale
10 Miles
LEEDS
BRADFORD
HALIFAX
HUDDERSFIELD
WAKEFIELD
ROCHDALE
TODMORDEN
KEIGHLEY
BARNSLEY
DONCASTER
SHIN
NESS
SPEY
DON
DEE
LOCHY
TAY
FORTH
CLYDE
TWEED
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EDEN
TEES
ABERDEEN
EDINBURGH
GLASGOW
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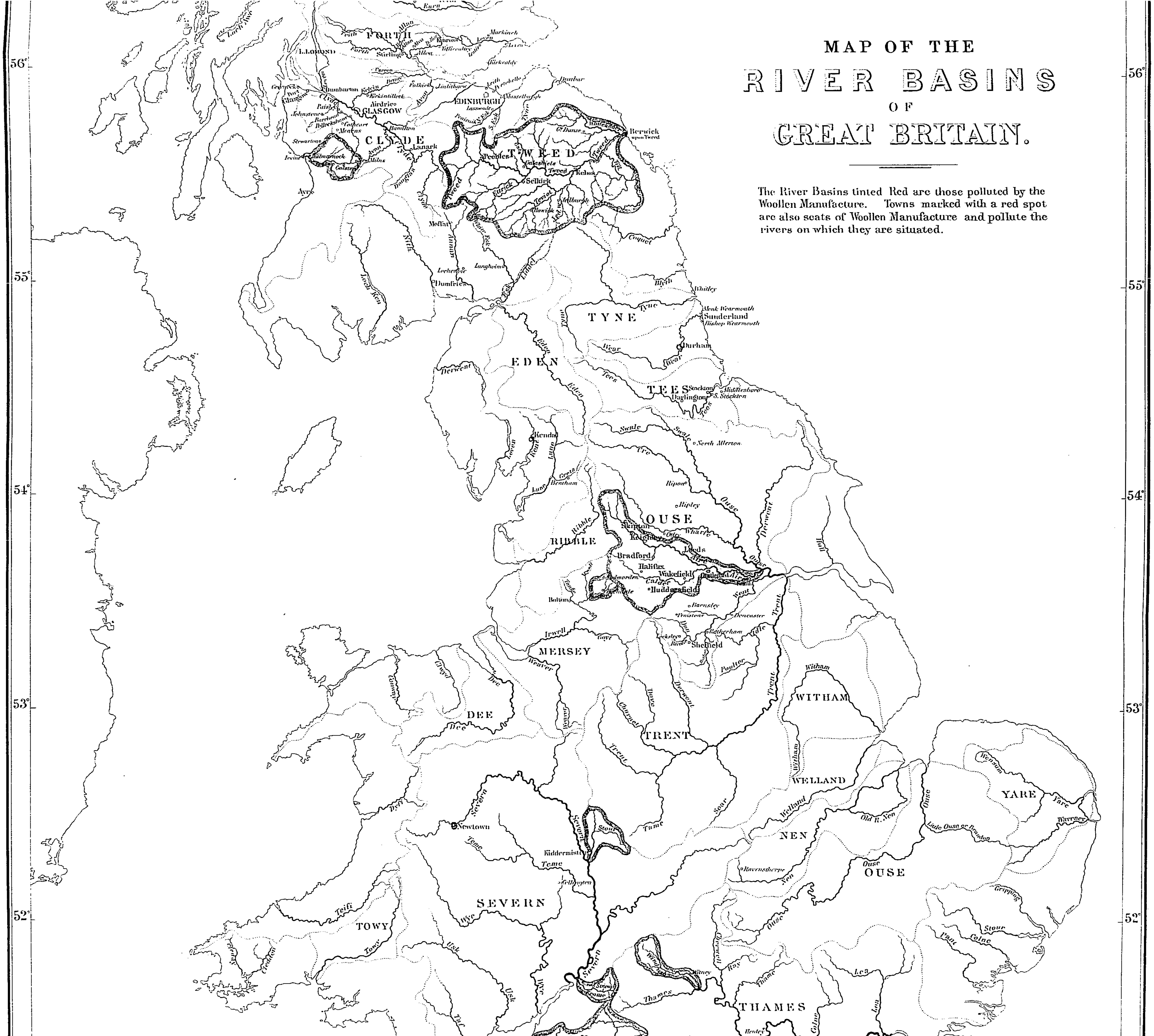

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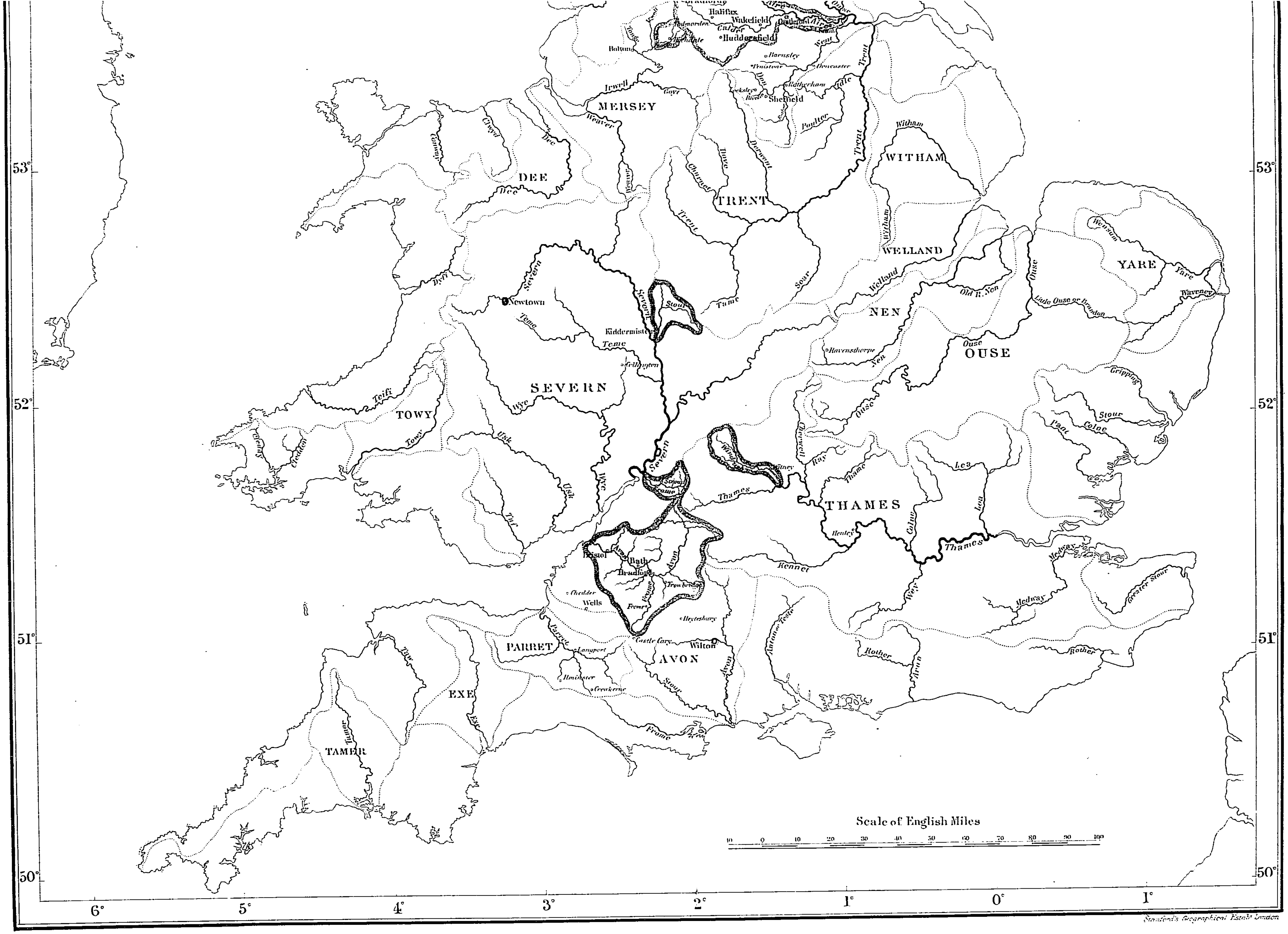

PART I.

Part I. Descriptive.

SECTION A.—DESCRIPTIVE.

Yorkshire clothing district.

We will now describe in detail the condition of the rivers in the two leading seats of the woollen manufacture in England; viz., (1) the Yorkshire clothing districts, and (2) those of the West of England; and then (3) refer to those manufacturing processes which, there and in other localities of the woollen industry, are the causes of river pollution.

1. The Yorkshire Clothing Districts.—In their report on the rivers *Aire* and *Calder*, the Commissioners first appointed by Your Majesty to inquire into the best means of preventing the pollution of rivers have minutely described the condition of the streams in the Yorkshire districts of the woollen manufacture in the year 1866. During our visit to the same districts three years later, we had abundant evidence leading us to substantially the same conclusions, which it is therefore unnecessary for us here to recapitulate. We have, however, greatly extended the basis of chemical facts, upon which the evidence of pollution and its causes rests, by analytically examining numerous polluting liquids, together with samples of the rivers and streams in their pure and polluted condition. We have also carefully studied the effect of each of the chief seats of the woollen trade upon the water flowing through it, and we now proceed to describe the results of our investigations.

The Aire.—The sources of the *Aire* lie around the little village of Malham. A strong stream flows from the foot of Malham Tarn, and after running a few hundred yards suddenly and silently disappears in a bed of limestone fragments, to reappear again at the foot of the escarpment of Malham Cove,—nearly a mile distant. There is a tradition that the stream from Malham Tarn formerly flowed along the surface and fell over the precipice of Malham Cove in a sheer leap of about 285* feet,—a tradition which is supported by the apparent traces of a river bed leading from the fissure, into which the water now sinks, to the summit of the precipice of Malham Cove—and it can scarcely be doubted that the river flowing out of Malham Tarn would now take this course if the "swallow holes," down which it at present disappears, were blocked up. Other streams on the high moors in the neighbourhood disappear in a similar manner, and doubtless furnish the water which gushes out in such abundance at several places on the plateau at the foot of the limestone crags of which Malham Cove and Gordale Scar form portions. Thus the floor of Gordale Gorge is covered with copious springs, whilst in the middle of a field just below the village of Malham a considerable river of sparkling water suddenly bursts from the earth. This last and the streams flowing out of Malham Cove and Gordale Gorge constitute the chief sources of the *Aire*, which here unite and form a river, the water of which is excellent, although somewhat hard from its solvent action upon the mountain limestone through which it has percolated; it also contains a larger proportion of organic matter than is present in the streams issuing from the chemically analogous chalk and oolite formations of the southern counties.

The following table contains the results of our analyses of the chief sources of *Aire*:—

Composition of the Headwaters of the Aire.

Results of Analysis expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.									
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Stream issuing from Malham Tarn—Sample taken where the water sinks into fissure, Sept. 30, 1869.	12·2°	12·45	·273	·030	·002	0	·032	·95	9·29	4·25	13·54
Large spring in Gordale Gorge, Sept. 30, 1869.	7·9	19·90	·176	·012	0	·064	·076	·90	12·09	4·52	16·61
Aire Head spring below Malham, Sept. 30 1869.	10·	15·70	·165	·007	·001	·017	·025	·99	8·92	3·33	12·25
Stream issuing at base of Malham Cove, Sept. 30, 1869.	8·0	16·20	·286	·014	0	·012	·026	1·15	11·56	4·52	16·08

* This height is given in Phillips' Yorkshire, Murray, 1865.

PART I. DESCRIPTIVE.

Aire Basin.

All these samples were clear and colourless, and fit for domestic and manufacturing purposes. A comparison of the constituents of the last-named two samples shows that the water from Malham Tarn becomes mixed with other water richer in chlorine and organic carbon before it again issues at the foot of Malham Cove. The great difference in temperature (4° C.) of the two samples taken within an hour of each other indicates that the water of Malham Tarn is not conducted in a simple conduit to the base of Malham Cove, but passes through a subterranean lake or subdivides itself into very numerous streamlets, either of which conditions of flow would enable it to assume the temperature of the surrounding rocks.

The pollution of the *Aire* begins at Skipton, where silk and cotton spinning and pasteboard manufactures are carried on; the cotton manufacture here as at Todmorden, having forced its way over the watershed which divides the *Ribble* and *Aire* basins. Soon after leaving Skipton the river encounters the woollen trade at Bradley, Keighley, Silsden, Bingley, Allerton, Saltaire, Bradford, Baildon, Guiseley, Yeadon, Rawdon, Horsforth, and Headingly; but the volume of its waters is so great that at Kirkstall bridge above Leeds, it was in September 1869, only moderately polluted, notwithstanding that it had been fouled by the sewage of more than a quarter of a million of people, and the refuse of, at least, the following manufactories; the numbers in both cases being taken from the tables published in the Third Report (1867) of the first River Commission:—

1 Silk mill.	26 Tanneries.
1,341 Cloth and woollen factories.	13 Chemical works.
1 Flax mill.	8 Grease extracting works.
7 Paper mills.	4 Glue factories.

The above include many gigantic establishments, of which the principal example—that of Sir Titus Salt, Bart., Sons, & Co., who employ 3,500 hands—may be quoted in detail. Here the following quantities of materials are used annually:—

Logwood and similar dyewares	320,000 lbs.
Chloride of lime, ammonia, and oil of vitriol	15,000 lbs.
Gallipoli oil	40 to 50 tons.
Soap	700,000 lbs.
Alkali	40,000 lbs.
Coal	14,000 tons.

Skipton, a town of 6,000 inhabitants, is situated on the *Eller Beck*, a mile or thereabouts above its junction with the *Aire*. The stream is fouled by the refuse from silk, and cotton factories, as well as from gasworks and from tanyards. The sewage of the town also passes at present into the *Eller Beck*, a tributary of the *Aire*, but the Local Board of Health is applying for powers to take about 70 acres of land conveniently situated for a sewage farm three-quarters of a mile below the town. The land is a fertile loam, varying from 8 inches to 20 inches in thickness, resting upon a moderately stiff clay. The average dry weather flow of sewage is said to be 150,000 gallons per day, but even storm water will be passed over the farm if its volume does not exceed $4\frac{1}{2}$ millions of gallons per day.

Ten miles below Skipton, Keighley, a town of 20,000 inhabitants, pours its drainage into the *Aire* through the river *Worth*, on which it is situated about a mile above the junction of the two streams. Both the *Worth* and the *North Beck*, which pass through the town, are polluted by town sewage and liquid refuse from manufactories; they are also the receptacles of slag and cinders and other solid refuse; the bed of the *North Beck* in particular has been raised four or five feet in this way. Mr. T. B. Laycock, a wool comber, spinner, and weaver at Aireworth on the *Worth* below Keighley, says—* "Opposite my works the bed of the river has silted up very considerably; forty years "ago the bed was five or six feet deeper than it is at present, and the silting up to this "great depth has been caused by ashes and rubbish thrown in by manufacturers and "others. Formerly trout were very plentiful in the stream, but now no living thing can "exist except rats, which feed on the dead carcases of animals thrown in. The river "for more than half a mile above my works is very seriously polluted by town sewage "and refuse from manufactories and works, and in the summer the stench is so bad that "the smell is perceptible for more than half a mile off." Mr. Laycock adds—"If the "river were clear and colourless it would be of considerable value to me." That it is not so is owing first to the discharge of the town sewage into it, and next to the fact that the liquid refuse of the factories finds its way into it uncleansed. Thus one of the largest firms at Keighley, employing 1,900 hands, and using 5 cwt. of soap a day, state in answer to our inquiries, "The soapsuds are not treated for the recovery of the "grease."—"The excrements of our workpeople are conveyed into the river."

* Volume 2, Section 2.

PART I. DESCRIPTIVE.

Bradford Beck.

At Shipley, the refuse of Bradford is poured into the *Aire* through the *Bradford Beck*. The population of the borough of Bradford at the last census was 106,000, but it is now estimated at 140,000. The *Bradford Beck* takes its rise about two miles above the town, and enters the borough in a not altogether unpolluted condition; it is, however, clear, fit for most manufacturing purposes, and appears to abound with fish. In passing through Bradford it receives, besides the sewage of 140,000 people, the drainage and refuse of numerous factories, some of them situated on the *Thornton Beck, Pinch Beck, Clayton Beck, Bowling Beck, and Eastbrook*, tributaries of the *Bradford Beck*. The following numbers, representing the factories of Bradford, are extracted from the tables accompanying the Report (1867) on the *Aire* and *Calder*, p. lxxvi:—

168 Worsted and woollen mills.	10 Chemical works.
94 Stuff mills.	10 Cotton factories.
35 Dyeworks.	3 Tanneries.
7 Size works.	3 Grease extracting works.

The character of the Bradford sewage, and the effect upon the *Bradford Beck* of the vast amount of polluting materials poured into its comparatively small volume of water, are seen from the following results yielded by samples collected for chemical examination:—

COMPOSITION OF RIVER AND DRAINAGE WATERS AT BRADFORD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.								Hardness.			Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Temporary.	Permanent.	Total.	Mineral.	Organic.	Total.
Bradford Beck above the town, Oct. 5, 1869.	13·8°	44·0	·349	·081	·105	·268	·435	0	1·87	1·34	10·46	11·80	trace	trace	trace
Ditto below town and sewer outfall, 5 p.m., Oct. 5, 1869.	30·5	75·5	4·024	·392	1·220	0	1·397	·002	5·45	10·76	13·75	24·51	15·95	36·05	52·00
Sewage at only outfall, 5 p.m., Oct. 5, 1869.	—	73·0	6·350	·617	1·956	0	2·228	·008	6·82	—	—	—	18·18	48·56	66·74
Sewage at Mr. Holden's experimental sewage works, 4.45 p.m., Oct. 5, 1869.	26·4	79·9	6·303	·577	1·845	·008	2·104	0	6·49	—	—	—	14·95	36·05	51·00
Ditto at 9 a.m., Oct. 6, 1869	23·6	74·6	3·602	·655	1·615	0	1·985	—	5·53	—	—	—	12·20	38·45	50·65
Ditto, average of 12 hours, Dec. 3, 1869.	—	95·0	9·505	·926	2·771	0	3·208	—	6·80	—	—	—	21·70	64·80	86·50

The *Bradford Beck* as it leaves the town is a black, filthy, and offensive stream; even above the sewer outfall, it was, at the time of our inspection, emitting offensive gases and could scarcely be distinguished in appearance from the sewage itself. It is the most filthy stream we have yet met with, surpassing even the worst examples in Lancashire. The *Cornbrook* just before it joins the *Irwell* at Manchester contains about the same proportion of soluble polluting ingredients, but it falls far short of the *Bradford Beck* in the proportion of suspended polluting matter which its waters carry with them.

The Bradford sewage receives a great amount of the refuse liquors from dyeworks, worsted mills, and other factories; it is also mixed with a great volume of dye water, which reduces its agricultural value. There are 6,500,000 gallons of water daily brought into the town and district by the corporation waterworks,—equivalent to about 40 gallons per head of the population—a quantity which, without taking the land drainage entering the sewers into consideration, is sufficient to account for the fact that it takes more than two gallons of average Bradford sewage to equal in manure value one gallon of average London sewage. Nevertheless we should not despair of making a profitable use of this sewage if it could be applied to land by gravitation. Much of the washing water from dyeworks which is now discharged into the sewers could doubtless be delivered direct into the river without infringing the standards of purity laid down in our First Report (1870)—on the *Mersey* and *Ribble* basins (Vol. I., page 130). The sewage would thus be preserved from excessive dilution, and might then even bear the cost of pumping, if necessary. Analysis reveals nothing in it likely to be injurious to plant life.

PART I. DESCRIPTIVE.

Pollution by Leeds.

At Leeds the river receives the sewage of a population now estimated at 270,000, and the refuse from the numerous manufactories, of which the following list is extracted from the Appendix to the Report (1867) on the *Aire* and *Calder* basins, p. lxxvii. :—

224 Cloth and woollen factories.	1 Silk mill.
62 Dye works.	28 Tanneries.
6 Dyewood mills.	29 Chemical works.
25 Flax mills.	10 Carpet factories.
22 Paper mills.	3 Glue factories.
7 Soap works.	

The marked effect of this mass of pollution even upon a large river is seen from a comparison of the analytical results yielded by samples of water taken at Kirkstall bridge and below the Leeds sewer outfall.

COMPOSITION OF AIRE WATER ABOVE AND BELOW LEEDS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
The *Aire* at Kirkstall Bridge above Leeds, Sept. 28, 1869.	12·8°	24·5	·749	·082	·068	·119	·257	trace	1·77	5·12	8·11	13·23	·54	·22	·76
The *Aire*, a quarter of a mile below the Leeds sewer outfall, Sept. 28, 1869.	—	37·5	1·350	·127	·611	·324	·954	·010	3·20	6·45	9·46	15·91	2·78	2·62	5·40

By comparing the composition of the *Aire* at Kirkstall bridge with the mean composition of its chief sources, we find that the aggregate of polluting matters poured into the river and its tributaries above Leeds has increased the proportion of *soluble* polluting elements to the following extent:—

Organic carbon - - 3·33 fold.
,, nitrogen - - 5·21 ,,

This increase represents the addition of ·524 lb. of organic carbon and ·066 lb. of organic nitrogen to every 100,000 lbs. of water; but the above analytical table shows that in passing Leeds the river receives a further increase of ·601 lb. of organic carbon and ·045 lb. of organic nitrogen; so that, in regard to soluble matters, the polluting effect of the single town of Leeds is not much less than the aggregate fouling produced by all the towns and factories above it.

At the time our samples were taken, the organic portion of the *suspended* impurities reaching Kirkstall was very small, only, in fact, ·22 lb. in 100,000 lbs. of water; but vast quantities of these foul matters were doubtless deposited in the still pools of the river, waiting for the next flood to carry them down the stream. Even in passing through Leeds the river has some opportunity to deposit its load of suspended matter, there being several weirs across the river within the borough boundaries: nevertheless it was, on the 28th of September 1869, leaving the town with a twelve-fold proportion of the organic or chief polluting portion of these suspended matters, as compared with the proportion it contained on entering the town. This difference was very obvious to the eye, the river at Kirkstall being but slightly muddy, whilst below Leeds it presented a very filthy and repulsive appearance. And a comparison of the above analytical results with those given at page 17 of our report on the *Mersey* and *Ribble* basins shows that while the *Aire* below Leeds is, in respect of dissolved matters, much less polluted than the *Irwell* below Manchester, as regards organic suspended matters the *Irwell* contained, only on two out of four occasions when we examined it, so large a proportion as the *Aire*.

The nature of the filthy liquids contributed to the river by the town of Leeds may be judged of from the analytical results yielded by the samples mentioned in the following table:—

PART I. DESCRIPTIVE.

Pollution by Leeds.

COMPOSITION OF VARIOUS DRAINAGE WATERS AT LEEDS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Sewage from the only outfall, Sept. 28, 1869.	92·5	3·981	·567	2·106	·058	2·359	·008	10·30	44·40	28·52	72·92
Hot water used in spinning flax. From Messrs. Ives and Tennant's mill, Sept. 27, 1869.	185·0	58·849	2·841	·717	0	3·431	—	72·00	1·46	6·84	8·30
Esparto liquor from Messrs. Mellor and Waddington's paper mill, Sept. 28, 1869.	4038·0	938·845	76·816	1·116	0	77·735	0	58·00	0	0	0

The sewage of Leeds enters the *Aire* about a mile below the town by a single channel, in which at the time of our inspection (2 p.m.) there was a stream 8 feet wide and about $2\frac{1}{2}$ feet deep flowing at the rate of 40 yards per minute. This corresponds to nearly 900,000 gallons an hour. We were informed that the dry weather sewage of the town amounts to 11,000,000 gallons daily, which, considering the diminished waste in the night time, is not inconsistent with our observation. The corporation have no jurisdiction over the *Aire*, which flows through the centre of the town. Twenty years ago the river was comparatively clean; it is now a black and greatly polluted stream. There are several weirs across its course in the town for the purpose of raising the water to give motive power to mills. These dams cause a silting up of the bed, and check the free flow of flood water. Property on the banks is thus injured during floods. Both the river and its affluents flowing through the town are, especially in time of drought, very foul, and consequently prejudicial to the health and comfort of the inhabitants. The corporation, from whose replies to our inquiries we quote these particulars, suggest as the best means of avoiding pollution for the future, that all local authorities and manufacturers should be compelled to utilize their sewage and liquid refuse, or to filter, deodorize, and precipitate it before allowing it to flow into rivers or their tributaries. We understand that the question of the utilization of Leeds sewage has been long under discussion by the corporation, in accordance with their own declaration of what they ought to be compelled to do.

In illustration of the quantity of filth which the town now throws into the river, we may add that there are in Leeds about 6,000 waterclosets besides a number of trough and tank closets, and some 10,000 privies, middens, and ashpits, all of which are connected with the sewers. These are cleaned periodically under the direction of the sanitary committee of the corporation, at a cost of about 12,000*l.* a year, and the corporation receive about 6,500*l.* a year for 70,000 tons of refuse; the cost of cleaning them exceeding the amount received for the manure by 5,500*l.* a year. This scavenging process, which thus costs about one shilling annually per head of the population, while about $6\frac{1}{2}d.$ a head annually is obtained for the excrementitious matter removed, is at the same time most offensive. "The cleaning of the privies, middens, and ashpits is complained of as a "a nuisance affecting the health and comfort of the inhabitants. The stench in Leeds "from 10 p.m. till 4 a.m. while this operation is going on is described as something "fearful." In addition to the sewage proper there is the waste from a very large number of dyeworks, woollen factories, tanyards, and chemical works. The replies from some of the firms to the inquiries addressed to them will be found in Vol. II. of this Report. They deserve perusal as furnishing both a graphic account of the existing condition of the *Aire*, and a statement, to some extent, of the contributions to that condition made by the manufacturers themselves.

Seventeen manufacturers of Leeds have answered our inquiry as to the money value to them of clear water if it could be had in place of the present foul river. Messrs. Kinnear, Holland, and Co., cloth manufacturers, say—"if the river were rendered clear and colourless "it would be a direct money value to us of from 60*l.* to 70*l.* a year." Messrs. W. Walker and Co., wool and cloth dyers, say—"If the river were rendered clear and colourless it "would be of considerable money value to us, but we cannot give the amount." A

PART I. DESCRIPTIVE.

Junction of *Aire* and *Calder*.

similar reply is given by Messrs. G. Hirst and Sons, dyers. Mr. J. C. Waddington, cloth dyer, says, "If the river, from which we might derive a supply of water, were rendered "clear and colourless, it would be a direct money value to us of 100*l*. a year." Messrs. Ives and Tennant, flax spinners, say "a cleansed river would be a direct money value to "us of 25*l*. a year, which we pay to the waterworks company, besides being indirectly of "great value." Messrs. A. Paterson and Son, hemp and tow spinners, value a clean river at 20*l*. a year. Messrs. Neill and Co., paper makers, value it at 75*l*. a year; Messrs. J. Houldsworth and Sons, silk spinners, at 200*l*. a year. Messrs. W. Robinson, stuff and woollen printers, value it at 34*l*. 10*s*. annually; Messrs. J. Crawford and Son at 100*l*. a year. Messrs. T. Smith and Sons, linen cloth manufacturers, value it at 15*l*. to 20*l*.; and W. Robinson, wool manufacturer, says, "If the river were rendered clear and colourless "it would be of great benefit to us, but we are not able to fix the amount." On the other hand, there are two or three firms who say that their arrangements for water supply being already perfect, the cleansing of the river would do them no service. There are not wanting, among the manufacturers in this river basin, those who fear the tax which will be imposed upon them by the cleansing operations on their drainage water, which they expect to be enforced before it can be permitted to be discharged into the river. On the whole, however, it is apparent that, as stated to us by other manufacturers, the foul condition of these rivers is really one of the heaviest taxes which manufacturing industry has to bear.

The Leeds sewage contained, when our sample was taken, rather a large proportion of suspended matters; but it was very deficient in soluble fertilizing ingredients, containing only about one third of the proportion present in average London sewage. This latter circumstance is due partly to the discharge of much slightly polluting water from factories into the sewers, and partly to the circumstance that "springs were tapped during the exe- "cution of the sewerage works" (*see* Vol. II., section I.). It is, however, probable that the sewage was exceptionally weak at the time our sample was collected (1.30 p.m.), since Glasgow, with a daily water supply of more than 50 gallons per head, furnishes sewage twice as rich in fertilizing ingredients as that of Leeds.

At a distance of about 10 miles below Leeds, and immediately above Castleford, the *Calder* joins the *Aire*. The inhabitants complain of the stench and filth brought down to them by both rivers. At the weir beside the Aire and Calder corn mill here, not only the water, but the foam upon it, was black at the time of our inspection; and the miller and his men complained of the frequent nausea which they suffered from the sickening filthy stench to which they were continually subjected.

We took a sample of the river water just below Castleford, where the two rivers had become thoroughly mixed, and again at Carlton Bridge, near Snaith, about 22 miles lower down, between which points the river receives the sewage of Brotherton, Ferry Bridge, Pontefract, and Knottingley. The results of the analysis of these samples are contained in the following table:—

COMPOSITION OF WATER OF THE AIRE BELOW ITS JUNCTION WITH THE CALDER.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness.			Mineral.	Organic.	Total.
										Temporary.	Permanent.	Total.			
The *Aire* just below Castleford, Sept. 17, 1869.	14·6°	25·40	·661	·091	·125	0	·194	trace	2·27	·28	14·11	14·39	2·90	1·50	4·40
Ditto at Carlton Bridge, Sept. 17, 1869.	15·7	35·60	·677	·116	·193	0	·275	·001	2·58	3·96	12·41	16·37	9·92	1·36	11·28

These results show that the pollution of the combined streams *Aire* and *Calder* is much less than that of the chief polluted rivers in Lancashire.

THE CALDER.—The *Calder* takes its rise on the ridges of millstone grit separating Lancashire from Yorkshire. Four upland valleys deliver the head waters of this river

PART I. DESCRIPTIVE.

Calder Basin.

into a common bed at or near Todmorden. The high road and railway from Todmorden to Burnley pass through one of these valleys, which assumes in places the character of a precipitous gorge with several lateral gullies. In rainy weather the water sometimes sweeps down these ravines with irresistible fury, carrying trees, rocks, and walls with it. At the village of Portsmouth we saw the débris of a substantial factory which had been thus suddenly destroyed last autumn by one of these torrents entering the main valley, and a portion of the line of railway had, on the same occasion, a narrow escape from being washed away. Another feeder of the *Calder* comes down the valley through which the Rochdale road winds, and is hence known as the *Rochdale Calder*. A third affluent takes its rise in a similar but narrower gorge of millstone grit, called Ramsden Clough; whilst the fourth tributary, called the *Migelden Brook*, has its origin chiefly in the adit of a coal mine situated near the summit of the road from Todmorden to Bacup. We collected samples of all these streams above all sources of pollution, and submitted them to analysis with the following results:—

COMPOSITION OF THE HEAD WATERS OF THE CALDER.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.									
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness.		
									Temporary.	Permanent.	Total.
The *Burnley Road Calder* near its source above Portsmouth, Jan. 26, 1871.	0·2°	7·80	·053	·008	·006	·040	·053	1·10	1·09	3·77	4·86
The *Rochdale Road Calder* above Red Lees, and near its source, Jan. 26, 1871.	0	7·30	·033	·012	·001	0	·013	1·20	·26	3·51	3·77
The *Ramsden Clough Calder* above Spring Mill, Jan. 26, 1871.	0	7·74	·093	·013	·003	·042	·057	1·10	·26	3·64	3·90
Stream flowing from coal mine into *Migelden Brook* near summit of Bacup Road, Jan. 26, 1871.	12·8	624·00	·187	·037	·120	0	·136	1·20	4·00	383·0	387·00

These analytical numbers show that the Burnley Road, Rochdale Road, and Ramsden Clough tributaries of the *Calder* were delivering water of a degree of purity rarely found in rivers or brooks. At the time the samples were taken a severe frost had prevailed for several weeks, and these streams were fed exclusively by deep seated springs; it may be anticipated therefore that in ordinary weather these head waters of the Calder will not exhibit so high a degree of purity as the samples we have analysed, but there can be no doubt from the geological nature of the two gathering grounds, that the three head waters of the *Calder* just mentioned are always softer and on the whole better adapted for domestic and manufacturing purposes than those of the *Aire*. Even at Todmorden the *Calder* has only about one-third the hardness of the *Aire* at its source. The *Migelden Brook* is so highly polluted by mine water as to be unfit for all purposes; it cannot be drunk, it would be useless for washing, and its corrosive action on iron is such as to prevent its being employed for feeding steam boilers. At present its admixture with the *Calder* at Todmorden is useful in precipitating the foul organic matters from the sewage and manufacturing refuse of that town, whilst by this act of purification its own acid and ferruginous character is nearly obliterated; indeed, as we shall show below, the *Calder* leaves Todmorden not more polluted by dissolved organic matter than it was on entering the town. The stream of water entering the *Migelden Brook* from the summit coal mine has an acidity equal to that produced by the addition of 220·5 parts of sulphuric acid to 100,000 parts of distilled water, and it contains, in 100,000 parts, 50·88 parts of metallic iron as sulphate of iron; it leaves no ferruginous or other deposit on the stones in the bed of the brook; but lower down, water containing carbonate of iron in solution enters the stream from other coal mines, and furnishes the red deposit which thenceforward characterises the bed of this brook.

Todmorden, where the first considerable pollution of the river *Calder* takes place, is a town of 12,000 inhabitants, engaged in the cotton manufacture, lying around the junction

PART I. DESCRIPTIVE.

Calder at Todmorden.

of the streams just described. The river is polluted by town sewage, liquid refuse from manufactories, chemical works, gas works, dye works, and mines. The river bed has been raised by making it the receptacle of all kinds of solid refuse, as scoria from iron foundries, slag, cinder and road sweepings. At page xi. of the report of our predecessors on the *Aire* and *Calder* (1867) will be found an account of the injury which Todmorden has suffered from floods, greatly aggravated by this condition of the river bed.

In passing through Todmorden the *Calder* receives the *Migelden Brook*, which consists in great part of highly ferruginous mine water, containing, near its junction, 6·504 parts of iron as sulphate in 100,000 parts of the water. We found the acidity of the water of this brook to be equal to that which would be imparted to 100,000 parts of water by the addition of 8·075 parts of sulphuric acid. After boiling for half an hour the acidity was reduced to 2·951 parts of sulphuric acid in 100,000 parts of water. The total quantity of sulphuric acid in this water, both free and combined, was 19·48 parts in 100,000. The further character of this stream, and the condition of the *Calder* above and below Todmorden, is seen from the analytical results in the following table:—

COMPOSITION OF CALDER WATER ABOVE AND BELOW TODMORDEN.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
Mixed sample of two branches of the *Calder* above Todmorden, Oct. 2, 1869.	13·6°	12·40	·270	·031	·015	·034	·077	0	1·17	1·04	4·11	5·15	—	—	Traces.
The *Migelden Brook* just before its junction with the *Calder*. Oct. 2, 1869.	—	32·00	·162	·036	·023	·253	·308	0	1·45	0	20·34	20·34	—	—	—
The *Calder* below Todmorden sewer outfall, Oct. 2, 1869.	14·4	15·10	·192	·056	·095	·094	·228	0	1·49	1·56	6·06	7·62	2·99	·910	3·90

The proportion of dissolved polluting material in the *Calder* is not very different below and above the town, a circumstance owing partly to the admixture of the purer water (as regards organic matter) of the *Migelden Brook*, but chiefly to the ferruginous character of this brook; such water being known to exert a powerful purifying action upon moderately polluted streams. On the day of our visit the river below Todmorden was muddy from dark coloured suspended matter, but after the separation of this by subsidence, the water, though unfit to drink, could not be complained of as a nuisance.

Below Todmorden, on the north bank, the *Calder* receives the water of the *Hebble*, a stream which brings down to it a very filthy contribution from the town of Halifax, where there are 65,000 inhabitants engaged chiefly in the woollen manufacture. The *Hebble* and the *Ovenden Beck* unite close to the town, and flow through it, carrying off the drainage from many manufactories and dye-works, and from about 1,000 water-closets and 8,000 privies, middens, and ashpits. The *Hebble*, rising in a moorland district about five miles north of Halifax, enters the town in a comparatively pure state. In its passage through the town it becomes discoloured and polluted. "In July 1869 " an injunction was obtained from the Court of Chancery to restrain the local board " from making any new sewer into existing drains in connexion with the outfall, and " from and after the 1st of June 1870, to remove the entire sewage of the town out of the " *Hebble*, until or unless the same shall have been sufficiently purified and deodorized." The local board have in the meantime removed the whole of the sewage by an intercepting channel to the lowest point on the river within their jurisdiction; and they have under consideration plans for abating the undoubted nuisance which it creates. The condition of the river above and below the town, and the character of the foul liquids poured into it, during its transit through Halifax, are seen from the following results of analyses of samples collected during our visit:—

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COMPOSITION OF RIVER AND DRAINAGE WATERS ABOVE AND BELOW HALIFAX.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
Mixed samples of the *Hebble* and *Ovenden* brooks above Halifax, Sept. 24, 1869.	16·8°	24·50	·474	·071	·044	·138	·245	0	2·15	·09	10·91	11·00	·88	·32	1·20
Waste liquor from Mr. E. Ingham's dye and bleach works, Sept. 24, 1869.	25·0	94·70	14·813	·823	·472	·435	1·647	0	4·72	—	—	—	34·80	81·00	115·80
Sewage from town sewer outfall, 9.45 a.m. Sept. 25, 1869.	17·0	63·00	6·188	1·834	3·465	0	4·687	Trace	7·70	—	—	—	32·12	55·60	87·72
Dye-vat water flowing into river from Messrs. Crossley and Co.'s carpet works, Sept. 25, 1869.	—	460·00	129·345	2·857	4·848	0	6·849	0	—	—	—	—	36·40	100·50	136·90
Residual liquor after extraction of grease from same works, Sept. 25, 1869.	—	366·00	23·264	3·267	4·812	0	7·230	·028	25·20	—	—	—	—	—	—
The *Hebble* below Halifax, Sept. 24, 1869.	22·2	57·60	2·472	·633	·064	0	·064	·004	4·30	7·36	25·71	33·07	9·36	13·28	22·64

Huddersfield, a town of 70,000 inhabitants engaged in the woollen manufacture, is situated on the *Colne* and *Holme*, which unite and form the *Colne* at Bradley Mills bridge, about four miles from its junction with the *Calder*. The streams are polluted throughout their course, and, especially as they pass through Huddersfield, by town sewage, refuse from chemical works, gasworks, dye and bleach works, and tanyards. The condition of the river and canals passing through the town is said to be a source of ill health and discomfort. (See Volume II., Sec. 1.) Films of tar were floating on the surface of the foul stream when we saw it. The following analyses show the effect of the pollutions of Huddersfield upon the water, and also the composition of the drainage from several woollen mills:—

COMPOSITION OF RIVER AND DRAINAGE WATERS ABOVE AND BELOW HUDDERSFIELD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
Mixed samples of the *Colne* and *Holme* above Huddersfield, Sept. 23, 1869.	14·7°	10·50	·556	·078	·005	·113	·195	·002	1·35	2·32	5·12	7·44	traces	traces	traces
Drainage from Messrs. Crowther's scouring and washing mills, Sept. 23, 1869.	—	29·70	2·469	·216	·356	0	·509	·004	1·76	—	—	—	34·76	35·84	70·60
Drainage from Shepley New Mill, Sept. 22, 1869.	—	112·3	22·455	4·143	10·350	0	12·667	·020	12·75	—	—	—	35·40	188·30	223·70
Waste woollen dye liquor from Bradley Mills.	—	204·7	43·207	2·719	2·340	0	4·646	0	14.40	—	—	—	1·80	25·28	27·08
The *Colne* at Bradley Mills Bridge below Huddersfield, Sept. 23, 1869.	16·4	16·25	1·227	·186	·109	0	·276	·008	1·94	0	8·77	8·77	—	—	—

It thus appears that in its passage through Huddersfield the water of the *Colne* more than doubles its proportions of organic carbon and organic nitrogen. The waste liquor draining from Messrs. Crowther's mills was polluting almost solely from its suspended matters. Were these strained off, or allowed to subside, the effluent liquid would only slightly transgress our proposed standards of purity in the item of organic carbon: the standard we have suggested being 2 parts in 100,000, (Report, 1870, *Mersey* and *Ribble* Basins, Vol. I., p. 130,) whilst the drainage in question contained 2·469 parts.

About six miles lower down on its north bank the *Calder* receives the water of a small beck, an extremely filthy stream which brings down the drainage of Batley and Dewsbury,—towns of about 20,000 inhabitants engaged in the blanket trade as well as in the

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Aire and *Calder.*

manufacture of woollen goods in which large quantities of shoddy are employed. The stream is polluted in the usual way by liquid drainage, and encumbered by all sorts of solid refuse. We collected a sample of the drainage from Messrs. Holdroyd and Son's woollen mill, which gave the following results on analysis :—

COMPOSITION OF DRAINAGE WATER FROM A WOOLLEN MILL.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

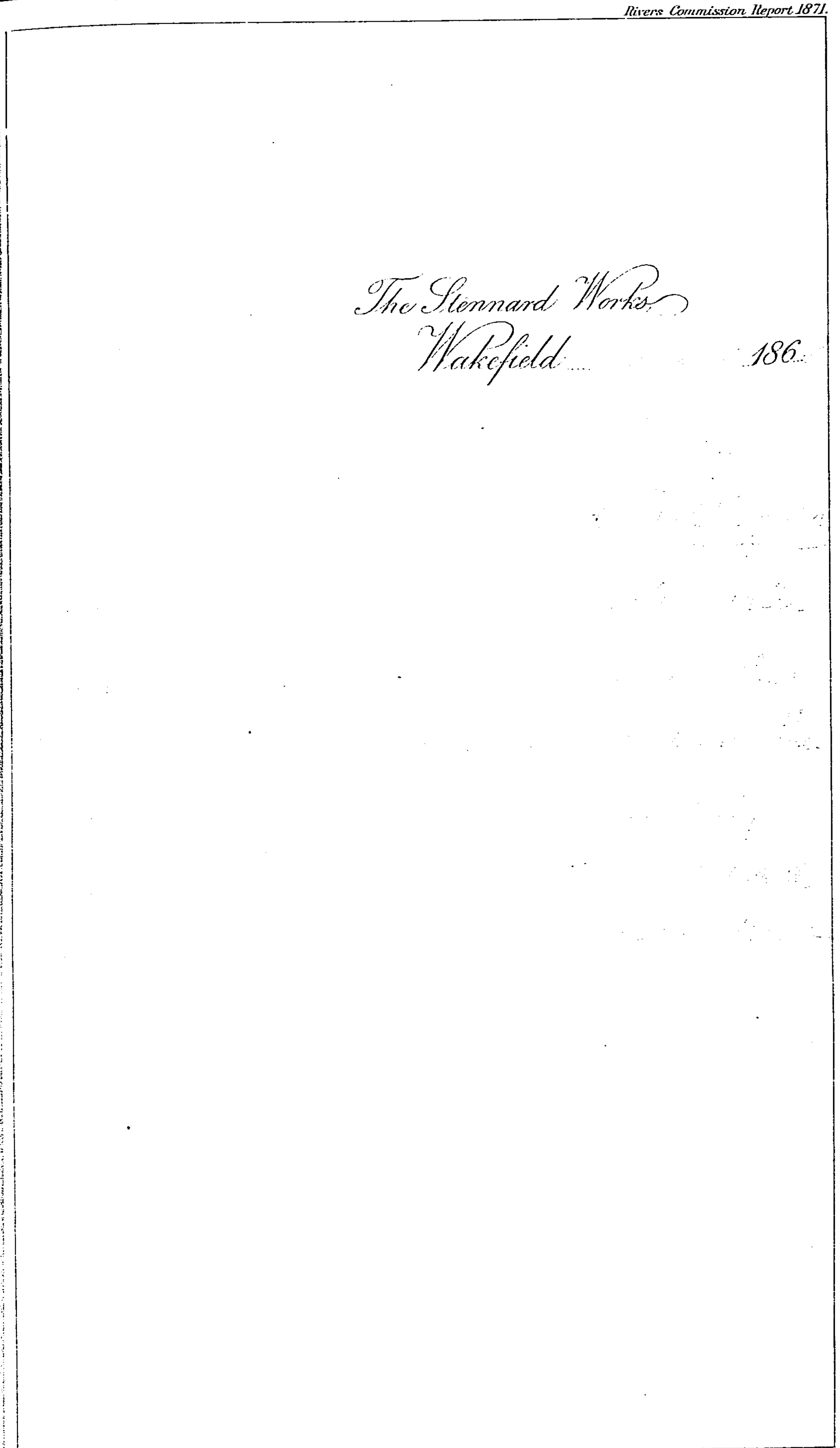
Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Drainage from Messrs. Holdroyd and Son's woollen mill, Sept. 21, 1869.	24·80	2·610	·262	·208	·144	·577	·002	1·82	3·64	9·16	12·80

Here, as at Messrs. Crowther's mills in Huddersfield, the polluting character of this drainage is chiefly due to suspended organic matters, the organic matters in solution but slightly transgressing our proposed standards of purity.

Wakefield with its 26,000 inhabitants is the lowest town on the *Calder*, making the last considerable addition to its pollutions, and suffering from all those which are brought down from the towns higher up the valley. The river is here polluted by many kinds of liquid refuse, and is very much discoloured. We received from Mr. Charles Clay, agricultural implement manufacturer, whose works are situate on the *Calder* at the foot of the town, the river's own testimony to its occasionally miserable plight, in the form of a memorandum reproduced in fac-simile on the adjoining page. This document was written on the date specified upon it, the pen having been dipped in the river water immediately below the outfall sewer of the town at a time when there was an unusually filthy discharge from it.

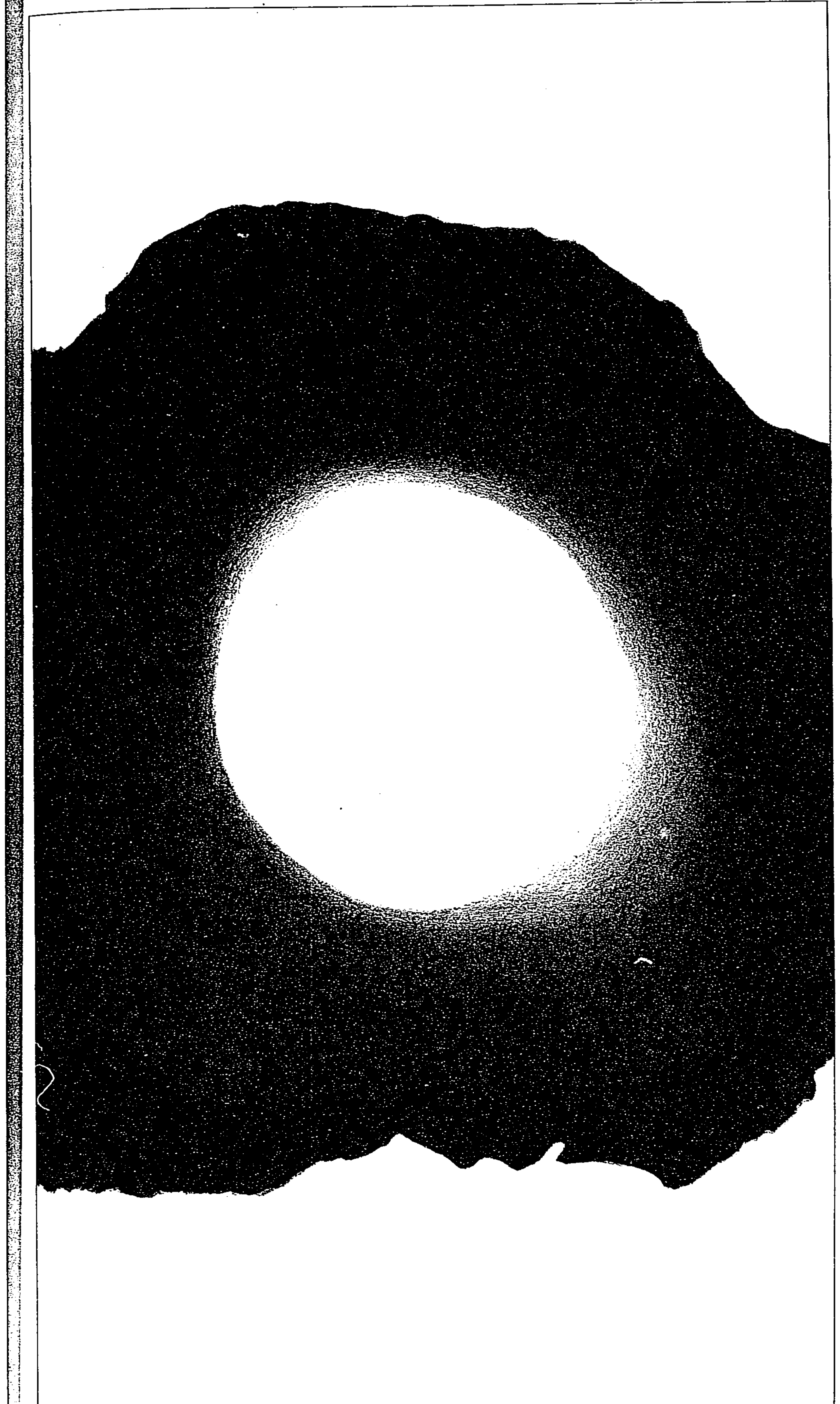
On the 29th of September 1869, the *Aire* and *Calder* Navigation Company kindly placed their steam yacht at our disposal for a more minute inspection of these rivers. Embarking at Wakefield, we proceeded up the *Calder* to a point above the town, where we took a sample of the river water, which was here of a brownish yellow colour, but inodorous and tolerably free from suspended matter. This sample was taken at 9.37 a.m. Returning down the river we took a second sample of the river water when fairly below the town. Here the river was turbid and of a dark brown colour; an oily film floated on the surface, and the water emitted a mixed odour of sewage and gas tar. At a point somewhat below this, "about a mile below the main sewer outlet," the water supply of Wakefield is taken from the river. At 12.10 p.m. the junction with the *Aire* was reached, chiefly through the *Aire* and *Calder* canal, which is fed by the river water, and at 100 yards above it another sample of the *Calder* was taken. The stream had here greatly improved in appearance; the improvement being due, as shown by the analysis, to the deposition of more than two-thirds of the suspended organic matters, and not to any important diminution of the dissolved impurities. The water was also here inodorous. It presented a marked contrast with that of the *Aire* at the junction of the two streams, the latter river emitting an offensive odour, and being black and much more turbid than the *Calder*. Analysis confirms these observations, and shows that on this day the *Aire* was polluted to more than twice the extent of the *Calder* by both dissolved and suspended matters. We then steamed up the *Aire*, taking a sample of its water about 100 yards above its junction with the *Calder* at 12.15 p.m.

On our way up to Leeds we landed at Woodlesford, and inspected the paper mill of Mr. Joseph Crampton Oddy. Here a delicately yellow tinted paper, for the packing of certain goods, is manufactured by hand. The tint is given to the paper by yellow chromate of lead, and the proprietor showed us a considerable quantity of this paper which had been utterly spoiled in the summer of 1868, as shown in the annexed fac-simile, by the gaseous emanations from the river water which he uses for power. Chromate of lead is instantly blackened by sulphuretted hydrogen gas, and therefore constitutes a test of considerable delicacy for the presence of that gas in the atmosphere. At the time of our visit the temperature of the river was only 14·1° C., and no evolution of sulphuretted hydrogen was observed; but in summer, when the temperature rises to 20° C., the river will doubtless hold a considerable volume of this gas in solution, and when the water in this condition is agitated upon the water wheel, the


The Stennard Works
Wakefield 186

FAC-SIMILE OF YELLOW PAPER SPOILED BY GASEOUS EMANATIONS FROM THE

Rivers Commission Report 1871.



Stanford's Geog^l Estab^t Charing Cross atmosphere in these works must become impregnated with sulphuretted hydrogen making it impossible to carry on the operations of the factory.

Aire and *Calder*.

The following table contains the results of our analysis of the samples above enumerated, and also of a sample of Wakefield sewage collected at 9.15 a.m. on the 22nd of September 1869 :—

COMPOSITION OF THE WATERS OF THE AIRE AND CALDER.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
The *Calder* above Wakefield, Sept. 29, 1869.	° 13·1	17·10	·424	·097	·088	·166	·335	trace	1·73	·43	5·50	5·93	4·39	2·31	6·70
Ditto below Wakefield, Sept. 29, 1869.	13·6	19·80	·530	·050	·086	·134	·255	·008	2·30	1·13	5·50	6·63	3·00	2·02	5·02
Ditto 100 yards above junction with the *Aire*, Sept. 29, 1869.	13·8	19·50	·480	·044	·082	·130	·242	0	2·31	·71	5·78	6·49	1·94	·61	2·55
The *Aire* 100 yards above junction with the *Calder*, Sept. 29, 1869.	14·1	27·60	·822	·105	·131	·075	·288	trace	1·81	9·10	5·64	14·74	1·84	1·46	3·30
Wakefield sewage from only outfall, Sept. 22, 1869.	—	85·50	2·665	·701	2·233	0	2·540	·010	14·76	—	—	—	3·36	7·40	10·76

These numbers show that, probably owing to a recent discharge of polluting matter from the mills above Wakefield, the river was, at 9.30 a.m. on the day of our inspection, slightly more polluted above than below the town by suspended organic matters. The Wakefield sewers are made the medium for the discharge of large volumes of dye-water, and consequently the sewage is, like that of Bradford, exceptionally weak,—one gallon of average London sewage being equal to about three gallons of the Wakefield discharge. Still even this dilute liquid might be profitably applied to land, if it could be conducted to an irrigation farm by gravitation.

It must not be supposed that the filth obvious to both eye and nose in the streams which drain these valleys is due to the woollen manufacture only. Town sewage, including the personal waste of a dense population, is a leading source of river pollution here as in all other populous districts. The waste from tanneries is a considerable addition to the polluting ingredients, especially of the *Aire* below Leeds. The report (1867) of the former Commission enumerated more than 30 kinds of manufactures or parts of manufactures situated on the *Aire* and *Calder*, to which, in different degrees, the present foul condition of these streams is owing. After the addition of town sewage, however, it is to the drainage from the dye and scouring vats of the woollen manufactories that the filthy plight of both the *Aire* and *Calder* in Yorkshire and of the *Fromes* of Gloucestershire and Somerset is due; and this has been exaggerated of late years, especially in the first-named district, by the extremely filthy character of much of the raw material employed; or rather by the work of preparing this raw material for its use. The great extension of the shoddy manufacture and of the woollen manufacture based on shoddy as its raw material, has unquestionably materially increased the filthiness of the waters of the *Aire* and *Calder*.

2. The West of England Clothing Districts.—The character of the pollutions due to the manufacture of short wools can be nowhere better studied than on the small streams uniting below Stroud in Gloucestershire. The Gloucestershire *Frome* drains an area of about 70 square miles, and below the lowest mill upon the stream, when our final sample of its waters was taken, it was four or five square yards in section, where flowing at the rate of about a mile an hour. On this stream, and on its tributaries in the valleys of Nailsworth, Chalford, Slad, and Painswick, above their junction at Dudbridge, there are 33 woollen mills turning out about 340 pieces of broadcloth, equal to 17,500 yards weekly; and below the point of their junction there are six woollen mills turning out about 170 pieces, or 8,700 yards weekly. In all, upwards of 25,000 pieces of cloth are made in this district annually, and the greater part of this large quantity is black and blue cloth, not above 10 or 15 pieces in every hundred being of fancy colours.

In addition to the drainage from this large manufacture, there is the waste from six or eight shoddy mills, as well as from the ordinary industries of the considerable population here located, including flour mills, saw mills, engineering shops, a small chemical and manure manufactory; not to speak of eight or ten dye houses, the waste of which, how-

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West of England clothing districts.

ever, we shall include in our estimate of the materials which drain away in the manufacture of 500 pieces weekly of finished woollen goods. And besides all these, there is the sewage of considerable villages—Avening, Horsley, Nailsworth, Woodchester, Chalford, Brimscombe, Painswick—and of Stroud, a town of 8,000 inhabitants, to whose sewage a process for extracting the manure contained in it has been applied, with, however, but little useful effect. See Report (1870) on *Mersey* and *Ribble* basins, vol. 1, p. 59.

The character of the water rising in the upper reaches of these valleys—in some instances, as at Chalford, in wonderfully copious springs,—may be gathered from the following analyses of samples collected on March 17th, 1870:—

COMPOSITION OF SPRING WATERS IN THE STROUD VALLEYS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.								Hardness.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Temporary.	Permanent.	Total.
Spring at Chalford, Mar. 18, 1870	11·7	28·86	·083	·019	0	·285	·304	0	·97	20·91	3·57	24·48
The *Frome* above the highest mill in the Chalford valley, Mar. 18, 1870.	10·8	27·50	·062	·009	0	·298	·307	0	1·05	19·62	4·04	23·66
The unpolluted *Avon* above the highest mill in the Avening valley, Mar. 17, 1870.	10·3	25·56	·053	·007	0	·398	·405	0	1·22	16·82	4·66	21·48

These spring waters are bright, clear, and useful for all manufacturing and domestic purposes, having the beautiful blue-green tint of pure water; and whenever, as in flood times, they can be diverted from the work of filling mill ponds, they are passed in several places along their course over water meadows with the best effect, owing doubtless to the considerable proportion of nitrates which they contain.

To the eye the *Frome*, where it receives the *Avon* from the Nailsworth, Avening, and Horsley valleys, appears to be considerably more polluted than the latter stream, and analysis confirms this estimate of comparative pollution. The following table gives the composition of samples taken above and below Stroud on the *Frome*, above Dudbridge on the *Avon*, at Dudbridge just below the junction of the two, and again below Eastington some miles lower on the united stream.

COMPOSITION OF GLOUCESTERSHIRE STREAMS ABOVE AND BELOW STROUD.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature Centigrade.	Dissolved Matters.								Hardness.			Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Temporary.	Permanent.	Total.	Mineral.	Organic.	Total.
The *Frome*, above Stroud and below Frampton Mill, Mar 17, 1870.	11·5°	30·30	·202	·031	·005	·273	·308	0	1·25	17·77	4·53	22·30	2·32	·63	2·95
The *Frome*, just above junction with the *Avon*, Mar. 17, 1870.	11·4	29·30	·239	·033	·010	·359	·400	0	1·50	17·47	4·29	21·76	·84	·46	1·30
The *Avon*, just above its junction with the *Frome*, Mar. 17, 1870.	11·1	29·24	·188	·021	·015	·281	·314	·003	1·55	15·28	6·20	21·48	·35	0	·35
The *Frome*, at Ebley, just below junction with the *Avon*, Mar. 17, 1870.	11·6	28·44	·165	·022	·013	·317	·350	0	1·40	16·93	4·29	21·22	·77	·29	1·06
The *Frome*, at Eastington and below Meadow Mill (the last mill), Mar. 17, 1870.	11·6	30·26	·157	·023	·013	·293	·327	0	1·46	17·86	4·16	22·02	·53	·10	·63

A comparison of these analytical results with those given in the previous table shows the extent to which the two streams, *Frome* and *Avon* respectively, were deteriorated in quality at the time of our inspection. Thus, the total solid matters in solution in 100,000 lbs. of the water of the unpolluted *Frome* was 27·5 lbs., whilst just before its junction with the *Avon*, the weight of these matters had increased to 29·3 lbs., showing an addition of 1·8 lb. besides 1·3 lb. of suspended matters consisting of ·84 lb. mineral, and ·46 lb. of organic matter.

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Gloucestershire woollen trade.

The actual pollution by soluble matters is measured by the increase of organic carbon and organic nitrogen; and a comparison of the analytical tables shows that the proportion of organic carbon had increased from ·062 lb. in 100,000 lbs. of the unpolluted water, to ·239 lb in 100,000 lbs. of the river water just above the junction with the *Avon* at Dudbridge, and that the proportion of organic nitrogen had been augmented from ·009 lb. to ·033 lb. in 100,000 lbs. during the flow of the *Frome* between the same places. Thus, the proportion of both organic carbon and organic nitrogen had increased nearly fourfold. Again the unpolluted *Avon* contained 25·56 lbs. of dissolved matters which had increased to 29·24 lbs. in 100,000 lbs. of water at its junction with the *Frome*, giving an addition of 3·68 lbs. per 100,000 lbs. of water, whilst it had received between the same points and carried down to the junction ·35 lb. of mineral matter in the form of suspended mud. The proportions of organic carbon and organic nitrogen at the junction were about threefold as great as those in the unpolluted stream. It is proper to remark that, as may be gathered from a comparison of the above analyses with those given below, the maximum pollution of these Gloucestershire streams takes place almost immediately. The analyses show that the foulest sample of the whole series was taken very near the head of the valley. Nowhere is the water of the *Avon* or the *Frome* more polluted than below the highest mill on the former of these streams. And not only is the effect of a single large mill upon the stream, where the latter is small, at once the maximum example of river pollution which the district offers, but the analyses indicate a gradual diminution of the pollution visible at stations lower down; so that, at the time when our samples were taken, the river below the lowest mill was really not so foul as it was immediately below the highest. This is owing to the number of short valleys which here unite, and to the confluence of so many streams, some of them altogether unpolluted, by which the intensity of the effect of the woollen manufacture on these rivers is diminished rather than increased the farther they flow.

In order to ascertain the character of the manufacturing pollutions poured into the Gloucestershire streams we collected samples of effluent liquors from Messrs. Wm. Playne & Co.'s mill (Longfords) at the head of the Gloucestershire *Avon*, from a factory for the extraction of indigo from waste wool near Nailsworth, from the woollen rag washing engines at the shoddy mill of Messrs. Grist, Brothers, at Brimscombe, near Stroud, and from wool washing and dyeing at Messrs. Alfred Smith & Co.'s dyeworks near Dudbridge. The analyses of these liquids gave the following results:—

COMPOSITION OF VARIOUS WASTE LIQUORS FROM WOOLLEN MILLS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Liquor entering the *Avon* from grease extracting process at Messrs. Wm. Playne & Co.'s mill, Longfords, March 17, 1870.	307·7	23·509	10·810	15·475	0	23·554	·080	21·40	·48	5·68	6·16
Waste liquor from indigo extraction entering the *Inchbrook* (tributary of the *Avon*) near Nailsworth, March 18, 1870.	363·0	59·049	14·380	2·480	0	16·422	0	10·00	·82	·43	1·25
Waste liquor from woollen rag washing engines in Messrs. Grist, Brothers', shoddy mill at Brimscombe, near Stroud, March 18, 1870.	32·80	1·364	·114	·180	0	·262	0	1·90	11·92	17·00	28·92
Water from wool washing and dyeing at Messrs. Smith's dyeworks, Dudbridge, March 17, 1870.	29·62	·189	·053	·011	·344	·406	·002	1·50	·72	·88	1·60

These analytical results show that the liquids discharged from woollen dyeworks differ widely in their polluting power, for whilst the liquors, which were being run from the grease extractors at Messrs. W. Playne & Co.'s mills and from the indigo factory at the time of our inspection, were of a highly polluting character, that being discharged from the Dudbridge dyeworks, at the time of our inspection, was in all respects far below the standards which we have suggested in our first report, as the limits above which liquids should be deemed inadmissible into running water. The effluent liquors from this mill are not submitted to any cleansing operations, and therefore we have no reason to suppose that they are in any way different from those discharged from Messrs. Wm. Playne & Co.'s mill; hence it is evident that large quantities of used water discharged from woollen mills might be admitted into rivers without any purification, if the much smaller volumes of highly polluting liquids were carefully kept apart for treatment by remedial agents.

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Wilts and Somerset woollen manufacture.

The polluting effect of a single large mill upon a stream of moderate volume is well illustrated by samples of the *Avon* near its source, above and below Messrs. Wm. Playne and Co.'s mill at Longfords:—

COMPOSITION OF RIVER WATER ABOVE AND BELOW A WOOLLEN MILL.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.										Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
The *Avon* above Longfords Mill.	25·56	·053	·007	0	·398	·405	1·22	16·82	4·66	21·48	0	0	0
Ditto below ditto	26·30	·277	·057	·017	·372	·443	1·28	16·04	4·92	20·96	·23	·16	·39

The stream below the mill had a slight blue-black tint, and we were informed that its volume during the day was about double the natural flow, the water being impounded during the night. The above comparative analyses show that the polluting elements, organic carbon and organic nitrogen, were much augmented—the former more than five-fold and the latter eight-fold. Nevertheless the water below the mill, although slightly tinted by dye, was in reality not more polluted than the *Thames* at Hampton; and in no part of the Gloucestershire streams which contribute to the *Frome* did we find any nearer approach than this to the condition of the frightfully polluted streams of Lancashire and Yorkshire.

The drainage liquors from wool factories are certainly not less polluting than those of calico printworks, but on these Gloucestershire streams their volume bears a very small proportion to that of the rivers with which they mingle.

We turn now to another *Frome* and *Avon*, draining the valleys in Somersetshire and North Wilts which are also an important seat of the woollen manufacture. The tributaries of the *Avon*, above Bath, are fouled in the same way and by very much the same processes as those in operation on the streams of Gloucestershire.

At Frome, Trowbridge, Bradford, and Bath, we collected samples of the rivers *Frome* and *Avon* above and below the towns, as also of the polluting liquids entering those streams; and the following table contains the results of our analyses of these samples:—

COMPOSITION OF RIVER AND DRAINAGE WATERS ABOVE AND BELOW BATH.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature, Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total
The *Frome* above the town of Frome and above Woodland's mill, Mar. 10, 1870.	8·3°	17·46	·326	·025	·004	·042	·070	0	1·55	6·59	5·81	12·40	trace	trace	trace
Ditto below Frome and Spring Garden's mill, Mar. 10, 1870.	—	26·10	·411	·046	·005	·191	·241	0	1·88	13·30	5·04	18·34	·76	·14	·90
Discharge from Messrs. Thompson & Le Gros's crape and silk mill, Mar. 10, 1870.	—	100·20	20·934	1·247	·360	0	1·543	0	2·80	—	—	—	3·20	7·60	10·80
The *Biss* above Trowbridge and Messrs. Brown & Palmer's mill, Mar. 11, 1870.	6·7	35·86	·325	·028	·003	·150	·180	0	1·93	21·62	5·04	26·66	0	0	0
Ditto below Trowbridge, Mar. 11, 1870.	8·9	39·10	·592	·074	·075	·108	·244	0	2·50	23·02	5·30	28·32	1·30	1·44	2·74
Waste liquor from Messrs. Webb & Co.'s woollen, dyeing, and scouring mill, mixed with town sewage, Mar. 11, 1870.	—	52·20	1·872	·211	·900	·115	1·067	·002	7·48	—	—	—	31·20	41·80	73·00
The *Avon* above Bradford, Mar. 11, 1870.	6·7	35·06	·357	·057	·008	·287	·351	0	2·00	20·03	5·81	25·84	·41	0	·41
Ditto below Bradford, Mar. 11, 1870.	6·7	35·20	·340	·071	·008	·306	·384	0	1·95	19·89	5·69	25·58	·56	0	·56
Ditto above Bath and Bath Easton, Mar. 12, 1870.	6·0	34·80	·238	·029	·004	·327	·359	0	1·90	20·10	4·66	24·76	0	0	0
Ditto below Bath, at suspension bridge, Mar. 12, 1870.	6·7	35·06	·259	·041	·028	·313	·377	trace	1·90	20·41	5·17	25·58	traces	traces	traces
Sewage from Broad Street sewer, Bath, Mar. 12, 1870.	—	89·00	7·904	4·530	10·980	0	13·572	·020	9·90	—	—	—	17·20	77·80	95·00
Ditto Avon Street sewer, Bath, March 12, 1870.	—	98·30	7·695	4·672	16·060	0	17·898	·020	18·00	—	—	—	18·50	37·70	56·20

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Wilts and Somerset woollen manufacture.

The *Frome*, being at this point a considerable stream, is but slightly polluted in passing through the town and mills of Frome, nevertheless the total solid matter in solution and the hardness are augmented by one half. The sample of waste liquor which we saw flowing into the river from Messrs. Thompson and Le Gros's crape and silk mill was, as the above analysis shows, of a very offensive character in respect of both dissolved and suspended organic matters; moreover the deposition of fœces around the drain outfall here was very unsightly, and showed that the excrements of the workpeople were turned into the river.

The *Biss*, a tributary of the *Avon*, above Trowbridge, is a tolerably clear and unpolluted stream of but small volume. Within and near the town it receives the drainage of several mills besides town sewage, and it issues from the last mill opposite Mr. Usher's malt house a black, turbid, and unsightly stream; analysis also shows that a considerable proportion of organic matters, both in solution and suspension, has been added to it; nevertheless, the tint of the dye-water causes the river here to look much fouler than chemical analysis declares it to be.

The main stream of the *Avon* flows through Bradford almost unpolluted. It here has a volume nearly one hundred times as great as its affluent below Trowbridge, so that, on reaching Bradford, the pollution of Trowbridge was scarcely detectable. At the time of our visit there was but little manufacturing activity in Bradford, and the river left that town with scarcely a perceptible increase of impurity. Indeed the volume of water here is so large that all the mills in Bradford, when at full work, would probably not produce a very marked effect upon it. Thence the *Avon* flows to Bath, receiving on its way the *Frome* and two other considerable but unpolluted streams.

It enters Batheaston above Bath a tolerably clear and but slightly polluted river, and although it receives the sewage of about 60,000, people in passing through Bath and its suburbs, the volume of its waters is so large that the total addition to the proportion of solid matters, both in solution and suspension, is only 0·26 part in 100,000 parts of water; and of polluting elements there is an increase of only ·021 part of organic carbon and ·012 of organic nitrogen. Owing to the deficient water supply, the sewage of Bath is exceptionally strong, being of about double the strength of London sewage. It is, we believe, the intention of the corporation no longer to waste this valuable fertilizing matter, which moreover renders the river unsightly, for we observed solid fœces floating down the stream.

There are several other localities of the woollen manufacture in England, as Witney, Kendal, Rochdale, Kidderminster, Newtown, and Wilton, to which reference will be made; but Yorkshire and the west of England are the only two considerable districts requiring the detailed description we have now given them, and we proceed, therefore, to describe the processes to which the characteristic river pollution of these districts is due.

3. The Processes of the Woollen Manufacture.

—In enumerating the various operations connected with the woollen industry, reference must first be made to the practice of sheepwashing, which, as carried on in brooks or tanks draining into them, occasionally creates a sensible pollution in many an upland stream during the spring months of the year. The character of the dirty water which thus finds its way into our rivers may be gathered from the following analysis of a sample of water pouring from the tank in which sheep were being washed last year on the farm of Rawburn on the southern slope of the Lammermoors, near Dunse, Berwickshire, sent to us by Mr. J. Wilson of Edington Mains in that county.

COMPOSITION OF SHEEP-WASHING WATER.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.						Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Mineral.	Organic.	Total.
Clean water supplied to washing pool, June 4, 1870.	30·74	·333	·117	·065	·391	·562	—	—	trace.
Water after sheep washing, June 4, 1870	181·00	25·819	3·942	1·914	0	5·518	64·48	51·96	116·44

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Pollution by sheep washing.

It was an extremely filthy liquid, much stronger in its powers of pollution than ordinary watercloset sewage, and far below the standards of purity which were proposed in our first report as those under which no water ought to be discharged into rivers. That such water has not created a nuisance, like that which is due to wool-washing in the manufacturing districts, is owing both to the wide distribution of a comparatively small evil, and to the fact that the pollution happens only during a few days at one season of the year. The quantity of home grown wool which thus receives its first washing is not one half* of the whole weight which is converted into textile fabric in our manufacturing districts; and moreover this washing is scattered over all the streams of the country as widely and as evenly as the sheep themselves; not confined, like that conducted by the manufacturer, to a few districts of limited area, whose streams are also fouled by the drainage of the large population whom he employs. In addition to this, it must be borne in mind that in and on the country streamlets, which every year are fouled by a few days sheep-washing, there is, in the spring and early summer, abundant vegetation, which must soon remove much of the highly fertilizing matter present in this washing water, to which its filthiness is due, and of which otherwise no doubt complaints would soon arise.

The fibres of wool as they come from the back of the sheep, even though it had been washed before it was shorn, are covered with a greasy brownish matter, the residue left behind on the evaporation of perspiration; and as this material protects the fibres from the attacks of moths, it is not desirable that it should be removed long before the processes of manufacture commence. A chemical examination of this greasy matter shows it to be composed chiefly of a species of potash soap, mixed with traces of acetate and carbonate of potash, and a peculiar animal matter of unpleasant smell. As a rule, the finer the wool the larger the proportion of this residue of perspiration which it contains.

Thus from one half to nearly two-thirds of Merino lambs' wool consists of this offensive material, whilst ordinary qualities contain of it only about one-third of their weight. From one-half to one-third of the grease is of a waxy nature and is left in the wool after the washing and scouring operations.

Wool Dyeing.—It is not our intention, neither is it necessary, to enter minutely here into the processes of wool dyeing, as this has been already done in the Report (1867) on the rivers *Aire* and *Calder* made to your Majesty by the first Rivers Pollution Commission, vol. I., page xxiii. It will suffice if to the following passage from that Report, descriptive of the process of dyeing black, we add a short description of the use of indigo and of some other dyes used in the production of fancy goods. The former Commission say:—

"The materials used in dyeing black, omitting indigo, are several different woods—" such as logwood, barwood, camwood, peachwood, fustic—and various salts, principally " copperas or sulphate of iron, iodine, 'argol,' or crude bitartrate of potash; to these " must be added an invention of a later date, 'chrome,' or bichromate of potash. Every " dyer may be said to have his own particular method of treating the wool; we do not " pretend to give a description which shall be absolutely true of any one case, but in " general the following may be taken as an outline of logwood dyeing *without* chrome:—

" A quantity of washed wool, say 200 lbs., is put into an iron vat or cistern holding from " 700 to 1,000 gallons of acid liquor made by boiling camwood and barwood with a " certain quantity of 'argol' and alum; by this process, which is called 'souring,' a " certain pink colour is given to the wool, and it is prepared for subsequent treatment by " logwood. After boiling for two hours the acid liquid is let off from the bottom of the " cistern by a valve or tap furnished with a grating, and the wool having been removed, " the vessel is again filled up with water. Bags of logwood reduced to the condition of " saw dust are now suspended in the liquor from a pole placed across the vat, so that a " clear extract may be obtained. A certain quantity of alum and argol is again added. " When the soluble parts of the logwood are supposed to be dissolved in the water, the " bags of exhausted wood are removed, and the wool which has been "soured" by the " last process is put into the vat. The whole is now kept at the boil for two or three " hours, at the end of which time the copperas, dissolved in a small quantity of water, is " added. The boiling is continued for some time longer, and the fire being withdrawn, " the whole is allowed to cool down to about 100° Fahrenheit, when the valve is opened

* At the meeting of the Statistical Society, on December 20th, 1870, Mr. A. Hamilton read a paper "On the Wool Supply," in which our home-grown wool was estimated thus: from sheep shorn, 124,017,421 lbs.; from lambs shorn, 2,470,158 lbs.; skin wool, 33,481,629 lbs.; total, 159,969,208 lbs. The amount of wool retained for home consumption in the year 1869, was stated as follows:—Domestic wool as estimated above, 159,969,000 lbs.; foreign and colonial imports, 255,161,000 lbs.; skin wool from sheep imported, 2,381,000 lbs.; total, 417,511,000 lbs. Exports,—domestic, 12,410,000 lbs.; foreign and colonial, 116,589,000 lbs.; total, 128,999,000 lbs. Leaving for home consumption, 288,512,000 lbs.

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" and the waste liquid is allowed to flow away.—This waste liquid is the great and chief " source of pollution of the rivers, so far, at least, as their offensiveness is concerned."

Wool dyeing.

We have only to add to the above description of this mode of black dyeing that the use of green copperas (sulphate of iron) has been nearly discontinued, bichromate of potash (chrome) being now employed in its place. This change in the process renders the waste black dye liquor to some extent less intensely polluting, but on the other hand, the somewhat increased difficulty which the chrome liquor opposes to purification has to be overcome.

It is a quantity of the blackest of this waste vat liquor that has been subjected to intermittent filtration in the laboratory of the Commission, with the result described in pages 33 and 34.

In dyeing the "superfine black" cloths of the West of England, the manufacturer depends on a basis of indigo colouring, or woading, as it is called. The process is conducted in the following way:—

In a copper or vat containing 1,000 gallons of water, about 40 lbs. of indigo are placed, and 10 lbs. of indigo or thereabouts are added weekly while the dyeing is going on. When the dye liquor is in proper condition, about 80 lbs. of wool are put into it for about 20 minutes; and three such quantities may be woaded thus in every 24 hours —a certain interval of time, and manipulation during it, being needed after one use before the liquor is fit for another. These vat liquors have, however, only an indirect relation to our subject. They are not directly discharged into the river. The same vat, its contents being constantly replenished, remains in use for a year or more: and when ultimately its accumulated sediment becomes excessive, it is emptied on to the dung heap. The wool thus woaded is, however, washed in running water, which of course carries off a certain quantity of vat liquor into the river. This woaded wool, after being thus washed, is then put into another vat of hot liquor prepared as follows:— About 60 lbs. of powdered dyewood—for the most part logwood, with, however, some barwood, camwood, or Brazil wood added to give a certain brilliancy of colouring— are boiled in about 1,500 gallons of water; the woody matter is then skimmed off, and the liquor receives 400 lbs. of woaded wool—a quantity equivalent to 560 lbs. of raw wool in the fleece,—and this is boiled for half an hour. Sixty lbs. of mordants (50 lbs. of alum and 10 lbs. of argol) are then added gradually, and the whole is boiled another half hour. The wool on being taken out is by some dyers washed, by others it is left unwashed. The liquor in which it has been steeped is then run to waste. The copper is filled again, and about 260 lbs. of logwood, with a proportion of the other dyewoods added, are again boiled for an hour or more in another charge of 1,500 gallons of water which is again carefully skimmed, and the same wool is replaced. About a quart of a solution of nitromuriate of tin, previously mixed with a quantity of the liquor, is then gradually added to the vat, and the whole is boiled for an hour or so; thereafter the wool is finally removed, and well washed in running water, being then fully dyed, and the vat full of liquor, is again sent to waste. Four vats full of the former waste liquor and four vats full of this deeper black liquor—12,000 gallons in all—thus go to waste per week from a single Gloucestershire manufactory where about one ton of finished goods (superfine black cloth) is made weekly. That is the extent to which this factory contributes to the colour of the Gloucestershire *Avon*.

Fancy goods, embracing in that term all other colours than black and blue, are for the most part dyed in the piece, after indeed all the other steps in the manufacture are complete. The piece of cloth already nearly finished is first passed continuously for an hour or two through a boiling liquor of argol, alum, nitromuriate of tin, or other mordant, being worked in an endless web over a windlass above the vat; and it is thereafter for an equal time similarly passed through the dye liquor. To take the case of a scarlet:—The liquor may be prepared in a copper holding 500 or 600 gallons of water; cochineal, with turmeric added to it (or weld, quercitron bark, fustic, or other yellow dyewood,) in a proportion, varying according to the tint of the scarlet that is wanted, is boiled in this vat. If a crimson be desired, these yellow dyes are not added to the cochineal. Eight lbs. to ten lbs. of cochineal and from three to ten lbs. of the mixed yellow dye, or thereabouts, are used for every piece of cloth to be dyed scarlet. A very small proportion of the weight of these dye stuffs is taken up by the cloth, the rest goes to waste. In a Gloucestershire woollen factory making 20 tons of goods annually, about four vats full, or 3,000 gallons of this spent liquor, are discharged weekly into the river. The subsequent washing of the dyed cloth makes a slight addition to the pollution thus occasioned.

For the dyeing of other tints, the magnificent colours now manufactured from coal tar, and known as *aniline colours*, are becoming gradually more employed, whereby the use of

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Cloth manufacture.

dye woods will be proportionately diminished in this branch of industry. This change in the character of the dye stuffs will have some influence in diminishing the pollution of rivers, for in the first place it reduces the amount of waste dye woods which are generally cast into the nearest watercourse, and in the second place the residual liquids of the dye vats are of a less polluting character and more easily purified; since, unlike the aqueous extracts of dye woods, they contain but very little extraneous matter either in solution or suspension. Thus, both as regards suspended and dissolved impurities, the introduction of aniline colours into the woollen industry must be regarded as favourable to the mitigation of river pollution. Nevertheless, the influence of these changes in the abatement of nuisances is at present scarcely perceptible, because the quantity of wool dyed black with indigo and logwood is overwhelmingly large as compared with the weight of that material tinted by all other dye stuffs.

At Kidderminster, wool dyeing is extensively carried on in connexion with the carpet manufacture. The washing of the dyed warps is performed in the river itself, the hanks of worsted being thrown over revolving reels so that the lower half of the hank is immersed in the water. At Wilton, again, they are washed by being simply hung on hooks and immersed in the rapidly flowing *Wily*. In both these cases the dyed goods carry with them into the river nearly as much of the liquid contents of the dye vats as they can retain in their pores.

Where the warps are printed in order to the production of a pattern in the course of weaving, the process is somewhat different, as appears in the following extract from our report (1870) on the *Mersey* and *Ribble* basins, Vol. I. p. 38:—

"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, contained a large proportion of nitrogenous organic matter and ammonia, sufficient to render it valuable for irrigation, 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

The Cloth Manufacture.—A complete list of the several processes which short wool undergoes in the manufacture of fine cloth, includes upwards of forty successive steps between the fleece and the finished goods. The wool is sorted, willied* to extract the dust, and scoured and washed to extract as much as possible of its natural grease. It is then hand-picked, woaded, washed, and dyed, and washed again and dried in the centrifugal machine. It is again hand-picked, and once more willied to extract any scraps of dye ware or waifs of any kind it may have caught; it is machine-picked for the extraction of burrs, and then oiled and teased, carded, and spun. The warps are then spooled, sized, and beamed.† Then comes the weaving, after which the web is carefully examined and hand-

* "Willied," *i.e.* torn and shaken in a machine by rapidly revolving teeth.

† "Spooled, sized, and beamed," *i.e.*, wound off the bobbins on which they have been spun, passed through a weak solution of glue, and placed on the weaver's beam.

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mended where required. It is then soaked in a ley of soda, urine, and other detergents to remove the oil which the wool, charged with it before carding, has carried ever since. This is washed out next day, and the web is again placed in the centrifugal dryer. It is then burled, *i.e.* carefully examined for the extraction of knots and undyed points or scraps. It is charged with soap and fulled, then washed and once more dried, then roughed up or dressed by teazels, and passed several times through the shearers; re-roughed and dried, and shorn successive times again; twice pressed; eight or nine times boiled on rolls, a process which takes as many days; then scoured and racked, *i.e.* stretched on frames; it is shorn many successive times once more, then picked and marked, and four times pressed; after which it is measured up and packed for sale.

The use of water has occurred at least ten times throughout this series of operations. In the first scouring and washing of the wool, in woading, washing, dyeing, and again washing, in segging,* fulling, and washing the woven piece, and in roll boiling, and a last scouring. In the first washing of the sorted wool, in the washing after dyeing, and in washing the web both before and after fulling, the water leaves the wool mill charged with grease and oil—united with the soda and ammonia of the various detergent substances, such as urine, and pig's dung, which have been employed—charged also with all the waste colouring matters it can carry off. The other waste substances of the manufacture, which do not necessarily find their way into the channel of the river, are the dust from the willying and teasing processes, and the worn-out teazels from the roughing machines, which may be serviceable for manure; the short clippings from the shearing machines, which are available for the upholsterer, or lastly for manure; and the furnace ashes which ought to be employed upon the roads. From certain of the washing waters, in which the oil and grease, saponified and taken up, are present in sufficient abundance to make the process of recovering the oil remunerative, a certain proportion of the oil purchased by the manufacturer is recovered. And it may be added that, in the case of black and blue cloths, the clippings from the shearers, as well as the "must" or residuum from the processes of the oil extractor, are treated in some localities for the recovery of the indigo which they contain.

With these exceptions, and of course with the exception of so much of the original wool and dye-stuffs as exists at the close of all these processes in the finished goods, the whole of the materials imported into a cloth mill find their way into the drain from it, and are carried to the neighbouring river. The consequence is obvious enough in every district of the woollen manufacture, as already described in the valleys of the *Aire* and *Calder* in Yorkshire; and it is also visible in the valleys uniting below Stroud in Gloucestershire; in the valleys above Bath in Somerset and Wiltshire; and on certain tributaries of the *Tweed*. The once colourless transparent waters of these districts are now opaque and foul, and spoiled for almost all domestic purposes.

The following are the manufacturing processes in detail to which the change is due: The raw wool is first boiled in probably, on the average, half its weight of urine besides 5 lbs. (to every cwt.) of other detergent substances. All these are afterwards carefully and thoroughly washed out of it, and the whole of the filthy water passes into the stream. The wool is then woaded and washed, and dyed and again washed; and the coloured water from all these washings also passes away. The clean wool receives, after being dried, 10 lbs. or thereabouts, of sweet oil to every cwt. of it before being carded; and after being spun, the thread is passed through a weak glue before weaving. After weaving, all these matters are taken out of the web by soaking and kneading it in a mixture of urine, pig's blood, pig's dung, and soda; and after being washed free of all these detergent substances it is fulled along with about 12 lbs. of soap per piece of cloth, —a process which felts the material together and causes the threads to shorten. Some two or three lbs. of fuller's earth are subsequently used, and this with all the soap is then washed out; and the subsequent use of water, as in roll boiling, is not attended with any further drainage of filthy material into the stream.

We have given below two estimates of the quantity of the various materials used in the manufacture of rather more than 500 pieces of cloth (the approximate weekly manufacture of the Stroud district) out of the 30 tons of wool, or thereabouts, which are required for that purpose. Under the first it appears that 12 cwt. of soda and 3,000 gallons of urine are used in washing the raw wool; and all this, carrying with it 8 tons of natural grease and about 4 tons of other dirt goes into the stream. In the subsequent processes one ton of soda, three tons of soap, about two tons of oil, one ton of glue, upwards of 500 gallons of pig's

* "Segging," *i.e.*, soaking in a ley of soda and urine ("*seg*").

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blood, as much pig's dung, and more than 10,000 gallons of urine are employed; besides, probably, 2 tons of fuller's earth. In addition to this, about 20 tons of dye wares, and 2 tons of alum, argol, and other mordants have been used. A considerable quantity of colouring matter is washed into and pollutes the neighbouring brook; but it is stated that not much of the spent dye wares escapes, as they are skimmed out of the coppers and burnt or cast upon the dung heap. With this exception, and with the exception also of a certain proportion of the oil, the whole of the waste materials go into the stream. About 10 lbs. of oil are used for every 100 lbs. of wool in carding; and the first thick runnings of the dirty water from the fullers, containing some of this oil, are subjected to the action of sulphuric acid; and the grease thrown up is removed for further treatment by the oil extractor. Twenty per cent. of this stuff is water, 40 per cent. pure oil, and the remainder consists chiefly of woollen fibres.

The second estimate of the waste connected with 500 pieces of cloth gives 10 tons of dirt and grease as being taken out in the first washing by means of 15 tons of urine and 27 cwt. of soda, soap, and other detergents; about two tons of oil as being used in carding; 6 or 7 cwt. of glue in sizing; and in the subsequent washing nearly 30 cwt. of pig's dung, 15 cwt. of soda, 50 cwt. of soap, about 8 cwt. of fuller's earth, and nearly 30 cwt. of common salt; about 21 tons of dye stuffs having been used. Putting these two estimates together, we have the following table of waste stuff from the weekly manufacture of rather more than 500 pieces of broad cloth in the Stroud district:—

Materials used or extracted.	Estimates. No. 1.	Estimates. No. 2.
Grease } removed from	8 tons	} 10 tons.
Dirt } raw wool	4 „	
Urine	14 „	15 „
Oil in carding	2 „	2 „
Glue	10 cwt.	7 cwt.
Pig's dung	2½ tons	30 „
Pig's blood	2¼ „	—
Urine	25 „	—
Soda	1 „	15 cwt.
Common salt	—	30 „
Soap	2½ tons	15 „
Fuller's earth	2½ „	8 „
Dye stuffs	20 „	} 21 tons.
Alum	2 „	

The difference between these estimates is principally in the use, in the former of them, of so large a quantity of pig's dung, pig's blood, and urine in the scouring process before fulling. This, however, we believe, still represents the ordinary practice; and we thus learn that about 40 tons of stale urine charged with grease and other dirt, together with about 400,000 gallons of coloured waters from spent dye vats, are weekly discharged into the stream from the manufacture of 500 pieces of cloth. This is a quantity equal to the urine discharged in that time by a population of about 5,000 of all ages (Report, 1870, on *Mersey* and *Ribble* basin, vol. I. p. 27); and though this urine, now collected from house to house, would no doubt have found its way, without the interference of the manufacturer into the ordinary drainage of the district, yet the effect upon the foulness of the stream is certainly aggravated by its concentrated and direct discharge in this way.

The above statement describes the wool manufacture in its most elaborate and finished style, including therefore all the processes to which the raw material is subjected, whatever the fabric that is made, whether fine or inferior cloth, flannels, blankets, or carpets. In all cases the processes, apart from the mere mechanical operations, are included within the list that has been given. The wool is deprived of its natural grease and foreign matters, and thereafter dyed; it is then supplied with oil or other lubricant, which is washed out of it, after it has served its purpose of conferring the necessary softness and flexibility for spinning and weaving; and thereafter it is fulled and felted, scoured, and dried. Some of these steps in the manufacture are omitted in some places and for some purposes, and there are various modes of conducting them; thus in the Wiltshire and Somersetshire district there is a larger manufacture of fancy goods and a greater variety of dye wares is used; and the process of washing, after dyeing, is carried on, not in

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machines or vats within the mill, but in open-work or latticed vats immersed in the midst of the stream. The water flows through these cages, and carries off the red or green or yellow colouring matter which has not been fixed upon the yarn or wool; and as every fresh parcel of newly-dyed material is brought, another cloud of wasted colouring matter is added to the river; the whole, however, soon resulting, as at Trowbridge, for example, in a blackish blue, opaque enough when seen in the mass, though scarcely perceptibly tingeing the water in a small cup or glass. The above description of the operations pursued in the Stroud valleys, however, will apply to the manufacture generally of fine and short wools wherever carried on.

The various processes of the long-wool manufacture are attended with a very similar, though, in proportion to the quantity of the raw material manufactured, a less filthy discharge. In the Yorkshire worsted manufacture, English skin wools and foreign long wools are used. They are torn and willied, washed in soap and water, perhaps dyed, then dried, oiled, and scribbled, carded, combed, and spun; and the yarns are afterwards scoured for the removal of the oil. A pack of the original wool (240 lbs.) is thus reduced to about 180 lbs. of the manufactured goods; and 20 to 30 lbs. of soap, and 10 to 15 lbs. of alkali, and about a gallon of liquid ammonia, or its equivalent in urine, have been employed in the scouring processes to which the pack of wool has been subjected; and 1½ gallons of olive oil has been used to prepare the wool for the combing and spinning processes. This corresponds to nearly ·8 lb. of oil, ·7 lb. of alkali, and 1·4 lb. of soap to every 10 lbs. of the finished goods.

Elsewhere, as at Witney and Dewsbury, and at Kidderminster, Durham, Kendal, and Wilton respectively, long wools are the staple material of the manufacture of blankets, carpets, and rugs; and at Newtown and other places wools of various quality are used in the flannel manufacture.

Blanket manufacture.

The Blanket Manufacture.—The contrast between the effect of the blanket and that of the cloth manufactures is seen on comparing the *Frome*, at its source and below Stroud, with the *Windrush* a tributary of the *Thames*, above and below Witney. The water of the *Windrush*, which, like that of the Gloucestershire stream, drains from a district chiefly of the upper oolite, reaches Witney not altogether unpolluted, but it is probably originally of very much the same character as that of Chalford spring, (see page 14), which feeds the *Frome*. It drains an area of about 100 square miles above Witney of very much the same kind of soil; and below Witney, where we took a sample, it is considerably more than double the volume of the Gloucestershire *Frome*. Above this point there are four blanket manufactories, together with the small town of Witney and its 3,000 inhabitants, which drain into the river. At these four mills about 140 packs of long wool, of 2¼ cwt. each, are used weekly. This amounts to about 15 tons of wool—one half the quantity used weekly in the neighbourhood of Stroud. It loses one-sixth of its weight in the course of manufacture into blankets. The wool is torn and willied, and oiled (10 lbs. of oil to every cwt. of wool), carded, and spun—unwashed; and not until the blanket is woven is it subjected to any cleansing process. It is then put into the "stocks" along with about 6 gallons of urine and 8 lbs. of fuller's earth to every charge of 120 lbs., and there milled and fulled for several hours. It is thereafter washed, and all the soapy, greasy, and refuse matters go direct into the river. This is almost the whole process, so far as any drainage from the mill is concerned, for comparatively little dyeing has hitherto been carried on. Latterly, however, there has been a considerable manufacture of particoloured blankets, so that red and yellow and blue, and even black yarns are produced to some extent for this purpose; and thus the usual spent dye-vat liquors, as well as the washing water—the washing as in the Trowbridge district, is carried on in the stream—do to some extent pollute the river. The comparatively large volume of the *Windrush* makes this pollution less mischievous than it would otherwise be, though we heard of some destruction of fish in consequence of it. Owing to a complaint of this kind Mr. Charles Early conveys his mill drainage into a settling pond dug upon an island in the river opposite his works; but at the time of our visit the pond was filled up with the solid deposit, and an extremely offensive liquid was flowing from it into the river. No attempt is made at Witney to recover from the waste water of the fulling process, any of the oil which had been added to the wool previous to carding.

A portion of this oil is recovered in the Yorkshire blanket factories. We went through the extensive works of Messrs. Cook, Wormald, and Co., at Dewsbury, where nearly 1,000 tons of woollen goods are manufactured annually—a larger quantity than

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the aggregate of the Witney manufacture; and the following figures, which this firm have supplied to us, indicate both the kind and quantity of the polluting materials which drain from this manufacture. Messrs. Cook and Co. make yearly 2,000,000 lbs. of goods, and dye 500,000 lbs., of the value of 200,000*l*. They discharge yearly 40,000,000 gallons of refuse waters which had been employed in washing and dyeing, and the whole of this, except about 6,000,000 gallons of the strongest soapsuds which are treated for the recovery of the oil, flows into the river *Calder*. They use yearly 33,600 lbs. of dye woods, 3,000 lbs. lac, 3,000 lbs. cochineal, and 67,200 lbs. of rough and rolled brimstone as bleaching material,—none of the last, however, reaches the river. They also use yearly 200 tons of various oils worth 9,000*l*., 110 tons of soap, 25 tons of alkali, and 50,000 gallons of urine. A portion of the soapsuds is treated for the recovery of the grease, and 130*l*. is thus annually gained. One hundred tons of waste wool are collected in the process of carding; 2,000 tons of coal are burnt annually; and the 300 tons of slag and ashes from the engine furnaces are employed upon the roads. The excrements of the workpeople (530 hands are employed) are partly utilised by earth closets, and partly drain into the river.

The following table gives the results of our analyses of the drainage water from two blanket factories, that of Messrs. Cook, Wormald, and Co., at Dewsbury, and that of Mr. Charles Early at Witney, and it will be seen that in the latter case the liquid is much richer in total combined nitrogen, and therefore in fertilising power, than average London sewage. The table also gives the results of analyses of the water of the *Windrush* above and below the town of Witney, and of the sewage of Witney from the sewer outfall at Gun Hole ditch; but eventually, and before it reaches the river, the sewage becomes mingled with at least one hundredfold its volume of clean spring water.

COMPOSITION OF THE WINDRUSH AND OF DRAINAGE WATERS FROM BLANKET MILLS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness.			Mineral.	Organic.	Total.
										Temporary.	Permanent.	Total.			
	°														
The *Windrush* above Witney and New Mill, Dec. 9, 1870.	3·1	28·30	·105	·033	·001	·293	·327	·020	1·13	18·00	5·00	23·00	traces	traces	traces
The *Windrush* about ¾ mile below Witney, Dec. 9, 1870.	1·7	28·24	·123	·033	·003	·304	·339	·040	1·10	18·30	5·00	23·30	traces	traces	traces
Drainage from Mr. Charles Early's blanket mill, Dec. 9, 1870.	—	678·00	120·710	19·508	·940	0	20·282	·004	35·60	—	—	—	60·40	314·20	374·60
Witney sewage from Gun Hole sewer outfall, Dec. 9, 1870.	—	227·20	37·974	13·734	25·720	0	34·915	0	40·00	—	—	—	7·68	35·52	43·20
Washing water from Messrs. Cook, Wormald, and Co.'s blanket mill at Dewsbury, Jan. 27, 1871.	—	29·40	4·089	·383	·117	0	·479	·032	2·75	—	—	—	2·84	15·28	18·12

It is probable that the *Windrush* receives considerable accessions of spring water as it passes through Witney, since, notwithstanding the admixture of the manufacturing and town drainage, both very rich in chlorine, it actually contains less of this element below than above the town.

The Flannel Manufacture.—The flannel manufacture, is extensively carried on at Newtown, Montgomeryshire; eighteen or twenty mills being there congregated on the *Severn*. In this case, too, there is little or no wool washing. The wools as bought are willied, oiled, carded, and spun, and the yarns are then washed in urine and thereafter woven. No attempt is made to recover the oily matter used; the whole of the waste liquid goes into the river, which is here a body of water large enough to hide the evil done in the case of a small town like Newtown, where little dyeing is carried on.

The following table shows the highly polluting character of the refuse liquor from the washing of flannel. It also shows that the volume of river water is here so vast as to render the refuse of Newtown scarcely detectable by chemical analysis. The proportion of organic nitrogen is only increased by ·002 in 100,000 parts of water, and the proportion of chlorine by ·03 part in 100,000.

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The carpet manufacture.

COMPOSITION OF RIVER AND DRAINAGE WATER ABOVE AND BELOW NEWTOWN.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness.			Mineral.	Organic.	Total.
										Temporary.	Permanent.	Total.			
	°														
The *Severn* above Milford mill, Newtown, April 27, 1870.	8·9	6·60	·123	·016	·003	·010	·028	—	1·35	0	3·09	3·09	trace	trace	trace
The *Severn* below Newtown, April 27, 1870.	10·5	6·02	·120	·018	·001	·010	·029	—	1·38	·35	2·28	2·63	trace	trace	trace
Waste liquor discharged into *Severn* from flannel washing at the Cambrian Flannel Co.'s mill, April 27, 1870.	—	1248·0	446·353	91·185	80·012	0	157·077	0	160·0	—	—	—	346·0	1733·4	2079·4

The composition of the waste liquor from flannel washing proves it to be, in the case examined, a most valuable manure, one hundredweight of it being worth, for this purpose, more than one ton of London sewage. The discharge of such liquors into rivers is a reckless waste.

The following analysis of a sample of wool suds (the liquid in which raw wool has been scoured) from Messrs. Kelsall and Kemp's Flannel Manufactory, in Rochdale, was given in our Report (1870) on the *Mersey* and *Ribble* basins (Vol. I., page 38), and is another illustration of 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 Carpet Manufacture.—In the carpet manufacture the pollutions due to washing and to dyeing or printing, are of a similar kind to those of the cloth and blanket manufactures. The total result of an industry, principally of this kind, is seen in the condition of the river *Stour* above and below Kidderminster. The river *Stour* reaches Cookley above Kidderminster in a fair though not entirely unpolluted condition; as it leaves the town it is a strongly coloured and offensive stream useless for man or beast. The following table contains the results of the analyses of the samples which we took above and below the town. Between these points, however, considerable and comparatively unpolluted affluents join the river; and the water used in dyeing is of a very pure description, being pumped from deep wells in the new red sandstone. Hence, although much organic and some saline matter is poured into the river as it passes through Cookley and Kidderminster, it still issues from the latter town containing somewhat less total solids in solution than when it entered the former. It will also be seen that the proportion of nitrogen as nitrates, and consequently that of total combined nitrogen, is reduced considerably, a circumstance that we have frequently observed to occur when foul town sewage or other similar polluting liquid is mixed with river water containing nitrates, the nitrogen of the nitrates being evolved as gas during the subsequent putrefaction. We have analysed a sample of the deep well water supplying Messrs. Brenton and Lewis's Carpet Mill, and the results are given in the following table, which also exhibits the composition of the mixed sewage taken at the outfalls of three sewers into which many dye works discharge their refuse. It will be seen from these analytical results that although the organic matter present in the sewage is only slightly nitrogenous, yet there is a considerable proportion of ammonia and no constituent which would be likely to hinder its use for irrigation.

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COMPOSITION OF RIVER AND OTHER WATERS ABOVE AND BELOW KIDDERMINSTER.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.											Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
The *Stour* above Cookley, April 28, 1870.	11·1°	42·84	·268	·039	·014	·352	·403	—	6·85	9·68	9·94	19·62	·34	0	·34
The *Stour* below Kidderminster, April 28, 1870.	13·6	40·00	1·224	·179	·016	·182	·374	—	6·32	10·33	9·55	19·88	1·28	·52	1·80
Deep artesian well in Messrs. Brenton & Lewis' carpet mill, April 28, 1870.	12·2	18·26	·015	·004	0	·169	·173	—	1·60	4·79	6·59	11·38	0	0	0
Mixed sewage from Calton's Lane, Daddle Brook, and Pitch Lane sewers, April 28, 1870.	—	155·20	18·849	·363	6·760	0	5·930	0	16·40	—	—	—	31·30	124·50	155·80

The analyses of the *Stour* above Cookley and below Kidderminster show that, in passing these places, the river water acquires nearly fourfold the organic carbon and organic nitrogen which it previously held in solution. The intensity of the pollution of the *Stour* below Kidderminster is, however, only about half that of the *Irwell* below Manchester.

We submitted to analysis samples of the water of the *Wear* above and below Durham, where there is a large carpet factory creating to some extent the same kind of pollution as that which exists at Kidderminster; but the pollution of the river by the refuse of this solitary mill was obviously overborne by that due to the sewage of the city, with its 14,300 inhabitants, and to "chemical works, gasworks, tanyards, and mines." Indeed the aggregate pollution of the river after its passage through Durham was not, at the time of our inspection, greater than that of the Thames at Hampton, and we saw salmon leaping opposite Messrs. Henderson's works. The following are the results of the analyses of the samples which we collected:—

COMPOSITION OF WATER OF THE WEAR ABOVE AND BELOW DURHAM.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.										Remarks.
		Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
The *Wear* above Durham, Oct. 5, 1870.	11·7°	49·56	·166	·030	·010	0	·038	4·60	11·31	10·89	22·20	Slightly turbid.
The *Wear* half a mile below Durham, Oct. 5, 1870.	12·2	61·46	·220	·058	·017	·026	·098	5·70	15·99	12·56	28·55	Slightly turbid.

These results show that in passing through Durham the *Wear* has the proportions of its organic elements (organic carbon and organic nitrogen), and ammonia increased about one-half, whilst its total combined nitrogen is more than doubled, and its total dissolved matters and hardness augmented by about one-fourth. The suspended matters were scarcely perceptibly increased, but it must be borne in mind, that our sample below the town was taken at a weir which formed practically a depositing reservoir of nearly still water half a mile in length; above this the river obviously contained a considerable amount of suspended matter, which, deposited for a time behind the weir, will be carried down the stream when the river is in flood.

The Woollen Yarn and Rug Manufactures.—There is an important seat of these manufactures at Kendal in Westmoreland. Here the raw material is subjected to the usual scouring and cleansing operations, after which it is dyed and then washed in the

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The woollen yarn and rug manufacture.

river. The performance of these washing operations in the open stream, as now carried on at the different places which we have visited, is in several respects very objectionable; in the first place it produces, upon a small stream especially, a very marked pollution of the water, and secondly, there would obviously be a great difficulty in any enactment prohibiting river pollution, in prescribing, wherever this practice prevails, any test which would disclose quantitatively the amount of injury done to a stream by any given factory. We have therefore carefully inquired into the necessity for performing the cleansing process in the open river; the result of the inquiry has convinced us that, in certain cases at all events, it would seriously interfere with the success of the dyeing operations if the practice were prohibited, since it is frequently absolutely necessary that the last traces of extraneous colouring matter should be removed from the dyed yarns before they are woven, and this can only be effected by the use of such vast volumes of water as, practically, are only obtainable in a mill race or river bed. If the yarns be imperfectly washed, the colours which come into juxtaposition when they are subsequently woven run into each other, and thus impair each other's beauty and brilliancy. After a full consideration of this process of wool washing it is satisfactory to be able to state that the operation may be carried on with scarcely any sensible injury to rivers if the manufacturer adopt the simple precaution of passing the yarns or other goods through squeezing rollers, after they leave the dye vats and before they are washed in the stream. The polluting liquor, thus expressed from the goods, would be kept upon the premises to be treated by any of the remedial processes hereafter described.

The river *Kent* enters Kendal a large and comparatively unpolluted stream, fit for most household and all manufacturing purposes; it leaves it, sometimes obviously polluted by dye water, sewage, and the refuse from tanneries; at other times the pollution is scarcely perceptible to the eye, for the flow of the river is very swift, and the occasional discharges of coloured and muddy water are rapidly swept beyond the boundaries of the borough.

We collected samples of the river water above and below the town, and the following table gives their composition, as well as that of a sample of water flowing into the river from a washing machine in Messrs. John J. and William Wilsons' rug factory, in which scarlet yarn was being washed:—

COMPOSITION OF RIVER AND DRAINAGE WATER ABOVE AND BELOW KENDAL.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature. Centigrade.	Dissolved Matters.										Suspended Matters.		
		Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Mineral.	Organic.	Total.
The *Kent* above Kendal and Messrs. Whitwell and Co.'s carpet works, Mar. 17, 1871.	3·3°	6·48	·149	·020	0	·044	·064	·90	0	3·90	3·90	0	0	0
Washing water from scarlet yarn entering the river from Messrs. Wilsons' rug factory, Mar. 17, 1871.	—	11·60	·624	·108	·040	·012	·153	3·10	1·09	3·77	4·86	·92	8·68	9·60
The *Kent* below Kendal and Low Mills, Mar. 17, 1871.	4·2	7·56	·217	·036	·001	·058	·095	·90	0	4·03	4·03	trace	trace	trace

In passing through Kendal, therefore, the elements indicative of pollution by organic matter were, at the time our sample was taken, increased by about one half, whilst the water was obviously to the eye polluted with suspended matters, and, half an hour previously, it had looked in this respect much worse. The water in which scarlet yarn was being washed at Messrs. Wilsons' rug factory was polluting only by reason of the fibres of yarn which it held in suspension. After these were strained off or allowed to subside the effluent water was far below all the standards of impurity which we have suggested as those above which dirty water should not be admitted into rivers. In the case of the Kendal factories, as soon as the sewerage works, now in course of construction, are complete, all such liquids will be conveyed to the sewage farm instead of passing into the river. The rainfall of Kendal, is however, very high, being 53 inches per annum, and therefore, in the interests of the irrigation works it would be advisable, especially in winter, to allow such polluted waters, as the one just mentioned, to subside for a couple of hours in a tank, and to run off a large proportion of the clear and unpolluting water

PART I. DESCRIPTIVE.

Purification of polluting liquids.

into the river, whilst the fibre suspended throughout the remainder may be discharged into the sewerage system; or the residual liquor might be passed through a Needham and Kite's press, by which the fibre would be retained, and the clear and unpolluting effluent water discharged into the river. In this way the strength of the sewage would be preserved.

At the time our sample was taken, the *Kent* below Kendal was somewhat superior, in the quality of its water, to the *Thames* at Hampton, but without the remedial measures now being adopted, there can be no doubt that with the extension of the woollen trade in the town and neighbourhood, the pollution of the river, which has already been complained of by Your Majesty's Inspectors of salmon fisheries, would soon become much worse.

REMEDIES.

SECTION B.—REMEDIES.

Having now fully described the character of the water which enters the chief seats of the woollen trade, the deterioration and pollution of this water on its passage seawards, and the nature and source of the various polluting materials which transform it from clear, useful, and wholesome streams into muddy, useless, and offensive rivers, we have now to consider the means available for remedying the evils described, which are everywhere recognised and deplored.

The polluting materials which foul the rivers of the woollen districts belong essentially to the same three categories as those which work similar mischief in the valleys of the *Mersey* and *Ribble*. They are:—

First, solid refuse, such as cinders, ashes, spent dye woods, and the sweepings from houses, yards, streets, and roads.

Second, sewage or the solid and liquid excrements of the population.

Third, foul liquids discharged from manufactories.

The materials enumerated in the two first-named categories are, almost without exception, the same in the river basins devoted to the woollen industry as in those where the various branches of the cotton manufacture have located themselves. We have in our first and second reports fully discussed the remedies which would, if judiciously applied, so far remove the evils arising from solid refuse and sewage as to render the rivers again clean and sweet, and useful to the industry of the district, so that although the water would still be unsafe for drinking purposes, it would be fit for household washing and cleaning operations. We also stated that, so far as regards these categories of polluting materials, an Act might at once be passed prohibiting altogether the discharge of solid refuse and sewage into rivers, the enactment being made to take effect immediately as regards solid matters, but a reasonable time after the passing of the Act being allowed to Corporations, Local Boards, and others, for the execution of the necessary works for the purification of sewage. Our inquiries in the river basins occupied by the woollen trade have in no respects modified these views, neither have they revealed any new facts regarding the amelioration and disposal of these refuse matters; we have therefore nothing to add to the full discussion which this section of our investigations received in the report just alluded to; and we proceed at once to consider the treatment of foul liquids from woollen manufactories, with a view to prevent the pollution of rivers.

PURIFICATION OF POLLUTING LIQUIDS FROM WOOLLEN MANUFACTORIES.—In addition to the sewage of the workpeople the chief polluting liquids discharged from woollen factories are the following:—

Waste liquid from dye vats.

Waste liquor from wool scouring and washing.

Water which has been used for washing the dyed, scoured, or fulled goods.

These liquids are usually allowed, more or less, to mingle together upon the premises of the manufacturer, and we consider that the first step to be taken in remedying river pollution from this source consists in establishing the means of keeping the very foul portions of these liquids separate from those of comparatively much larger volume, but which possess so slight a polluting character as to render them directly admissible into watercourses without infringing the standards of purity which we have suggested. (First Report, 1870, *Mersey* and *Ribble* basins, p. 130.)

The following analytical table exhibits strikingly the great importance of this separation, for it shows that the dye-vat liquor is many hundredfold, and the scouring liquor many thousandfold more polluting than the washing water, which last is far below our suggested standards of polluting liquids, and could be discharged into any stream without appreciably fouling it:—

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Treatment by evaporation.

COMPOSITION OF POLLUTING AND NON-POLLUTING LIQUIDS FROM WOOLLEN FACTORIES.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Mineral.	Organic.	Total.
Waste liquid from woollen dye-vats.	107·60	48·969	3·321	·492	0	3·726	—	24·08	77·92	102·00
Waste liquor from wool scouring and washing.	1099·40	132·480	9·880	54·610	0	54·850	traces	870·95	2611·65	3482·60
Washing water from dyed and scoured goods.	29·62	·189	·053	·011	·344	·406	·002	·72	·88	1·60

Such a separation of polluting from comparatively innocuous liquids would present no formidable difficulties to the manufacturer, whilst it would greatly facilitate the purification of the really noxious portion of the discharges, inasmuch as the volume of polluting water requiring remedial treatment would be immensely reduced. We find in fact that a very large proportion of the water which has been used in washing woollen goods may be discharged at once into rivers without causing any serious pollution to the latter. Indeed it may be stated as a general proposition, that the polluting materials in the woollen trade are diffused through a much smaller proportion of water than is the case in the cotton-dyeing and -printing trade, where the chief dye stuff used, madder, requires a very large volume of water for the extraction of the colouring matter which it contains. Consequently it may be inferred that the remedies required for the purification of liquid refuse from the woollen trade will entail less trouble and expense than those which we have recommended for the calico printing industry. Moreover these liquids from woollen factories, both on account of their greater concentration and by reason of their containing a larger proportion of combined nitrogen, which confers upon them a considerable manure value, are generally well adapted for the agricultural remedy. Furthermore, the extraction of highly polluting matter from these liquids, as for instance the oil from the soapsuds obtained in the washing both of the raw and manufactured material, yields, in some cases, a handsome profit. Partly on this account, and partly because of proceedings in equity or of actions at law, instances are not wanting of more or less successful attempts at the purification of these refuse liquors.

Treatment of Refuse Liquids by Evaporation.—The great concentration and consequent small bulk of the more highly polluting liquids produced in the woollen manufacture, render feasible a method of disposing of them which would be utterly impracticable in the case of more dilute and voluminous foul waters; we allude to their evaporation. Under even moderately favourable circumstances 1 lb. of coal will evaporate one gallon of water, consequently, in cases where the volume of the highly polluting liquids is known, the cost of thus disposing of these liquids is easily ascertained. At Messrs. Caleb Metcalf and Co's. dye works at Kendal, we were informed that the aggregate amount of such polluting liquor daily discharged from these works into the *Kent* is 240 gallons, consequently the daily expenditure of 240 lbs. of coal would entirely prevent the pollution of the *Kent* from these works, if, in addition, the dyed goods were passed through squeezing rollers before being washed in the river. Now at the somewhat extravagant price of 15*s*. per ton of coal, this most effective and simple mode of purification, or rather prevention, would cost rather less than 1*s*. 8*d*. per working day; again, to take the case of one of the largest cloth factories in the west of England district, turning out one ton of superfine cloth weekly, we are told that 12,000 gallons of strong liquor are weekly discharged into the river. The evaporation of this liquid would require an expenditure of 5·4 tons of coal weekly, costing at 15*s*. per ton, 4*l*. 1*s*. Even such an expenditure as this cannot be regarded as an insupportable tax upon a large factory turning out one ton of finished goods per week, valued at 770*l*.* Nevertheless, whilst we adduce this mode of getting rid of polluting material as one applicable under any, even the most adverse, circumstances, we must not be understood as recommending it to be employed, at all events exclusively, in any case where the remedies mentioned below would be applicable. As an adjunct to other modes of purification, however, we believe that evaporation might be resorted to in all woollen factories, wherever situated, with ad-

* See Evidence of Messrs. William Playne & Co., Longfords Mills, Minchinhampton, Gloucestershire, Vol. II., Section 2.

PART I. REMEDIES.

Purification by chemical agents.

vantage; in all these factories heat, if not steam power, is employed, and in many cases the waste heat from furnaces could be utilized in evaporating such liquids, whilst in all, they might be run into the ashpits of furnaces, where the radiation of the fire above, the dropping of red hot cinders, and the rapid current of air, would all aid in effecting at once rapid evaporation of the liquor and preservation of the fire-bars from the destructive effects of the very high temperature to which they are often raised with a dry ashpit beneath them.

Purification of Refuse Liquids by Chemical Agents.—Amongst the processes which we have witnessed for the purification of the polluting liquids resulting from the woollen manufacture, there is none which has received such extensive application as that which was devised some years ago for the recovery of grease from the soapsuds produced in the washing operations.

Extraction of Grease.—In their Report (1867) on the rivers *Aire* and *Calder* our predecessors entered minutely into a description of this process (pages xxvii. to xxxv.), examining its results both as regards its remunerative character and its effect in purifying the foul liquid. They show the proportion of oil recovered and of that allowed to escape, and they arrive at the result that in no case is more than 83 per cent. of the grease obtained, whilst in others no less than from 50 to 80 per cent. is discharged into the neighbouring stream. They also state their opinion of the effect of the process as then carried on as follows (page xxxi):—" Our own experience is not in favour of the success of this " method of clearing the water. It has not been our fortune to see any instance of this " process being carried out with the result of 'very clear' effluent water. On the con- " trary, in the examples which we have seen the appearance of the liquid has not been " sensibly affected by the treatment, and the water has escaped foul and objectionable." We perfectly coincide in this expression of opinion. The method in itself is exceedingly crude, and it is carried out in a most clumsy and slovenly manner, whilst the resulting so-called *purified* effluent water was found to be, in every case where we have examined it, one of the most filthy and polluting liquids which we have met with; in proof of which the following analyses may be adduced:—

EFFLUENT LIQUOR FROM THE GREASE-EXTRACTION PROCESS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
From Messrs. Crossley and Co.'s carpet works, Sept. 25, 1869.	366·0	23·264	3·267	4·812	0	7·230	·028	25·20	—	—	—
From Sir Titus Salt and Co.'s works at Saltaire, Oct. 5, 1869.	662·0	81·359	8·825	3·655	·011	11·846	·016	17·00	8·95	145·55	154·50
From grease extraction works at Trowbridge, March 11, 1870.	739·0	48·613	8·287	54·240	0	52·955	·048	55·40	3·00	11·04	14·04
From Messrs. Playne and Co.'s mill at Longford, Gloucestershire, March 17, 1870.	307·7	23·509	10·810	15·475	0	23·554	·080	21·40	·48	5·68	6·16

There are many well-known processes in technical chemistry which point to a much more effectual method for separating the oily matters from these soapsuds. After the addition of a slight excess of sulphuric acid the liquor ought to be briskly agitated with bisulphide of carbon, which would dissolve out the minute oily globules diffused through it in the form of an emulsion, and would then rapidly subside to the bottom of the vat, whence it could be drawn off into a still, where a steam heat would volatilize the bisulphide of carbon, which might then be condensed and recovered for repeated use in similar operations. At present the grease-extracting process is carried out only with a view to profit, and cannot be said to be conducted with any regard to the prevention of river pollution.

Purification by Irrigation.—The best and most profitable mode of cleansing the foul liquids of woollen factories will doubtless be found to be their application to land, but their utility for this purpose would be much augmented if they were previously mixed with several times their volume of town sewage.

In Yorkshire we met with five examples of attempts to irrigate grass lands with such liquids, but unmixed with sewage, in order to escape the injunction of the Court of Chancery, which had forbidden the nuisance occasioned by them.

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Purification by irrigation.

Near Shepley, on land below the mill of Messrs. Barnicott and Kenyon, the whole of the soapy, greenish, greasy mill drainage is conducted by a contour carrier along the upper edge of a steep grassy bank, down which it is made to trickle at intervals by means of a roughly managed set of stops in the carrier, reaching at length a flatter plot of grass, not more than an acre or two altogether, where it disappears. Samples were taken both from the carrier and from the surface water trickling into the brook at the foot of the bank; these samples yielded on analysis the following results:—

COMPOSITION OF MILL DRAINAGE BEFORE AND AFTER IRRIGATION.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
New Shepley Mill, waste liquor before application to land, Sept. 22, 1869.	112·3	22·455	4·143	10·350	0	12·664	12·75	35·40	188·30	223·70
Ditto, after use in irrigation, Sept. 22, 1869.	43·9	·790	·091	·032	·303	·420	4·85	5·54	1·66	7·20

These numbers show that, with the exception of suspended matters, the foul liquid was more than sufficiently purified to render it admissible into running water; and if we could have collected the sample of effluent water without disturbing some of the soil of the field, the proportion of suspended matters would doubtless have also been within the standards suggested in our First Report.

The clear bright water running into the brook from a drain in this field, which was apparently the only outlet it had, no doubt contained all the previously filthy drainage of the mill thus brought on to the land, but it was probably much diluted by ordinary subsoil drainage water, and an analysis of a sample of it would not have been so directly instructive as to the effect of irrigation. The result here shown was from the very roughest style of irrigation; and it will be easy to obtain even a better result than was possible here, by care being taken to distribute the water more evenly over the surface which is to receive it, and more perfectly throughout the mass of soil to be fertilized.

Above this mill, and on the opposite side of the narrow valley in which it is placed, a much more careful attempt to abate the nuisance of mill drainage by irrigation had been made. The whole sewage of the mill had been pumped through underground pipes to a field above the factory, where, through hydrants, it was forced into surface carriers and thus distributed over a sloping surface of old grass land. The produce of the field was increased by this dressing and the whole operation promised to be successful; but the coarser grasses, strengthened by the irrigation, had killed the finer, and the quality of the produce was injured. Moreover the pipes, originally too small, had choked by incrustation; and lastly, the foul water had sunk into neighbouring wells and spoiled them. The proprietors' own well and one at a neighbouring inn had thus suffered; and they were afraid therefore to renew their irrigation works.

Notwithstanding the unpromising character of the greasy coloured waste liquors from these mills, which do not at first impress one as having, like town sewage, much agricultural value, yet it must be remembered that they contain not only useless oil and dye stuff, but much urine, pig's dung and blood, as well as the original foul animal matter from the fleece; and their composition, as shown by analysis, proves them to possess a higher fertilizing power than that of ordinary sewage. If therefore strong and rapidly growing plants be selected for cultivation, and if the land be occasionally broken up and well aerated by deep tillage, care being taken to distribute the sewage over a sufficient surface—it is probable that all the evils which have arisen here will be avoided, and a satisfactory agricultural result will be realised, at the same time that the effluent water will be discharged, no longer offensive, into the stream.

At Messrs. John Foster and Sons' mohair and alpaca works at Queensbury, near Halifax, the liquid refuse which escapes is carried on to land below the factory, and reaches the natural watercourse after the cleansing effect of irrigation. At Messrs. Townends' works also, at Cullingworth, near Bingley, the drainage of a large mill, mingling here however with that of the village, flows on to some hill-side grass land, and produces a large growth of grass before finding its way into the stream. The

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Purification by irrigation.

result here, if not attributable wholly to the fertilizing effect of dirty wool washings, at any rate proves that such dirty waters with the spent liquors from dye works may be discharged into ordinary house sewage without injury to its value as manure; and we have no doubt that the corporation of Kendal, who are now carrying out sewerage works, so as to intercept the drainage from the woollen mills of that town, and conduct it with the sewage to an irrigation farm, will find themselves fully justified in thus relieving the *Kent* of the polluting manufacturing refuse now discharged into it.

At Guiseley near Leeds, the Ings Mill (Woollen) Company have attempted to cleanse their offensive drainage water, first, by the use of successive subsidence tanks arranged round the factory—the top water being pumped from the last into the first again, and the water thus cooled being used for condensing purposes—and then by letting the final overflow trickle roughly over eleven acres of grass land before reaching the watercourse.

The wool-scouring water is received in a separate pond and is passed directly upon the land. There was, however, here no attempt at levelling or preparing the land, and the foul liquids found their way into the neighbouring brook, chiefly through runnels and trenches, thus coming but very sparingly in contact with the soil and vegetation. The result was therefore very unsatisfactory, as seen from the following analyses of samples here collected:—

COMPOSITION OF WOOLLEN MILL DRAINAGE BEFORE AND AFTER IRRIGATION.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Waste liquor from Ings Mill, Sept. 28, 1869.	123·8	7·892	·838	1·551	1·265	3·380	trace	17·40	10·12	11·28	21·40
Ditto after subsidence, mixture with wool-scouring water, and irrigation, Sept. 28, 1869.	73·0	7·669	·440	·458	0	·817	0	8·19	1·48	3·28	4·76

In all these cases the management is of the roughest kind, and in some instances the success was far from perfect; but this ought not to discourage the attempt to apply the agricultural remedy wherever it may be available for the abatement of any nuisance arising from mill drainage.

At the Jackroyd dye works, near Halifax, a system of filtration and rough irrigation has been adopted with considerable success. The waste dye liquors, which are here dark blue and of a very foul description, are conducted first into a series of settling ponds, and then upon a sand filter, whence the effluent water, which is of a pale yellow tint, flows through the grass of a rough and unprepared meadow, at the foot of which it is collected in a small reservoir, and passes over a water wheel before it enters the *Hebble* brook. Owing to the continually varying character of the discharges into the settling tanks, no useful sample of the raw liquors could be taken; but we collected one of the mixed liquors before filtration, after they had already undergone considerable amelioration by subsidence. In the following table the composition of this sample is compared with that of the effluent water from the irrigation meadow.

COMPOSITION OF DYE WORKS DRAINAGE AFTER SUBSIDENCE AND IRRIGATION.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Waste liquors from Jackroyd dye-works after subsidence, Sept. 24, 1869.	70·5	3·283	·344	·283	·058	·635	0	6·60	3·64	3·64	7·28
Ditto after filtration through sand, and application to meadow land, Sept. 24, 1869.	62·1	1·248	·303	·273	·200	·728	0	5·54	0	0	0

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Thus the suspended impurities were entirely removed, and a considerable reduction was effected in the polluting elements, organic carbon and organic nitrogen. The effluent water was sufficiently purified to be admitted into a stream.

Purification by intermittent filtration.

Purification by Intermittent Filtration.—The successful results of the application of intermittent filtration through porous earth to the purification of sewage and the waste liquors of calico printworks, described in our first report (1870) on the *Mersey* and *Ribble* basins, (Vol. I., pp. 60 and 99) encouraged us to try the effect of this remedy upon the waste liquors from woollen factories. For this purpose we obtained from Messrs. James Brooke and Sons, Bradley Mills, Huddersfield, a quantity of the foulest waste liquors discharged from their factory, and passed it through the cylinder of Dursley soil, described in the report above alluded to at page 68, which had been employed in our previous experiments for the purification of large volumes of sewage during a period of more than six months. This liquor was black as ink, and contained much more polluting organic matter in solution than the proportion present in London sewage; it was not therefore to be expected that the Dursley soil would purify so large a daily volume of the former as it did of the latter; indeed the following table shows that satisfactory purification could not be continuously counted upon when the volume of liquor filtered reached 2·8 gallons per cubic yard per day of twenty-four hours.

INTERMITTENT FILTRATION OF WASTE LIQUORS FROM WOOLLEN WORKS THROUGH DURSLEY SOIL.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.										Remarks.
	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Waste liquor before filtration - - -	**204·8**	**43·207**	**2·704**	**2·340**	**0**	**4·646**	**14·40**	—	—	—	Suspended organic matter - - 25·28; Suspended mineral matter - - 1·80; Total - 27·08
At rate of ·56 gallon per cubic yard per 24 hours.											
Effluent water, Aug. 20, 1870 -	57·9	·608	·117	0	trace	·117	2·60	21·87	5·98	27·85	Clear and colourless.
" " " 27, " -	48·5	·668	·090	0	0	·090	1·90	24·24	2·21	26·45	" "
" " Sept. 3, " -	52·5	·642	·260	·004	0	·263	1·75	27·79	2·21	30·00	Slightly turbid.
" " " 10, " -	52·8	1·184	·266	·005	·384	·654	1·60	24·67	8·88	33·55	Clear and colourless.
" " " 17, " -	51·4	·546	·072	·003	·309	·383	1·60	21·38	8·62	30·00	" "
" " " 24, " -	63·4	·495	·172	·016	1·391	1·576	1·65	27·98	7·02	35·00	" "
" " Oct. 1, " -	73·2	·584	—	·010	1·914	—	2·10	33·42	7·28	40·70	" "
" " " 8, " -	93·0	·645	·205	·046	2·549	2·792	4·20	41·00	12·00	53·00	" "
" " " 15, " -	90·7	·527	·199	·010	2·985	3·192	7·00	31·30	18·00	49·30	" "
At rate of ·84 gallon per cubic yard per 24 hours.											
Effluent water, Oct. 22, 1870 -	97·1	·541	·268	·016	3·466	3·747	11·65	31·72	18·28	50·00	" "
" " " 29, " -	112·2	·512	·194	·014	3·821	4·027	18·15	46·14	28·16	74·30	" "
" " Nov. 5, " -	135·2	·627	·287	·016	4·056	4·356	25·50	47·96	36·34	84·30	" "
" " " 12, " -	142·9	·392	·214	·008	3·773	3·994	31·40	—	—	85·70	" "
At rate of 2·8 gallons per cubic yard per 24 hours.											
Effluent water, Nov. 19, 1870 -	157·0	·274	·103	·006	4·012	4·120	35·60	—	—	92·90	Slightly turbid.
" " " 26, " -	170·4	·584	·164	·003	3·483	3·649	42·20	—	—	106·00	Slightly turbid.
" " Dec. 3, " -	190·8	1·283	·580	·012	2·111	2·701	51·50	—	—	116·50	"
" " " 10, " -	211·9	1·667	·409	·005	0	·413	56·00	—	—	128·60	"
" " " 17, " -	208·0	3·177	·333	·036	·021	·384	59·00	—	—	125·60	"
" " " 24, " -	225·2	1·967	·166	·005	0	·170	63.00	—	—	128·60	Turbid.

These analytical results prove that for many successive weeks, at the commencement of the experiments, the action of the soil upon the polluting matters was to a great extent one of absorption; it was not until after the filthy liquid had been poured upon the filtering material for a period of six weeks that nitrification set in with energy; and nitrates, the inorganic product of the oxidation of nitrogenous organic matters, appeared in large proportion in the effluent water. Even up to the termination of the experiments there was a continual increase in the proportion of chlorine, and of total solid matters in solution in the purified water, but this is to some extent accounted for by the circumstance that the soil having been well washed with clean water before the commencement

Part I. Remedies.

Purification by filtration.

of the experiments, was saturated with comparatively pure water, which was afterwards only gradually displaced by the foul liquid used in the experiments. The purification continued to be satisfactory until three weeks had elapsed after the maximum rate of flow had been attained, when on the third of December our standard* of organic nitrogen (·3 part in 100,000 parts of water) was transgressed, the organic nitrogen in the sample drawn on that day amounting to ·58 part in 100,000 parts of water; the following week the organic nitrogen was again above the standard but by a smaller amount, and the succeeding week the standard of organic nitrogen was transgressed only very slightly, but that of organic carbon (2 parts in 100,000 parts of water) was seriously infringed. In the following and concluding week, however, the effluent water would have been admissible into a river without infringing any of our standards, although in colour it approached the limit of prohibition. These experiments therefore show that intermittent filtration will satisfactorily purify the foulest waste liquids from woollen works, if such liquids be passed through the filtering materials at a rate not exceeding ·84 gallon per 24 hours to every cubic yard, and they render it probable that the purification would continue to be satisfactory if this rate were doubled; but they demonstrate that at the rate of 2·8 gallons per 24 hours the purification is uncertain, and would probably be unsatisfactory if this rate were continued for a considerable length of time. In regard to purification from suspended matters the result was satisfactory throughout the whole course of the experiments; our standards of turbidity were not once infringed.

Although simple intermittent filtration thus provides an efficient remedy for pollution caused by woollen factories, yet it would obviously be desirable to hasten or stimulate the process of oxidation which goes on in the aerated pores of the filter so as to enable the manufacturer to diminish the volume of filtering material necessary for the purification of his waste liquors. A clue to an improvement of this kind was afforded by the observation which we have frequently made in studying various processes for the purification of sewage involving the addition of lime in excess, that sewage, to which excess of lime has been added, undergoes nitrification much more rapidly than it does without such addition. We are therefore not without hope that the nitrification and consequent purification of the waste liquors from the woollen manufacture during the process of intermittent filtration will be hastened by the addition of a slight excess of lime to the liquid before filtration. Experiments with reference to this point are now in progress in our laboratory, and we hope they will be sufficiently advanced to enable us to state the results, in our Fourth Report,—on the rivers of Scotland.

The process of intermittent filtration has not yet, so far as we are aware, been tried on a large scale for the purification of polluting liquids from woollen factories; but at Messrs. Townend and Co.'s mill at Cullingworth, near Bingley, some approach is made to this process by filtering the waste dye-water through a bank of cinders and ashes. As the black and filthy water impounded behind this bank rises and falls in level, a considerable amount of aeration of the filtering material must be effected; and the sample of effluent water which we collected showed a satisfactory degree of purification, and was admissible into the neighbouring stream without causing pollution, as is seen from the following analysis:—

Purification of Woollen Dye-water by Filtration through Cinders and Ashes.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters.										
	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Arsenic.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.
Effluent dye-water from Messrs. Townend & Co.'s mill, percolating through a bank of cinders and ashes, Oct. 1, 1869.	40·0	1·757	·158	·004	·410	·571	0	2·75	3·38	16·38	19·76

Although the process was here carried out in the roughest manner, the effluent water was colourless and nearly free from suspended matter, and the above numbers show that, in respect of soluble polluting ingredients, it did not transgress our standards of purity. At the same place, the filthy waste liquid from the process of grease extraction is

* See Report (1870) on the *Mersey* and *Ribble* basins, Vol. I., p. 130.

Part I. Remedies.

Purification by filtration.

received into pits dug in furnace ashes, their surface being first covered with a layer of sawdust, and we were informed that as much as 50*l.* worth of additional grease is collected off the surface of this sawdust in the course of twelve months. The waste liquid filtering slowly through the heap was alleged to find its way into the *Harden Beck* in a perfectly cleansed condition, an assertion which we would gladly have put to the test of chemical analysis, had it been possible, at the time of our visit, to collect a sample of it.

Ordinary continuous filtration through sand and ashes is employed for the cleansing of very foul liquors at the Jackroyd woollen dyeworks near Halifax. We inspected these works on two occasions and took samples, which yielded the following results on analysis:—

Purification of Woollen Dye-water by Filtration.

Results of Analysis expressed in Parts per 100,000.

Description.	Dissolved Matters.							Suspended Matters.			Remarks.
	Total solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.	
Liquor before filtration, Aug. 12, 1868.	114·7	11·323	·512	1·678	0	1·894	7·45	—	—	—	Suspended and dissolved matters mixed. Very muddy and blue.
Liquor after filtration, Aug. 12, 1868.	84·7	3·753	·599	·279	0	·829	—	0	0	0	Clear and yellowish.
Liquor before filtration, Sept. 24, 1869.	70·5	3·283	·344	·283	·058	·635	6·60	3·64	3·64	7·28	Dark blue and muddy.
Liquor after filtration, Sept. 24, 1869.	69·8	2·406	·181	·140	0	·296	8·05	·84	·80	1·64	Turbid, brownish.

The above results show that on both occasions the suspended polluting matter was satisfactorily removed, but at neither visit was the purification from dissolved organic matters sufficient to bring the effluent liquid within the prescribed limits of impurity; and, constrained by legal proceedings, the proprietors of these works were further purifying the filtered water by causing it to irrigate a grassy slope before it reached the neighbouring stream. See page 32.

At Durham the large carpet works of Messrs. Henderson and Company discharge into the *Wear* 2,745,000 gallons of liquid refuse, besides 225,000 gallons of soapsuds. The excrements of their workpeople (about 530 hands are employed) also drain into the river. The liquid refuse is run into two tanks, each about 40 square yards in area and 3 yards deep, sunk in a bank of made ground by the side of the river. The floor of the tanks is of gravel, and the sides are built of brickwork without mortar, so as to permit of the escape of the liquid into the surrounding porous earth, whence it was intended to filter into the river. The filtering material had, however, far too small an area for the volume of liquid to be cleansed, and consequently its pores were soon choked, so that, when we saw them, the filters were little more than subsidence tanks, in which solid mud accumulated to the depth of about one foot in the course of a month, and was then given to farmers. When the tanks are full the partially clarified water is run off into the river through a sluice. These tanks, filled alternately, might have afforded a fair illustration of the power of intermittent filtration to deal with the waste liquors of a carpet mill, if the greater portion of the suspended impurities had been first arrested in a subsidence tank, or by passing the crude liquor through a Needham's press after the addition of a slight excess of lime, as recommended by our predecessors.

Part II.
Water
Supply.

Aire and
Calder
basins.

PART II.

THE WATER SUPPLY.

In our visits to the different seats of the woollen manufactures we have not only ascertained, by chemical analysis, the character of the water employed, or available, for manufacturing purposes, but we have also investigated the quality of that supplied to the inhabitants of towns and villages for domestic purposes, taking samples from the mains where waterworks existed, from wells and springs in cases where the supply was obtained directly from such sources, and from springs and streams which appeared likely to afford an additional quantity if required. We again reserve, however, for a final report the complete discussion of this department of our inquiries, and confine ourselves here to statements of the results of our analyses and to special observations on the mode of supply and the quality of the water in the different localities visited. As a rule the larger towns, especially in Yorkshire, are abundantly supplied with water of good quality, by gravitation works which are the property of the Corporations or other Local Authorities; whilst the smaller towns and villages are often dependent for this necessary of life upon polluted streams and shallow wells of suspicious character. The water of the larger towns, often brought from great distances, is generally free, or nearly so, from previous excremental pollution, and filtration is therefore considered superfluous; but we would here repeat the recommendation already given in our First Report (1870) on the *Mersey* and *Ribble* Basins, Vol. I., p. 120, that all water taken from streams or gathering grounds should always be filtered before delivery to consumers, for increased experience only serves to confirm previous observations, that such water, when not filtered, is frequently turbid and of repulsive appearance; these characteristics not unfrequently leading the water drinker to reject it for the bright and sparkling but often dangerous beverage drawn from shallow wells sunk into ground reeking with excrementitious matters.

The Potable Waters of the Aire and Calder Basins.—The following table contains the results of our analytical examination of the waters used, or which might be used, for domestic purposes in the basins of the *Aire* and *Calder* :—

POTABLE WATERS OF THE AIRE AND CALDER BASINS.

RESULTS OF ANALYSIS expressed in Parts per 100,000

Description.	Dissolved Matters.											System of Supply.	Remarks.
	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.		
AIRE BASIN.													
Spring in Gordale Gorge, Sept. 30, 1869	19·90	·176	·012	0	·064	·076	520	·90	12·09	4·52	16·61	- - -	Clear and colourless.
Ditto at *Aire* Head below Malham, Sept. 30, 1869.	15·70	·165	·007	·001	·017	·025	0	·99	8·92	3·33	12·25	- - -	Do. do.
Ditto at base of Malham Cove, Sept. 30, 1869.	16·20	·286	·014	0	·012	·026	0	1·15	11·56	4·52	16·08	- - -	Clear and slightly yellow.
The *Wharfe* at the Strid, Bolton Abbey, Oct. 4, 1869.	16·30	·364	·023	·001	0	·024	0	·92	6·85	7·05	13·90	- - -	Clear and yellow.
SKIPTON—Gathering ground, Oct. 4, 1869.	16·40	·361	·038	·002	·012	·082	120	1·41	3·27	7·34	10·61	Intermittent.	Very turbid.
BRADFORD—High level service, Stubden reservoir, Oct. 6, 1869.	10·10	·582	·079	·004	0	·082	0	1·02	·92	5·50	6·42	Constant -	Very turbid; yellowish.
DITTO—Intermediate service, Manywells spring, Oct. 6, 1869.	11·80	·184	·020	·002	·076	·098	460	1·29	·85	5·64	6·49	Do. -	Turbid; colourless.
DITTO—Low level service, Heaton reservoir, Oct. 6, 1869.	13·20	·396	·036	·003	·026	·064	0	1·13	·77	6·35	7·12	Do. -	Turbid; yellowish.
DITTO—Deep well in millstone grit at Messrs. Ingham and Sons' mill, Oct. 5, 1869.	55·49	·159	·005	·028	·038	·066	290	3·23	6·77	7·34	14·11	- - -	Clear and colourless
LEEDS—From rivers *Wharfe* and *Washburn*, and from gathering grounds at Eccup. Sept. 29, 1869.	15·00	·258	·025	0	0	·025	0	1·30	1·76	6·56	8·32	Constant -	Clear.
CASTLEFORD—New Well, March 2, 1871	71·70	·198	·023	·080	0	·089	340	30·75	10·44	9·71	20·15	—	Turbid.
CALDER BASIN.													
The Burnley Road *Calder*, Jan. 26, 1871	7·80	·053	·008	·005	·040	·053	130	1·10	1·09	3·77	4·86	- - -	Very slightly turbid.
The Rochdale Road *Calder*, Jan. 26, 1871	7·30	·033	·012	·001	0	·013	0	1·20	·26	3·51	3·77	- - -	Do. do.
The Ramsden Clough *Calder*, Jan. 26, 1871.	7·71	·093	·013	·003	·012	·057	120	1·10	·26	3·64	3·90	- - -	Do. do.
HALIFAX—From gathering ground, Sept. 24, 1869.	8·16	·133	·031	·005	·029	·064	10	1·10	0	3·20	3·20	Constant -	Very turbid.
HUDDERSFIELD—Springs at Longwood, Sept. 23, 1869.	11·48	·049	·018	·001	·066	·085	350	1·20	0	6·49	6·49	Nearly constant.	Clear and colourless.
BATLEY—From gathering grounds, Sept. 21, 1869.	7·60	·324	·043	·002	0	·045	0	·93	0	3·33	3·33	Constant -	Very turbid; yellow.
WAKEFIELD—From the *Calder*, Sept. 15, 1868.	44·76	·431	·062	·001	·065	·128	340	4·47	5·93	9·46	15·39	Constant -	Very turbid; yellowish.
DITTO—From the *Calder*, Sept. 18, 1869	40·00	·457	·049	·004	·095	·147	660	4·49	7·76	5·78	13·54	Constant -	Clear; yellowish.

Part II.
Water
Supply.

Aire basin.

The head waters of the *Aire*, especially the great spring at Aire-head, are admirably suited for domestic use, but they have not been taken up for this purpose, being too far away from the masses of population in the *Aire* basin.

Skipton.—A private company supplies this town with water by gravitation from about 230 acres of gathering grounds, partly upon millstone grit and partly upon limestone; it is therefore of medium hardness, being softer than the drainage from limestone but harder than that from millstone grit. It is said to be filtered through sand and gravel, but at the time our sample was taken, this operation must have been either omitted or very imperfectly performed, as the water was then being delivered in a very turbid condition. Our analysis shows the water to be peaty, and some of it comes from pasture land, but it is not exposed to further excremental pollution, and is otherwise of fair quality. The supply is intermittent in dry seasons, being only turned on at such times for 8 to 12 hours daily. It amounts on the average to about 25 gallons per head, inclusive of that used for manufacturing purposes. This quantity is stated to be very inadequate for the requirements of the town, indeed last summer it entirely failed, and water had to be got from the Eller Beck; but the higher parts of the town were for a period of three months without even this impure water. Powers are therefore now being sought to bring in a new and softer supply of 300,000 gallons daily from the millstone grit, by gravitation.

Bradford is supplied with water on the constant system by gravitation, partly from springs, but chiefly from gathering grounds on the millstone grit. There are three distinct services, viz., a high-level, an intermediate, and a low-level service. The works belong to the corporation, and the daily supply to Bradford and the district is 6,500,000 gallons. The high-level service is derived from millstone grit only, and is therefore a soft water well adapted for manufacturing purposes. It exhibits no evidence of excremental pollution, but contains too much peaty matter in solution to be agreeable for drinking; moreover, not being filtered, it was very turbid with yellowish suspended matter. The intermediate service is also derived exclusively from the millstone grit, and is therefore as soft as the high-level service, but being partly spring water it is much more palatable than the latter, indeed it scarcely contains one-third as much organic matter. Unfortunately the spring water is allowed to mix with unfiltered surface water, which renders it turbid as delivered in the town. This water exhibits a moderate amount of previous animal contamination, which, however, probably belongs to the spring water, and consequently, on account of the filtration it has undergone, does not indicate any appreciable risk. The low-level service is derived chiefly from millstone grit, but partly also from limestone; it is therefore harder than the two other services, but only to a very unimportant extent (less than 1 part in 100,000). It exhibits no evidence of previous animal pollution, and is in other respects of a quality intermediate between that of the two other services. Like them it was also, at the time of our visit, turbid with yellow suspended matter.

At the dye works of Messrs. Ingham and Sons we had an opportunity of becoming acquainted with the water of the deep wells in the millstone grit beneath Bradford; these works are supplied from a well 360 feet deep, the influx of water from the first 150 feet being carefully excluded. The water from this well has, when first drawn, a very slight taste of sulphuretted hydrogen, which, however, soon passes off; it is in other respects an excellent water, but has double the hardness of the supply furnished by the corporation. Like many other deep well waters it contains a considerable proportion of ammonia, derived in all probability from the reduction of nitrates.

Leeds is supplied with water on the constant system from gathering grounds at Eccup, from the river *Wharfe* at Arthington, and from the river *Washburn* at Leathley. The works belong to the corporation, and have cost 535,620*l*. The chief works are a store reservoir at Eccup containing 257,000,000 gallons; the Westwood reservoirs and filter beds containing 22,000,000 gallons, the Woodhouse reservoir of 6,000,000 gallons capacity, and the pumping stations at Arthington and Headingley. The Eccup reservoir receives the drainage of 1,200 acres. This water and that taken from the *Washburn* are said to be free from pollution, but the river *Wharfe* receives, above the intake, some of the sewage of Otley, Burley, Ilkley, and Addingham; the water from this source is therefore filtered through sand 18 inches deep. Our sample was taken from the main in the Great Northern Railway station supplied from the reservoir at Eccup. It exhibited no previous sewage or animal contamination, was of moderate hardness (8·3 parts in 100,000) and clear, but contained rather a large proportion of peaty matter.

PART II. WATER SUPPLY.

Calder basin.

Castleford.—We can only confirm the unfavourable report in regard to the water supply of this town made by our predecessors (Report, 1867, on the rivers Aire and Calder, Vol. I., p. xlvi), "Castleford has no water supply, the inhabitants about 6,000 in number " have to provide water for themselves; for this purpose they resort mainly to wells, but " partially still to the river. The river is very foul, and the wells appear to be not " sufficiently guarded against impurity, and are liable to be drained by the pumping of " collieries in the neighbourhood, in consequence the inhabitants of Castleford suffer in " health as well as comfort." At the time of our visit a new well was being sunk, and had reached a depth of 33 yards. This well has since been completed, and the water from it, the analysis of which is given in the above table, is now about to be supplied to the town through distributory pipes. The water is somewhat chalybeate, and becomes turbid on exposure to the air from the deposition of oxide of iron. It also contains a remarkably large proportion of common salt. Its chalybeate character would be entirely destroyed by the addition of lime to it, in the proportion of 1 lb. to each 1,000 gallons. The lime should be first slaked and converted into so-called "milk of lime," or better still into "lime water," before it is added to the chalybeate water. Allowed afterwards to repose for 12 hours in a reservoir, the water would become perfectly clear, a considerable proportion of the organic matter which it contains would be removed, and the hardness would be reduced to one-half its present amount.

The head waters of the *Calder*, which we collected in January last, are derived from springs in the millstone grit. In excellence for domestic purposes they are superior to the head waters of the *Aire* and are scarcely surpassed by any natural water in the United Kingdom; they are soft and palatable, and contain but very small proportions of organic matter. They are, however, at present not utilized for domestic supply.

Halifax is supplied by gravitation works belonging to the Corporation. They cost about 300,000*l*., and consist of reservoirs at Ogden and Mixenden, with 8,000 acres of gathering ground, situate on the range of millstone grit hills between Lancashire and Yorkshire. The reservoirs contain about 440,000,000 gallons, of which about 2,000,000 gallons per day are discharged as compensation water, and 3,700,000 gallons daily are used in Halifax. The water is soft and of excellent quality, both for domestic and manufacturing purposes; but to the water drinker its good qualities were effectually concealed, when our sample was taken, behind a cloud of suspended matters, which a sand filter would at once remove. Filtration would make this one of the finest potable waters in the kingdom.

Huddersfield is at present supplied with water on the constant system in winter, but in summer the water is laid on for only eight hours per diem. The works now belong to the Corporation, and are at present quite inadequate to the demands of the town, but further extensive works were authorised by the Huddersfield Water Act of 1869, and are now in progress. The new source of supply is from springs and gathering ground at Meltham and Marsden, about eight miles south of the borough. The water is of excellent quality. The reservoirs of the existing works are situated at Longwood, and are fed chiefly by springs; hence the water, though not filtered, is clear and colourless, and the above analysis shows that the proportion of organic matter in it is small, rendering it, at the time our sample was taken, a very palatable and agreeable beverage. It has nearly double the hardness of the Halifax supply, but is still a comparatively soft water, being less than one-third as hard as the Thames water supplied to London.

Dewsbury, Batley, and Heckmondwike.—The waterworks supplying these towns on the constant system were established in 1853, and are the joint property of the Corporations of Dewsbury and Batley and the Local Board of Heckmondwike. The reservoirs are at Dunford Bridge, Broadstone, Dewsbury Moor, and Stancliffe. The reservoir at Dunford Bridge is for compensation to millowners only, and contains 250,000,000 gallons; the others are for storage and supply of the district. These reservoirs are fed from about 2,000 acres of gathering ground. The water is not polluted before it enters the reservoirs, and is therefore not filtered. It flows by gravitation into the high-service reservoir, and thence into the town. Our sample was taken from the main at Batley; it was yellow and very turbid. The water is soft and well adapted for manufacturing and washing purposes, but in September 1869 it contained too much peaty matter to be an acceptable beverage. It could also scarcely be regarded as a potable water without previous filtration. Analysis reveals no previous animal contamination. The authorities in all three towns concur in stating that the health of the people has improved since the introduction of this mountain water in the place of the previous supplies from polluted rivers and wells.

Wakefield is supplied, on the constant system, with water for domestic purposes, one-fourth from springs and three-fourths by water abstracted from the polluted river

PART II. WATER SUPPLY.

Severn basin.

Calder. The waterworks are stated to have been established in the year 1837, and belong to a joint stock company called the Wakefield Waterworks Company. The reservoirs are situated at Stanley Fall, two miles from Wakefield, and a volume of 1,000,000 gallons is daily pumped from the river. The water is stated by the Corporation of Wakefield to be "polluted before entering the reservoirs by town sewage and " liquid refuse from manufactories, chemical works, gasworks, dye and bleach works, " tanyards, and also by mines; not only from the towns and district situate in the " basin higher up, but from the borough of Wakefield itself, as the water is abstracted " from the river about a mile below the main sewer outlet." Our own analyses and observations entirely confirm this statement, incredible as it may appear; and although " the water is filtered by a patent process," it is difficult to conceive anything more disgusting and dangerous to health, than a populous community thus systematically, and by an elaborate and costly arrangement of reservoirs, pumps, filters, and distributory apparatus, drinking its own filtered sewage, taken from a stream in a black and putrescent condition. We have analysed two samples of this water supply, taken at an interval of a year. Although the water, owing in part to putrescent fermentation and subsidence, and in part to filtration, was chemically less contaminated than might be expected, yet on both occasions it contained a large proportion of nitrogenous organic matter. It was of a greenish yellow colour, and, on one occasion, very turbid.

Potable Waters in the Severn Basin.—The *Severn* drains a very extensive valley containing, at or near its surface, rocks of very varied geological and chemical character; the potable waters of this basin, therefore, exhibit a corresponding wide range of quality. Those which come from the calcareous formations, such as the oolites and lias, are distinguished by great hardness, which is, however, generally of the *temporary* kind, that is, it may be removed by boiling the water for half an hour, or by the addition of milk of lime in suitable proportion. On the other hand the non-calcareous portions of the upper and lower silurian formations yield water of great softness, whilst the new and old red sandstones furnish supplies of intermediate hardness. Water obtained from a depth of 100 feet or more from any of these formations generally contains only minute traces of organic matter, and is otherwise of excellent quality for drinking, unless the source be surrounded by human habitations, and sometimes even then, if the surface water be carefully excluded. But surface drainage water of all kinds is necessarily much affected by the character of the soil which it washes; that portion which is collected upon rocky slopes being of excellent quality, especially after subsidence and filtration; that running from moorland is often peaty and unpleasant to the palate, though otherwise wholesome; whilst that draining from cultivated fields, or even rich pasture land, is certain to be contaminated with excrementitious matters.

The following table contains the results of our analyses of various waters collected in this river basin:—

POTABLE WATERS IN THE SEVERN BASIN.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Temperature Centigrade.	Dissolved Matters.											Remarks.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
NEWTOWN, N. WALES.	°												
The *Severn*, above Newtown, April 27, 1870	8·6	6·60	·123	·016	·003	·010	·028	0	1·35	0	3·09	3·09	Slightly turbid.
Lady Well, April 27, 1870	10·6	16·30	·011	·003	0	·295	·298	2,630	1·87	1·32	8·00	9·32	Clear.
Pump, in Pump Court, April 27, 1870	9·0	41·86	·059	·011	·001	·561	·575	5,320	6·08	8·13	8·91	17·04	Do.
Canal Road pump, April 27, 1870	—	27·10	·081	·015	0	·659	·674	6,270	2·70	1·84	9·17	11·01	Do.
KIDDERMINSTER.													
Well, 160 feet deep in new red sandstone, at Messrs. Brenton and Lewis's mill, April 28, 1870.	13·3	18·26	·015	·004	0	·169	·173	1,370	1·60	4·79	6·59	11·38	Do.
Shallow well, in Alderman Tovey's yard, April 29, 1870.	—	83·64	·253	·079	·090	3·069	3·222	31,110	8·38	26·87	14·43	41·30	Do.
Ditto in Three Tuns yard, April 29, 1870	—	83·52	·102	·056	0	5·322	5·378	52,900	8·20	11·28	17·30	28·58	Do.
LEAMINGTON.													
Water supply from the *Leam*, May 12, 1870	—	68·92	·180	·035	0	·191	·226	1,590	2·30	15·94	11·56	27·50	Slightly turbid.
Mr. Jones's well, May 12, 1870	—	134·04	·095	·025	0	6·086	6·111	60,540	14·20	35·63	28·32	63·95	Clear.

Description.	Temperature Centigrade.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks
FROME	°												
The *Frome*, above the town of Frome, March 10, 1870.	8·3	17·46	·326	·025	·004	·042	·070	130	1·55	6·59	5·81	12·40	Slightly turbid.
Fountain, at foot of churchyard, March 10, 1870.	11·7	52·16	·044	·005	·002	1·136	1·143	11,060	2·75	29·71	9·04	38·75	Clear.
Shallow well, in Blue House school, March 10, 1870.	10·0	86·30	·397	·064	·025	2·525	2·610	25,140	6·67	29·39	20·96	50·35	—
Spring, near Frome, March 16, 1870 -	—	11·60	·053	·015	·003	·116	·133	860	1·80	1·03	4·66	5·69	Clear.
TROWBRIDGE.													
The *Biss*, above Trowbridge, March 11, 1870	6·7	35·86	·325	·028	·003	·150	·180	1,200	1·93	21·62	5·04	26·66	Slightly turbid.
Water Company's deep well in lias, March 11, 1870.	11·1	141·34	·236	·057	·002	·550	·609	5,200	36·70	27·40	29·70	57·10	—
STROUD.													
The *Avon*, above Longfords, March 17, 1870	10·3	25·56	·053	·007	0	·398	·405	3,660	1·22	16·82	4·66	21·48	Clear.
Spring, in lower oolite, at Pensile, March 17, 1870.	—	23·50	·241	·026	·154	·456	·609	5,510	2·15	10·45	6·33	16·78	—
Well, in lower oolite, 60 feet deep, at Theescombe Nailsworth, March 18, 1870.	—	27·48	·106	·020	·002	·778	·800	7,480	2·50	12·64	8·58	21·22	—
Spring, at Chalford, March 18, 1870 -	11·7	28·86	·083	·019	0	·285	·304	2,530	·97	20·91	3·57	24·48	Clear.
The *Frome*, above the highest mill in the Chalford valley, March 18, 1870.	10·8	27·50	·062	·009	0	·298	·307	2,660	1·05	19·62	4·04	23·66	Do.
GLOUCESTER.													
Water supply, March 18, 1870 - -	—	24·82	·375	·042	0	·026	·068	0	1·52	16·05	3·57	19·62	Turbid.
BATH.													
Spring, from oolite on Hampton down, Feb. 17, 1871.	8·1	22·40	·140	·007	0	·100	·107	680	1·30	15·07	3·51	18·58	Slightly turbid.
Monkswood spring, from upper lias, Feb. 17, 1871.	10·0	35·18	·131	·012	0	·328	·340	2,960	1·55	23·08	6·00	29·08	Clear.
Eyford spring, Feb. 17, 1871 - - -	10·0	30·76	·009	·004	0	·130	·134	980	1·46	21·81	5·43	27·24	Do.
Water supplied to Walcot district from Batheaston, Feb. 17, 1871.	—	31·60	·337	·013	·002	·507	·522	4,770	1·66	17·51	6·71	24·22	Do.
Water supplied to Belvidere district from Beacon Hill spring, Feb. 17, 1871.	—	40·62	·253	·041	0	1·205	1·246	11,730	2·60	18·96	11·04	30·00	Do.
Water supplied to Bathwick district from Beacon springs, Feb. 17, 1871.	—	20·40	·149	·012	0	·270	·282	2,380	1·45	10·71	5·57	16·28	Do.
Water supplied to Lincombe and Widcome district from springs under Beechen cliff, Feb. 17, 1871.	—	41·80	·274	·018	0	1·131	1·149	10,990	2·35	20·39	10·89	31·28	Do.
ater supplied to Abbey district from Sham Castle springs, Feb. 17, 1871.	—	30·70	·171	·016	·001	·516	·533	4,850	1·65	18·12	7·00	25·12	Do.
Hetling Thermal spring, March 12, 1870 -	44·4	240·52	·161	·036	·029	·439	·499	4,310	26·50	22·00	82·80	104·80	Do.
King's Bath Thermal spring, March 12, 1870	42·2	245·40	·190	·019	·030	·447	·491	4,400	26·67	22·00	82·80	101·80	Do.

Newtown.—Monmouthshire has no waterworks, but is supplied with water for drinking and culinary purposes from springs and from wells about 20 or 30 feet deep, and for other domestic purposes from the river *Severn*. The river water is soft and otherwise of excellent quality, and an abundant supply brought into the town from this source would be a great boon to the inhabitants, who must, at present, either carry this water considerable distances, or resort to but moderately deep wells sunk in the midst of privies and cesspools. The authorities consider that the health of the town suffers from this cause, and its frequent visitation by epidemics of cholera and typhoid fever supports this opinion. The annual rate of mortality per 1,000 has in some years been as high as between 29 and 30, which is excessive for a town of 5,000 inhabitants. There is, however, much over-crowding in some parts of the town, and we have everywhere found that the conditions included under that term are the most potent causes of sickness and a high rate of mortality.

At the time our samples were taken the water of these wells, although exhibiting a considerable amount of previous animal contamination, contained remarkably small proportions of organic matter, showing that the animal and sewage matters had been almost entirely oxidized and destroyed during their percolation through the porous soil. Indeed the water of the spring which fed the Lady Well was, as our analysis shows, of almost unsurpassed purity, and, if carefully guarded from excremental pollution, would be a real treasure to the neighbourhood; but the well supplied by this spring is surrounded by privies and filthy surface drains, and is therefore never secure from pollution. The natural spring which supplies the pump in the Canal Road rises in a manured meadow about 100 yards from the nearest houses. The pump in Pump Court is surrounded by privies and middens of a very filthy description, which must continually imperil the purity of the water.

Kidderminster is supplied with water from private shallow wells and by casks carried in carts from a neighbouring polluted river. The town stands on new red sandstone, which supplies the deep wells of the manufactories with potable water of excellent quality, as is seen from the analytical results yielded by our sample from the deep well in Messrs. Brenton and Lewis's mill, furnishing 100,000 gallons per day. One of the two shallow wells, which were pointed out to us as yielding water of average quality, was situated in Mr. Alderman Tovey's courtyard, it is only 5 feet deep and contained a liquid which was very similar in composition to that which we have obtained in our laboratory by allowing London sewage to soak slowly through 5 feet of gravel. The drinking of such water, especially in periods of epidemic disease, cannot but be fraught with great risk to health. The other well, from which we drew a sample, contained water which analysis shows to have had a like origin, but the animal matters had been somewhat more oxidized than those in the water of Alderman Tovey's well, consequently the present pollution was less, whilst the previous contamination was greater. We do not remember to have visited a town of this size (the estimated population in 1870 was 20,000) in which the water supply has been so completely neglected. The splendid water in the new red sandstone immediately beneath the town ought to render easy to the inhabitants of Kidderminster a remedy for this state of things.

PART II.
WATER SUPPLY.

Severn basin.

Leamington is supplied, on the constant system, with water from the river *Leam*, the intake being above the town, but below the influx of sewage from Southam and other smaller places, and of drainage from cultivated land. The water is very hard, and was not, when our sample was taken, efficiently filtered. Considering its source, its quality was not otherwise bad, but the previous sewage or animal contamination which it exhibits renders its character suspicious, and many of the inhabitants prefer to drink the water of shallow wells. We took a sample of one of these, the water of which had a high reputation for purity and brilliancy. Analysis shows this well to be fed entirely by sewage, and although the organic matters were nearly all oxidised, we cannot but condemn this use of water which has so recently had such a disgusting origin.

Frome is supplied with water for domestic purposes from wells and springs. The chief public supply is from a fountain at the foot of the churchyard; the water is brought in a brick drain from a spring in the cellar of a house at some little distance. The burial ground is, however, above the level of the fountain, and it is not known how its drainage water is disposed of. Our analysis shows considerable anterior animal pollution, which, as indicated by the comparatively small proportion of chlorine, does not appear to have been entirely derived from sewage. The proportion of organic matter actually left in the water was very small; nevertheless the evidence of so much previous pollution relegates it to the class of suspicious waters. Moreover it is too hard for domestic purposes. This water, however, is greatly superior to a sample which we drew from a shallow well in the Blue House School, and which contained unoxidised sewage matters, besides exhibiting a very large anterior pollution of the same kind. The use of this water by the boys is dangerous; the well ought to be carefully examined, and if the access of foul liquids to it cannot be prevented it ought to be closed.

We are indebted to Messrs. Cruttwell and Daniel, of Frome, for the sample of water from an open spring which they state gushes with considerable force out of the side of a chalk hill near Frome, and which it is believed would be well adapted for supplying the town with water. The analysis given in the foregoing table shows this water to be soft and of excellent quality, both for domestic and manufacturing purposes. It is clear, sparkling, and palatable, and contains but a very small proportion of organic matter. From its chemical composition, we infer that this water springs from the greensand, which crops out about two miles from Frome.

Trowbridge.—The Local Board state that the town is very inadequately supplied with water for domestic purposes from private wells; that the water is of very indifferent quality; and that waterworks have been in course of construction for some time by a joint stock company, but they are still incomplete. We visited the waterworks, which are at a short distance from the town, and found that the company had sunk a well into the lias 160 feet deep, at the bottom of which was a borehole 18 inches in diameter and 40 feet deep. In sinking the shaft a salt spring was tapped and afterwards stopped out, but we were informed that some water came in at about 20 feet from the surface. Our analysis, given in the foregoing table, shows the water to be excessively hard, and to contain a considerable proportion of common salt (6 lbs. in 1,000 gallons, 3 oz. in this volume of water being about the usual proportion in good potable water), besides a rather large proportion of organic elements.

Stroud is supplied with water to a small extent from wells, but chiefly from waterworks belonging to the Board of Health, on the intermittent system. The upper portion of the town has water from grass land gathering grounds; the lower streets are supplied from Gainer's well—a copious spring thrown out by the lias about half way down the

Part II. Water Supply.

Severn basin.

hill. The supply is quite inadequate to the wants of the town, and is only given from one to three hours each day; it amounts to less than seven gallons per head of population. We have not analysed the water, but it is said to be of good quality. We have however examined several samples from sources available for the supply of Stroud. The spring at Chalford would furnish an abundant and excellent supply, especially if it were softened before delivery by the addition, to each 60,000 gallons, of 1 cwt. of quicklime previously slaked and diffused through about 500 gallons of water. The Chalford spring water would thus be reduced from 24½° to 3½° of hardness.

Gloucester derives its supply of water from springs thrown out by the lias about five miles from the town. Our analysis reveals no evidence of excremental pollution; but the water is hard, and contains a somewhat large proportion of organic elements; it would be greatly improved in both these respects by being subjected to the liming process just described. Its hardness would be thereby reduced from 19½° to 3½°. The water was turbid and needed filtration at the time our sample was taken.

Bath.—This city is in the singular position of being supplied with water by 18 different private companies besides the corporation. The corporation works are the most important, as they supply 30,000 inhabitants, whilst the whole of the private companies supply only about 13,000. The water is derived from springs, chiefly above the upper lias. There are also a few private wells which are sunk into the inferior oolite. The supply is intermittent, and the mains are charged only two hours daily. For domestic purposes alone, only eight gallons per head of population are delivered daily; in this calculation, however, the increase of population (which is stated to be great) since the census of 1861 has not been taken into account. The corporation state that, although they have expended more than 35,000*l.* on waterworks, the supply is inadequate to the requirements of the city and district. This expenditure, however, represents but little more than 1*l.* per head of the people supplied, whilst, as we have shown in our report (1870—Vol. I., p. 109), many of the towns in the *Mersey* and *Ribble* basins have expended sums amounting to from 4*l.* to 8*l.* per head of population supplied. The corporation are impressed with the urgent necessity for a more abundant supply, and they acquired from Parliament, last session, powers to obtain it.

The samples of the waters at present supplied to Bath which we have examined vary considerably in quality, that supplied to the Bathwick district from Beacon springs being the best, but even this sample, besides exhibiting some evidence of previous animal contamination, contains more unoxidized organic matter than is usually met with in spring water. The next water, in point of quality, is that supplied to the Abbey district from Sham-Castle springs; it contains rather more organic matter than the sample from Beacon springs, and exhibits twice as much previous animal contamination; but, as shown by the small proportion of chlorine in both cases, the pollution was caused nearly, if not entirely, by solid animal matters and not by sewage or the soakage of cesspools. The water supplied to the Walcot district from Batheaston exhibits about the same evidence of previous contamination by the same kind of animal matters as the last-named two samples, but it contains twice as much organic matter, and is therefore not a desirable water for domestic use. The remaining two samples, which resemble each other closely (the water supplied to the Belvidere district from Beacon Hill spring and the water supplied to Lincombe and Widcombe district from springs under Beechen Cliff), have been heavily contaminated with animal matters and are altogether of very inferior quality, containing, for spring waters, a very large proportion of organic matter. With the exception of the water supplied to the Bathwick district all the samples are excessively hard, and therefore not well adapted for cleansing operations. Such being the character of the present water supply of Bath, it is satisfactory to find that the new supply which it is intended to bring into the city shortly, is of much better quality. We have examined samples from the two springs which will form the projected supply, the Eyford spring and the Monkswood spring. The first is excellent water for drinking, containing, as it does, the merest traces of organic elements, whilst, although the Monkswood spring water contains ten times as much organic matter, yet it is fully equal in quality to the best sample of the present supply which we have examined. But even these new waters are very hard and would be greatly improved, in this respect, by the application to them of Clarke's simple and inexpensive process of softening by lime. This process has for some time past been applied with the best results to similar hard waters delivered at Canterbury, Caterham, and Tring. By being submitted to this operation the Eyford spring water would have its hardness reduced from 27¼ to 5½ parts in 100,000, and the Monkswood spring water from 29 to 6 parts in 100,000. The palatability of the softened water would be fully equal to that of the original spring, whilst it would be rendered suitable for washing and cleansing operations, for which purposes it

Part II. Water Supply.

is not adapted in its original condition. Moreover, the softened water would have no tendency to form encrustations in the mains, of which there are some remarkable examples at Bath.

Wear, Tees, Kent, and *Windrush* basins.

The moderate amount of previous animal contamination which the Eyford and Monkswood waters exhibit need not be regarded with suspicion, as the very perfect filtration through rock which they have undergone reduces the risk from the presence of noxious matters to a vanishing quantity.

We examined a sample of spring water issuing from the oolite on Hampton down. The land immediately above the spring is pastured by sheep whose excrements are scattered profusely over the surface, there are also some cultivated and manured fields at some distance, but they probably do not affect the spring much, if at all. We find comparatively small evidence of anterior animal pollution in this sample.

Although the thermal springs of Bath have frequently been submitted to careful chemical analysis, the organic elements contained in them have never been determined; we have therefore analysed the waters of the Hetling and King's bath springs, and find that they contain, for deep spring waters, a large proportion of organic elements, and they thus resemble, in this respect, most of the cold spring waters of the neighbourhood.

Potable Waters in the Wear, Tees, Kent, and Windrush Basins.—The basins of the *Wear* and *Tees* contain, in addition to the coal measures, chiefly new red sandstone and magnesian limestone. These strata being calcareous, the water which is derived from them is hard, but where the rocks are compact, and consequently but slightly porous, they expose less surface to the rain falling upon them, or percolating through their fissures, and the water leaves them of only moderate hardness. This appears to be the case in the *Tees* basin, the water flowing from which has scarcely more than half the hardness of that collected by the basin of the *Wear*. We have had but one opportunity of examining the deep well water of these basins, viz., that supplied to Sunderland from the dolomite. Judging from this sample, the dolomite water is of excellent quality and of but moderate hardness. This hardness is, however, of the permanent type, and therefore not removed by boiling or by the addition of lime.

The basin of the *Kent* above Kendal consists almost entirely of the non-calcareous members of the Upper Silurian series of rocks; the water collected within it and forming the rivers *Sprint* and *Kent* is therefore very soft, and as the mountain slopes have upon them but a moderate amount of peat, it is tolerably free from peaty matter. The upper reaches of the *Kent* basin were proposed a few years ago by Messrs. Hemans and Hassard, in their scheme for supplying London from Ullswater lake, as subsidiary sources of supply. Although the river is somewhat polluted by paper mills and receives the drainage from some manured land before it reaches Kendal, yet it is still much purer than many waters supplied to large communities. We have had no opportunity of testing the deep subterranean water of this basin.

The basin of the *Windrush* (a tributary of the *Thames*) lies almost entirely in the middle and lower oolite, the upper part of the stream only penetrates into the lias; and these formations being both calcareous and considerably porous, the water collected in and upon them is hard, but the hardness is temporary, and can be reduced to less than one-fourth of its original amount, either by boiling for half an hour, or by the process of liming already repeatedly referred to.

The following table contains the results of our analyses of potable waters from these basins:—

Potable Waters in the Wear, Tees, Kent, and Windrush Basins.

Results of Analysis expressed in Parts per 100,000.

Description.	Temperature Centigrade.	Dissolved Matter.											Remarks.
		Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness.			
										Temporary.	Permanent.	Total.	
Durham.	°												
The *Wear* above city, as it entered subsidence reservoirs of waterworks, Oct. 5, 1870.	11·7	49·56	·166	·030	·010	0	·038	0	4·60	11·31	10·89	22·20	Slightly turbid.
Water supply in city, Oct. 5, 1870 - -	13·0	54·50	·082	·020	0	·011	·031	90	4·85	11·58	13·42	25·00	Do. do.
Medical officer's private well, Oct. 5, 1870 -	14·4	113·72	·124	·045	0	6·268	6·313	62,360	9·75	24·30	45·70	70·00	Clear.

Description.	Temperature Centigrade.	Dissolved Matters. Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Permanent.	Total.	Remarks.
SUNDERLAND.													
Water supply from dolomite well, Sept. 16, 1868.	11·0	41·18	·035	·030	0	·416	·416	3,840	4·17	·79	13·95	14·74	Clear.
DARLINGTON.													
Water supply, June 30, 1870 - - -	—	16·26	·241	·025	0	0	·025	0	1·15	2·60	7·88	10·48	Do.
Blackwell pump, Oct. 6, 1870 - -	—	127·00	·129	·033	0	6·724	6·757	66,920	8·45	36·90	41·70	78·60	Do.
MIDDLESBOROUGH.													
The *Tees* above the town, as delivered by pumps in Stockton and Middlesborough waterworks, Oct. 6, 1870.	11·7	17·92	·183	·029	0	0	·020	0	·95	10·43	2·99	13·42	Slightly turbid.
Ditto, after filtration by Stockton and Middlesborough Water Company, Oct. 6, 1870.	12·2	17·24	·180	·013	·001	0	·014	0	·90	8·64	3·64	12·28	Clear.
STOCKTON.													
Well in the courtyard of Joseph Dodds, Esq., M.P., Oct. 7, 1870.	—	133·12	·195	·047	0	1·927	1·974	15,950	16·70	46·70	39·00	85·70	Slightly turbid.
Mr. Trotter's well, Oct. 7, 1870 - -	11·1	150·08	·195	·037	·014	1·913	1·962	18,950	25·30	52·00	35·10	87·10	Do. do.
KENDAL.													
Water supply, March 23, 1871 - -	5·6	8·50	·128	·021	·001	·093	·115	620	1·10	0	4·17	4·17	Slightly turbid.
The *Kent* above the town, March 17, 1871 -	3·3	6·48	·149	·020	0	·044	·061	120	·90	0	3·90	3·90	Do. do.
Shallow well in King's Arms Yard, Mar. 17, 1871.	7·8	100·20	·362	·110	·625	2·465	3·090	29,480	17·00	22·31	19·14	41·45	Clear.
WITNEY.													
The *Windrush* above Witney, Dec. 9, 1870	3·0	28·30	·105	·033	·001	·293	·327	2,620	1·13	18·00	5·00	23·00	Turbid.
Shallow well in Wiggin's yard, opposite Blanket Hall brewery, Dec. 9, 1870.	9·4	145·00	·527	·250	·240	4·432	4·880	45,980	22·90	37·87	16·43	54·30	Slightly turbid.
Deep well in Messrs. Clinch & Company's brewery, Dec. 9, 1870.	10·3	71·04	·142	·053	·001	·308	·362	2,770	7·80	26·44	12·86	39·30	Clear.

Durham is supplied with water on the constant system for domestic purposes from the river *Wear* and from private wells. The pumping station of the Durham Waterworks Company is situated about one mile and a half above the city, and about 350,000 gallons of water are pumped from the river daily. The water is subjected to filtration before it leaves the works, but the operation was not being quite satisfactorily performed when we took our sample at the County Hotel, as the water was slightly turbid. The river is stated to be polluted by "hush"—the debris from the washing floors of lead works, and by sewage from Bishop Auckland and other small towns higher up the stream; there was, however, but small evidence of this pollution in our sample, which shows the water to have been on that occasion of good quality, considering its source; indeed a comparison of the water, before and after filtration, indicates a much greater improvement than is usually effected by that process, which is perhaps accounted for by the circumstance that the filters are of the unusual depth of seven feet. Although we do not consider that water taken from a river subject to direct sewage contamination is a safe supply for a town, yet it is greatly to be preferred to that of the shallow wells of the city, if the well of the medical officer be, as described to us, one of the best. This water, though clear and sparkling, is shown by our analysis to be little else but the percolations from sewers and cesspits; 100,000 lbs. of it contain the inorganic remains of as much excrementitious matter as is present in 62,360 lbs. of London sewage, whilst the large proportion of chlorine, which it contains, shows that a good deal of urine mixes with it; indeed the pump is in a back yard close to a privy and ashpit, and the waste water from the pump trough passes down a sewer-grid close to the pump. With such arrangements, it is impossible to prevent the surrounding earth from becoming soaked with excrementitious matters, and although, in this case, the well itself is a few yards distant, under an adjoining dining room, the soakage obviously gains free access to its water.

Sunderland.—This town is supplied with excellent water, on the constant system, from deep wells sunk into the dolomite. The water contains but mere traces of organic matter, and it has about the same degree of hardness as water from the limestone; but the hardness is permanent, and therefore not removeable by boiling or by the addition of lime. As dolomite is a double carbonate of lime and magnesia, it was to be expected that both these alkaline earths would be present in the water, analysis confirms this supposition and shows that 100,000 lbs. of this water contain 8·24 lbs. of lime, and 6·59 lbs. of magnesia. As the wells are deep, the evidence of original animal contamination exhibited by the water is of no importance.

Darlington is supplied by the Local Board of Health with filtered water on the constant system from the river *Tees*. The pumping station and filter beds are at Tees

PART II. WATER SUPPLY.

Tees, Kent, and *Windrush* basins.

Cottage about two miles from the town; 1,000,000 gallons, or 43 gallons per head of population, are delivered daily, besides 500,000 gallons for trade purposes. The water is to some extent polluted above the intake, by the sewage of Barnard Castle,—a town of about 4,000 inhabitants,—and by that of the houses and villages between Darlington and Barnard Castle. To this circumstance is probably due the somewhat high proportions of organic carbon and organic nitrogen revealed by our analysis. In other respects the water is of good quality and but moderately hard. Previously to the establishment of these works the town was supplied with water from wells; the authorities state that "an inexhaustible supply of excellent water has been introduced into our streets, yards, "and houses, which has not only changed the aspect of the town, but has necessarily "proved a source of inestimable benefit to the health and comfort to the inhabitants." The Board of Health will doubtless use its best endeavours to preserve this bountiful supply from being fouled by the filth of the villages situated on the higher reaches of the river. It is also desirable that wells like that supplying the Blackwell Pump near the centre of the town should be closed. They are fed almost entirely by soakage from sewers.

Stockton.—This town is supplied with water on the constant system by the Stockton and Middlesborough Waterworks Company. The water is obtained from the river *Tees*, the pumping station being at Tees Cottage above Darlington. The source of supply is therefore identical with that from which the Local Board of Health of Darlington obtain water, and our remarks upon the risk of pollution to which the upper part of the *Tees* is exposed, are therefore equally applicable to the water delivered at Stockton and Middlesborough. Our analyses, in the above table, exhibit the condition of the water at the Company's works before and after filtration, from which it is seen that, not only are the suspended impurities removed, but an appreciable diminution, even of the organic matters in solution, is effected.

The water, at the time our sample was taken, was of unimpeachable quality; it was clear and bright and nearly as palatable as deep well or spring water. Its hardness was moderate 12¼°; but by boiling for half an hour or by the addition of quicklime in the proportion of 7 cwts. to each 1,000,000 gallons, we find that it can be softened to 3½°; it thus becomes better adapted for washing, cleansing, and manufacturing purposes, whilst it is at the same time rendered more palatable for drinking. The supply is twenty-four gallons daily per head of population for domestic purposes. Some of the inhabitants of Stockton prefer to drink the water from wells sunk upon their own premises, but these contain the remains of much animal matter, and, if not carefully protected from surface soakage, constitute dangerous sources of potable water. Two examples of water from wells of this description about 90 feet deep are given in the foregoing analytical table. The water was slightly turbid in both cases, and this circumstance together with the, for deep well water, very high proportions of organic elements (organic carbon and organic nitrogen) point unmistakably to the flow of surface drainage into the upper part of the shafts of these wells.

Middlesborough derives its water supply from the same source and the same company as Stockton. The supply is constant, and 5,000,000 gallons are delivered to the district daily for domestic and trade purposes. Previously to the establishment of the waterworks in 1851, the town obtained its supply from private wells.

Kendal.—This town is partially supplied by a private company on the constant system with water from two reservoirs fed by gathering grounds, supplemented by water pumped from the river *Kent*. Our analysis shows it to be soft, and of good quality, but slightly turbid. The daily volume brought into the town is said to be about 200,000 gallons, which gives only 16 gallons per head of population. Shallow wells are consequently used to a considerable extent, and these, sunk as they are in the foul soil of an ancient town, yield a beverage of a dangerous quality. Thus the sample from the pump in the King's Head Hotel yard, the analysis of which is given in the above table, is frightfully contaminated by soakage from neighbouring privies, piggeries, and stable yards.

Witney.—This town, situated in the basin of the *Windrush*, has no waterworks, but derives its supply from wells varying in depth from 6 to 15 feet; the water of these wells is frightfully polluted and entirely unfit for human consumption, one of them which we have analytically examined is supplied chiefly from percolations from sewers and cesspools, and contains a large proportion of unoxidized sewage matter besides ammonia from urine. There is a well 65 feet deep near to Messrs. Clinch and Co.'s brewery, sunk in an orchard of about ¾ acre area, on which are grown carrots, parsnips, and potatoes. The ground has been broken up for two years and manured with stable dung; never-

PART II. GENERAL SUMMARY.

theless, owing to the depth of this well, the water is of very much better quality. The *Windrush* at the time of our visit contained purer water than any of these wells, but the best supply for Witney would be obtained by sinking a well at least 100 feet deep into the oolite outside the town.

Condition of the rivers *Aire* and *Calder*.

GENERAL SUMMARY.

The Condition of the Rivers Aire and Calder—which drain the principal seat of the woollen manufacture in this country—has been already represented to Your Majesty in the report of our predecessors. They state (Report (1867) on the *Aire* and *Calder*, 1867—p. xi) that these rivers and their tributaries "are abused by passing into them " hundreds of thousands of tons per annum of ashes, slag, and cinders from steam boiler " furnaces, iron works, and domestic fires; by their being made the receptacles to a vast " extent of broken pottery and worn out utensils of metal, refuse bricks from brick yards " and old buildings, earth, stone and clay from quarries and excavations, road scrapings, " street sweepings, &c.; by spent dyewoods and other solids used in the treatment of " worsteds and woollens; by hundreds of carcases of animals, as dogs, cats, pigs, &c. " which are allowed to float on the surface of the streams or to putrify on their banks; " and by the flowing in, to the amount of very many millions of gallons per day, of " water poisoned, corrupted, and clogged by refuse from mines, chemical works, dyeing, " scouring, and fulling worsted and woollen stuffs, skin cleaning and tanning, slaughter- " house garbage, and the sewage of towns and houses."

The present condition of the running waters in these valleys and in other seats of the woollen manufacture has been sufficiently indicated by the character of the samples whose composition has been stated in the foregoing pages.

It is extremely desirable that the regulations by which river pollution may be prevented shall be of universal application; and, in summarising these examples of the pollution due chiefly to the woollen manufacture, we have therefore borne in mind the condition of other valleys whose rivers are fouled by the sewage of factories and towns engaged for the most part in other industries. A comparison of samples from the Yorkshire and Lancashire valleys respectively shows, however, but little difference, except one of degree, in the pollution of their river waters, notwithstanding the difference in the predominating industries of the two districts. We learn from it, indeed, that when there is a large area occupied by an immense population—necessarily therefore engaged in a great variety of occupations,—the preponderance of the cotton or the woollen manufacture does little to impress a specific character on the condition of the river water. When a small stream drains a particular locality engaged almost exclusively in one industry, no doubt its water has a recognisable distinctiveness. This is seen obviously enough in the case of the *Sankey Brook* which receives the drainage of the chemical works at St. Helens; in that of the *North Esk* and of the *Water of Leith* near Edinburgh, fouled by the paper mills on their banks; also in that of the *Dichty Burn* near Dundee, which receives the drainage of many bleach works. In such cases, however, as the *Mersey* and *Ribble* basins, and the *Aire* and *Calder* valleys, whose rivers and streams receive the drainage from many hundreds of thousands of inhabitants, the characteristic liquid refuse of a preponderating industry is almost entirely lost, and the foulness of their running waters, due in part to manufacturing drainage, and in part to house sewage, is substantially the same in kind, depending for its degree simply upon the frequency and population of the towns upon their banks. The *Irwell* drains an area of rather less than 200,000 acres, occupied in 1861 by rather more than 1,000,000 people; the *Aire* and *Calder* drain an area of rather more than 500,000 acres, occupied in 1861 by rather less than 1,000,000 people. There must be nearly the same quantity of the waste products of industry and of life in the one district as in the other, but considering the great difference of the areas,—even allowing for a considerably larger rainfall in Lancashire than in Yorkshire,—such of these waste products as are soluble in water must be laden upon a much smaller body of river water in the former case than in the latter, and the rivers of the one county are therefore much fouler than those of the other. For the accurate illustration of a fact which might thus have been reasonably anticipated, we have collected in one table the analyses, already discussed, of the various river waters, polluted by the Yorkshire towns occupied chiefly in the woollen manufacture, for comparison with a corresponding series of analyses of the running waters of Lancashire, polluted by the much denser population there engaged principally in the cotton manufacture; and a glance will show that—agreeing very nearly in the composition of their waters, as the several rivers do at their respective sources,—they speedily come

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to differ, not indeed to a great extent in the kind, but in the intensity of the pollution which they exhibit.

Comparison of the *Aire* and *Calder* with the *Irwell*.

In the first of the following tables are collected analytical results yielded by samples taken at various points on the *Aire* and *Calder* and their affluents; the population of the whole district being in 1861 about 1,200 to the square mile.

I. COMPOSITION OF RIVER WATERS IN THE AIRE AND CALDER BASIN.

(Population, 1861, about 1,200 per square mile.)

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Aire Head spring below Malham, Sept. 30, 1869.	**15·70**	**·165**	**·007**	**·001**	**·017**	**·025**	—	**·99**	**0**	**0**	**0**
Bradford Beck below town and sewer outfall, 5 p.m., Oct. 5, 1869.	75·5	4·024	·392	1·220	0	1·397	·002	5·45	15·95	36·05	52·00
The *Aire* at Kirkstall Bridge above Leeds, Sept. 28, 1869.	24·5	·749	·082	·068	·119	·257	trace	1·77	·54	·22	·76
The *Aire*, a quarter of a mile below the Leeds sewer outfall, Sept. 28, 1869.	37·5	1·350	·127	·611	·324	·954	·010	3·20	2·78	2·62	5·40
The *Aire* 100 yards above junction with the *Calder*, Sept. 29, 1869.	27·60	·822	·105	·131	·075	·288	trace	1·81	1·84	1·46	3·30
Mixed sample of three of the branches of the Calder above Todmorden, Jan. 26, 1871.	**7·61**	**·060**	**·011**	**·003**	**·027**	**·041**	—	**1·13**	**0**	**0**	**0**
The *Calder* below Todmorden sewer outfall, Oct. 2, 1869.	15·10	·192	·056	·095	·094	·228	0	1·49	2·99	·910	3·90
The *Hebble* below Halifax, Sept. 24, 1869.	57·60	2·472	·633	·064	0	·686	·004	4·30	9·36	13·28	22·64
The *Colne* at Bradley Mills Bridge below Huddersfield, Sept. 23, 1869.	16·25	1·227	·186	·109	0	·276	·008	1·94	—	—	—
The *Calder* above Wakefield, Sept. 29, 1869.	17·10	·424	·097	·088	·166	·335	trace	1·73	4·39	2·31	6·70
Ditto below Wakefield, Sept. 29, 1869 -	19·80	·530	·050	·086	·134	·255	·008	2·30	3·00	2·02	5·02
Ditto 100 yards above junction with the *Aire*, Sept. 29, 1869.	19·50	·480	·044	·082	·130	·242	0	2·31	1·94	·61	2·55
The *Aire* just below Castleford, Sept. 17, 1869.	25·40	·661	·091	·125	0	·194	trace	2·27	2·90	1·50	4·40

With the above we compare a series of samples taken in the *Irwell* basin where the population was (in 1861) about 3,200 per square mile:—

II. COMPOSITION OF RIVER WATERS IN THE IRWELL BASIN.

(Population, 1861, about 3,200 per square mile.)

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.	Metallic Arsenic.	Chlorine.	Suspended Matters. Mineral.	Suspended Matters. Organic.	Suspended Matters. Total.
The Irwell near its source, June 12, 1869.	**7·80**	**·187**	**·025**	**·004**	**·021**	**·049**	—	**1·15**	**0**	**0**	**0**
The *Irwell* above Bury, June 24, 1868	39·02	1·083	·059	·394	0	·383	—	4·32	—	—	—
The *Roch* below Rochdale and above Bury, June 24, 1868.	43·30	4·518	·288	·512	·230	·940	—	4·57	2·82	3·18	6·00
The *Croal* below Bolton, June 22, 1868	69·20	·842	—	·972	1·368	—	—	10·08	8·20	2·92	11·12
The *Medlock* in Manchester just before its junction with the *Irwell*. Mean of summer and winter samples.	55·00	1·798	·596	1·388	0	1·739	·004	9·11	10·93	6·53	17·46
The *Irk* just before junction with the *Irwell*. Mean of summer and winter samples.	59·5	1·822	·309	1·004	0	1·136	·016	9·83	4·85	4·95	9·8
The *Cornbrook* just before its junction with the *Irwell*. Mean of summer and winter samples.	109·9	4·169	·313	·887	·024	1·068	·012	25·73	23·39	19·37	42·76
The *Irwell* below Manchester, June 17, 1868. Mean of four samples.	50·75	1·892	·264	·371	·177	·746	·022	8·73	2·10	2·06	4·16

A comparison of the river waters in these two basins might be made by taking the average of the eleven samples named in the first table, and contrasting it with the average of the thirteen samples referred to in the second; but in order to the accurate use of each

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Effect of density of population on rivers.

sample in any such comparison it would be necessary to multiply the composition of each into the volume of the river at the point where it was taken before the average was struck, and for such a calculation we do not possess the data. The lesson, however, which would thus be given as to the effect of a large manufacturing population upon the running waters of an extensive district is taught by a comparison, more easily made and less open to objection, of the samples taken below Leeds, Manchester, and Bradford where the river represents the drainage of 342, 311, and 14 square miles respectively—occupied, the first by about 1,400, the second by about 3,200, and the third by about 10,000 inhabitants per square mile.

COMPARISON OF RIVERS IN DISTRICTS OF VARYING DENSITY OF POPULATION.

RESULTS of ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
Aire below Leeds—Population 1,400 per square mile.	37·5	1·350	·127	·611	·324	·954	·010	3·2	2·78	2·62	5·40
Irwell below Manchester—Population 3,200 per square mile.	50·75	1·892	·264	·371	·177	·746	·022	8·73	2·1	2·06	4·16
Bradford Beck below Bradford—Population 10,000 per square mile.	75·5	4·024	·392	1·220	0	1·397	·002	5·45	15·95	36·05	52·00

It must be observed, in order that the full signification of these figures may appear, that in addition to the ordinary drainage water of about fourteen square miles which flows out below Bradford, the water supply of that town, brought from other valleys, amounting to several millions of gallons daily, comes in to dilute the pollution of the beck. The same disturbance no doubt also obtains in the case of the *Irwell* below Manchester, into which the water supply of that city brought from the *Etherow* basin is discharged, but the volume of the river is here relatively very much larger. The comparatively small quantity of solid matter in suspension in the water below Leeds and Manchester is owing to the weirs which in both towns make the river bed in many places a large subsidence pond above the points where our samples were taken.

This comparison shows that the proportion of polluting constituents in solution, represented by organic carbon and organic nitrogen, augments with the density of population. The rate of augmentation of polluting matter is indeed not identical with the rate of increase of density of population, owing doubtless to the disturbing causes which affected the relative volumes of water, per acre of gathering ground, flowing in the different rivers at the time our samples were taken; and their comparison instituted in this table must, therefore, be taken as only roughly illustrating the dependence of the intensity of the pollution of rivers upon the density of the population in their basins. Wherever indeed a large area is occupied by a closely packed industrial population,—the foulness of the stream, due equally in their several proportions to mansions, cottages, and mills, is dependent ultimately on the density of the population located on its banks; the preponderance of either the cotton or the woollen manufacture doing little to impress any specific or distinctive character on its condition. Nevertheless, the large amount of arseniate of soda used in the calico printing industry announces itself in the much higher proportion of metallic arsenic present in the *Irwell;* and the use of enormous quantities of chloride of lime in the bleaching of cotton fabrics, whilst none is used in the bleaching of woollen goods, makes itself strikingly felt in the column headed chlorine in the above table, from which it is seen that the proportion of this element in the Lancashire river is far greater than that in the Yorkshire streams.

In the following table, analytical results are collected yielded by river waters in other parts of England, which are also polluted chiefly by populations engaged in the woollen manufacture; and, although in these cases we have not the exact figures representing definite areas occupied by known numbers, yet the same general truth, illustrated by the above comparison of the *Aire*, the *Irwell*, and the *Bradford Beck*, is obvious in the much smaller degrees of pollution observable in the rivers and streams of the sparsely populated counties, Gloucestershire, Somerset and Wiltshire, Montgomeryshire, Worcestershire, Oxfordshire, and Westmoreland, when compared with those of Yorkshire.

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Effect of density of population on rivers.

COMPOSITION OF RIVER WATER POLLUTED BY THE WOOLLEN MANUFACTORIES.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
GLOUCESTERSHIRE.											
The Frome above the highest mill in the Chalford valley, Mar. 18, 1870.	**27·50**	**·062**	**·009**	**0**	**·298**	**·307**	**0**	**1·05**	**0**	**0**	**0**
The *Frome* above Stroud and below Frampton Mill, Mar. 17, 1870.	30·30	·202	·031	·005	·273	·308	0	1·25	2·32	·63	2·95
The *Frome*, just above junction with the *Avon*, Mar. 17, 1870.	29·30	·239	·033	·010	·359	·400	0	1·50	·84	·46	1·30
The *Avon*, just above its junction with the *Frome*, Mar. 17, 1870.	29·24	·188	·021	·015	·281	·314	·003	1·55	·35	0	·35
The *Frome*, at Ebley, just below junction with the *Avon*, Mar. 17, 1870.	28·44	·165	·022	·013	·317	·350	0	1·40	·77	·29	1·06
The *Frome*, at Eastington and below Meadow Mill (the last mill), Mar. 17, 1870.	30·26	·157	·023	·013	·293	·327	0	1·46	·53	·10	·63
SOMERSET AND WILTS.											
The Frome above the town of Frome and above Woodland's mill, Mar. 10, 1870.	**17·46**	**·326**	**·025**	**·004**	**·042**	**·070**	**0**	**1·55**	**trace**	**trace**	**trace**
Ditto below Frome and Spring Garden's mill, Mar. 10, 1870.	26·10	·411	·046	·005	·191	·241	0	1·88	·76	·14	·90
The *Biss*, below Trowbridge, Mar. 11, 1870.	39·10	·592	·074	·075	·108	·244	0	2·50	1·30	1·44	2·74
The *Avon*, above Bradford, Mar. 11, 1870.	35·06	·357	·057	·008	·287	·351	0	2·00	·41	0	·41
Ditto below Bradford, Mar. 11, 1870.	35·20	·340	·071	·008	·306	·384	0	1·95	·56	0	·56
Ditto above Bath and Bath Easton, Mar. 12, 1870.	34·80	·238	·029	·004	·327	·359	0	1·90	0	0	0
Ditto below Bath, at suspension bridge, Mar. 12, 1870.	35·06	·259	·041	·028	·313	·377	trace	1·90	traces	traces	traces
OXFORDSHIRE.											
The Windrush above Witney and New Mill, Dec. 9, 1870.	**28·30**	**·105**	**·033**	**·001**	**·293**	**·327**	**·020**	**1·13**	**traces**	**traces**	**traces**
The *Windrush*, about ¾ mile below Witney, Dec. 9, 1870.	28·24	·123	·033	·003	·304	·339	·040	1·10	traces	traces	traces
MONTGOMERYSHIRE.											
The Severn above Milford mill and Newtown, April 27, 1870.	**6·60**	**·123**	**·016**	**·003**	**·010**	**·028**	**—**	**1·35**	**trace**	**trace**	**trace**
The *Severn*, below Newtown, April 27, 1870.	6·02	·120	·018	·001	·010	·029	—	1·38	trace	trace	trace
WORCESTERSHIRE.											
The Stour above Cookley, April 28, 1870.	**42·84**	**·268**	**·039**	**·014**	**·352**	**·403**	**—**	**6·85**	**·34**	**0**	**·34**
The *Stour*, below Kidderminster, April 28, 1870.	40·00	1·224	·179	·016	·182*	·374*	—	6·32	1·28	·52	1·80
WESTMORELAND.											
The Kent above Kendal, Mar. 17, 1871.	**6·48**	**·149**	**·020**	**0**	**·044**	**·064**	**—**	**·90**	**0**	**0**	**0**
The *Kent* below Kendal, Mar. 17, 1871	7·56	·217	·036	·001	·058	·095	—	·90	trace	trace	trace

* For an explanation of this reduction of the nitrogen in nitrates, and of the total combined nitrogen, see p. 25.

That the smaller intensity of pollution of the Yorkshire rivers, and the comparative purity of the rivers and streams in other seats of the woollen manufacture in England, when these are contrasted with the rivers of Lancashire, is not due to any comparative cleanness of the woollen manufacture—any greater foulness of the drainage from the cotton manufacture—is plain from an examination of the various refuse liquids from a number of individual factories. On the contrary, the former drainage waters are, as might have been expected on the whole, fouler than any we have taken from cotton mills which deal with an originally much cleaner raw material. The following list of analyses of waste waters from the scouring, dyeing, and washing processes of the woollen manufacture contains many examples of a filthier refuse, than any recorded in our report on the pollutions to which the filthy condition of the rivers in the *Mersey* and *Ribble* basins is due.

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Remedies.

COMPARISON OF DRAINAGE WATERS FROM WOOLLEN AND COTTON MILLS.

RESULTS OF ANALYSIS expressed in Parts per 100,000.

Description.	Dissolved Matters.								Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Metallic Arsenic.	Chlorine.	Mineral.	Organic.	Total.
WOOLLEN MILLS.											
Drainage from Messrs. Holdroyd and Son's woollen mill, Batley, Sept. 21, 1869.	24·80	2·610	·262	·208	·144	·577	·002	1·82	3·64	9·16	12·80
Drainage from Messrs. Crowther's scouring and washing mills, Huddersfield, Sept. 23, 1869.	29·70	2·469	·216	·356	0	·509	·004	1·76	34·76	35·84	70·60
Drainage from Shepley New Mill, Huddersfield, Sept. 22, 1869.	112·3	22·455	4·143	10·350	0	12·664	0	12·75	35·40	188·30	223·70
Waste woollen dye liquor from Bradley Mill, Huddersfield.	204·7	43·207	2·719	2·340	0	4·646	0	14·4	1·80	25·28	27·08
Drainage from Mr. Charles Early's blanket mill, Witney, Dec. 9, 1870.	678·00	120·710	19·508	·940	0	20·282	·004	35·6	60·40	314·20	374·60
Waste liquid from woollen dye-vats.	107·60	48·969	3·321	·492	0	3·726	—	3·60	24·08	77·92	102·00
Waste liquor from wool scouring and washing, Messrs. Kelsall and Kemp, woollen factory, Rochdale.	1009·40	132·480	9·880	54·610	0	54·850	traces	—	870·95	2611·65	3482·60
Waste liquor from woollen rag washing engines in Messrs. Grist, Brothers', shoddy mill at Brimscombe, near Stroud, March 18, 1870.	32·80	1·364	·114	·180	0	·262	0	1·90	11·92	17·00	28·92
Water from wool washing and dyeing at Messrs. A. Smith and Co.'s dyeworks, Dudbridge, March 17, 1870.	29·62	·189	·053	·011	·344	·406	·002	1·50	·72	·88	1·60
From Messrs. Crossley and Co.'s carpet works, Halifax, Sept. 25, 1869.	366·0	23·264	3·267	4·812	0	7·230	·028	25·20	—	—	—
From Sir Titus Salt, Bart., Sons, and Co.'s works at Saltaire, Oct. 5, 1869.	662·0	81·359	8·825	3·655	·011	11·846	·016	17·00	8·95	145·55	154·50
Waste liquor discharged into *Severn* from flannel washing at the Cambrian Flannel Co.'s mill, April 27, 1870.	1248·0	446·353	91·185	80·012	0	157·077	0	160·0	346·00	1733·40	2079·40
Liquor entering the *Avon* from grease extracting process at Messrs. W. Playne and Co.'s woollen mill, Mar. 17, 1870.	307·7	23·509	10·810	15·475	0	23·554	·080	21·40	·48	5·68	6·16
Discharge from Messrs. Thompson and Le Gros' crape and silk mill, Frome, March 10, 1870.	100·2	20·934	1·247	·360	0	1·543	0	2·8	3·2	7·6	10·8
Waste liquor from Messrs. Webb and Co.'s woollen, dyeing, and scouring mill, mixed with town sewage (March 11, 1870).	52·2	1·872	·211	·900	·115	1·067	·002	7·48	31·2	41·8	73·0
Average of fifteen samples -	**337·00**	**64·783**	**10·384**	**11·647**	**·041**	**20·015**	**·011**	**21·94**	**102·39**	**372·45**	**474·84**
COTTON MILLS.											
Polluted water from cotton dye, print, and bleach works. Average of five samples.	**50·2**	**4·226**	**·299**	**·125**	**0**	**·399**	**·034**	**4·86**	**7·02**	**18·97**	**25·99**

Remedies.—In so far as the polluted condition of the rivers and streams in Yorkshire, or in any other district of the woollen manufacture is due to the admixture of town sewage, a perfectly trustworthy remedy for it exists, and one which is, in general, easily adopted. In our Report (1870) on the *Mersey* and *Ribble* basins (Vol. I., pp. 70–95), the efficiency of irrigation for the abatement of the nuisance created by town sewage was amply illustrated and explained.

By many examples, carefully investigated, it was shown that when the drainage water of a house or town is evenly spread over a sufficient surface of land, and there, as well as within the soil beneath that surface, exposed to the cleansing influence of the earth, and subjected to the oxidising effect of the air,—undergoing at the same time an actual consumption of its foul but fertilising ingredients by the roots of growing plants,—this filthy water becomes so far cleansed and purified as to be no longer a polluting

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Remedies.

liquid. The condition of the effluent drainage from land thus treated is indeed perfectly satisfactory, being superior to those standards of purity below which we have proposed that no liquid shall be deemed admissible into running waters.

It is the great advantage of the irrigation remedy for this class of river pollutions that their filth is not merely destroyed but converted into wholesome food. Valuable marketable products are obtained, and thus the expense of the process may be recovered.

We have also pointed out, for the benefit of those places where the expense of this process might be excessive, owing either to the cost of land, or the cost of taking the sewage to it, that another remedy exists,—from which however there are no returns. In this alternative method, one of the agencies to which the efficiency of the land remedy is due, is so organised and perfected, that in place of acres of deep soil and subsoil being required, a comparatively small bulk of earth is found to be sufficient. The oxidising effect of mixture with the air upon and beneath the surface of a farm may thus be realised within a comparatively small quantity of properly worked filtering material. And whereas 100 acres or more might be needed to cleanse, certainly to profitably utilise, the drainage of a town of 10,000 people by means of irrigation, it would need but three acres of a porous medium six feet deep, worked as an intermittent filter, to oxidise and therefore purify the drainage water of such a town, provided the mass of earth through which it percolated were frequently and effectually aerated, and the foul liquid were so added that every part of this aerated filter had its equal share and equal interval of aeration. The laboratory experiments, on which we build our confidence in filtration thus conducted for cleansing sewage, may be considered conclusive as to the satisfactory and permanent efficacy of the remedy thus provided; and although it is by no means certain that such an apparatus, on the scale needed for a large town, would not itself be a formidable nuisance, yet there is every reason to believe that the water running from it would be sweet and clean; and the previous treatment of the sewage, by some precipitant of its suspended matters, would, as pointed out in the Report (1870) on the *Mersey* and *Ribble* basins (Vol. I., p. 128), tend to 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.

This alternative method of dealing with the sewage difficulty may therefore be adopted with advantage by towns in steep and narrow valleys where a sufficient area of land for irrigation cannot be obtained below the sewer outfall, and where the cost of pumping on to higher lands would be excessive. Such a case exists at Halifax, which is now under an injunction to abate the nuisance occasioned by its filthy drainage water. We gather from a report to the Corporation of Halifax, by Messrs. Lawson and Mansergh, Civil Engineers,* that neither the uplands (300 or 400 feet above the sewer outfall) nor the lower lands (required by the towns and villages to which they more properly belong) being available for irrigation, they have recommended this process of intermittent filtration, after a preliminary precipitation of suspended matters, as the only hopeful plan of abating the nuisance—all known methods of precipitation for dealing with the soluble polluting ingredients of sewage water having failed. It is indeed suggested by Messrs. Lawson and Mansergh, that it may be ultimately necessary for Halifax and the other large towns situated in the *Aire* and *Calder* basins to combine for "the entire interception of the sewage from the whole of the towns and villages in this part of Yorkshire by means of conduits or sewers which shall convey it entirely away and utilise it on many thousands of acres of land which are to be found admirably adapted for the purpose in the neighbourhood of Thorne." Unless, however, this scheme were supplemented by an immense system of upland storage reservoirs, in which to collect heavy rainfalls for the supply of the rivers and streams during summer time and drought, such an interception of all sewage would result, not merely in cleansing the river channels, but in seriously diminishing the volume of their dry weather flow.

It is moreover against the probability of such a scheme ever being voluntarily adopted, that the great town of Leeds, which of itself, as we have shown, doubles the pollution of the *Aire*, and, like Halifax, is under injunction to abate the nuisance it creates, which moreover is situated the nearest of all the great towns in these valleys to the proposed area for sewage irrigation near Thorne,—being, indeed, within thirteen miles of suitable land on which its sewage could be delivered by gravitation,—has yet, after due consideration, preferred a smaller expenditure, on what, as we have shown in our second Report—on the "A.B.C." method of treating sewage,—is a hopeless experiment in

* Report to the Corporation of the borough of Halifax on the best mode of disposing of the sewage of the borough, by Messrs. Lawson and Mansergh, civil engineers. Printed by order of the Corporation, 1870.

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precipitation; to the cost of irrigation works which, while certain of success, would at the same time have been hopeful of a profitable return.

Remedies.

There remain for consideration the remedies proper for the nuisance created by the refuse from manufactories. The *Aire* and *Calder* and their affluents are, as our predecessors reported, poisoned, clogged, corrupted by refuse from various manufactories and mines. The remedy for the "clogged" condition of the river channel is obvious enough:—"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, should be absolutely prohibited under "adequate penalties." See Report (1870) on the *Ribble* and *Mersey* basins, (Vol. I., p. 136.)

The remedies for the pollutions due to the drainage from calico-print, dye and bleach works, from chemical works, and from tanneries, have been fully described in our former report and in the reports of our predecessors.

In discussing the river pollution due to woollen works, that which is caused by the waste liquor from scouring and dye vats should be considered apart from that which is produced in wool, yarn, and piece washing. The former, connected with which most difficulty exists, does not according to our analyses contain anything likely to injure plants when poured into a sufficiently large body of otherwise fertilising drainage water; and there is no reason, therefore, why it should not be discharged into the sewers of a town, where the town sewage is cleansed by irrigation before being passed into the river. When, however, no such exit for these waste dye liquors exists, it will be necessary to cleanse them before allowing them to escape. The experiments recorded in the preceding pages show that at a certain rate, probably three gallons daily for every cubic yard of filter, the blackest waste dye liquor may be cleansed and purified by intermittent filtration. This would indicate a filtering bed about 40 feet square and 6 feet deep for the purification of every 1,000 gallons of such liquor flowing daily from a factory, and this is but a small portion of the daily waste of this kind from many a mill or dyeworks in the *Aire* and *Calder* valley. (See Volume II., section 2.) But as it is only the waste vat liquor which requires careful treatment of this kind, the quantities to be treated would be enormously below those stated, in some of the returns referred to, as being discharged.

The much weaker washing waters of the dyed goods might be poured into the general mill sewer, and used in irrigation; or if the dyed and scoured goods were passed through squeezing rollers before washing—an operation attended with but trifling trouble or expense—the washing water might be passed direct into the river course without infringing the proposed standards of purity. The more strongly polluting liquors could be considerably reduced in bulk by utilising the waste heat of furnaces in their evaporation; or if filtration be depended upon, they could be improved for the application of that remedy by chemical treatment (see Report on *Aire* and *Calder*, pp. xxiv, xxv), so that the filter would deal effectually with a much larger quantity per cubic yard than is indicated by our experiments, in which an extremely black and foul liquor was used.

As regards all the other drainage liquors from a woollen factory, they are either admissible directly into running waters owing to the extreme dilution of any filthy ingredients they contain, or they possess an agricultural value and might be used upon the land. It is hardly necessary to add that when the manufacturer has to depend upon a filter for cleansing his waste liquors, he will take care to keep his fouler liquids separate and undiluted; whereas if he be able to use his drainage water in irrigation, he will throw all his waste liquors into the common sewer, using his diluter drainage as a carrier for the filthier stuff, so as to distribute the whole over a sufficient area of land. Some of the waste liquors whose composition is given on pages 30 and 50, are many times stronger in fertilising power than ordinary London sewage. Liquids containing in every 100,000 parts from 20 to 150 parts of combined nitrogen, as some of the waste liquors of wool, flannel, and blanket scouring do, are extremely valuable as manure; and the analyses given on pages 31 and 32 of the effluent waters, from such imperfect irrigation works as we have seen in Yorkshire, in connexion with mill drainage, prove that the agricultural remedy is probably as efficient against nuisances of this kind, as it is in the case of town sewage.

With regard to the washing of yarns and scoured or dyed wool in open streams, believing that its prohibition would seriously interfere with the success of dyeing operations, especially where bright colours are used, we are of opinion that this practice ought, in any legislative enactment, to be permitted, on condition that the dye or

scouring liquor is removed from the goods as far as possible by passage through squeezing rollers or otherwise before the washing operation is commenced. If this precaution be taken *bonâ fide*, no perceptible pollution of the stream will take place. It will be necessary, however, to restrict this permission rigorously to textile fabrics and the raw materials from which they are made, and not to allow of its extension to such things as raw or tanned hides, or even to the raw materials from which paper is made.

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Water Supply.

It is satisfactory to find among the large mass of evidence collected in the volume accompanying this Report (Vol. II., Section 2.), many instances in which manufacturers who have supplied us with the statistics of their operations have borne testimony to the possibility of applying a remedy to the filthy condition of their rivers and streams. In particular we direct attention to the evidence of the following firms:—Messrs. Henderson and Co., carpet manufacturers of Durham, on the river *Wear;* Messrs. Dewhurst and Sons, cotton and worsted spinners, at Skipton; Mr. T. B. Laycock, (woolcomber, spinner, and weaver), near Keighley, and Messrs. Ives and Tennant (flax spinners) of Leeds, on the *Aire;* Messrs. Joseph Smithson and Co. (fancy dress stuff manufacturers), Halifax; Messrs. Colbeck Brothers (woollen cloth manufacturers), Batley; Messrs. Cook, Son, and Wormald (blanket manufacturers), Dewsbury; and the Yorkshire Fibre Company (China grass manufacturers), Wakefield, on the *Calder;* Messrs. Stanton and Sons (woollen cloth manufacturers), Stroud, on the Gloucestershire *Frome;* and Mr. J. Thomas Clark (woollen manufacturer), Trowbridge, on the *Biss*, an affluent of the Somersetshire *Avon*. Messrs. P. and S. Taylor (woollen manufacturers), Bogor's mill, Stainland, on an affluent of the *Calder*, give the following testimony to the possibility of cleaning the waste liquors of the dye house:—"We are of opinion that 90 per cent. of "the liquid refuse from manufactories and mills could be kept out of rivers and streams, "which is now sent into them, if depositing tanks and filters were adopted. . . . . . . "If our dyehouse were in operation we should be able to comply with the standards "of purity stated in the report of the Rivers Pollution Commission on the *Mersey and* "*Ribble Basins*, and we are of opinion that everybody could bring all their liquid refuse "within that standard of purity before turning it into rivers and streams." Messrs. Houldsworth and Co., employing 3,000 hands in the woollen manufacture, at Shaw Bridge mills, Halifax, say:—"We suggest as the best means of avoiding river pollution for the "future, that all solid and liquid refuse from manufactories, mills, and works, should be "kept out of rivers and streams as far as practicable,—that the turning in of this "pollution be made penal, and that the offenders on conviction be fined."

The Water Supply of the larger towns in the woollen districts is generally abundant and of good quality, whilst in smaller towns and villages it is not unfrequently very insufficient in quantity and greatly polluted with excrementitious impurities. The importance of pure and soft water in many of the operations of the woollen trade, has assisted in enforcing the claims of the populations, on sanitary grounds, for an unpolluted beverage, claims which, without such support, are often ignored. There are only two safe sources of water for the supply of towns and for domestic purposes; these are,—1st, the unpolluted head waters of rivers; and 2nd, the waters of deep-seated springs and deep wells. As the chief condition of danger in potable water is excremental pollution, the safety of the first source is sufficiently obvious. The water derived from the second source has, however, usually been originally more or less contaminated, but its wholesomeness is guaranteed by the very perfect filtration through great thicknesses of rock, to which it has been subjected before it gushes from the spring or is drawn from the well. It has in fact undergone what may be appropriately termed an exhaustive process of intermittent filtration. We have repeatedly had occasion to recommend intermittent filtration through a few feet of porous soil, as one of the best methods of transforming foul and offensive liquids, whether sewage or manufacturing refuse, into unpolluting liquids; and if the few feet be multiplied by 100; and the porous soil be replaced by moderately compact rock, this process is competent to transform the polluted water, which sinks into the soil of cultivated fields and manured pastures, into a bright and sparkling beverage almost absolutely and sometimes quite free from organic matter, and containing suspended matters in such minute proportion as to require for their detection the most refined methods of physical research.

Waters from the first source are generally preferred for manufacturing purposes, on account of the extreme softness which always characterizes them when they are derived from non-calcareous gathering grounds, but they ought always to be filtered before use for domestic purposes. Those from the second source are usually more palatable as beverages, owing to their complete, or almost complete, freedom from organic matter, a

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Conclusions.

comparatively small proportion of which communicates to the water a more or less pronounced bitter taste. This general superiority of deep well and deep seated spring water as a beverage, renders it very desirable that it should also be rendered suitable for manufacturing operations. The only obstacle to this is the very frequent hardness of such water, an obstacle which can however be readily removed, in a great majority of cases, by the addition of lime to the water, in the manner we have already described. Such artificially softened spring water is even better adapted for the purposes of the dyer and calico printer than much of the naturally soft water of rivers, because it is absolutely free from that yellow colouring matter which generally distinguishes soft river water, and which often perceptibly impairs the brilliancy of goods dyed with fancy colours.

The use for domestic purposes of river water to which sewage (even after deodorization or employment in irrigation) gains access, and of that pumped from shallow wells in populous districts, ought to be carefully avoided, since the analyses which we have made of very numerous samples of water from such sources, in various localities, have rarely failed to reveal in it the presence of organic matter of disgusting origin; and we have proved in our First Report (1870) that no possible length of flow in any British river affords any guarantee that such sewage or organic matters have been oxidized and destroyed. If it be admitted that it is disgusting and dangerous for man to drink water containing his own excremental discharges, it is our deliberate opinion that all water which is intended for domestic purposes should be intercepted either by reservoirs, conduits, or deep wells, before it reaches the beds of sewage-contaminated rivers.

CONCLUSIONS.

We have now given a detailed description of the condition of the rivers and streams in the *Aire* and *Calder* basins, and of the pollutions, due principally to the woollen manufactures, there and, in a less aggravated degree, elsewhere. We have also considered the remedies of which river pollution arising from these and other causes is susceptible. It remains that we now humbly submit to Your Majesty the conclusions at which we have arrived, after a careful review of the whole subject.

In thus bringing our Report to a close we are able to state that it has had, virtually throughout the whole of it, the co-operation and approval of our late colleague, Sir William Denison; and although it must unhappily be presented to Your Majesty without the additional weight which his signature would have given to it, yet its whole subject-matter, and the results to which our investigations and inquiries led us, having been thoroughly discussed with him, we claim for it his co-authorship, and submit it as the Report of all the members of the Commission, notwithstanding his lamented death before the entire completion of it.

At the close of our Report on the *Mersey* and *Ribble* basins (Vol. I., p. 130), having then in view only the chief sources of pollution in those valleys, we proposed certain definitions of liquids which should be declared inadmissible into any stream. We have since carefully compared these suggested standards of purity with our analyses of the effluent waters from the various remedial processes, including irrigation and filtration, to which, in examples known to us, liquid refuse from woollen factories has been subjected. In every instance a certain amount of amelioration had been obtained, and in those cases where the remedy was obviously imperfect, it had been very roughly carried out. In several examples, both of filtration and of irrigation, the results were satisfactory; and, judging from these as well as from our laboratory experiments on intermittent filtration, we cannot doubt that whenever sufficient care is taken, all the waste liquids from woollen factories may, without difficulty, be thus cleansed, so that they shall not transgress our proposed standards of purity. Where these remedies cannot be adopted, the foul liquids may be got rid of by evaporation.

After this further investigation, therefore, of the pollutions due to the woollen manufacture, we repeat the suggestions made after an examination of those arising from town sewage and from the cotton and alkali manufactures (Report, 1870, on the *Mersey* and *Ribble* basins, Vol. I., p. 130), that the following liquids be deemed polluting and inadmissible into any stream:—

(*a.*) Any liquid containing, *in suspension*, more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts by weight of the liquid.

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(*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 1 part by weight of free chlorine.

(*g.*) Any liquid which contains, in 100,000 parts by weight, more than 1 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 2 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 1 part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

The enforcement of these standards of purity would, as we have repeatedly stated, inflict no serious injury upon industrial processes and manufactures, nor would the remedies required involve any risk to the public health; nevertheless there is, in the case of town sewage, a condition of things which ought, in our humble opinion, to be taken into careful consideration in the framing of a legislative enactment. The condition to which we allude is that caused by excessive rainfall, or "storm water," as it is technically called. To provide for the exceptional occasions when this condition prevails would entail in many cases an expenditure, in sewerage works, many times greater than that necessary in ordinary weather. We are therefore of opinion that, however undesirable, it will be necessary to permit storm water to flow directly into rivers and streams without preliminary cleansing. Unfortunately, chemical analysis shows that storm water, so far at least as its earlier portions are concerned, is more polluting than dry weather sewage, owing to old deposits in the sewers being then swept to the outfall; and it will be very important, therefore, to guard against any unnecessary use of this exceptional permission.

There being, however, no reason known to us in the circumstances of the woollen manufacture, and of the industries connected with it, why the same rules should not be applied to these branches of trade and manufacture as were proposed in our Report (1870) on the *Mersey* and *Ribble* basins, for the prevention of river pollution by the cotton, alkali, and other manufactures, we repeat the recommendations which we then humbly submitted to Your Majesty.

In the first two of these recommendations we had the entire concurrence of our late Colleague and Chairman, when reporting on the river nuisances of the *Mersey* and *Ribble* basins, and on their possible abatement.

On the constitution of the authority, however, by which these and other provisions, if enacted, were to be enforced, we were unable perfectly to agree.

Impressed by the necessity of a prompt and local remedy for local grievances, the late Sir William Denison proposed to make each locality responsible through its local board, its corporate or its parish officers, for the condition of the streams within its boundaries; and in order to ensure a uniform discharge of the duty which he would have thus imposed, he recommended that county or provincial boards, elected by these local authorities, should have power conferred on them to enforce the observance of such byelaws as, in the interest of river conservancy or river restoration, they might deem it necessary to frame.

On the other hand the importance of putting sufficient power for the enforcement of the law into hands which should be independent of local prejudice or personal influence, and also of so legislating that any enactment imposing restrictions on manufacturers and others should affect all seats of industry alike, led us to doubt the policy of localising the authority on which river restoration and conservancy are to depend.

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There are other considerations (stated in our Report (1870) on the *Mersey* and *Ribble* basins, Vol. I., pp. 134, 135), which need not be repeated here, but which also indicate, as we believe, the necessity of a central board for river conservancy, which shall act through its inspectors, both in the detection of offences against rivers and for the conviction of offenders; and shall afford to existing local authorities greater facilities than they now possess for the prosecution of works connected with the purification and supply of water.

RECOMMENDATIONS.

In accordance, therefore, with the foregoing Report and Conclusions, we again 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, which transgress the limits assigned in the above definitions (pages 54 and 55), 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.

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.

(Signed) E. FRANKLAND. (L.S.)
JOHN CHALMERS MORTON. (L.S.)

S. J. SMITH, *Secretary*,
22nd April 1871.

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