The water of the Lee they found naturally not only wholesome, but comparing favourably with that supplied to other places. They agreed with the Rivers Commission that it was liable to serious contamination, but they suggested certain alterations in the remedial measures proposed, and expressed their opinion that when these were carried out the water supplied by the companies would be of unquestionable character.

They also approved the North Kent water, and considered this company had an adequate command of quantity for many years to come.

They went elaborately into the question of constant supply, and recommended that it should be enforced, under strict provisions to prevent waste, and to ensure the suitable condition of all the house fittings.

They finally recommended that the duty of seeing that the water companies properly fulfilled their obligations should be imposed on the Metropolitan Board of Works; and that a new Act should be passed consolidating all the laws at present in force as to the metropolitan supply, and introducing the new measures they had proposed.

129. In 1868 an Act (31 & 32 Vict. cap. 154) was passed to make better provision for the preservation and improvement of the River Lee and its tributaries. It was analogous to the Thames Conservancy Act of 1866, altering the constitution of the managing body, and rendering illegal the admission of sewage or offensive matter into the river, except in the case of certain towns where measures had been adopted for its purification.

PART IV.

ON THE SUPPLY OF WATER AVAILABLE FROM THE BASIN OF THE THAMES.

130. We have now to consider the eligibility, for the future service of the metropolis, of the great source from whence its supplies have hitherto been drawn, namely, the basin of the River Thames.

The gigantic schemes proposed for supplying London with water gathered in the distant mountain ranges of the country have been projected on the assumption that the nearer and more natural supply derived from the Thames valley was either deficient in quantity or unsuitable in quality, or both. It becomes, therefore, our duty to inquire whether there is sufficient justification for either of these suppositions; and we will consider them each in turn.

Section I.

AS TO QUANTITY.

131. At the end of Part II. of this Report we have endeavoured to give a general view, scientifically considered, of the most important natural features of this great basin, having reference particularly to its underground storage, and the nature and distribution of its springs. It will be here our object more practically to consider the evidence as to the quantity of water actually obtainable from the rivers and wells in this district.

On this point we have received a large amount of information from a great number of witnesses, who, from their position, experience, and knowledge, are most competent to judge of the subject.

132. The portion of the basin first to be considered is that above Hampton and Ditton, where the water companies have their intake. This portion extends over a length and breadth of 80 or 90 miles, its superficial area being given as 3,676 square miles.

The Thames first assumes importance near the small town of Lechlade in Wilts, where a number of small streams, forming the head waters of the river, unite. From this point down to Ditton it follows a tortuous course of about 120 miles in length, and is joined on either bank by several important tributaries.

133. The rainfall in the Thames basin has been determined with considerable accuracy by many years' observations by numerous persons at various localities from London to Cirencester. It is found to vary, on an average, from about 25 inches at the former place to 30 inches at the latter. Taking the mean of the whole area, Mr. J. T. Harrison estimates the average rainfall to be 27¾ inches, and of this it is estimated that one-third flows down the Thames. 4671. 6838. 2966. 3036.

134. It is desirable, however, to investigate the volume of the stream more particularly; taking our data at the point most important for our purpose, namely, at the intake of the companies, a little above the highest point reached by the tide, and where the natural fresh water stream has its maximum volume.

It has been shown that the total discharge at Kingston for eleven years was 5,432,418 millions of gallons, which is equal to an average of about 1,350 millions of gallons per day, or equivalent to about nine inches of rainfall. If this were the constant flow, no question could arise as to its sufficiency; but we need hardly say that it varies very widely at different times. In floods the stream is so large as scarcely to admit of accurate measurement; but in dry seasons it is much reduced; and it is in reference to the volume in these seasons that the doubt has arisen. It is therefore to this that we must direct attention. 3904.

135. Several witnesses have spoken to this point; we may first give Mr. Bateman's views as to the supposed deficiency in quantity, which has been one ground why he has considered the Thames ineligible, and has proposed to go to the mountains of Wales. He says:

App. E. "When the Acts of 1852 were passed it was estimated that the minimum quantity of water at Hampton was 362,000,000 gallons per day, and this minimum has been habitually considered, in round numbers, as 400,000,000. During the month of September in this year (1865) the river has been carefully measured above the waterworks at Hampton, and the gross daily quantity for a considerable period together has scarcely exceeded 300,000,000 gallons."

6515*a*–6522. 6540–54. In subsequent evidence he explains that the actual quantity given by his gaugings at Hampton in 1865 was 308,720,000 gallons per day, and he describes fully the mode in which the measurements were taken.

4561–4651. 136. Other witnesses give larger amounts. Mr. Simpson states that he has gauged the quantity flowing down at Kingston daily since 1852, and found the minimum in 1864, the driest year known, was 380,000,000 gallons per day, after the whole of the companies had taken their supply. He adds that this was in extreme drought, the usual flow in dry seasons being seldom lower than 600 to 700 millions of gallons.

3266. Mr. Beardmore states that the mean flow at Kingston in the months of June, July, August, and September, for 1864 and 1865, the two driest years, was between 380 and 390 millions, including the companies' supplies, and the absolute minimum only a little lower.

2931 *et seq.* Mr. John Thornhill Harrison, C.E., member of the Royal Commission on the Pollution of Rivers, (who specially investigated the subject, and during their inquiry received much information on the capacity of the basin for affording a water supply,) has put in an extensive series of tables illustrating the meteorology and hydrology of the Thames basin. Confining our attention to those portions of the tables which illustrate the state of the water in the driest seasons, we find that he has given particulars of the actual discharge in the three years 1858, 1859, and 1864, at the times when the quantity was under 400,000,000 gallons per day, and he shows the number of days in each year when the volume attained certain amounts.

The quantity was below 400,000,000 gallons

In 1858	for 36	days.
„ 1859	„ 32	„
„ 1864	„ 8	„

The lowest quantity noted was 350,000,000 gallons per day, and this was observed

In 1858	for 20	days.
„ 1859	„ 14	„
„ 1864	„ 2	„

4259. Mr. Leach, the engineer to the Thames Conservancy Board, says that having often gauged the river at Teddington, he has never found it less than 380,000,000 gallons per day.

6005–8. Mr. Quick, engineer to the Grand Junction and the Southwark and Vauxhall Companies, says the lowest gauging that has ever been taken of the Thames has amounted to 360,000,000 gallons at Teddington.

All these quantities, except Mr. Bateman's, are below the intake of the water companies, and therefore are exclusive of the quantity abstracted by them, which is at present about 50,000,000 gallons per day.

137. We think from this evidence we may fairly conclude that a daily flow of 350,000,000 gallons per day is a very exceptional thing, occurring only for a few days in the course of many years.

138. The companies are empowered, under their present Acts and agreements, to take as follows:—

	Gallons per day.
Chelsea Company	20,000,000
West Middlesex	20,000,000
Grand Junction	20,000,000
Southwark and Vauxhall	20,000,000
Lambeth	20,000,000
East London	10,000,000
Total	110,000,000

139. We are led to believe that it would be easy to make storage reservoirs and other works on the upper part of the river to collect the flood waters; and that by means of these the flow might be so equalized as to neutralize the effect of the severe droughts, and therefore to admit of a still larger abstraction of water if the growing requirements of the metropolis should render it necessary.

140. We will give a summary of the evidence we have received as to the quantity obtainable from the river.

Mr. Hawksley considers there is capacity in the Thames watershed to supply a sufficient quantity for the metropolis. The companies might take the maximum supply they are entitled to without injury to the river, or interference with the navigation. Below Teddington the river is tidal, and the abstraction of water would not interfere at all with the scour; for this reason, that the upland water of the Thames in its ordinary state has little or no influence upon it. It is chiefly when in flood that it has an influence on the scour, and the floods of the Thames are so enormous that practically the quantity taken by the water companies then disappears from the calculation altogether. The maximum flood in the Thames is about 20,000 to 25,000 millions of gallons per day. He considers that a quantity nearly double the statutory limit might be taken from the Thames without any storing process; half the lowest volume of the Thames (which he calculates at 360,000,000 gallons) might be taken, and he does not believe it would have any sensible influence. 5055–70. 5106–7.

He believes the average flow of the Thames in three consecutive dry years to be about six inches of rainfall, which would give nearly 900,000,000 gallons per day.

If more was wanted than could be taken at present it might be obtained by impounding the flood waters, and there would be no difficulty in finding sites for reservoirs. 5071–3. 5094.

Mr. Simpson is of opinion that, by proper arrangements, the Thames basin is capable of supplying 200,000,000 gallons per day. There is no necessity for making reservoirs at present; there is plenty of water. The supply might be increased considerably, and afterwards might be supplemented by reservoirs to double the amount. But it may be fourteen or fifteen years before such works become necessary. 4572–6. 4596. 4646–7.

He assumes that 200,000,000 gallons could be obtained from the Thames, and 60,000,000 gallons from the Lee, which would, at 30 gallons a head, be sufficient for a population of 8,700,000, and that practically, therefore, the Thames may be looked forward to as able to supply London beyond any probable increase. 4721–2.

Mr. Simpson says, that supposing it desirable that large works should be made in the Thames valley to admit of the supply being increased to four times its present amount, the various companies to be benefited should contribute to the cost of such works, but that their execution and maintenance should be left in public hands. 4587–93.

Mr. Beardmore agrees that by the provision of storage reservoirs for the flood waters it is quite practicable to take a much larger quantity from the Thames than at present, not only without any injury to the river below Teddington, but with very great advantage. He considers that from the Thames and Lee together 300,000,000 gallons may be obtained. 3321. 3328.

Mr. J. T. Harrison is of opinion that reservoirs might be made, in the upper districts of the Thames, sufficient to provide for a very large deficiency in droughty seasons. 3092–100.

The Rev. Mr. Clutterbuck, and Mr. Bailey Denton, whose plans and suggestions we have noticed in Part II., agree in the opinion of the sufficiency of the Thames for any probable requirements for the supply of London, if proper provisions were made for storage. 1839. 1532.

Mr. Rawlinson expresses his opinion that a supply may be obtained from the Thames sufficient for London, both present and future. 1360.

Mr. McClean (whose plan for bringing water from Henley has been noticed in Part II.) is of opinion that by storing the flood waters in the upper reaches of the Thames more water may be obtained than can ever be required. He quotes as follows from a Report on the Thames by the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal:— 5637. 5498 *et seq.*

"In a geological point of view the River Thames is, of all the large rivers in England, that in which we may expect the slowest and most constant influence of the rain that falls. From the basins of its tributaries, the rivers Kennet and Loddon especially, consisting as they do almost entirely of chalk or other pervious subsoil, the water finds its way very slowly; and it is not until after many weeks of drought that any diminution of the quantity they supply is perceived.

"The results of my own carefully repeated experiments quite agree with the conclusions that a scientific consideration of the above data would lead to. The volumes of the Thames at Henley, as well as those of the

Kennet and the Loddon, have been repeatedly gauged, and the results obtained lead me to the conclusion that at the time of the shortest water the quantity passing the point at which we propose to take our supply is not less than 55,500,000 cubic feet, or 345,000,000 gallons daily. This is the minimum of the gaugings, and taken near the termination of an unusually long protracted season of drought."

5746–59. Mr. Thorpe, the acting chairman of the Thames Conservancy Board, is of opinion that the whole quantity of 100,000,000 gallons per day, which the companies are empowered to take, might be abstracted without any evil effects on the river as a navigable stream, and that if certain alterations were made, and certain works executed for storage, the quantity might be exceeded.

3601–13. Captain Burstal, secretary to the same board, considers that an enormous quantity more than is drawn already may be drawn above Teddington lock, without the river feeling it to any great extent. He considers reservoirs might be made above Oxford for this purpose with facility and advantage.

4244 *et seq.* Mr. Leach, engineer to the same board, has never observed any evil effects on the scour from the abstraction of water, nor does he apprehend any, supposing the companies to draw to their full authorized extent. For the greater part of the year the largest abstraction they could make could not be detected in the volume of the river. He thinks the Thames basin and the Thames stream are equal to the growing requirements of the metropolis without injuring the scour.

4300–14. He considers storage reservoirs would be desirable auxiliaries; they would equalize the flow, but still would give sufficient flood action for scouring purposes. There is a district above Oxford well calculated for the formation of reservoirs. The companies might take more than 100,000,000 gallons without reservoirs. With storage reservoirs he thinks 200,000,000 gallons might be taken per day and the river still maintained in a perfect state.

In reference to complaints which are stated to have been made as to the effect of abstracting the water on the upper part of the tideway, he says:—

"I think that more complaint has been made from persons residing in that part than any other of the ill effects which have been presumed to follow the abstraction of the water. In my opinion they have been quite mistaken upon that, they have attributed to the abstraction of the water from the river that which has arisen from an entirely different cause. The fact is that the Thames in the tideway for the last 30 years or more has been undergoing very great changes. The bed of the river in and about London has been depressed by the excavations which have been made in it, but at the upper extremity of the tideway it has remained pretty nearly the same. The consequence is that the inclination from that point down to where the excavations have taken place has become much greater, and consequently the stream is much more rapid, and therefore instead of the normal flow of the river passing off gradually as it did formerly, it now runs off very quickly, producing a much sharper stream in the upper part of the tideway towards the time of low water than there used to be, and whatever supply there is of water is consequently carried off more rapidly."

6005–8. Mr. Quick thinks there is no doubt that the basin of the Thames would be able to supply a larger quantity than the companies have power to take. If it were necessary storage reservoirs might be provided in the upper Thames; but as the companies only take now one-seventh of the minimum flow, it would be a long time before anything of that kind would be required.

It will be seen by the above extracts that there is a general accordance among the witnesses as to the sufficiency of the Thames. Mr. Greaves, however, the engineer of the East London Waterworks, says,—

5182–9. "I do not think these rivers are going to last as long as Mr. Hawksley does; I think it is necessary to be cautious in time; I would not like speculating upon any one of those rivers round London lasting for the next half century; not only the Lee or the Thames, but other rivers; I mean lasting as a source of water supply independent of any foreign aid. I think it is quite a fair thing in prospect to talk about going beyond the Thames basin; that is to say, you will either have to do that or to store very largely, more largely than anyone has entered into the practical estimation of."

At the same time Mr. Greaves adds that he does not think the time is yet come for going beyond the Thames; and when further examined as to his reasons for doubting the capacity of the river, he appears to base them on the assumption of a possible change of climate as affecting the flow.

It is to be regretted that there is almost an entire absence of reliable information as to the flow of the river except at one point. It would be very desirable to establish a series of gaugings of the Thames at various points of its course, and of its chief tributaries, showing the variations at different times.

141. Considering the whole of the evidence above referred to, we believe we are justified in inferring, in the first place, that the quantity at present authorized, namely, 110,000,000 gallons per day, might safely be drawn from the main stream of the Thames in its present state; and, secondly, that by means of proper works for storage this quantity might be doubled if required.

Subsidiary Basin of the Lee.

142. But apart from the main stream of the Thames it is also necessary to inquire into the additional quantity which may be obained from the subsidiary basin of the River Lee. Full information as to this basin is contained in the Report of the Rivers Commission. Its area is about 500 square miles; and the mean rainfall, which is equally well determined with that of the Thames, is given by Mr. Beardmore, the engineer of the river, at about 25½ inches. The upper part, above Hertford, is entirely chalk, the lower part almost entirely London clay.

The two companies who draw water from the river appear to have the right of appropriating the whole flow, with the exception of a quantity of about five millions of gallons per day reserved for lockage on the navigation. The actual mean quantities at present drawn by the companies from the river are:—By the New River 18 millions of gallons per day, taken at the upper part of the river, between Hertford and Ware (this being part of their whole supply of 23¾ millions):—by the East London Company 19¼ millions of gallons, taken lower down:—making on the whole 37¼ millions of gallons per day on the average of the year, the quantity in the summer months being increased to about 40 millions. Adding to this the lockage, it gives a total present demand on the river in the summer of about 45 millions. 3961.

We may now compare this with the quantity naturally flowing down the river.

Mr. Beardmore has given us tables of the flow of water in the Lee for 19 years. He makes the average daily flow at Feilde's weir over this time 108·8 millions of gallons; and in the months of June, July, August, and September, of five dry years, he makes it (including the companies' supplies) average 45·2 millions, which is increased by springs in the valley below the weir. 7444.

It is therefore clear that in dry seasons little or no increase is to be relied on from the river in its present state; the only question is, to what extent might the dry weather flow be augmented by storage reservoirs.

143. The evidence on this point is as follows:—

Mr. Beardmore believes that reservoirs may be made within practicable and reasonable limits of expense, so as to store the winter flood waters, and deliver about 70 to 90 millions of gallons daily. 3313–4. 3438–9.

Mr. Muir, the engineer of the New River Company, states that the company calculate that by making such reservoirs they might obtain an additional 10 million gallons; and he believes the East London Company might do the same. 3972–80. 4020–1.

Mr. Greaves, engineer to the East London Waterworks, says that at one time in 1864 they took the whole volume of the river, after the New River had served themselves; there was nothing went by: they are now increasing their reservoir room to store partially the flood waters, which would give, say, five millions of gallons extra over 100 days' drought. He adds, however— 5131–9.

"I am of opinion that as the larger portion of London is dependent upon the Lee, it ought not to continue any longer dependent upon the Lee alone for its supply of water as to quantity. The caution that we had from the drought of 1864 was convincing. There is no room to doubt the question any longer." 5177.

Mr. Greaves's attention being directed to the propositions of the New River engineer above quoted, he says:

"I am not inclined to store so largely, or to depend upon storage to that extent, because I know that there are winters when it is quite likely those reservoirs might not be filled; the winter of 1858 went off without a single flood; we have charge of the floodgates ourselves on the river at Lee Bridge, which govern the whole flow, and in the winter of 1858 we did not draw a single gate; therefore where would the reservoirs be filled from in such a season? I consider the Lee alone not to be depended on, even for the East of London, and less so supposing the New River Company do an equal amount of work." 5178–9.

Mr. Mylne, whose plans for increase of the supply from the basin of the Lee we have noticed in Part II., conceives that by these plans the quantity derivable from this source might be raised by storage to 70,000,000.

The Rivers Pollution Commission, in their Report on the River Lee, 1867, say:

"With regard to the capability of the River Lee to meet the increasing demand for water supply in the eastern districts of London, it may be taken that no dependence can be placed upon an increase of the supply from the river without the construction of impounding reservoirs on a much larger scale than those now in existence."

144. We believe that we ought not to calculate on any material increase from this source, and that we may consider the quantity which the Lee valley can contribute to the supply of London as not more than 50 millions of gallons daily.

Subsidiary Supply from the Chalk.

145. We have referred fully in Part II. to the great store of water contained in the chalk round London.

6141. The only use now made of this for the metropolitan supply is by the Kent Company; who draw at present from it above seven millions of gallons daily, and appear to rely on an almost unlimited power of increase.

2520. Many witnesses before us have testified in favour of this source, and the suggestions of Mr. Clutterbuck, Mr. Homersham, Mr. Barlow, and Mr. Meeson for utilizing it will be found noticed in Part II.

5083. Mr. Hawksley says that there are large districts of chalk where an immense quantity of water might be obtained, and that there is very fine water surrounding London in all directions, which only wants utilizing.

4045. Mr. Muir also speaks of the ease with which water is obtained in the chalk, and the abundant supply.

146. We do not agree with those who expect to get an almost unlimited increase of quantity of water by simply tapping the natural reservoirs in the chalk, for the supply to them must obviously be limited by the amount of rainfall. Moreover, as the water which penetrates into the reservoirs, raising the water line more or less above the level of the adjoining valleys, ultimately in greater part finds its way by springs into streams at the lower level of the district, any water drawn from the store by artificial means will most probably be at the expense of those streams.

If this be true, it follows that any water obtained by tapping the chalk reservoirs that feed either the River Lee or the Thames above Hampton, would only *pro tanto* diminish these streams, and would therefore be little or nothing gained to the general supply.

147. But there is, in the large area of chalk to the south and south-east of London, a reservoir which does not feed either of these streams, as its surplus waters find their way by innumerable springs into the Thames below London. From this reservoir, in all probability, large quantities might be drawn, and these quantities would be real additions to the supply.

We have no complete data as to the quantities which could be so obtained; but looking to the facts that the present few wells of the Kent Company are supplying above seven millions of gallons, and are said to be capable of supplying twice as much; that the Grays springs are said to be capable of supplying 10 millions; and that a small district near Gravesend has furnished an equal quantity; we believe we are very moderate in estimating the addition that might be made from this source by proper works at 30,000,000 gallons per day.

It is further probable that a considerable quantity of water, soft and of good quality, might be obtained in the neighbourhood of London by means of artesian wells in the *Lower Greensands;* but of this quantity there is no means of forming an estimate without further investigation.

Summary.

148. Combining now these several sources, we may estimate that if ever the metropolis should increase to such an extent as to render necessary such a large supply, and to justify the outlay for works necessary to obtain it, we may calculate on getting, from the basin of the Thames—

	Gallons per day.
From the main stream, supplemented by the aid of store reservoirs, say	220,000,000
From the Lee	50,000,000
From the chalk to the south and south-east of London	30,000,000
or say, a total of	300,000,000

Section II.

AS TO QUALITY.

149. We now proceed to consider the part of our subject which is probably the most important as well as the most difficult of the whole, namely, the *quality* of the water obtained or obtainable from the basin of the Thames.

The importance of this point is indisputable. It admits of no question that the metropolis ought to be supplied with water that is perfectly wholesome in quality. Water is a necessary of life; the consumers in a place like London have no power to choose their own source, but are at the mercy of the parties undertaking the supply; the health, often even the life, of the inhabitants is in the hands of these parties, and it is therefore a matter of paramount public interest that the manner in which they exercise this immense power should be jealously watched, and efficiently controlled. And if it could be clearly proved that either now, or in a proximate future, wholesome water could not be obtained from the Thames basin, the question of the abandonment of the source would demand prompt attention.

We have alluded to the difficulty of this question, because we have found not only that opinions are divided upon it, but that the elements which enter into its determination are of a very subtle character, and by no means admit of the satisfactory kind of treatment which we are in the habit of expecting from the modern advanced state of physical science. We have endeavoured to get the best information possible, from scientific men of the highest reputation, and who have had the best means of making themselves acquainted with the subject, and we have given their evidence its due weight; but we have also been obliged on some points to rely on other considerations in arriving at our decision.

150. It is nearly half a century ago that attention was first directed to the quality of the water supplied to London, and the Royal Commission of 1828, appointed in consequence of complaints on this head, reported to the effect that the water was naturally good, but was fouled by the admixture of foreign matters; and this led to the introduction of filtration, by which the quality was much improved.

The Board of Health report of 1850 pointed out the impure state of the Thames within the tideway, but objected generally to the Thames water, even in its purest state. The Chemical Commission of 1851 reported fully on the subject, in terms we shall have to quote hereafter; and in 1852 a great improvement was effected by the passing of the Metropolis Water Act, which compelled the companies to take their water from a point above the tideway, to filter it effectually, and to preserve it in covered reservoirs.

In 1866 and 1868, in consequence of the reports of the Royal Commission on the Pollution of Rivers, Acts were passed compelling towns and villages within certain limits to dispose of their sewage without polluting the Thames and the Lee; but the effects of these Acts have not yet been proved.

151. We may most conveniently divide this part of our inquiry into two heads:—

A. What is the evidence as to the present quality of the water in the Thames and its tributaries?

B. What are the influences likely to affect its quality for the future?

A.—ON THE PRESENT QUALITY OF THE WATER IN THE THAMES AND ITS TRIBUTARIES.

152. We have taken a large amount of evidence, tending to illustrate this question, from persons of the highest authority, and whose opinions on the various points involved in the inquiry we shall quote in their proper places. But as, on several previous occasions, the waters of the Thames have been analysed and reported on, we have deemed it right also to refer to such of these analyses as appear to us most authoritative and trustworthy. And we may mention the following as deserving of special attention:—

The Chemical Commission of 1851 gave a full analysis of the waters then supplied to London, which we have reprinted in Appendix A F.

In 1856, after the water companies had removed their sources of supply from the Thames to points above the tideway, in accordance with the Act of 1852, a further analysis was made on behalf of the Government, by Messrs. Hofmann and Blyth. We have reprinted portions of this analysis in Appendix B G.

On the inquiry by the House of Commons Committee in 1867, analyses were put in evidence, made by Dr. Letheby, Dr. Odling, and Professor Abel; these we have reprinted in Appendix A G.

The same chemists have also made for the London water companies a later analysis, which has been sent to us, and which we have printed in Appendix A H.

2847. Another set of analyses that deserve special attention are those published monthly by the Registrar General. It appears that after the cholera epidemics of 1849 and 1854 the attention of this department was drawn to the water supply of the metropolis, and an arrangement was instituted by which a monthly analysis of the waters was made, in the first instance by Dr. Robert Dundas Thompson, then by Professor Hofmann, and latterly by Dr. Frankland. The results are published once a month in the Registrar General's returns of the health of the metropolis, and a summary is made at the end of each year. We give some examples of these documents in Appendix A J.

153. The analyses above referred to all apply to waters actually delivered in London by the various companies, and taken from their ordinary sources of supply; but we found that the extended nature of our inquiry rendered these data insufficient. It was our business to report on the water of the Thames basin generally, and therefore it was necessary that our information should not be limited to one point, but that we should know something of the general quality of the water in different parts of the basin, and should endeavour in the first place to ascertain its natural condition when in its pristine state of purity, and then to trace, as far as we could, the various influences it was subject to during its flow. For this purpose, with the sanction of Your Majesty's Treasury, we determined to have samples of water collected from various parts of the basin and analysed in the same manner as in the cases of the Welsh and Cumberland districts. The selection of the samples was entrusted, as before, to Mr. Pole, whose report thereon will be found in Appendix O, and the analyses of the waters by Drs. Frankland and Odling are given in Appendices A X, 1 and 2.

154. We shall, in treating of the chemical quality of the waters, adopt the usual plan of making a broad distinction between the *mineral or inorganic contents*, such as metallic and earthy salts, which in the case of river waters are found present in their first sources; and the *organic contents*, which become added to the waters by accidental circumstances during their flow.

155. The mineral or inorganic contents of the Thames water supplied by the companies from Hampton appear to amount usually to from 15 to 20 grains per imperial gallon of water, of which more than one half is carbonate of lime, and the rest sulphate of lime with salts of magnesia, soda, potash, and silica, and traces of alumina and iron.

The waters of the Lee valley, as supplied by the New River and East London companies, differ little from those of the Thames; but those of the Kent Company being drawn directly from the chalk, contain a considerably larger quantity of the salts of lime.

156. The point, connected with these mineral contents, which is of the main importance in our present inquiry, is their influence (chiefly caused by the presence of lime) in giving to the water the peculiar quality called *hardness*. In the investigations that have taken place from time to time on the water supply of the metropolis, the hardness of the water has always been a prominent topic of discussion, often involving elaborate general comparisons between the eligibility of hard and soft water respectively for the supply of towns. It is, therefore, necessary that we should give a summary of the information we have obtained on this point, and the conclusions at which we have arrived thereon.

On the Hardness of the Thames Water.

157. Owing to the solvent power of water, all waters percolating through or flowing on the surface of the earth take up more or less mineral matter, consisting in almost all cases of carbonate of lime as the essential ingredient, and of a few other salts as subordinate ones. When these mineral matters are in excess the waters are called mineral waters; but in moderation, say 15 to 30 grains to the gallon of 70,000 grains, they are present in almost all river waters.

Water charged with salts of lime has the property of decomposing soap to a certain extent, by the combination of the lime with the alkali, and this is what is meant by the popular description of the water being "hard." Soft water makes a lather freely, but

hard water curdles a portion of the soap, and requires consequently more of it for the purpose of washing.

158. The first attempt to investigate the hardness of water in a way combining scientific research with practical utility, was by the late Dr. Clark of Aberdeen, who shortly before his death wrote to our chairman the letter on the subject which we have printed in Appendix G. His attention was directed about thirty years ago to the hardness of the London waters, and in March 1840 he took out a patent for a mode of softening them. This invention has proved to be a practicable process of much utility, and we shall have occasion to refer to it hereafter; it is important to our present object that in his patent Dr. Clark described a mode by which the hardness of water could be *defined* with great exactness. He first formed a series of artificial waters of several grades of hardness, each containing a known proportion of bicarbonate of lime; and when any unknown water was to be tried he compared its effect on soap, by an ingenious process, with these as standards, and so at once obtained an accurate measure of its hardness. He proposed to designate the hardness of water by the *number of grains of bicarbonate of lime contained in one imperial gallon* (or 70,000 grains) of a standard water producing the same curdling effect. This process is known as "Dr. Clark's test," the number of grains being called "degrees." It is exceedingly easy of application, even by persons without any chemical experience; it is very definite and accurate; and it has been very generally approved and adopted by chemists treating of the subject. The Registrar General's reports, however, give the number of grains of carbonate of lime in 100,000 grains instead of 70,000, so that to compare these degrees of hardness with those usually adopted, they must be reduced in the ratio of 10 to 7.

159. The water of the River Thames, supplied as it is in great part by springs from chalk and oolitic limestone, is naturally somewhat hard. It is, however, well known that flowing water tends to part with a portion of the carbonate of lime it holds in solution, and therefore, whatever may be the hardness of the water as it issues from the chalk or any calcareous strata, after a flow of some miles it falls to a nearly uniform standard, varying from about 12 to 15 degrees in the imperial gallon.

The Chemical Commission of 1851 gave the hardness of the metropolitan waters as follows:—

"The hardness was remarkably uniform in the water of the eight principal metropolitan water companies.

"The degrees of hardness, by Clark's soap test, of the waters of the eight principal London companies, observed on the 29th, 30th, and 31st of January, were as follows:—

"From other sources than the Thames.	New River	14°·9
	East London	15°·0
	Kent*	16°·0
"From the Thames.	Grand Junction	14°·0
	West Middlesex	14°·6
	Vauxhall and Southwark	15°·0
	Chelsea	14°·4
	Lambeth	14°·2
	Lambeth (from Thames Ditton, March 8)	14°·2

"The variation observed in this property is from 14° to 16°; or if the Kent water be excepted, from 14° to 15°, or one degree only. It appears also, from observations made at different seasons, that this range is not considerably exceeded at any period of the year, except during floods, when the hardness of Thames water may fall to eight or nine degrees."

The analyses by Drs. Letheby, Odling, and Abel of waters taken between December 1866 and February 1867 give the hardness from 13 to 14½ degrees; that of waters taken in May, June, and July 1868 is somewhat less. They say,— App. A G. App. A H.

"On reference to Table No. 1, it will be observed that the hardness of the water supplied by the Thames companies ranges from 11·3° to 12·5°—that from the New River being 11·9°; while the water from the East London Company has a hardness of 11·7°; and that of the Kent Company a hardness of 17·6°.

"After boiling for fifteen minutes, the hardness of the water from the Thames companies is reduced to between 2·4° and 3·5°; the New River water to 2·3°; the East London water to 2·6°; and the Kent Company's water to 6°.

"On comparing these results with the return of analyses made by us in the winter of 1866–7 (in reference to the Metropolis Water Inquiry, conducted by a Committee of the House of Commons in 1867), it will be observed that in all instances excepting that of the Kent Company's water (derived solely from deep wells), the hardness is less than that of the water collected during the winter season, a result which is in accordance with previous experience regarding the fluctuations in the composition of river water at different seasons."

The analyses of the Registrar General, when corrected on account of their unusual form, give a variation in 1847 from 11¼ to 16 degrees, omitting the Kent water, which varied from about 15 to 20 degrees.

* At this time the Kent Company took water from the river Ravensbourne.

App. A X. The analyses made for ourselves by Drs. Frankland and Odling show the following results when reduced to Dr. Clark's scale:—

	Hardness according to Dr. Clark's scale.	
	Before boiling.	After boiling.
Head Waters.		
Oolite Springs	15·3	3·4
Main Stream of the Thames.		
At Lechlade	15·3	3·6
Above Oxford	12·7	5·4
A little below Oxford	13·4	5·7
Seven miles below Oxford	15·4	6·3
Above Reading	14·7	5·7
A little below Reading	12·7	4·0
Five miles below Reading	14·0	5·3
At Medmenham	13·6	5·3
Above Windsor	15·5	5·2
Below Windsor sewer	15·7	5·2
Three miles below Windsor	14·6	7·4
At Hampton	14·0	3·0
Tributaries.		
Cherwell	15·9	3·6
Thame	17·9	4·5
Chalk Spring, Watford	17·3	2·6
Kennet above Hungerford	15·2	2·5
" " Reading	13·7	1·7
Bagshot Sands	1·0	1·0
Wey	5·8	5·6
Mole	11·3	3·1
Outlying Waters.		
Lee and Mimram mixed	14·0	1·5
Amwell Well	14·7	4·1
Caterham Well	16·4	6·3
Croydon Well	15·4	6·4
Wandle at Mitcham	14·8	6·8

160. The hardness of the London water does not seem prominently to have attracted attention, as forming any serious objection to the source, till the appearance of the Board of Health Report of 1850. Indeed, on the contrary, the more general desire seems to have been, when the Thames was found fault with, to resort to the chalk springs, whose water was harder still. The Board of Health, however, were of a different opinion, and laid so much stress on the supposed evils of the hardness of the water as to recommend the abandonment of the Thames almost on this ground alone.

161. The effects of hardness have been discussed in regard to the use of the water—

a. For drinking.
b. For culinary use.
c. For washing and for manufacturing purposes.

We propose to give a summary of the evidence we have been able to collect on each of these points: but before doing this we may quote a few explanatory observations, by the Chemical Committee of 1851, who devoted much attention to this branch of the subject, and to whose opinions on it we attach great value.

162. They say—

"It may be useful to distinguish the quality known as the 'hardness' of water according as it is of a temporary or permanent character. Perfectly pure or soft water, when exposed to contact with chalk (carbonate of lime) is capable of dissolving only a very minute quantity of that substance; one gallon of water, in weight equal to 70,000 grains, taking up no more than two grains of carbonate of lime. This earthy impregnation is said to give the water two degrees of hardness. But waters are often found containing a much larger quantity of carbonate of lime, such as 12, 16, or even 20 grains and upwards in the gallon. In such cases the true solvent of the carbonate of lime, or at least of the excess above two grains, is carbonic acid gas, which is found to some extent in all natural waters. But this gas may be driven off by boiling the water, and the whole carbonate of lime then precipitates in consequence, or falls out of the water, with the exception of the two grains which are held in solution by the water itself. The gas-dissolved carbonate of lime gives therefore temporary hardness curable by boiling the water. An artificially prepared hard water, containing 13½ grains of carbonate of lime to the gallon, was observed to decrease from 13·5 to 11·2 degrees of hardness, merely by heating it in a kettle to the boiling point. Boiling for five minutes reduced the hardness to 6·3 degrees, 15 minutes to 4·4 degrees, 30 minutes to 2·6 degrees, and one hour to 2·4 degrees. The softening effect of boiling does not therefore appear all at once, but the greatest proportional effect is certainly produced by the first five minutes' boiling. The West Middlesex and New River waters were both found to soften by boiling, very much in the same manner as the preceding pure chalk water, except that the ultimate hardness of the two waters specified was somewhat higher. By an hour's boiling the West Middlesex fell from 14·6 to 5·5 degrees, and the New River from 14·7 to 4·1 degrees.

"Other salts of lime, such as sulphate of lime, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution although the water is boiled, imparting hardness.

"The carbonate of lime in water decomposes about 10 times its weight of soap in washing (more exactly 8·8 white curd soap and 10·7 common yellow soap), and other salts of lime act injuriously upon soap, in proportion to the lime they contain; the soluble soap containing soda being converted into an insoluble and useless compound containing lime. The water is then deprived of lime or softened at the expense of the soap. The lime in 100 gallons of Thames or of New River water thus occasions the destruction of about 34 ounces of soap, before any portion of it becomes available as a detergent."

a. Effects of Hardness of Water for Drinking Purposes.

163. The Board of Health collected evidence on this point, and expressed an opinion "that the presence of lime and other mineral matter deteriorates the wholesomeness and "value of waters for the purposes of drinking."

The Chemical Commission of 1851 held different views. Their Report says:—

"When in good condition, the Thames water possesses the peculiar and agreeable brightness of chalk waters, arising from the entire absence of colour, combined also usually with good aëration.

"The Thames water may be described to be, in circumstances not unfavourable to purity and coolness, a palatable water. The amount and nature of its saline constituents probably contribute to its general acceptability as a beverage.

"It may be safely stated, that no sufficient grounds exist for believing that the mineral contents of the water supplied to London are injurious to health. No reasonable doubt indeed can be entertained of its salubrity. The shallow well waters of London vary from 32 to 80 degrees of hardness, yet these waters have never been pronounced unwholesome.* An aërated water is manufactured and safely consumed to some extent which contains 92 grains of carbonate of lime to the gallon, instead of 12 or 14 grains, as in Thames water. The portion of lime and magnesian salts in the water drunk must indeed be greatly exceeded in general by the quantity of the same salts which enters the system in solid food. The only observations, from which an interference of the lime in water, in deranging the processes of digestion and assimilation in susceptible constitutions, has been conjecturally inferred, have been made upon waters containing much sulphate of lime and magnesia, as the Brighton shallow well water, or the hard selenitic water of the New Red Sandstone, and have no force as applied to the Thames and its kindred waters, as the earths exist in these principally in the form of carbonate."

164. Mr. Bateman expresses his firm conviction that soft water is very much more wholesome than hard water, but he remarks at some length on the difficulty of finding any tests by which the effects can be truly ascertained. 6680–6700.

Mr. Hawksley says on this point: 2600.

"I imagine there are quite as many fine-raced people living in hard water districts as there are living in soft water districts. I am well acquainted with districts of both characters, and I may say that quite four-fifths of the whole surface of the globe yields hard water—in fact, the cretaceous strata and the other lime formations occupy a large portion, from which alone hard water can be obtained. I think these extend quite to four-fifths of the earth's surface."

Mr. Beardmore states that his experience leads him to consider hard water is preferable for drinking purposes, and Mr. McClean agrees in this opinion. 3381–7. 5641.

Mr. Rawlinson thinks the evidence conflicting as as to what is the best water for health, and believes that change either from hard to soft water, or *vice versâ*, is prejudicial. He considers that by far the greater quantity of water drunk in England is hard water, all above six degrees of hardness being so designated. 1363–80.

Mr. Way thinks the question of hardness would have a reference more to habit than anything else. It is exceedingly doubtful whether water of two or three degrees of hardness is more healthy, because people are in the habit of drinking waters of 17 or 18 degrees of hardness without any apparent injury to health. The waters which are the brightest and most liked are the hard waters—the chalk waters. There is no reason to believe chalk water injurious, except perhaps in some special instances. As to the question of health, he does not attach importance to the hardness, either one way or other, if it is in moderation. 1457–61.

Mr. Duncan mentions the opinion of the medical officer of Liverpool, that a change from hard to soft water was prejudicial. 2185–97.

* The objection more recently brought against the shallow well water in London, is on account of its pollution by the infiltration of organic matters from the soil, and not from the natural mineral contents or hardness.

3934. Dr. Letheby considers a moderately hard water best for drinking purposes and for the general supply of cities. He illustrates this opinion by reference to the supplies of Paris and Vienna. A large proportion of the earth's surface consists of calcareous districts, supplying hard water. He is not aware of any instance of moderately hard water producing gravel or surgical affections.

2646-2719. Dr. Lyon Playfair gives evidence as follows:

As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health; in extreme cases I would consider a hard water injurious to health, but in ordinary cases, such as the Thames water, I do not think it injurious to health, if there are no other impurities in the water than the mere differences in the amount of carbonate of lime.

In some cases hard water might prove injurious, as in calculous affections and in dyspepsia, still, generally, a tolerably hard water may be taken without much inconvenience; but water of 20 degrees of hardness is very hard water, and I would much prefer, even for purposes of health, that it should be softer.

2661. Taking the water which comes from the springs in the chalk, do you consider that water generally to be prejudicial to health?—No, not prejudicial to health, except in the circumstances which I have mentioned.

2691. Are you aware of any experiments which have been made with regard to the advantages of the use of either hard water or soft water for drinking purposes?—I can only rely upon the experiences of large towns where they have been supplied with hard water and the supply has been suddenly changed to soft water; of course I do not know of the reverse instances where soft water has been suddenly changed to hard, but in the former cases I never saw any deterioration of health.

2692. Do the returns of the mortality of the towns now supplied with soft water show any improvement in consequence of the use of soft water?—I might mention such towns as Liverpool, for instance, where there has been a very large improvement in the health, but the introduction of soft water was only one of many hygienic improvements which took place at the same time; therefore, the proportion which should be attributed to that is difficult to distinguish from the others.

2693. That probably would be the case in almost all instances where a new water supply has been introduced?—It is; for a new and enlarged supply of water generally arises when a population has become awakened to the necessity of hygienic improvements generally.

3124-3218. Dr. Parkes's evidence on this subject is as follows:

With regard to the effect upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime, and sulphate of magnesian waters, the carbonate of lime waters appear in some cases certainly to produce some effect upon health, for instance, dyspepsia, and they do not agree with some class of persons, whereas to others they appear to be quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease—calculus or anything of that kind, but at the same time persons do sometimes suffer from indigestion.

3125. What degree of hardness would, in your judgment, be a safe water, taking an average constitution; some people will live in spite of difficulties; their resistive force being such that nothing seems to affect them, but my question has reference to an average constitution?—I do not think with regard to pure chalk water that there is any evidence that a moderate amount of carbonate of lime in the water does any harm, certainly not on the large scale; in some individuals it produces indigestion.

3126. Would 16 or 20 degrees of hardness be prejudicial?—I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons; but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned, but I should draw a marked distinction between that and the hardness arising from sulphate of lime, or sulphate of magnesia, or chloride of calcium, which would certainly disagree in much smaller quantities, so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than according to its temporary hardness.

3134. But supposing the water was equal in purity and free from organic matter, does the question of simple hardness or softness enter into the consideration of those whose special duty it is to care for the troops with regard to the kind of water that they should use?—In all cases we would prefer a soft water if it were possible to obtain it; and if the water were permanently hard, to a large extent that water would be reported upon unfavourably, and better water as regards that property would be procured if it were possible.

3137. Speaking generally, you are of opinion that the mere presence of carbonate of lime of 15 degrees of hardness would not be injurious to health?—With 15 or 16 degrees of carbonate of lime hardness I should say that it would be hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees if possible. At the same time I should wish to state that one would prefer water free from that even, if it were possible to get it.

3201. The greater part of the troops I presume in this country are located in districts where the water is of a moderate degree of hardness; for instance, Dover, Portsmouth, Southampton, Plymouth, and the greater part of Ireland?—Yes, and at Chatham. At Southampton we have no troops, and at Aldershot the troops are upon soft water. At Chichester the water is hard, and at Colchester it is hard. For the most part they are chalk waters.

3202. Have you known instances of any ill effects from the use of such waters?—Not of the good chalk waters.

3203. Have you known any instances where troops have been located in districts where they have been using water of a moderate degree of hardness, and have suffered when they have been removed to a district where the water was soft?—I have never seen any reports of that kind.

3212. Are you aware whether a certain quantity of carbonateof lime may not in many cases be rather beneficial than otherwise to health?—I think that is again very doubtful. The fact is, that almost all kinds of food contain enough lime for the supply of the body, and the quantity of carbonate of lime supplied in water might no doubt be applied to the wants of the system, but I can hardly think that it would be necessary, that is to say, I do not think it should be an argument for the supply of chalk water that lime is thereby supplied.

3217. I see that one disorder which you mention is calculi; have you been able to trace that back to the use of water?—In Germany especially there is a very strong opinion in certain parts that the phosphate of lime calculi and calculi generally are more common in districts where the inhabitants use very hard waters, but in this country the evidence is so far negative; we have not many districts supplied with limestone

waters or the magnesian limestone waters; most of our lime waters are chalk waters, and so far, I think, in this country there is no evidence of there being a greater amount of calculi than in other districts not supplied with this water, but in Germany and, perhaps, in France the evidence is stronger that the use of some of the lime waters may have an influence in the production of some of the calculi.

3218. Would that be in the case of water of an ordinary degree of hardness, or of an excessive degree of hardness arising from the chalk or from the presence of sulphates?—I believe especially from the large amount of hardness arising in most cases from the mixture of chalk and of sulphates, at least it is so in most of those waters.

Mr. Simon says:— 2777-2835.

2777. Has your attention been directed to the quality of the water in London for drinking purposes, as to the effect upon the health of the inhabitants, as compared with water of a softer and purer character?—I have no evidence upon that subject. I think that, practically, the only very important sanitary question as regards the quality of the water supply to London is the question of organic admixture. I do not think that the question of a few grains of lime in a gallon of water can be regarded as a very important sanitary question.

2778. Then, in your judgment, the presence of lime, or two or three degrees of hardness in the water, would not be a matter of much consideration, supposing the water were free from organic impurities?—Quite so, as regards the public health.

2779. For drinking purposes, probably a little hardness in the water would add to its life and pleasantness to the taste?—I would not quite say that; I have found soft waters, or at all events, hard water artificially softened, very agreeable.

As regards drinking purposes, I am not sure of any important difference, but am inclined to prefer the soft water.

2791. Do you know of any experiments which have been made with regard to the use of soft water and hard water upon health?—If by hard water is meant such water as we have in London, I am not aware of any facts of the smallest value showing difference of effect between such water and soft water.

2792. It has been stated that there are certain classes of diseases more prevalent in districts where hard water is used than in others, for example, diseases of the bladder and the stone; can you give us any evidence on that point?—I do not think there is any evidence that is worth a rush upon that subject.

2793. That evidence which was given by Dr. Prout some years ago you do not attach much importance to?—I do not remember the exact language of Dr. Prout upon the subject, nor know whether he professed to argue from any large field of observation; but I believe that no statistics of value exist in proof of such an assertion.

2823. Although it is a hard water, in some cases to even 18 or 20 degrees, yet it would not be in your mind, in a sanitary point of view, objectionable to use that water?—It would not make it unwholesome water, so far as I know, for drinking, but there would remain of course the economical question.

2824. Therefore we may assume that the question, as between the existing water in the Thames basin and pure soft water, would be practically reduced to its economical results for the purposes of washing and culinary purposes and domestic use?—Yes.

2825. As far as the simple sanitary question goes, you see no objection at all to it?—No.

As regards health my bias is in favour of soft water, but I cannot say that I think the case established against hard water (*i.e.*, against hard water of such comparatively few degrees of chalk hardness or carbonate of lime hardness as you have in the London waters) that it acts injuriously on health. It is different, of course, when you come to certain other hardnesses of water; but I do not think that the hardness, for instance, of the New River Company's water can be considered detrimental to health.

Dr. Frankland says:— 6259. 7777. 352-6.

6259. You have spoken as to the properties of the London water with regard to health; what is your opinion as to the effect upon health as between hard water and soft water?—My opinion is that there is no difference.

6277. For drinking water you say you attach no importance to that difference of degree of hardness?—Not as regards its effect upon health, but I attach great importance to it in the use of water for cleansing purposes.

6352. Some difference exists, does there not, in the opinion entertained by medical men and chemists with regard to the effect on health of soft and hard waters?—There has been some difference of opinion on the subject, but I think the general impression now is that there is not much to be said upon that point, that they are equally good as regards their effect upon health.

6355. Have you any reason to suppose that hard water as drinking water might exercise, not any direct influence in the way of supplying carbonate of lime to the body, but in taking away less organic or mineral matter from the body than soft water?—I have never considered the subject from that point of view, I confess; but the quantity of matter dissolved in the hardest water ever used for drinking purposes is such a very small fraction of the total solvent power of the water, that I should not imagine that there could be any substantial difference between the two kinds of water in that respect.

6356. Have there been any experiments upon that point?—No, not that I know of.

Dr. Odling says:— 7054-8.

6439. On the score of health do you make any distinction between soft and hard water?—I do not think there are any facts which enable one to give a positive opinion. Some gentlemen who have considered the subject entertain very strong opinions both ways; but I do not know any facts upon which one can speak positively.

6478. What is your opinion with regard to the presence of carbonate of lime?—For mere drinking purposes I do not consider it a matter of any disadvantage at all.

Sir Benjamin Brodie's evidence is as follows:—

7023. Have you any reason to suppose that the use of soft or hard water as a drinking water produces any difference of effect upon health?—I cannot say I have reason to think so.

7024. Have you any reason to suppose that the health of a district is independent of that?—I have no reason to think it to be dependent upon it.

7025. Is there not a want of direct experiment upon that subject?—Oxford is a place where the spring water is extremely hard, and injuriously hard for every purpose, but I never heard that it had been made out

that Oxford was liable to any particular class of complaint from that reason. If it were so, I think it would have been discovered; but perhaps some physician from the infirmary might tell you to the contrary.

Dr. Miller thinks any precise observations on this point are difficult to obtain, but he thinks, so far as observation goes, it is a matter of indifference whether it is hard or soft water. He adds:—

"It depends upon the quality of the hardness. Chalk waters, I consider, are waters which are perfectly wholesome, but waters which have a similar degree of hardness from sulphate of lime there appears to be some reason to believe are found occasionally to disagree with persons. Still there are waters which are supplied to large populations containing sulphate of lime, and very hard sulphate of lime waters. For instance, the population of Wolverhampton and Birmingham are supplied with water of this kind. It is certainly objectionable, but what I was going to say was that the evidence in that case is that there is no sensible injury to health directly traceable to the water as far as observations go. I believe, generally speaking, the impression is that the hardness caused by sulphates of lime and magnesia is more likely to produce certain slight derangements than the use of chalk waters of a similar degree of hardness. I should not think there was the slightest reason to suppose that any injury would result from such water. From long habit I should certainly prefer hard water for drinking purposes to soft water."

7095. Are not a very large proportion of the waters consumed in this country, or in any other country, flowing as they do over calcareous formations principally, hard waters?—Yes, they are.

7096. And the proportion of soft water used is comparatively small?—The Scotch waters are many of them very soft, and some of the waters in Cumberland are soft. Whitehaven and several large towns are supplied with soft water now, but in the south of the island the water supply is generally hard.

7097. Have you had occasion to notice whether the change from one water to the other produces any ill effects upon the health of the inhabitants?—I have no observations upon that point.

"Have you formed any opinion yourself as to the comparative value of a supply of water of a moderate degree of hardness to a town, or of a soft water supply?—I should say that for drinking purposes a hard water is preferable, and it is liable to a less frequent change than a soft water. The principal objection which appears to me to arise in the case of soft water is that it is liable to peaty discolouration, which makes it at times very disagreeable for drinking purposes, and it is also more liable to absorb organic impurities. I should prefer, merely looking at it as an abstract question, water of a moderate degree of hardness for drinking. I must say that for domestic use soft water is preferable on account of its economy, but for dietetic purposes I think hard water has the preference.

"Do you know of any experiments bearing directly upon that question with regard to the effect upon health?—No, I have no observations upon that point. Having always lived in a hard water district I certainly prefer it for drinking purposes, but I believe persons who live in soft water districts are equally favourable to the use of soft water."

7124. Dr. Angus Smith gives evidence as follows:—

7260. Have you been able to form any opinion as to the effect upon health of the use of soft water or hard water?—I do not think there is good evidence upon that point. I have heard of horses losing their appearance when they used hard water, and of persons of my own acquaintance who got indigestion by coming into hard water districts; but then I must say that those cases are somewhat balanced by people being rather disagreeably affected on going to soft water districts, and especially some of the hilly districts of the north.

7261. That depends a good deal, I presume, upon the previous habits of people?—Yes. I do not think that there is a great deal of evidence on either point. I do not think it is fair, in fact, to take the appearance of the population as any criterion. If we did so, we might find some arguments in favour of soft water. I should think that the tallest people in Great Britain are to be met in soft water districts; for instance, in Cumberland and, probably, in Aberdeen; I may say that the tallest people I have seen in Great Britain are in Aberdeen, which is a very soft water district.

7264. Are not soft water districts generally mountain districts, where they have the purest air as well as pure water?—Yes; I believe, however, it is quite possible for the blood to take up matter which is inorganic dissolved in water.

165. From the above evidence, at any rate, there is no reason whatever to suppose that the hardness of the Thames water would be in the least degree prejudicial to health.

Some eminent chemists have contended that a moderate quantity of carbonate of lime is not only harmless, but that it is actually useful in supplying material for the bones of men and animals. Considering, however, the much larger quantities of carbonate of lime taken in our solid food, such an additional source of supply would seem to be unnecessary. Judging in fact from the condition of the inhabitants of soft water districts well supplied with a variety of food, it is evidently perfectly immaterial, although it may be otherwise in districts short of carbonate of lime, and when the local produce suffers from the same deficiency as the water. Still it remains to be shown whether when large quantities of water are drunk, those waters which contain the smallest quantities of mineral ingredients may not dissolve and take away more from the body than harder waters, and whether there should be any cause for preference on these grounds.

It may also be a question whether, from the better keeping qualities of waters of a moderate degree of hardness, from their general better aëration and greater freshness, and from their lesser solvent power, such waters are not the best for drinking purposes. Perfectly pure water does not exist in nature. All spring and river waters contain more or less mineral ingredients, and it is only in limited mountain districts, where hard and non-calcareous rocks prevail, that water is found approaching a nearer standard of purity. That the use of these purer waters is more conducive to health is without proof; there is, however, a great want of exact evidence on the subject of the dietetic value of soft and hard waters.

b. For Culinary Purposes.

166. Another of the objections of the Board of Health to the Thames water was that, by reason of its hardness, it was unfit for the preparation of tea, by occasioning waste, and for all culinary processes by diminishing their efficiency and increasing their expense.

167. The Chemical Commission of 1851 remark on this point as follows:—

"The hardness of the metropolitan water supply, which is due to its mineral constituents, may be considered as the same whether derived from the Thames or the Lee, and amounts on an average to about 14 degrees. Although this degree of hardness is considerable and highly objectionable, still it is exceeded by the hardness of pure chalk waters, such as are supplied by water companies to the towns of Gravesend, Dover, and Brighton, and which may be estimated at from 18 to 20 degrees. The deposit which Thames water gives rise to in boilers is also friable and less coherent than the stony deposit from selenitic waters; and means exist, such as the use of sal ammoniac, for entirely preventing the occurrence, in steam boilers, of deposit from chalk but not from selenitic waters.

"The hardness of the London water is also of the least objectionable kind, being chiefly, as has been already stated, temporary hardness, which is removed by boiling. The whole 14 degrees of hardness can be ascribed only to that portion of the water which is used cold. To ascertain the average state of hardness of heated water, portions of water were drawn on six different occasions from the fixed boiler of a kitchen range supplied with New River water; the hardness was found to be 5·4, 4·9, 4·1, 4·1, 4·9, and 5·3 degrees, of which the mean is 4·8 degrees. The hardness of London water, as it is commonly used after boiling, appears, therefore, to be about five degrees, while without heating it amounts to 14 degrees. The distinction between permanent and temporary hardness was illustrated to us at Greenwich, where the brewer described the deep well-water of the Hospital (which is only occasionally pumped up) as a soft water, although its hardness is 21 degrees; but it is only used by him for mashing after being boiled, when, being a pure chalk water, its hardness is reduced to about four degrees. The importance of this distinction was likewise shown, though in another manner, at Whitehaven, where a great and apparently disproportionate advantage has been experienced, from a change in the town supply, from a water which we found to be of 6·7 degrees of hardness to another water of 1·4 degrees. The hardness of the former water, however, although not great in amount, proved to be of the permanent description, as after an hour's boiling the water of the old supply was still of 6·4 degrees, that is, harder than even the Thames water is after boiling. The hardness of the former town supply in Lancashire, although often inconsiderable, was generally of the same permanent character as the old Whitehaven supply.

"The hardness of water forms an objection to its use, both in cooking and washing, but the force of the objection to the Thames water for culinary purposes is much diminished by the large amount to which that water is softened by boiling. Tea is prepared in London with water which, it appears, is practically of only five degrees of hardness. It appears impossible to obtain any standard or test, by which the strength of an infusion of tea can be expressed in numbers, or to find any means of judging of its quality more precise than the indications of taste. On carefully comparing infusions, prepared as for family use, of an equal quantity of tea in the New River water before described, which averaged about five degrees of hardness, and in water of 2·4 degrees only, the observation made on several different occasions was, that the inequality in strength and flavour of the two infusions was altogether insensible to some palates. But an increase in the bitterness was more generally remarked in the soft water infusion, without enhancement of flavour. Where a preference was expressed it was in favour of the quality of the hard water infusion, but the difference between the two infusions was not considered material by anyone.

"Hard water is disadvantageous for making tea chiefly, it appears, by requiring the heat to be longer maintained in preparing the infusion. Tea is habitually made of excellent quality and with economy, in some families, by means of spring water of a high degree of permanent hardness; but then the infusion is continued for half an hour, and the temperature maintained near the boiling point during that period. The tea for the Greenwich pensioners is infused in a large copper, surrounded by a steam case, with water from a well in the superficial gravel, of 24 degrees of hardness, of which 18·6 degrees are permanent. But in the private residences adjoining it is found necessary to use carbonate of soda for softening, with the same water, in the absence of the efficient means of infusing described. Where any great loss of strength of the tea infusion has been observed, in passing from a soft to a harder water, it may be probably referred to the circumstance that the mode of infusing has not been properly adapted to the hard water. The use of hard water must on this account be attended with a frequent waste of tea. The rapid process of infusion generally employed in London indicates the use of a comparatively soft water. The water to which M. Soyer gave a preference for tea-making, even over distilled water, in experiments reported to the General Board of Health, was the London deep-well water. This is usually softer than Thames water after boiling, and contains, in addition, a sensible quantity of carbonate of soda, to which its superiority is probably due in part. The water of the Trafalgar Square deep well has an original hardness of 5·4 degrees, which is reduced to 1·1 degree by boiling. No great objection can be taken to the use of the London water for other culinary purposes. The presence of much sulphate of lime in water makes it unsuitable for cooking vegetables, owing to the tendency of that salt to form an insoluble compound with their legumine; but this effect is insensible with Thames water."

168. Mr. Bateman refers to the evidence of M. Soyer before the Board of Health, substantiating, as he considers, an economy in cooking. 55–63.

Mr. Hawksley coincides in opinion with the Chemical Commission, and refers to the fact that the London water, and all chalk waters, are very soft after they are boiled; adding that for manufacturing and many other purposes water is boiled, and also for many domestic purposes. 2511.

Mr. Rawlinson considers there would be great economy in household purposes by the use of soft water. 1345–6.

1457–61. Mr. Way also thinks soft water would be economical for cooking purposes. But he adds:—

"Hard water makes better tea than soft, although this is contrary to the general impression. The truth is that soft water makes a darker coloured tea, and dissolves a quantity of bitter extract, which makes the tea strong; but to a refined taste hard water gives much the best flavour, as it leaves the disagreeable matter undissolved."

6267–8. Dr. Frankland, while preferring generally soft water, states that boiling the London water causes it to lose more than half its hardness. As to making tea, he says: —

6359–61. "It is generally held that soft waters make better tea than hard waters, but I do not think that, as an abstract proposition, that is the case. I think that both waters are capable of making equally good tea, but the difference depends upon the length of time that the brewing is conducted. A hard water requires to be longer in contact with the tea at an elevated temperature than a soft water does, and there may be some influence of that kind in dyeing, so that by prolonging the operation you get an equally good result, and it may be perhaps in some cases a better result from hard water than you can get from soft water.

"What is the case with regard to brewing?—With regard to brewing, the case I think is this, that where you want to brew a pale ale it is absolutely necessary to have hard water, and not merely hard water, but water that is permanently hard, that is, water which contains sulphate of lime; but in brewing any other kind of ale, where the colour is not of importance, probably soft water is best to be used as extracting a greater amount of matter from the malt.

"In brewing tea with the London water, which I suppose would probably be softened down to six or seven degrees of hardness, or seven or eight degrees at all events, if the boiling has been continued for half an hour, the length of time during which the tea ought to be brewed to get the most delicate beverage is not more than five minutes, and therefore with a very soft water like that supplied to Manchester it ought not to be more than two minutes. In fact I remember that the best tea was obtained there by pouring the water on to the leaves and almost immediately off again. If you allow a soft water to remain upon the leaves for 10 or 15 or 20 minutes you get a bitter principle out of them, which is unpleasant to me, although I believe it is pleasant to some tea drinkers. Some tea drinkers think that kind of tea the best, and that is more easily got out by soft water than by hard, and therefore from that point of view it might be said that the tea would be more likely to be spoilt by hard water than by soft."

App. D. He further adds that a constant supply of hot water has become almost a necessity in every household, but refers to the difficulties thrown in the way of its attainment by the use of hard water, owing to the formation of thick calcareous crusts in the heating apparatus.

7124. Dr. Miller says:—

"I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always, in our chalk districts, a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents. That seems to me to be one of the serious practical inconveniences from hard water which I do not think has been prominently touched upon.

"No inhabitant of London can be unacquainted with that inconvenience?—No doubt they are, and I suppose they feel the inconvenience to some extent."

169. We cannot gather from this evidence any important objection to Thames water, by reason of its hardness, for culinary purposes, except the incrustation in kitchen boilers. With water containing a large proportion of carbonate of lime this would be a serious objection, but practically with the Thames water the inconvenience is not great. A deposit is certainly slowly formed in the boilers or kettles, but it is in most cases of a loose incoherent character, and is removable without difficulty, while in the pipes beyond the reach of the fire very little deposit takes place, and they may remain for years without the necessity for cleaning.

c. For Washing and for Manufacturing Purposes.

170. This is the point on which the greatest stress of the objections to hard water has always been laid; the Board of Health considering that great economy, principally in the saving of soap, would accrue by the substitution of soft water for hard.

171. The Chemical Commission of 1851 say:—

"The injury sustained in washing, from the hardness of the present water supply, is greatly more important; but the estimation of its amount is difficult, and involves the consideration of a variety of circumstances.

"The softer the water the better is it adapted for washing with soap; the earthy salts present causing a definite and calculable loss of soap, which may be taken as amounting, with every gallon of water used in washing, to 10 grains of soap for each degree of hardness of the water. Thus, with one gallon of Thames water, at 14 degrees of hardness before boiling, the loss of soap would be 140 grains and at five degrees of hardness after boiling the loss of soap would be 50 grains; or with 100 gallons of water, the loss in the first case would be 32 ozs., and in the second about 11½ ozs. But such data are not alone sufficient for calculating the saving of soap effected by the use of a soft over a hard water; for soap is used in washing not merely in quantity sufficient to soften the water, but in excess to act as a detergent. The problem is to determine how great the portion of soap lost in softening is, compared with the portion profitably used for washing in the softened water. Such data, however, are not easily obtained. In the bleaching of white goods, as scientifically pursued, soap is not made use of, the process being a series of operations in which the cloth is exposed to lime-water, carbonate of soda, chloride of lime, and acid. The only practice in cotton manufactories, where quantities are exactly noted, analogous to common washing, is the soaping of dyed goods; we have found 7 lbs. of curd soap then used with 250 gallons of water, which is nearly 45 ozs. of soap for 100 gallons of water. Now if this water were of 14 degrees of hardness, 32 ozs. more of soap would be required for softening; and of the whole 77 ozs. consumed, 45 ozs. would be available, and 32 lost, which is a sacrifice of nearly 42 per cent. of the soap. With boiled Thames water of five degrees of hardness, 11½ ozs. would be required for softening with the 45 for washing, making 56½ ozs. together, of which 11½ ozs., or about 20 per cent. of the whole soap, is wasted. In the washing of woollens, we find water employed with so much as one-eightieth part of its weight of soap, that is, 200 ozs. of soap with 100 gallons of water. Here the loss of soap by using water of the two different degrees of hardness referred to, being constantly 32 and 11½ ozs., would form a much smaller proportion of the whole soap consumed than before, namely, about 14 per cent. in the one case, and 5 per cent. in the other.

"The maximum loss of soap by the use of Thames water employed cold, would therefore be estimated from such data at 42 per cent. of the soap employed with linens, and 14 per cent. with woollens; or when the same water is softened by boiling, at 20 per cent. with linens, and 5 per cent. with woollens.

"With woollens the loss is too small to entitle it to further consideration, particularly when it is also known that the proportion of woollen articles washed is very small with the poorer classes who frequent the public wash-houses; not more it is believed than two or three per cent. of their whole washing.

"Nor is it to be supposed that in the washing of linen a loss of 42 per cent. of soap is necessarily sustained in all cases. Carbonate of soda is generally employed by laundresses in London to soften water for washing. Indeed, this salt is used in the public wash-houses in a considerably larger proportion than is necessary to precipitate the hardening salts of lime, on its own account, as a powerful detergent, particularly in the first boiling of the linen, and is not omitted although the water is soft, as with the Trafalgar Square water used in the St. Martin's public wash-houses. This use of soda does not appear to be attended by any injury to the linen, with the excellent means of wringing, by which the discoloured water is got rid of, and the abundant supply of cold water for rinsing, which are provided in these establishments.

"The proportion of dyed articles washed by the poor is small, and the colours are generally of a permanent kind which resist soda. In all their washing of woollens and coloured cottons, as well as white cottons, soda is in consequence equally used.

"The following opinion of Mr. W. Hawes is recorded in the evidence upon this subject collected by the General Board of Health, that 'Since the manufacture of crystals of soda at a very low price, and its 'almost universal use in washing, the waste of soap from washing in hard water has been very trifling. 'The quantity of soda used to soften water, as it is called, is a source of expense, but of a trifling amount.' This appears to be strictly true, at least of the washing of the poorer classes as conducted in the public washhouses.

"In regard to the extraordinary injury and wear of linen from London washing often observed, and which has been ascribed to the hardness of the water, it may be remarked, that no such injury to the linen occurs in many private laundries, where handwashing only is practised, and the use of chloride of lime and acids entirely avoided. It is most marked in the larger establishments, where much of the washing of the metropolis is conducted.

"It is in the more careful washing for the middle and upper classes that the advantages of soft water become fully sensible. In the digestion of linen in hot water with soap and carbonate of soda, preliminary to the proper washing, the hardness of the water can only occasion a trifling loss of soda; but afterwards in the wash-tub, where soda is avoided, the earthy salts must occasion a loss of their full equivalent of soap. It is found proper also to avoid boiling any portion of the Thames water that is used in the wash-tub, or even heating the water above a certain point, for the carbonate of lime precipitates on the linen, carrying down the colouring matter of the water with it, and producing stains which there is the greatest difficulty in afterwards removing from the linen. The colour from the water is thus indeed fixed upon the cloth, by the precipitated lime, with the tenacity of a mordant. The evil of the hardness of the water is therefore aggravated by the flood-tinge or clay-colour which the London waters often exhibit for several months in the year.

"The number of gallons of water generally used with a certain weight of soap appears also to be considerably greater in London washing than in the practice of the Lancashire bleachers, so that the waste of soap from hardness cannot fall below, but may exceed, the previous estimate.

"In the washing of the person the saving of soap by the use of soft water is most obvious. For baths soft water is most agreeable and beneficial, and might contribute greatly to their more general use. Its superior efficiency to hard water in washing floors and walls is calculated also to promote a greater cleanliness in the dwellings of all classes, both within doors and externally. While in the occasional domestic washing of linen, the smaller preparation necessary for washing in soft compared with hard water, the saving of soap which would then be sensible to its full extent, and the more easy and agreeable nature of the operation, would make a supply of soft water in a high degree desirable. The use of soda in washing would be gladly avoided by most housekeepers, owing to its injurious action on the colours of certain prints, and the permanent yellow tinge and weakness of fibre which it may occasion even in white linens when exposed to heat before the soda is entirely washed out, as in ironing. A strong desire exists to avoid its use, and where soda is avoided there is no doubt that a saving of about one-third of the soap would be made by washing linen in water entirely soft; supposing the comparison to be made with water of the ordinary hardness of the London supply, but of which one third part was previously softened by boiling. The saving in labour would be even more considerable, if the comparison be still made between washing in soft water, and washing in hard water without the aid of soda."

172. Mr. Bateman thinks there is great advantage and economy in using soft water, because it produces a lather with a less amount of soap; and he refers to the saving effected in Glasgow and Dublin after the introduction of soft water supplies. He estimates the saving in the former of these cities to have amounted to 36,000*l.* per annum. He quotes evidence by Mr. Hawes and by Dr. Clark on the same subject, and also mentions the experience in his own family. 55–63. 66–80.

Mr. Hawksley states that the quality of water most suitable to a large population depends very much on their habits and their necessities with regard to trade and manufacturing purposes. In the north of England, where the great manufactures of the country are concentrated, it is very important the water should be soft, its quality 2504–15.

in other respects being a minor question. He explains the preference for soft water in the manufacturing districts. He points out, however, that the saving of soap is often much exaggerated, the error of calculation in this respect being often enormous. In dyeing, hard water is sometimes advantageous as regards certain colours.

1345–6. Mr. Rawlinson explains that great economy would result in manufactures by the use of soft water, and also refers to its superiority for personal ablutions.

1499, 1520. Mr. Way considers that for most manufacturing purposes soft water has a great advantage. In dyeing they much prefer soft water; the quantity of soap used in this trade is immensely large. For the dyeing proper, however, particularly with bright colours, harder water is considered preferable. At Lyons hard water is preferred. Still the washing process is so much the more important that on the whole soft water is preferable. For brewing soft water is not good, except for the darker kind of beer. It will not brew bitter ale or light coloured beer; all the Burton ales are brewed with hard water. For London porter, however, soft water might be desirable. In washing, the saving of soap and of linen from soft water are undeniable. In scouring cloth this is of much importance. He believes the manufacturers of Yorkshire went to the valleys of the Aire and the Calder more for soft water than for the supply of coal; though now the streams are so foul they cannot use them.

2185–97. Mr. Duncan agrees that soft water is preferable for general manufacturing purposes.

Dr. Letheby gives evidence on this point as follows:—

3938–40. "Are you acquainted with the evidence which was given before the Board of Health, with regard to the economy in the use of soft water, some years ago?—Yes.

"What opinion have you formed with regard to that?—My opinion is, that it is very much exaggerated, and that exactly coincides with the opinion which the chemical commissioners, Messrs. Hofmann, Graham, and Miller, formed of it. I think that those statements which were made by the old Board of Health upon that subject were founded upon wrong premises. They were founded upon the supposition that water was always taken of the degree of hardness that it has in its unboiled condition.

"You would separate the permanent from the temporary degrees of hardness?—Yes, the permanent hardness being that upon which I founded my calculations, while the non-permanent is that upon which the Board of Health founded their calculations; and this makes a good deal of difference in the result."

2646–719. Dr. Playfair states, at considerable length, his opinion that soft water is generally preferable for detergent and manufacturing purposes. He says:—

"Hardness is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. The effect of a hard water upon its ordinary detergent use is seen in the waste of soap and the difficulty of washing which washerwomen experience, and they are far more important members of the industrial community than is generally supposed.

2647. I gather from your statement also that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes.

2648. And it is therefore more conducive to health?—Yes, a more thorough cleansing takes place.

2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

2650. Could you give us any illustrations of the economical use of soft water in manufactures?—I could give an instance to show the great difference caused by even a small per-centage of additional impurity in a water. In the River Clyde there is a dam or weir across the river to dam up the fresh water for the supply of the manufactories; below this dam several sewers come in and deteriorate the water very slightly as regards analysis, but very greatly as regards its effect upon manufactures. A piece of calico above this dam, although the difference in value of the water is only about half a grain per gallon of impurities, requires four ounces of madder less to bring it up to the same dye; below the dam of course it requires four ounces more, and the difference of that to an ordinary work where they dye 1,000 pieces a day is 1,562*l.* in the year.

2651. Do you mean that that represents the difference between the use of the water above this dam and below?—Yes, the calico printers dyeing with the water above the dam would save 1,562*l.* a year, supposing they dyed 1,000 pieces a day, which is what good works would do, and they would have to spend that money if they used the water below the dam.

2652. Therefore, that is not a distinction between softness and hardness, but a question of purity or impurity?—In this case the deterioration of the water is owing to its containing iron; the water contains half a grain of oxide of iron below the weir more than it does above.

2705. You have referred to the effect of soft water in the use of dyes; could not that question be looked as in two points of view, one with regard to the economy in the use of the dyes, and the other with regard to the effect of the dyes themselves?—Yes; it has three influences upon dyeing: first, upon the original bleaching of the cotton; secondly, in the waste of the material used in dyeing; and thirdly, in the cleansing or clearing operations after the dyeing is completed; and in all those cases a pure water is preferable to a water containing any hardening matter.

2706. Does not water of a moderate degree of hardness bring out many colours better than soft water?—I have never found it so; I have carefully experimented, and I have found that distilled water brings out the best colours, and in all the experiments that I have made I have found that hard waters do not bring them out so well; but you will get plenty of manufacturers and dyers to tell you differently, and for this reason, that a dyer gets thoroughly accustomed to the water with which he operates, and he uses his materials and his mode of operation to suit that water; and if any other water is brought to him suddenly, seeing he is guided almost entirely by experience, he will get a worse result with a better water, because he is not accustomed to use it; and it requires the experiments of a chemist to elicit those sources of error. Every brewer who has been accustomed to brew with hard water will inform you that hard water is much better and more suitable for brewing, whereas a brewer who has been accustomed to brew with soft water will tell you that soft water is better than hard; manufacturing use is entirely a matter of experience, in which people suit themselves to the case before them.

2707. Are you acquainted with the experiments of Dupasquier with regard to the effects upon dyes in using distilled water, river water, and spring water?—No, I am not. I may mention that I was once the chemist to large calico printing and dyeworks, and that therefore my attention has been practically directed a good deal to that question. In early life I was chemical manager to Messrs. Thompsons' calico printworks in Lancashire.

Dr. Parkes and Mr. Simon agree with the opinion of Dr. Playfair. Mr. Firth and Mr. Jubb, cloth manufacturers in Yorkshire, state that they find an economy, the one of 25 per cent. and the other of 15 per cent., in soap for scouring by the use of soft water, and they prefer it for dyeing purposes, though for some colours they find hard water do as well; but it appears that their hard water contained iron, in the one case in considerable quantity, and that the total amount of solid residue was 50 grains in the gallon. 3138. 2782. 5212. 5320.

Dr. Frankland considers there is great advantage in the use of soft water in manufactures and for cleansing purposes. He explains the disadvantages of hard water for personal ablutions. As to the saving in soap, he says: 6261. 6277. 6357–8.

"You have, I presume, seen various estimates of what might be the saving if soft water were used instead of hard water?—Yes. 6368–9.

"Do you think that those estimates are generally correct, or do you consider them as rather in excess?—I think that there ought to be considerable latitude allowed in them. I do not think that the estimate would be correct as regards the amount of soap used in personal ablution, for the reason which I have just now mentioned. It is somewhat different in the case of washing linen. Supposing that the water were not softened with soda, then I believe that the estimate would be correct, because you must get the whole of the lime salts precipitated in the water before this washing of the linen can be effectually carried out."

He further expresses his opinion that the advantages of temporary over permanent hardness have been considerably overrated; as water used hot for domestic purposes is either not boiled, or boiled for too short a time to produce the full softening effect. App. D.

Dr. Odling thinks that except for drinking purposes soft water is on the whole preferable to a hard or even to a moderately hard water like the Thames. For manufacturing purposes soft water has great advantages over hard, except in very special cases. 6437–8.

Dr. Miller says there is no doubt that soft water, for all purposes except dietetic, is preferable to hard. There would be a certain saving in soap, but he thinks the amount of saving has been somewhat exaggerated in some estimates which have been made regarding it. As regards personal ablution, undoubtedly soft water is far more agreeable than hard. 7046–53.

Dr. Angus Smith concurs in the advantage of soft water for manufacturing purposes, but he considers the saving in soap has been somewhat exaggerated. 7218–22.

Mr. Heron says that in Manchester the supply of soft water for manufacturing purposes is an enormous benefit. There are many cases where calico printers and others pay a very large sum per annum to the corporation for the water in preference to water which might be obtained at a less cost probably, but which is not of the same quality. The income derived from the water sold for trading purposes is very large, and it is by that income alone that the corporation are enabled to supply the water at the low price they do for domestic purposes within the city. 7343.

173. There is no doubt that this evidence is conclusive and cogent as to the great advantage of soft water over hard for washing and, with some few important exceptions, for general manufacturing purposes; and if we were treating of the supply of a town like those in the manufacturing districts of England, where large quantities of water were required for these purposes, the objection to the present supply would assume a more serious aspect. But the amount of manufacturing industry in the metropolis, of a kind to demand large supplies of soft water, is exceedingly small in proportion to the population, and it must be recollected that the softening influence of boiling largely diminishes the evil. To these exceptional cases, also, the softening process of Dr. Clark would be easily applicable.

There is no doubt also that in personal ablutions and washing generally the use of soft water is more pleasant and economical, but we think the latter advantage has been much over-estimated. The soap is usually applied out of the water, and therefore it is with the small quantity of water adherent to the object washed that we have to deal, and not with the total quantity used for rinsing to remove the soap. It is certain, however, that when a soft water or rain water can be obtained for these purposes it will always be preferred.

All the witnesses have deposed to the general great economy of soft water for most manufacturing purposes, but we find it difficult to reconcile the opinions of some of the witnesses respecting the advantages in dyeing (except on the score of economy) with the fact that the largest and most important manufactories in France for silks, woollens, and

cottons have risen in Lyons, Rheims, Amiens, and Rouen—all using hard waters, and the three latter towns situated in chalk districts. Dupasquier, a well-known chemist, when called upon some years since to report on the waters of Lyons, showed as the result of his researches that waters of a certain degree of hardness were preferable generally for dyeing purposes, so far as regarded brilliancy of colour generally.

On the whole we cannot see that the advantages of soft water in this respect are of sufficient importance to justify going to a great distance to obtain it, in place of the ample supply nearer at hand.

Other Elements of Comparison between Hard and Soft Waters. Action on Lead and Iron, &c.

174. When speaking of the quality of water proposed to be supplied by Mr. Bateman's plan, we have alluded to the danger which may arise in some cases from the action of soft water on lead; and there is, further, the inconvenience of its acting on the iron pipes, leading to the deposition of concretions, interfering with the flow, and eventually destroying the pipes. Several witnesses have deposed to this action, especially Mr. Duncan, who states that at Chorley "they had to take up and relay a number of pipes "in the town, because they had become choked up in consequence of corrosion." In the same way the pipes at Grenoble became so damaged and choked after ten years' use that they had to be removed. A similar thing, but in lesser degree, happened at Cherbourg. Like, however, the action on lead, this action on iron is uncertain and irregular, and may most probably be guarded against by artificially coating the pipes.

From both these evils the water supplied from the present sources is perfectly free. The Chemical Commission of 1851 say: "The water at present supplied may be circulated "through leaden pipes, or preserved in leaden cisterns, with an unusual degree of safety. "The corrosion of water cisterns in London is generally occasioned by the mud which "subsides to the bottom. This corrosion is not attended by any sensible solution of "lead in the water. The London water may indeed be said to exert the least degree "of solvent action upon lead.

"The circulating system of iron pipes appears also to receive a certain amount of "protection from the alkaline character of the present supply. The erosions and bulky "deposits in cast-iron pipes, which have given great trouble in the distribution of certain "waters, are quite unknown in London."

Further, in considering the relative advantages of a water in a dietetic point of view, it must not be overlooked that hard water is less absorbent of gases and of organic impurities, and is therefore less liable to change than soft water. This, it is true, is in most cases a matter of very little importance, but in large towns, and with a poor population, it is to be weighed in the balance.

The Commission of 1851 say: "Putrefactive decomposition appears also to occur less "rapidly in hard than in soft water, and hard water seems to be the more easily preserved "in reservoirs or tanks without deterioration for a short time."

Artificial Softening.

175. It has been frequently suggested that the hardness of the London waters might be removed by the softening process invented by the late Dr. Clark, who has given a full account of it in his letter, Appendix G.

The Chemical Commission of 1851 had so good an opinion of this process, that on the ground of its peculiar applicability to chalk waters, they recommended that these waters, so softened, should be resorted to for the supply of the metropolis. As to its application to Thames water, they, after witnessing certain trials made at the Chelsea Waterworks, came to the conclusion that it was not attended with any peculiar difficulty on the large scale, and that the softening of Thames water in its ordinary condition to a point under four degrees of hardness was perfectly practicable. They estimated that the cost would be about 20*s*. per million gallons. They added, however, the following remarks:—

"The liming process, even when combined with filtration, proved to be unequal to remove the yellow flood tinge of Thames water, nor did it appear to abate an objectionable taste of vegetable matter which the water also then possessed. Had the result been different, the grounds for the adoption of the softening process would have been most cogent. But it seems that it is not to river waters that this elegant and useful purifying process is most advantageously applicable."

4026. Mr. Muir states that the New River Company have been prevented from adopting this process by the difficulty of accomplishing it on a very large scale, and also by the risk of deposit in the pipes. He adds:—

"I think, taking into account the fact that the temporary hardness of the New River water is so much greater than its permanent hardness, that the gain would not be very great; and from the difficulty of applying the process on a large scale, and the large quantity of water used for sewer flushing and street watering and other purposes (where the softening process is really useless), we have not much encouragement to go into the thing."

Mr. Homersham tells us that he has applied the process with perfect success to chalk waters supplied at various places; the current expenses being about 27*s*. per million gallons. He adds, however, that a river water is not adapted for being softened by it. He says, alluding to the trials at the Chelsea works:— 6762 et seq.

"The effect was this, that if the water operated upon is filtered water, so that it is clear before you apply the lime, the deposit settles quickly and you have no difficulty; but if the water contains any clay or is discoloured by a flood, as river water frequently is, the organic matter in the water, or whatever it may be which discolours the water, mixes with the crystals of the carbonate of lime and alters the specific gravity, and they do not fall down, but keep floating about in the water. The result is, that you must filter that water after it is softened." 6812.

176. Apart from the expense of this process (which would be very large for the whole supply of London), it does not appear to be applicable to the Thames waters on a large scale. It appears more suitable for small districts supplied from chalk wells, or for private use in manufactories where soft water is specially required.

On the Organic Impurities and Contamination of the Thames Water.

177. We now approach the more difficult part of the subject. If the waters of the Thames had no impurities beyond the solid mineral contents, the question as to their wholesomeness and general suitability for the supply of the metropolis would be easily disposed of.

But attention has been called strongly to the *organic impurities* contained in Thames water, which, though more indistinct in their form, and less appreciable in their quantity, are said to be more deleterious in their nature, and to render the water, if not dangerous and unwholesome, at least liable to suspicion.

178. It is easy to understand how streams and rivers may become contaminated with organic matters. The pure rain or spring water, flowing over the surface of the land, will dissolve vegetable matter with which it comes in contact, and if the land be highly cultivated there will also be taken up animal refuse from the manures, or from the droppings of live stock kept upon the farms. But the contamination may go further than this. In spots where the population is collected into villages, the excretions from the inhabitants will often find their way, to a greater or less extent, into the streams forming the natural drains of the land; and in the cases of large towns this effect is artificially aided by the establishment of waterclosets and systematic sewerage.

179. The waters of the Thames are of course liable to organic contamination from all these sources, though perhaps not in so great a degree as is generally supposed. In the first place, as regards the matters, vegetable and animal, washed from the land, it must be remarked that although the greater part of the basin of the Thames is cultivated, and some of it very highly, yet nearly half the area consists of porous permeable strata, such as chalk, oolite, and sand; and that the waters falling on these, except on occasions of large and sudden floods, will be rapidly absorbed, filtering through the earth and going to form the springs. It is from the retentive soils that the washings will be most plentiful and most charged with organic matters.

As regards the excretions from the inhabitants, the basin of the Thames above Hampton is comparatively thinly populated, from the absence of minerals and the non-attraction of any large manufacturing interests. Taking the area of the watershed above the point of intake of the companies, we find by the Report of the Rivers Pollution Commission that the number of inhabitants is about 888,000, and the area is 3,676 square miles, which gives about 230 persons per square mile, or rather less than three to an acre. Then a very large portion of the inhabitants live in villages or small towns dispersed about the agricultural districts, where no regular sewerage is either applied or required, the produce being considered valuable and used for direct application to the land. The population in towns of above 2,000 inhabitants amounts to only about 212,000, and it is only in the larger of these towns, such as Oxford, Reading, Windsor, and probably some few smaller places, that human excrements can be considered as being turned systematically into the stream; and even in some of these cases, from the incompleteness of the drainage arrangements, the effect is at present only partial. Thus it may be shown that only a portion of the inhabitants of the basin can effectively contribute to the sewerage contamination of the river. 2591–5.

180. But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly imagined, still it would be sufficient to do great mischief, were it not for a most beneficial provision of nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but in addition to these abstractions, important changes are effected by chemical action. The organic compounds dissolved in the water appear to be of very instable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now as such waters always contain naturally much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere; and when (as in the Thames) the water falls frequently over weirs, passes through locks, &c., causing further agitation and aëration, the process must go on more speedily and more effectually.

The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous and free from any deleterious quality. This purifying process is not a mere theoretical speculation; we have abundant practical evidence, which we shall hereafter refer to, of its real action in the Thames and other rivers.

181. The question now naturally arises, can we not, by careful analysis of the Thames water, discover what quantity of organic matters it contains; what is the nature and character of such matters; and how far they are deleterious or otherwise? We have endeavoured to arrive at a solution of this question, but unfortunately without much success. The inquiry seems beset with difficulty. The organic matter is present only in very small quantities, and in shapes and conditions which are very difficult to identify and to reduce to actual measure. The treatment of them is still a problem in chemical science, only now beginning to be effectually studied, and the most eminent chemists are yet by no means agreed either as to the processes most proper to be followed in the analyses, or as to the value and bearing of the results obtained.

It does not follow that all organic matter in water is prejudicial; great mistakes have arisen on this point, as it is often given out that the very suspicion of organic contents of any kind in a drinking water should disqualify it for use. But almost all our drinks other than water owe their distinctive qualities to the varieties of their organic contents, and hence it is clear that the presence of organic matter *per se* is not necessarily prejudicial. It is however necessary, in potable waters which contain organic matter, carefully to distinguish between such combinations as are innocent and such as are noxious; and here lies one of the greatest difficulties.

We now proceed to state the evidence before us on the quality, as regards organic contents, of the water supplied to London.

Earlier Analyses.

182. The Scientific Commission of 1828 called attention to the organic impurities of the Thames water, as taken in the immediate neighbourhood of the metropolis; and added the following general remarks on its salubrity:—

"The statements which have been made respecting the insalubrity of the Thames water as supplied by the companies have also been considered by us, and although, from the few cases which have been brought before us of disorders imputed to this cause, we do not feel ourselves warranted to draw any general conclusions, we think the subject is by no means undeserving of further attention. There must always be considerable difficulty in obtaining decisive evidence of an influence, which although actually operating to a certain extent as a cause of constitutional derangement, may yet not be sufficiently powerful to produce immediate and obvious injury. It cannot be denied that the continued use of a noxious ingredient in diet may create a tendency to disorders which do not actually break out until fostered by the concurrence of other causes, for we unquestionably find an influence of the same kind exerted by other agents which occasion merely a certain predisposition to disease, and of which the immediate operation must therefore be extremely insidious and difficult to trace. It is obvious that water receiving so large a proportion of foreign matters as we know find their way into the Thames, and so far impure as to destroy fish, cannot, even when clarified by filtration, be pronounced entirely free from the suspicion of general insalubrity."

App. A F. The Chemical Commission of 1851, who tested the water with all the chemical skill then attainable, report in the Thames water (then still taken within the tideway) a quantity of organic matter varying from 1½ to 3 grains per gallon, on which they remark as follows:—

"The soluble organic matter from two of the Thames waters was submitted to ultimate analysis, and found to give 0·105 grain of nitrogen in the Grand Junction water, and 0·031 grain of nitrogen in the Southwark and Vauxhall water. The existence of nitrogen is generally supposed to imply the animal origin of organic matter, and on such evidence a minute and probably unimportant portion of animal organic matter would be admitted to be present.

"None of the waters had any marked taste or odour, nor betrayed any indication of putrescence, either when first taken up or after being kept in bottles for several weeks at a temperature between 50° and 60°; nor even after remaining in close vessels for two weeks at 80°.

"In these waters when submitted to microscopic examination no animalcules were observed in any case. But the period of the year was not that at which any considerable development of animal life is to be looked for."

They allude to the colour and contamination to which the river is liable in the late autumn and early winter, from the extensive decomposition of vegetable matter, which they state to be a serious evil; but they appear to draw, in a sanitary point of view, a broad distinction between this and organic matters of animal origin, on which they remark as follows:—

"As the main drain of a large and populous district, the Thames becomes at all seasons polluted by the sewerage of several considerable towns, and by the surface drainage of manured and ploughed land. At the same time, we doubt whether the existence of organic contamination from town drainage is at present perceptible in the Thames above the reach of the tidal flow, or amounts there to a sensible evil. The indefinite dilution of such matters in the vast volume of the well aërated stream is likely to lead to their destruction by oxidation, and to cause their disappearance. The river may reasonably be supposed to possess, in its self-purifying power, the means of recovery from an amount of contaminating injury equal to what it is at present exposed to in its higher section."

They add further observations tending to justify a recommendation that the supply should be drawn from a point above the tideway.

Messrs. Hofmann and Blyth's analysis in 1856, made after this recommendation had been carried out, in pursuance of the Act of 1852, showed in a striking manner the advantage of the change. The chemists found that the hardness and mineral contents had undergone little variation; but in regard to the organic matter they reported as follows:— App. B G.

"*A very considerable diminution, however, is observed in the amount of organic matter.*

"In fact, in 1856 the water supplied to the metropolis contained not more than one-half of the organic matter which was present in the year 1851.

"This result is certainly not accidental. The diminution is not merely an average result, but uniformly observed throughout. The waters examined in 1851 were taken in January; those investigated in 1856, partly in January and partly in April. The diminution of the organic matter cannot therefore be due to the influence of the season. Nor can it be due to any difference in the mode of determining the organic matter in 1851 and 1856. These determinations were made by exactly the same method; for it so happens that the analytical part of the inquiry in 1851 which refers to the organic matter was likewise made in the laboratory of the Royal College of Chemistry. The diminution is obviously partly due to the alteration of the localities from which many of the companies derive their supply. The Grand Junction, the West Middlesex, the Southwark and Vauxhall companies, formerly supplied respectively at Kew, Barnes, and Battersea, derive their present water from Hampton; the Lambeth Water Company used to take their water at Lambeth, but have now erected extensive works at Thames Ditton. The diminution of the organic matter in the London water supply is, however, by no means confined to the companies that have changed the locality of their source, and it must therefore be attributed in a great degree to the considerable improvement which has taken place in the collection, filtration, and general management of the supply of water to the metropolis."

The analyses of Letheby, Odling, and Abel, in 1867, state that the quantity of organic matter in the filtered water could not have exceeded one grain per gallon, and shew the ammonia to be almost infinitesimally small. The average total quantity of organic matter in the water supplied in 1867 appears only about two-thirds of that in 1856, and only about one-fourth of that in 1851, showing the beneficial change effected from further improvements in the supply. App. A H.

In the Returns of the Registrar General, there are now given monthly reports by Dr. Frankland on the condition of the waters supplied by the different London companies. The analyses which accompany these reports show a general agreement with those just referred to. As, however, they are elaborated on a principle not ordinarily employed, it is not easy to compare them with those of other chemists. They give very careful and definite determinations of organic matter, but on the value of the mode employed, and on some of the inferences, there is a difference of opinion amongst men of science; and we shall presently have to make some remarks on this subject.

183. We have had before us many witnesses conversant with the subject, including some of our ablest chemists, and have endeavoured to ascertain fully their opinions on this question, which we will now give, as far as practicable, in their own words.

Evidence on the Organic Impurities of Thames Water.

Chemists and Medical Men.

184. Dr. Lyon Playfair, Professor of Chemistry in the University of Edinburgh:—

2681. Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and what would be the effect of the presence

of organic matter in such water?—The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river, such as the Thames above London, the action of the aëration of the water would be in that case to destroy any moderate amount of organic matter, would it not?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination; by a chemical examination you can do so, but the presence of the most highly oxydised form of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

2683. Is it not considered that by the time the Thames water, with which London is now supplied, reaches the delivery pipes all organic matter is converted into the state of nitrates and nitrites?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not.

2684. That was confined to one particular district, was it not?—Yes.

Mr. Simon, Medical Officer to the Privy Council:—

2751. You of course have analysed, and you are well acquainted with the quality of the London water?—Yes.

2752. What is your opinion as to its character?—Judging by chemical analyses, performed on it in what I may call its normal state, I am not aware that there is much fault to be found with it.

2753. You are speaking now of all the water supplied by the various companies?—Yes, speaking quite generally. Speaking of it in its broad ordinary chemical characters, as it would be reported on from a chemical laboratory, I should say it is a fair water supply.

2754. Are you now speaking of the whole supply of the metropolis?—Yes, speaking generally of it. But what I thus say of its average chemical constitution in its normal state does not touch the question of the water's liability to accidental very dangerous pollutions. There are dangerous qualities of water supply, with regard to which, so far as I know (but I do not speak as a skilled chemist), chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect.

2812. My practical point is, that what one has to do is not to take water out of a reservoir or out of a tap and give it to a chemist and say, "Tell me, is this wholesome water"? What one has to do is to guard the supply with the utmost strictness against every foul admixture. It ought to be made an absolute condition for a public water supply, that it should be incontaminable by drainage.

2837. Have you, apart from the question of sewage, considered the condition of the Thames basin as a gathering area, having regard to the high state of cultivation of the land and the use of manures, artificial and other, and the washing of water into the Thames, what the effect upon the water would be for domestic purposes?—The earth is a most powerful absorbent and disinfectant of the materials used as manure, and I do not think that practically any important danger would attach to the outflow from cultivated lands.

7135. I think when you were examined before you were asked your opinion as to the effect of sewage contamination in rivers, and after how long a period, and at what distance of flow, the river would get rid, if at all, of that sewage contamination; have you formed any opinion upon that point?—I cannot venture to answer that question with any confidence; it is a very difficult question to answer.

7136. But are you of opinion that the water of a river which had been under the influence of such contamination would ever after be a safe water for domestic purposes?—The answer to the question, if it is to be absolutely correct, must vary with the quantity of sewage, the volume of water, and the distance between the point of contamination and the point to which the question applies.

7137. Supposing that sewage is discharged from one of the sewers, say, at Windsor, would it be possible to detect the presence of that sewage seven miles lower down the river, having regard to the volume of water in the river?—I believe it would be absolutely impossible for chemists to discover it, but the practical sanitary question is different. Supposing tape worm eggs to be sent into the river with that sewage, would those tape worm eggs be alive seven miles down? Or, supposing cholera discharges to be sent into the river, or the discharges of typhoid fever, and assuming (which is a frequent pathological opinion) that the respective contagia of typhoid fever and cholera are living germs, would those germs be alive seven miles down? It is not a question whether a chemist would find out the organic matter so much as it is a question whether those particular molecules would still have their property seven miles down. I cannot say that they would not.

7138. Could you detect them at that distance?—Only by their effects.

7139. Might not the same disease be produced from any other cause?—The particular parasite will only come from its particular egg. You would not get hydatids except from eggs any more than you would get chickens without eggs.

7140. Are the Commission to understand you to state that it is impossible for a chemist to discover the existence of sewage at the distance named?—The possibility varies with the conditions I have stated.

7141. If it is not possible for a chemist to discover it, is it not presumptive evidence either that it does not exist, or that if it does exist it is in such minute quantities that it is in no way deleterious to human health?—I am very decidedly of opinion that that principle is not a safe one to adopt as a basis for sanitary regulations in the matter. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think, even, that allowance should be made for the proper decent taste of people. Water into which sewage has been discharged is, in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. Moreover, as a mere matter of taste, people would rather not drink water into which sewage has been discharged, and I think that that in itself deserves consideration.

Dr. Farr, Superintendent of the Statistical Department of the General Register Office, has given us lengthy information as to the outbreak of cholera in 1866 in the East of London, and has put in valuable statistics, &c., thereon. The following extracts will illustrate his general views:— 2845 et seq.

2876. Am I to understand you to say that in those districts where the cholera prevailed very largely the principal cause was the impure water?—I conceive that the cause of cholera existed here, and that the elements of disease from cholera patients were distributed all round London. Cases occurred in every part of London, but in the other districts the mortality was inconsiderable. For instance, in all the districts supplied by the Grand Junction, the West Middlesex, and the Chelsea Water Companies, the mortality was about 3 in 10,000, in those supplied by the Southwark and Lambeth Companies, which were formerly so heavily visited, it was about 6 in 10,000, and in those supplied by the New River Company about 8 in 10,000, but in those supplied by the East London Company from the Old Ford reservoirs it was 79 in 10,000. I do not ascribe the whole of that mortality to the water, but I ascribe a large portion of it to the circumstance that the impurity causing cholera was distributed through the water of that company.

2877. Will you be good enough to tell us what you consider those other circumstances to be?—The density of the population also had an influence. We found that where people were packed very closely together they suffered more than where they were distributed more widely over the ground. We have found also that the condition as determined by the annual value of the houses that the people lived in, their poverty had a considerable influence, but not so striking as I should have imagined it would have had. We found also that the elevation of the ground in which the people were living had a very marked influence. In the first report I showed that the mortality on the low banks of the Thames both on the south and on the north side, was from 100 to 150 per 10,000, but as you ascended on successive terraces the mortality was reduced, and at the higher points it came down to 8, so that the elevation of the soil had a considerable influence. That I have been led to suppose since had a good deal of influence upon the purity of the water also.

2890. Do you think that if this London water could be free from all its impurities it is a good quality water for consumption?—I confess that when I see that this Loch Katrine only contains in 100,000 grains three grains of impurities of any kind, and that it contains no trace whatever of sewage or anything like sewage, I should have greater confidence in water brought in that way from the hills than I should in water taken from the river; at the same time I am not prepared to say that the water from the river, with great precautions as to letting sewage into it, might not be made a very decent sort of water.

2929. As far as your experience goes, are we to take it that this view which is conveyed in the report of Dr. Frankland is one that you concur in, namely, that at the present moment taking his analysis there is nothing that is really bad in the water supplied to London?—Not on that particular day. I should qualify it myself always in that way. I can conceive that the character of the water varies from day to day; it varies with the temperature and with the rainfall, and with a variety of circumstances. All we know is that from the analyses which Dr. Frankland has hitherto made he has come to the conclusion that the water supplied to London has contained something very noxious, but that it did not contain anything noxious at the time that he took it at the mains.

Dr. Parkes, Professor of Military Hygiène in the Army Medical School at Netley:—

I have made a list of diseases all of which are occasionally communicated by means of water, not solely communicated by water, but occasionally. For example, typhoid fevers; of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me, arising from water impregnated with typhoid sewage, or possibly with simple sewage.

3123. As far as your special observation has gone, in all cases where there has been a discharge of human excreta into water where the parties have been suffering from typhoid fever, that has generated disease in every district where the water has been taken for domestic purposes?—It has not generated typhoid fever in all cases, because in some cases it has generated diarrhœa and dysentery; typhoid fever has prevailed in some cases and not in others, and therefore that is an argument in favour of the view that it requires the typhoid sewage especially to pass into the water for the development of that particular fever, and that simple sewage will not cause it. But the question is surrounded with difficulties; it is so difficult to get reliable scientific evidence that it is still *sub judice*.

Dr. Parkes proposes to divide potable waters into several standard classes. He says:—

I would propose to form a class of "wholesome waters," under which two sub-classes of waters may be included, first, the purest and most wholesome water, which is free from suspended matters and contains very little dissolved organic matters, say under one grain per gallon, and that probably vegetable, and of dissolved mineral matters under seven grains per gallon. That will include all the best waters supplied from the primitive rocks, and from some of the sands which contain under that quantity of mineral matter, and is probably the purest water on the whole which can be obtained in that way.

Then the second sub-class in the first order would be what I would call pure and wholesome water, to which no objection can be taken, I believe, in a sanitary point of view, but which is not so pure as the former. This water is also free from suspended matters, having dissolved organic matter under two grains per gallon, the greater part of that being vegetable. Of dissolved mineral matters it would contain under 12 grains per gallon, consisting principally of carbonate of lime and alkaline carbonates and chlorides. That second sub-class would include the best chalk waters, which are often very free indeed from organic matter. Then the second grand class I would make I would propose to call "useable waters;" waters which cannot, perhaps, be very much objected to, not so good as the former class, but yet which in many cases might be used, and which would not produce, perhaps, any bad effects. Those are all waters with no suspended matters or suspended matters easily separated by the coarse filtration usually resorted to by the water companies. The organic matter would be chiefly vegetable, but it should not exceed three grains per gallon, owing to the diseases which would probably arise if it exceeded that quantity, and if the organic matter is apparently of a mineral origin it ought not to exceed two grains per gallon. Then it should contain mineral salts not exceeding 20 to 30 grains per gallon, and consisting of a class of salts which do no injury to the system, such as alkaline carbonates, alkaline chlorides, chloride of sodium, and chloride of potassium, in less quantity, and possibly a little carbonate of lime also.

3149. The third class would be what I would call "suspicious water," which would be any water with much matter suspended, which would be separated readily by coarse filtration. Such a water as that would in all probability contain either fine particles of mineral matters, which are hurtful, such as clay, or possibly it might contain suspended organic matters very finely divided, and not very readily separable by filtration. It might contain dissolved organic matters vegetable and animal, amounting to about three or four grains per gallon, and mineral matters of large amount, such as alkaline and chlorides, carbonates, and carbonate of lime in large amount, that is to say, perhaps over 9 or 10 grains per gallon, or sulphate of lime or magnesia, and chloride of calcium or magnesium in certain quantities; all those I should consider make a water suspicious; or if it contains any indication of nitrites, nitrates, ammonia, &c., showing that organic matters had passed into the water and had there been oxidized; any indications of that kind I should consider would bring the class under the head of suspicious water. Then the fourth class would be "impure water," which would include any turbid and bad smelling water with suspended matters not easily separated by coarse filtration; also dissolved organic matters above four grains per gallon, especially if of animal origin, large quantities of mineral substances, especially of sulphate of lime and sulphate and chloride of calcium and magnesium, which all give permanent hardness to the water, or large indications of nitrites, nitrates, fatty acids, ammonia, &c., all of which indicate the passage of organic matters, animal in all probability, into the water.

3150. Under which of those heads would you put the London water?—I should put the London water under head No. 3, suspicious.

3151. Would you do that because there are indications of nitrates?—Yes; I should call any water containing large indications of nitrates and nitrites suspicious water. Such indications may, however, come from water not impregnated with sewage, as some soils give off nitrates and nitrites. . . . . I think that the mere presence of nitrates and nitrites in water in small quantities would not be hurtful at all; their importance is as indicating their source, and showing that there must have been contamination, probably by animal inorganic matter, in most cases sewage, and of course rendering the chances of such organic matter passing in in sufficient quantities to affect the health very probable, but when such organic matter has been oxydized, then no doubt it becomes, at any rate in most cases, harmless.

3160. Sewage is the most dangerous parent of those things, is it not?—Yes. But any indication of them should lead at once to an examination, so as to trace the origin of nitrates and nitrites, and the water would be suspicious in the proportion that it contained any large quantity.

3161. It would not be a certain inference that it was from sewage?—Certainly not.

3177. Is there in your judgment an objection to the Thames basin as a gathering area for water by reason of the high state of cultivation in some parts, and from the manuring that it undergoes?—Yes, I think there is a very great objection. No doubt the effect of water passing through a soil with manure is to cause a very rapid oxydation of the organic matter, and a very large quantity is converted into nitrates and nitrites and ammonia, but there is a limit to that, and it is impossible to ensure the safety of water where there is the possibility of contamination on a large scale with organic matters derived from sewage.

3178. If it passed through a sufficient depth of earth it would be deprived, would it not, of this matter?—The earth would be a great purifier, no doubt.

3181. Have you observed in a case where sewage has been discharged into a river that after running for three or four miles the effect of that sewage has been destroyed?—Yes, we have that in the case of the Southampton water supply; some sewage passes into the Itchen river, but it is quite destroyed by the time the water is distributed in Southampton, at least there is no detectable quantity.

3182. What is the distance?—The distance is six or eight miles. I could not undertake to say the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance, or what time, or under what precise circumstances I could not say.

3183. I presume that the sewage, probably by the action of the water and the atmosphere, would really be broken up into other elements of a less injurious character?—Yes, broken up into compounds of nitrogen and ammonia, nitrates and nitrites.

3184. You do not get rid of it, you have it in a different form?—Yes.

3185. And in a less objectionable form?—Yes, in a form I presume quite unobjectionable in a small quantity. A very large quantity might be irritant, but in a case in which they would be in water not very largely impregnated with sewage, I should think that they would not be hurtful.

3186. Do you think, taking the upper part of the Thames as a gathering area, that any injurious result from manuring or other washings into the river would by the course of such water down the Thames be somewhat neutralized?—I think that very likely it would be neutralized to a very considerable extent. That would rather depend upon the amount passing in; if any experiments could be made as to the amount of manuring and the number of acres that would furnish sewage matter, and the amount of sewage matter which would pass in, and the rapidity of the flow of the Thames at different parts of the year, and the volume at different times in the year, we should be able to form a better idea. It would be modified by a great many circumstances.

3187. But there would in your judgment be a process of purification going on?—Yes, it would be simply a question of degree.

3237. Do you think that in point of health the population of London generally suffer from any impurity in the existing water apart from any special case of cholera in the east of London?—I think that where the population of every town shows a considerable amount of diarrhœa, and also of typhoid fever, it makes one believe that there must be some impurity in the water at times, and the health of the population as regards those diseases of the intestines seems to be very much influenced by the purity or impurity of its water supply.

3245. If the subject had been considered one of vital importance by the medical profession generally, do not you think it would have been proposed that it should be scientifically investigated by some specially appointed body either of medical men or chemists?—We must remember with regard to the effect of different things upon the health of the community in this country that it has only been the subject of investigation for the last 30 years. Till we began to have statistics of deaths we had not learnt to know the relative prevalence of the several forms of disease, and it was impossible to form any opinion as to the condition under which the people were living. We may say that these questions are almost in their infancy.

Dr. Letheby, Medical Officer of Health to the Corporation of London:—

3879. Having regard to those waters, and the several tests which you have yourself made, what is your opinion generally of the water supplied to this metropolis?—My opinion is founded in the first place upon the actual analyses of the waters over a long period of time, monthly analyses; it is founded in the next place upon

an observation of the use of those waters very extensively, and I am bound to admit that there is no evidence whatsoever that those waters are in any way objectionable as a public supply. I am now speaking of the whole of the metropolitan waters.

3880. Notwithstanding the amount of organic impurity, that is your opinion?—The organic impurities are not large in the London waters. The loss by incineration, although a grain, is not regarded as a serious quantity, because the loss by incineration represents a great deal more than the organic impurities.

3891. When that interception takes place, will the water of the Thames in your judgment be greatly improved?—I do not think that it will be much improved. Not but that I am quite ready to admit that the discharge of sewage into such a river is a most improper thing, but considering the powerfully oxydizing influence of water upon sewage, the many agencies which are at work destroying it, the power of precipitation, the using of it up by vegetables and aquatic plants and by fish, and above all by the power of oxydization, I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome. But at the present moment I cannot perceive through the most refined chemical processes the existence of a particle of sewage in the water at Hampton where the Thames Companies take their supply.

3894. Have you at all ascertained in what length of time or distance polluted matter will be decomposed and transformed in its chemical qualities; for example, supposing we had the sewage from Richmond poured into the Thames, how far down the river would it be lost as sewage and broken up into other chemical elements?—I have made a very great number of chemical experiments to determine that. I have examined most of the rivers in England, and this is the conclusion that has been come to, not only in my mind but in the minds of all the engineers who have devoted their attention to this subject, that if ordinary sewage, containing we will say nearly 100 grains of solid matter per gallon, such as our London sewage, out of which probably something like 14 or 15 grains are organic, be mixed with twenty times its bulk of the ordinary river water and flows a dozen miles or so, there is not a particle of that sewage to be discovered by any chemical processes.

3898. Taking the case of the cholera disease and the discharges from the human body being mixed up with the sewage, do you consider that any germs of that disease would be carried down in water?—At the present moment we do not know what the germs of the disease are. If the germs of the disease be decomposing matter, then I do not think that they would exist in the water; but if the germs of the disease be living matter, then it is possible that they may exist in the water, but as nobody as far as I am informed can tell us what the germs of cholera are, it would be premature for me or anybody to theorize as to the probability or the possibility of their existing in the water.

3901. You are aware that it has been alleged that the main cause of the cholera in the east end of London was due to the water supply, do you entertain that opinion?—No, I entertain the opposite opinion. It was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply. In the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connexion with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease. I therefore investigated it very fully.

3902. Are there two distinct waters supplied to that district?—Yes, but I will tell you this with regard to it, there is hardly anybody who can say, except in certain parts of the East London Company's district, whether the water had come from the reservoir at Old Ford or whether it had been received from the filter beds at the Lee, which is considered to be a good water, for the water was oscillating backwards and forwards in the mains in such a manner that the engineer himself had no knowledge what water was in any main at any particular time. But on the other hand there are places at which Old Ford water, and that water alone, is supplied, namely, Stamford Hill, Upper Clapton, Walthamstow, Woodford, Wanstead, Leytonstone, North Woolwich, and Silvertown, and excepting the two last-named places there was no cholera in any of them; there was a little in Silvertown towards the end of the epidemic, but the other places were free from it, and those were the only places where we actually knew that that water did go.

3904. Do you think the present supply of water to the London people is wholesome water?—I do, a thoroughly wholesome water.

Mr. Wanklyn, Professor of Chemistry at the London Institution, Finsbury, informs us that his attention has recently been directed to a new method of analyzing water for organic matters, and which he now considers sufficiently perfect to be worked. The preliminary experiments he has made show a larger quantity of free organic matter in the Thames water than Dr. Frankland's method, which he considers cannot detect all the nitrogenous matter. He says:—

. . I have to remark that the method of determining the organic matters which I use is a very simple one, and can be carried out in about three hours, and the determination is a perfectly direct one. I do not determine the total nitrogen in a water and then determine the nitrogen present as ammonia and nitric acid and give you the difference, but I determine directly the nitrogen present as organic matter, and that you will see is an important thing. The project of 10 years ago, (and it has been tried to be carried out, and it is admitted that it will be very difficult to carry it out,) was to give you the organic matter by a double process, giving you a difference; but my method is a direct one. I give you directly the nitrogen which is present in the organic matter.

5482. It has been stated in evidence before us that if you pour into water a volume of sewage equal to five per cent. of the volume of water into which it is cast, the water will so operate upon it in deodorizing and destroying and breaking up its elements into its primitive elements in fact, that it would no longer be sewage or possess any of its noxious qualities You apparently hold a contrary opinion?—This I am sure of; the urea in the sewage in such a water would be very readily broken up into ammonia and carbonic acid, and a little exposure would dispose of the urea, but the albumenoid matter in sewage is extremely persistent, and one of the results of the

whole investigation is this, that albumenoid matter is very persistent indeed, and you could not depend upon any treatment such as you have mentioned getting rid of the albumenoid matter.

5485. But will not certain changes take place, even in the albumenoid matters?—Yes, certainly; but the change is very slow, and it is very irregular. The change in urea is very rapid, so that you have to operate upon water recently taken in order to get your full quantity of urea.

Mr. Wanklyn subsequently sent us further testimony in a letter (Appendix A K), which is to the following effect:—

The result of a prolonged examination carried out by myself, Mr. Chapman, and Mr. Smith on the water supply of London, Manchester, Glasgow, and Edinburgh, last summer is the following:—

The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow.

The water supplied by the New River Company is also very good.

Dr. Frankland, Professor of Chemistry in the Royal Institution and the Royal School of Mines:—

6222. What does your experience tell you is the effect of the quality of the present supply in London upon the health of the population generally?—I cannot of course trace any direct connexion between the present supply and the health of the metropolis; but I consider that water contaminated with sewage contains that which is noxious to human health. There is no process practicable upon a large scale by which that noxious material can be removed from water once so contaminated, and therefore I am of opinion that water which has once been contaminated by sewage or manure matter is thenceforth unsuitable for domestic use.

6224. Are we to understand that you are of opinion that this noxious matter exists in the water from analysis, or from knowing that sewage runs into the river from whence the companies draw their supply?—From both circumstances.

6225. Take the analysis first. What leads you to believe that there is that amount of sewage matter in the water which would be detrimental to health?—I find on analysis, as is shown in the table at page 17 of our report, that there is present in the waters delivered into London the following quantities of material, which may be regarded as the skeleton of the sewage which has been previously poured into the water; namely, of nitrogen, in the form of nitrates and nitrites, a mean quantity of ·192 part in 100,000 parts of water, that is, in the Thames water; in the river Lee water, as delivered by the New River Company, ·221 part in 100,000 parts; in the water delivered by the East London Company, which is also river Lee water, ·132 part; and in the chalk water delivered by the Kent Company, ·365 part in 100,000 parts. This skeleton, as I have called it, of previous sewage corresponds to the following quantities of average filtered London sewage, namely, in the Thames water to 1,751 parts of sewage in 100,000 parts of water; in the river Lee water, delivered by the New River Company, to 2,013 parts of such sewage; in the river Lee water, delivered by the East London Company, to 1,077 parts of such sewage; and in the chalk water delivered by the Kent Company, to 3,393 parts of such sewage. I must mention, however, that this chemical record is defective, especially in the summer months. It is defective in one direction, namely, that it gives the minimum amount of sewage only, with which the water has been contaminated; because in rivers we have vegetation in a state of activity during the spring and summer months, and also to some extent in autumn, and those aquatic vegetables remove this skeleton of the sewage to a greater or less extent from the water.

6226. You state that you have come to the conclusion that sewage has been the cause of the contamination of this water because you find a skeleton there in the form of nitrates and nitrites?—Yes, and also of ammonia, which I think I omitted to mention, but that is a very insignificant part of the skeleton.

6227. Is it possible that those nitrates and nitrites could be present in the water without its having been contaminated by sewage?—Could they be produced by some other cause than that of sewage?—They could be caused by manure thrown into the water, and by manure applied to the land.

6228. But are they attributable to nothing else?—To nothing else, I believe.

6233. With regard to the Kent water, we had some evidence yesterday to the effect that you must have been mistaken in finding traces of sewage in those chalk wells, the water being taken at a depth of 250 feet in the chalk, and the upper part of the wells themselves being lined; therefore the water must have filtered through the chalk, and there could be no trace of the skeleton of sewage. Is it your opinion that the skeleton of sewage as you describe it will find its way down to a depth of 250 feet, and that after filtration through gravel, and ultimately through the chalk, its presence will still be detected?—There cannot be a doubt about it, that this skeleton of which I speak, but which is a very different thing from the sewage itself, is present. I have never stated that the water which has filtered through the chalk in this way contains unaltered sewage; it is this inorganic skeleton of sewage that I find in water so filtered.

6234. Is it prejudicial to health?—It is not in a moderate quantity, such a quantity, for instance, as is contained in this chalk water of the Kent Company.

6235. With regard to the Kent water, the mean of the nitrates and nitrites according to the figures which you have just given us is ·365, and that amount in water in your opinion would not render it injurious to health?—That amount of nitrates I should say would have no deleterious effect upon health.

6236. It is scarcely necessary to say that in the case of the water delivered by the East London Company, which has ·132, the water of the New River Company, which has ·221, and the Thames water delivered by the Chelsea and Grand Junction and other companies, which has ·192, none of those four waters as at present supplied to London could have an injurious effect upon the health of the metropolis, in consequence of the presence of those nitrates which you say are the skeletons of previous sewage contamination?—Certainly not. Those nitrates would not in any case, I believe, be in the least prejudicial to health; but they reveal the fact that those waters have been previously contaminated with sewage, and, as I have already stated, there is no method which, with certainty, can be applied to water by which the noxious qualities of sewage can be effectually removed from it.

6237. But in all those four waters, as I understand you to say, after having had them analysed, you find the presence of those nitrates and nitrites, which shows that the waters had been in previous contamination with sewage?—Yes.

6238. But although they are in that state, you state, do you not, that there is nothing in them that could be injurious to health, and therefore the water is a wholesome water to drink?—I did not intend my statement to go so far as that. I meant only with reference to those nitrates in themselves, that the skeleton of the former sewage which is represented by nitrates and nitrites is not injurious to health; but we have no guarantee that other portions of that sewage may not have escaped the process of filtration through the chalk, and filtration through the land or over the land, and may be present in that water. Those substances are in too minute a quantity to be capable of detection by chemical analysis.

6239. Then your answer would apply as far as the nitrates would enable you to judge?—As far as the nitrates themselves are concerned that quantity of sewage matter which they represent is an innocuous form in the water.

6240. The presence of what other elements would lead you to a conclusion upon the quality of water as regards health?—In the first place when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water. Filtration will not do it in certain cases, at all events. I have proved that the excrements of cholera patients cannot be filtered out of water; that after a degree of filtration which I believe is never attained by the water companies, and rarely attained perhaps by the passage over soils in irrigation, this water still remains opalescent, from the rice-water evacuations with which it has been mixed. The degree of danger which still remains in waters from different sources varies obviously according to the amount of filtration that the water undergoes. I would much rather drink the chalk water of the Kent Company, even if it had been contaminated to four times the extent of the Thames water, than I would drink the Thames water, because if I could have the assurance that none of that sewage or manure water had found its way into the wells through fissures in the chalk, the chalk water having passed through say 100 feet of chalk, would be very much better filtered than any water which finds its way to the Thames.

6241. When you speak of the difficulty of removing the effects of sewage contamination, does that difficulty apply to that which is held in mechanical suspension, or to that which is held in solution?—To that which is held in mechanical suspension. I believe that the noxious part in sewage is that which is held in mechanical suspension, not that held in solution.

6402. Still you are able to detect those globules?—No, they are beyond the reach of the chemist, and so far of the microscopist, I believe.

6242. Will no system of filtration remove it?—I would not say that it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed; the one is by boiling for a long time, and the other is by distillation; and therefore it is that I say that, inasmuch as those two processes are impracticable on a large scale, in my opinion water that has once been contaminated by sewage ought not afterwards to be used for domestic purposes.

6244. Then are we to understand you to say that no amount of filtration would render those waters fitted for the supply of the metropolis?—As I have stated, no process of filtration that has hitherto been devised will remove cholernic dejections from water; and inasmuch as it is generally believed that the noxious matter of sewage exists there in the form of minute germs which are probably smaller than blood globules, I do not believe that even filtration through a considerable stratum of chalk could be relied upon to free the water perfectly from such germs.

6246. Do I correctly gather from your evidence that you think that no water that had passed over or through any cultivated district would be proper for the supply of the metropolis or other large towns?—I do think that that water is not safe for human consumption afterwards.

6247. That being your idea, would not it follow that no water could be supplied to the metropolis in a wholesome state from the Thames basin, because the whole of the Thames basin is as we all know very considerably cultivated?—Yes, I think it is very likely that that would be so; and inasmuch as the chalk water from shallow chalk wells exhibits this previous sewage contamination, I should infer that the springs feeding the Thames would also exhibit that contamination; but that does not necessarily follow, because it is stated that the deep chalk wells furnish a water free from nitrates and ammonia, or very nearly so, and consequently they are not so contaminated.

6248. Do you think then that there is a point below which the sewage matter would not get down?—At all events there is a point apparently below which the skeleton of the sewage no longer finds its way, it is either consumed by some living organisms and converted into other forms of matter, or it is absorbed by the strata themselves through which it passes. I have not myself analysed the waters of the deep chalk wells, but Mr. Dugald Campbell has done so, and he states that they are free from nitrates.

6278. Apart from the degree of hardness, in searching for water for the supply of a town, what should you be most careful in avoiding, having reference to the health of the population?—In avoiding a water which had ever been contaminated with sewage or manure matter.

6279. You stated, did you not, just now that the previous contamination, so far as it had ended in the formation of nitrates and nitrites, was of no importance?—That portion of the sewage which has been converted into nitrates and nitrites is of no importance.

6280. Therefore generally that might be left out of the question also?—Yes, so far as that itself is concerned.

6281. Apart from those two elements of consideration, what should you consider the substance to avoid?—In any water nitrogenous organic matter would be a substance to avoid.

6292. You conclude that it is very difficult to get rid of sewage matter by running water?—I do. That portion of it which remains undecomposed after its passage through the sewers oxydizes with extreme slowness. About four-fifths of the nitrogenous matter contained in fresh sewage, which has just been produced, as it enters the sewer is decomposed before the sewage, after a run of two or three miles, emerges into the river, and the remainder, I believe, as far as my experiments teach me, is decomposed with extreme slowness afterwards.

6296. Reverting to this particular question of the presence of organic nitrogen in those waters, what do you consider to be the effect upon water of the presence of organic nitrogen, whether derived from an animal or vegetable source?—As far as we know, the presence of organic nitrogen in the form of vegetable organic matter, such as peaty matter, is innocuous, unless contained in a considerable quantity in the water; but when contained in the water in the form of sewage matter it is believed to be noxious.

6297. Did I rightly understand you to say that you cannot distinguish in those cases whether it be derived from vegetable matter or from animal matter?—I have said that until recently it had been impossible to distinguish between the two, but that now I considered that the proportion between the carbon and the nitrogen in the two cases afforded a basis from which we could in many instances, decide.

6298. That is only an indirect method?—Yes, because the analysis itself gives no difference between the nitrogen from the two sources.

6328. It would seem that you could not very well refer the presence of nitrates and nitrites in all waters exclusively to previous sewage contamination. Without contesting that that may in many cases be so, are there other causes in operation which may have produced the same result?—There are, undoubtedly, causes which will produce a result of that kind to a certain extent. We have the presence of those materials, as I have already mentioned, in rain water, and it is conceivable that rain water falling upon a very dry sandy district, and evaporating there mostly from the surface, might leave those nitrates behind, and they might accumulate there to some extent from that source, and they may also be produced by the decay of purely vegetable matter. This strict analysis of water for nitrates is comparatively a new thing, and it is possible that we may find sources of those nitrates which we are at the present moment not aware of. But it is a remarkable circumstance that waters which it is well known cannot be contaminated by manure or by sewage never do contain those nitrates in a proportion bringing them near to the point of contamination.

6372. Then you do not accept the theory that sewage discharged at point A, and travelling down the river, is so oxydized as it passes a distance of six or seven miles, and is so entirely destroyed that its original elements are not to be found, but it is converted into some other substance or substances which are not detrimental to human health?—I believe that that is by no means a generally true proposition. I believe that under favourable circumstances, that is, when the water is warm, and there is a large volume of water, and the water is a good deal agitated in its course, that effect may be produced so far as regards the dead organic matter in the sewage, but not at all as regards the living germs that may be present in that sewage.

6382. And with regard to that which you do say is injurious [the unoxydized portion of sewage], you are hardly able to detect it?—Only rarely. Those waters are examined only on 12 days out of the 365, that is one point that must be taken into consideration. And I have only, in the case of the entire water supply, been able to get evidence which I consider anything like conclusive on this one occasion to which I have already alluded, namely, last month, on the 21st of January, when those waters contained this large proportion of organic nitrogen as compared with the organic carbon which they contained.

6383. That case to which you refer in January was quite exceptional, as I gather from your report of the 31st of January?—Yes; during the whole of the three years that I have examined these waters I have never found them in so bad a condition as upon that occasion, or in a condition approaching to that, but I may say that this condition of things having once set in lasted the greater part of a month.

6384. In this report of the 31st January you again repeat the words which I have just quoted; after giving the amount of sewage contamination in the water of the Chelsea Water Company, you say: "By gradual "oxydation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reser- "voirs, filters, and conduits of the company, this sewage contamination had been converted into comparatively "innocuous organic compounds before its delivery to consumers," and I think I find that almost word for word in all your weekly reports?—It is copied, in fact, from one to the other; it goes through the whole of them.

6385. Would that not rather lead the public to take it that your view was that this water was perfectly wholesome, or as nearly as possible perfectly wholesome?—I think it would, and that was the impression which I intended to convey, so long as I had not actually detected the presence of sewage matter unoxydized in the water; at all events I was very anxious not to convey the impression that analysis had discovered anything actually injurious in the water.

6386. Do you agree with those remarks of your friend Dr. Odling, which are separate from your report, "Although London is at present provided with an agreeable and in my opinion perfectly wholesome water," &c.?—No, I do not consider it a perfectly wholesome water, I did not at the time this was written, and that, I believe, caused my colleague to give a separate postscript to this report.

6389. In the month of January this year in your report you say: "The waters delivered in London during "the latter part of January by the Chelsea and especially by the Southwark and Lambeth companies, were "in such a muddy condition as to render them totally unfit for domestic use." On that point, filtration properly carried out would have met, would it not, that part of your objection as to the water being muddy?—Yes, certainly.

6390. From that we may gather, may we not, that your view would be that the question of the proper filtration of the waters is one of vital importance?—I think it is a very important point.

6391. You also state in your annual report: "The New River Company stands alone in the perfection of "its filtering apparatus. On no occasion during the past year has this company's water exhibited the slightest "turbidity, thus proving that perfect filtration is compatible with the largest daily supply furnished by any "one company in London." Do you see any reason why every company should not give out their water in the same perfect state that you here describe the New River Company does?—I see no reason whatever why the other companies should not.

6392. And do you consider that it would be a desirable thing in case of necessity that such a delivery of water in a pure state should be enforced by legislative enactment?—I do; in fact, it is so enforced at the present moment.

6426. What should you consider the essential conditions of a good drinking water?—The essential conditions of a good drinking water I should take to be, first, coolness and aëration; secondly, freedom from animal organic matter of all kinds; thirdly, that it should never have been contaminated by sewage or manure in any form; and, fourthly, that it should be soft water, not over five degrees in hardness.

Dr. Odling, Professor of Chemistry at the Royal Institution and at St. Bartholomew's Hospital:—

6447. You have examined the Thames water from time to time, have you not?—I have examined it fully.

6448. Have you found in those examinations of the Thames water the presence of sewage not decomposed?—I have not.

6451. Has your attention been directed to the important principle of the self-purifying process which is going on in rivers running at a given velocity?—Yes, it has. There may be great differences of opinion as to the degree to which that self-purification takes place, but that it does take place to a very considerable extent I think is undeniable.

6452. You will understand my question as not referring to sluggish waters, but to rivers where the body of water would become exposed to the action of the atmosphere as it passes along?—You may see in many rivers, even sluggish rivers, having sewage discharged into them, that for a mile or two the appearance of the river is affected by the sewage, but beyond a certain distance there is no recognizable effect at all, the weeds are perfectly clean and perfectly healthy.

6453. Do you know Leicester at all?—Yes.

6454. Do you know the condition of the river there?—Yes, I do.

6455. Near to the town it was in a very bad condition, and the water quite black, was it not, when you saw it, from the refuse of manufactories and the discharge of sewage?—Yes.

6456. Did you observe the condition of that river three miles from the town?—Yes, and from its appearance you could not tell that it had been contaminated, it was running clear, with fish swimming in it, and the weeds were clean.

6457. And that simply from the process of self-purification?—Quite so.

6459. You have not detected any of the skeleton forms which Dr. Frankland has given utterance to?—That is a point on which I am a little at issue with Dr. Frankland with regard to the interpretation to be put upon the presence of nitrates in water. It is admitted that the presence of nitrates says nothing for the present condition of water at all, and I rather dispute that it says anything very important for its history. There is no doubt that a very large quantity of sewage, or the equivalent of sewage, is discharged into the river Thames above the source of the present water supply, and I do not mean to say that Dr. Frankland exaggerates that proportion at all—I do not know whether he does or does not—but I contend that the estimation of the nitrates in a water does not give any ground on which to estimate its proportion of sewage.

6460. But when found are they in your judgment injurious to the water?—In such quantities as are found in the river supply of London they are, in my opinion, perfectly innocuous.

6461. Still less, I suppose, if found in chalk?—Yes, quite innocuous if found in chalk.

6462. Is it your opinion that those which have been found in chalk are due to sewage?—It is a point upon which there is no positive evidence, but I am inclined to think that it is not so, for we find them distributed so irregularly. For instance, the deep well water at Trafalgar Square, and the deep well water from the greensand, and lower chalk all over London, is nearly free from nitrates and nitrites; whereas the water of equally deep wells elsewhere in the chalk is found to contain very considerable quantities of nitrates. The deep well water from nearly all formations has been found to contain nitrates. Then, moreover, a proportion of the nitrates which the sewage itself undoubtedly does furnish, in one case is destroyed and in another case is not; and so far as the history of the water is concerned, in the one case where the nitrates are destroyed, that water may show but a very small amount of previous sewage contamination, whereas it might have had a much larger amount than the other.

6463. Apart from the question of sewage, is it your opinion that the condition of the Thames basin is such as to render it an unfit gathering ground of water for domestic purposes?—I do not think it at all unfit.

6467. Do you agree with Dr. Frankland, that supposing a system of perfect filtration were adopted (and he appears to consider that the New River Company has a perfect system of filtration), and if all the companies were to use the same process, we should have a water perfectly wholesome for domestic purposes?—Certainly I do.

6472. The presence of nitrates, if not in excess, is a comparatively unimportant element?—It is an unimportant element as to its state, and I believe it to be in many cases an unimportant element as to its history.

6473. You have heard the questions that were put to Dr. Frankland with regard to the probable origin of nitrates. Are you of opinion that their origin may be traced to several sources?—I am quite of that opinion.

6474. With regard to the presence of nitrates in the deep chalk wells of the Kent Company that have been referred to, they show a quantity of nitrates present as large or larger as in the Thames water; but it does not follow, does it, that they are necessarily derived from the same source?—Certainly not.

6477. What do you consider to be an essential quality of good water for drinking purposes?—It should be bright, colourless, and brisk, and it should not contain any considerable amount of nitrogenous matter.

6479. Do you think that there is no risk in using for drinking purposes waters which are derived from rivers the population on the banks of which is constantly increasing?—Of course it is conceivable that the amount of impurity discharged into the river may exceed the power of the river to purify itself, or approximate so nearly to that power as to leave a balance that it would not be safe to rely upon.

This gentleman also makes the following remarks in his report (Appendix D.) on the analysis on the Welsh and Cumberland waters:—

Although London is at present provided with an agreeable, and in my opinion perfectly wholesome water, still it is evident that for general town supply a soft water such as that of Wales or Cumberland is upon the whole more suitable than a somewhat hard water such as that of the Thames and Lee; and, further, that a water which neither contains nor has received sewage impurity is at any rate preferable to a water which certainly has received, even though it does not actually contain any such impurity.

Sir Benjamin Brodie, Professor of Chemistry in the University of Oxford:—

6986. It has been stated in evidence before this Commission that in the case of sewage discharged at Windsor into the river, and flowing down the stream six or seven miles, or rather more, at that point they have failed to detect the presence of the sewage, that from oxydization or the breaking up of the elements it is in such a condition that they have found nothing which in the judgment of the witness would be prejudicial to human health. Have you made any observation bearing upon that point?—I have not myself made any observations on that point, and indeed I do not know how such an examination could be satisfactorily conducted.

6988. Have you formed any opinion as to the probable effect of the flow of seven miles upon water contaminated with sewage, whether at the end of that distance or any other distance it would be fit for human use, or could be considered to be a safe water?—The sewage would be during its course to a certain extent oxydized and destroyed, and resolved into other compounds, but how shall we say that all the sewage is resolved and destroyed so that the water should be safe. To do that we must be able to apply some extremely sensitive test to the water which would enable us to ascertain the presence or the absence of sewage in it, and I want to know what the test is which we are so to apply. There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end, but the question, as I understand it, is whether those causes are really adequate to destroy the sewage not partially, but absolutely and entirely, during a given course of the river.

6991. You have been supplied with a copy of the medical evidence which has been laid before the Commission, and no doubt you have observed that we have evidence on both sides, one party alleging that water impregnated with sewage will be purified by the action of the air and oxydization in its course a few miles down the river, but, on the contrary, Dr. Frankland states very distinctly, that water once contaminated with sewage is unfit for human use, and that you will still find what he calls the skeleton of sewage present,

although it may have travelled 100 miles and been exposed to filtration?—I think what is asserted by Dr. Frankland is true, that there are no known causes in operation on which we can adequately rely to remove the sewage from the water. That causes are in operation which partially remove that sewage and diminish its injurious effects is true, but the question is whether those causes, as I said before, are adequate to produce a complete result; that is to say, whether they will take out of the water all the injurious matter which is contained in it, so as to render it fit for drinking. I do not think it possible, in the present state of our knowledge, to pronounce an absolute opinion upon that point. But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no positive means of getting that sewage out of it, that is a question which anyone can answer for himself, assuming always the injurious character of sewage. I am not now pronouncing any opinion upon that point, or saying in what degree sewage is injurious; that does not appear to me to be a chemical question. I think that is a question of very great importance, but which is much more likely to be solved by other agencies than by chemical experiments. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do. It does not seem to me that we have, as I before said, any accurate chemical measure of the sewage in the water, at all events I do not know what that measure is. I have read the evidence which has been given by Dr. Frankland and one or two other witnesses also before this Commission, but I still hold to my opinion that we have no accurate measure of the sewage matter in the water, or even of the previous sewage in the water.

7004. In all those analyses a certain value is ascribed to previous contamination, as determined by the presence of nitrates and nitrites in the water; will you give your opinion whether the presence of nitrates and nitrites is to be ascribed to that one source alone, or may it be ascribed to several sources?—I think the probability would be that the presence of a large quantity of nitrates and nitrites would indicate the previous presence of organic matter in the water; but I do not know that you could take that nitrogen, in the shape of nitrates, as an absolute measure of that organic matter, which is a different thing.

7006. But is it not possible that in many cases such salts may be derived from other sources than that of previous sewage contamination, using that term in its common acceptation; may they not arise from other matters in the soil, and therefore is their presence a fair indication of previons sewage contamination?—I believe that nitrates may occur from other causes, but I cannot speak from positive experience.

7009. Dr. Franklin considers that this organic nitrogen in the London water is of a different value from that in the lake waters, because the proportion of organic carbon to the nitrogen in the waters is different?—Yes. This appears to me a very important fact, and may really indicate that the organic matter in the water had, in two cases, a different origin.

7011. You think that the tests of the greatest delicacy are yet insufficient to determine the point at which sewage ceases to be present?—I may take a case which really is an absolutely analogous case to the case of water, namely, the case of the atmosphere. You may look at the atmosphere as really a great ocean. Gases from drains are being discharged into this gaseous ocean just as the water from the drains is going into the river. Those gases are so diluted when they get into the atmosphere that chemical analysis is absolutely impotent to reveal their presence in any given portion of the atmosphere. But nobody can doubt the injurious effect, under certain conditions, of the gases and other organic matters present in the atmosphere. Take the case of the Westminster drain, the opening of which is known to have occasioned a great outbreak of fever here. You say that you would not live in a house next it, nor at the end of the street, nor at the end of the next street; but where should you begin to live so as to be safe from the effluvia of that drain? We cannot answer that question. I suppose if I get to Oxford I am safe from that drain, but we have no chemical tests,—because that really is the only point at issue,—to apply to the air to say whether or not it contains injurious or poisonous organic matter from the drain. In the atmosphere just as in the water there are constant processes going on with great efficiency to destroy those noxious gases; and a person would argue, just as is done in the case of water, that you have sulphurous acid from the chimneys of London, you have the oxygen of the atmosphere, you have nitric acid, you have ozone in the atmosphere. All these agents, happily for us, are at work destroying those noxious gases from the drains and sewers and other places. But when is their work completely done? That is what we do not know. Another most important thing is this, that really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends, fundamentally, upon the quantity of that sewage or of that gas; in all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all. Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal it is absolutely impossible to answer; and I say as I said before, that I think you have a much better chance of getting at these relations through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities. You cannot get at those small quantities at all. Chemical analysis must be limited by our power of weighing and measuring; we can only do those two things. We can weigh and we can measure, and we can do that with a certain accuracy, and there we stop; but that accuracy is not capable of being multiplied *ad infinitum*. It may go on to a certain point, but we cannot go beyond that point. I think that it is impossible absolutely to answer those questions, for we have not the data; but the question arises, as I said before, whether a prudent person likes to drink water which contains a certain quantity of nitrates and nitrites, or that when analysed is found to contain a certain quantity of organic carbon and nitrogen, water into which you have deliberately put cartloads of sewage at some time or other in its course.

7014. Oxydization is constantly going on in the soil and in the river, and therefore there must be some point at whichethe perfect destruction or oxydization of this animal matter must take place?—What I think is muh more important still is another point, namely, the great dilution of the material, and I should rely upon the dilution quite as much and more than upon the destruction of the injurious matter. Supposing the sewage of a large town such as Oxford pouring into the river, there are numerous feeders and tributary streams to the river which effectually dilute the sewage. The sewage is gradually getting proportionately less and less, and therefore its noxious character diminishes and ultimately disappears.

7028. It is a perfectly possible and conceivable thing that a very minute proportion indeed of sewage in the water might be most extremely injurious to health. I say that partly from general experience, and partly because I have had occasion myself very frequently to observe the vast importance in chemical changes of what people so frequently pass by as inappreciable quantities of matter. Indeed, I have occasion to see more and more every day that minute portions of matter, which previously were not suspected at all to exist, exercise important influences on chemical transformations.

7041. If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town and produces no ill results, and chemical analysis fails to detect anything unusual in its character, is it not a fair presumption that such water is wholesome and good water for the use of a town supply?—If it be used without injury to the inhabitants, really chemical analysis is altogether superfluous. But the question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that, under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might long go on using it, for years, and it might not be discovered, and yet you might have some outbreak of disease in the place which, nevertheless, might be connected with the use of that sewage water.

7043. You consider then that with regard to the effect of water upon the health of the inhabitants, it is rather a question for the medical observer than for chemical analysis?—I really think so. I think that chemical analysis is not yet sufficiently advanced (whether it ever will be I do not know) to pronounce a decision upon the matter, and that you have a better chance of getting at the real connexion between the injurious matters in the water and diseases generated by those matters through statistical observations carried on upon a large scale than through chemical analysis. Statistics elicit relations of cause and effect on which you cannot deliberately experiment.

Dr. Miller, Professor of Chemistry in King's College, London:—

7066. What was [in 1859] the state of the water at that part of the river above Teddington lock where the water companies are now taking their supply?—Above Teddington lock the water was very good, even at that time when there was but a scanty supply of water in the river.

7068. Did you detect in the water taken from above Teddington lock the presence of sewage?—There was organic matter, but I should not have called it sewage.

7069. Did you then form an opinion that it was traceable to sewage or partially traceable to sewage or to some other cause?—I did not specially determine whether it was sewage matter or what the origin of the organic matter was.

7070. Would there be a difficulty in determining whether the nitrates were due to one source or partly to one source and partly to another; for instance, the drainage of land, the manuring of farms upon the watershed, and the washing of the remains of the sewage into the river?—I do not think there is any means of determining what proportion of the nitrates is due to the natural supply from the chalk springs, and what is due to the oxydized sewage. In fact there is no means of determining that. They exist exactly in the same condition in the water, and therefore a proportion of the nitrates may be due partially to the one cause and partially to the other, the proportions varying with accidental circumstances.

7072. You have seen the evidence of Dr. Frankland in which he refers to the presence of sewage in the form of skeleton; if the view which he takes is a correct one would the presence of that skeleton be injurious to health do you think?—I understand that merely as a figurative expression showing the existence of nitrates and ammonia in the water. Neither of those things in themselves in small quantities is in the least degree injurious. I am speaking now simply of them after they have been completely converted into that condition of nitrates or of ammonia.

7074. You are aware Dr. Frankland takes a very strong view of the presence of that skeleton of sewage, because, in referring to certain wells used by the Kent Waterworks Company, where the water is pumped from a depth of 250 feet through the chalk, notwithstanding the filtration at that depth he still detects the presence of those skeletons of sewage?—That is to say, he finds nitric acid or nitrates, and he assumes what I think he is not justified in assuming, namely, that those nitrates are the result of the putrefaction, or rather of the decomposition of sewage matter. No doubt they are formed by that operation in a great number of cases, but to say that they are always formed so would be, I think, far beyond what the facts warrant.

7077. I do not deny or doubt that in a great number of cases the presence of nitrates does indicate the previous existence of some organic contamination. The only difference between Dr. Frankland's view and mine is this, that he assumes, apparently in all cases, at least if I read his evidence aright, that nitrates invariably point to previous sewage contamination. I think that that is not justified by other observations. The experiments of M. Boussingault and others show distinctly that the formation of nitrates does occur where there can be no suspicion of previous sewage contamination.

7082. Are you of opinion that water once contaminated with sewage can never be considered a safe water afterwards?—I think experience is quite against that. I think it is safe; evidence shows that it is safe in the majority of instances. There may be cases in which danger is produced.

7088. Have you made any experiments upon the power of water, in a given course, to oxydize organic matter?—I ascertained a remarkable result in the course of the summer of 1859 upon the river. I took specimens of the water at Kingston, at Hammersmith, at Somerset House, at Greenwich, at Woolwich, and at Erith on the same day, and I examined the quantity of oxygen which the water contained at all those different points. I found that the quantity of oxygen at Kingston was the ordinary or normal proportion; at Somerset House it was much diminished; at Greenwich the whole of the oxygen had disappeared; at Woolwich it was much in the same condition, and at Erith the water was very much improved, showing that this diminution of oxygen had been produced by its action upon the water contaminated with the sewage of the London district, and that as it passed lower down the oxygen was again absorbed from the air, and again it became diluted with a large volume of water from below, from other sources, the Lee, the Ravensbourne, and other tributaries, and in this manner the water had again become oxydized. I look upon this as a direct proof of the effect of oxygen in destroying those organic contaminations which are thrown into the river.

7099. You consider, do you not, that in small quantities the presence of such nitrates would be innocuous?—Yes; the presence of large proportions of nitrates would no doubt indicate communication with some source of animal refuse. Well waters in towns very commonly contain large quantities of nitrates, especially in the neighbourhood of graveyards.

7100. But they contain very unusual quantities?—Yes, quite large quantities; sometimes I have seen as much as 20 grains in a gallon.

7101. Have you had occasion to analyse any waters which you have reason to believe are removed from the possibility of previous sewage contamination, and yet found nitrates present in them?—Yes, the waters from Watford, which come from chalk wells, where there can be no suspicion of previous sewage contamination, always contain nitrates.

7104. Organic nitrogen, I presume, is the substance the presence of which in any excessive quantity is to be avoided?—The presence of organic nitrogen may be derived from substances which are quite harmless,

or it may be derived from substances which are very injurious, and we have no means of distinguishing between the two. Nitrogen is always present in such combination, not as nitrates, and not as ammonia; but the presence of nitrates is always a suspicious circumstance in water, and the greater the quantity of nitrates the more suspicious is the nature of the water and the more reluctant one would be to use such a water as a source of supply.

Dr. Robert Angus Smith, Government Inspector of Alkali Works:—

7184. Have you directed your attention to the quality of waters supplied for domestic purposes?—Yes, I have.

7185. Have you made any analyses which you can refer to as giving information on that point?—I have made a great many analyses, but I have not brought any with me. I only intended to speak here on general principles, and especially about the organic matter which seems to have raised a discussion of more importance than, I think, any other subject in connexion with water.

7186. Will you be good enough to state your views upon the subject?—Some time ago, in studying the organic matter of water, I divided it into many parts. It had been common in analyses of water to write down the organic matter as if it had some special quality. Afterwards, however, I found it necessary to consider organic matter as a very complex substance, and instead of putting it down under one head I have put it down under at least eight heads, and some of those heads have subdivisions. The first head which I think it would be worth attending to is organic matter, which is putrefied. This would include the gases and vapours arising from putrefaction, and this is the thing which strikes one more especially on coming in contact with water which is impure; for example, in drinking it would be offensive to the smell, and generally it will give those characteristics that were found in the Thames some two or three years ago. I examine this part by means of permanganate of potash. It is very readily done.

7187. As I understand it, although you break up that which is usually designated organic matter into eight parts, still those eight parts form but one matter that is called organic?—It is so; it is one of the great divisions.

7188. None of those eight parts would have reference to anything except the original matter which is called usually by chemists organic matter?—No; but they will be as different in their properties as, I may say, organic or inorganic matter are—so widely apart are they in quality. It is difficult for one to give exactly all the particulars, but I will first say how I examine the gases of putrefaction. I use generally permanganate of potash for that purpose; that was the plan adopted by Professor Vorckhammer, of Copenhagen, some years ago, for organic matter generally, and it has been adopted by several chemists since, and rejected by several others as of no value. I find that it is of value. . . . . .
I may say what I found in the Thames. Above Reading very little impurity was found in the Thames, but below Reading it was very marked indeed, and it never disappeared in any part below Reading.

7198. For what distance down?—Any part. I went down to London Bridge, and it was visible in any part below Reading.

7199. Did you detect the presence of sewage from every sample that you took below Reading to London Bridge?—Yes, what I believe to be caused by sewage; it was organic matter, which in its decomposition showed a great deal of animalcular life, and which I believe to indicate so much organic matter of a very active kind, probably dangerous.

7200. Supposing there had been no source of contamination below Reading, would you then have been able to detect the presence of sewage in the river, because, as you are aware, down the river there are fresh sources of contamination going on?—Yes, I think there would have been a little. I may say that above Oxford I considered the water extremely pure, but below Oxford and I might say down to Pangbourne, it was, perhaps, a little less pure, but very little. I considered at that time that it was not proper to take water from any source below Pangbourne at any rate. Perhaps I might be inclined to go higher now, but that was my view at the time when I examined the water for the Metropolitan Sanitary Commission, which is now 20 years ago nearly.

7201. Are you of opinion that a water once affected with sewage contamination is never after a safe water for domestic purposes?—I think it may be quite safe. It is so in some cases, in others not.

7202. Under what condition?—Supposing it were very impure indeed, the first thing that would occur would be putrefaction; that gives out a number of nauseous gases, and the most prominent to the senses is, perhaps, sulphuretted hydrogen. After the putrefaction had finished a great deal of the organic matter would be removed. If any remained, and it were exposed to oxydation nitrates would be formed. Those nitrates are, I consider, so far offensive as they indicate very bad company, but in small quantities I am not aware that they can be considered hurtful. On the contrary, to some extent they are a very valuable accompaniment of organic matter. They themselves are disinfectant and prevent processes going forward which would be unpleasant. . . . . If the germs pass into rivers we do not know how far they may be carried; on the other hand, we do not know that they ever can be carried in pure water; the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission in otherwise pure water is wanting. We might ask if a cholera germ in the water at Oxford would produce disease in London; and we might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know; but it seems probable that disease cannot be carried far by pure air or by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs; but the evidence seems to be that it requires an unusual excess to attack us successfully. It seems to be a question of quantity. Still there is the sentiment remaining; we do not like that any sewage should enter the water that we drink. I am disposed to think it well to listen to this sentiment, so far as large towns are concerned, although even then we must remember distance and quantity; but so far as villages and ordinary agricultural drainage is concerned, I am not aware of any experiments showing sufficient room for fear.

7242. Are we to understand you that you would be guided as to the objectionable quantity of organic matter in water rather by the results showing the development of animalculæ than by the results of chemical analysis?—I think that one of the most important experiments that can be made, although I would not neglect the others. I have seen some very striking instances indeed, in which an enormous number of animalcules have been found in water which at first appeared perfectly pure, and quite a contrary result has taken place in water which I thought to be inferior.

7244. I understand you also to say that if you give the water a sufficient length of flow this organic matter will be oxydized more or less completely?—Yes, that is always the case. It is a question of length of flow, or length of storage, or depth of drainage; those are the three most important points.

7247. The nitrates are what I have called old organic matter. There is no doubt that by the oxydation of nitrogen compounds nitric acid is formed. I imitated this process long ago, using chiefly yeast, and so produced nitrates from yeast or vegetable matter. The nitrate comes from animal and vegetable albumenoids indifferently. When estimating the London sewage we may readily refer most, if not all of it, to animal matter or sewage. In the river above London some of the nitrates come I do not doubt from vegetable matter. I have not estimated how much comes from one and how much from the others. I am inclined to think that nitrates coming down may be divided into the animal and vegetable nitrates, and measured. Albumen, &c., would produce nitrates without being used by animals. When nitrates are caused by matter from animals there is always a corresponding amount of common salt. Men take from 200 to 300 grains at least of common salt every day, and it is given out every day. This is the most unchangeable accompaniment of sewage.

7253. In most cases where there is danger to be apprehended from the presence of nitrates have you not been able to detect the presence of chlorides?—Always. Whenever chlorine is high in the water it is necessary to look for nitrates derived from sewage, and, as a rule, it is so constant that there is scarcely any exception. When we find much more than the average quantity of chlorine in a well water, nitrates are found also, and if the water in a district is pretty well known, that is to say, if the amount of chlorine in water from any district is pretty well known, and a specimen of that water should indicate rather more chlorides than usual, you may conclude with almost certainty that it is from sewage.

Messrs. Letheby, Odling, and Abel, in the analyses for the metropolitan water companies, given in Appendix AH, add the following remarks:—

With reference to the second part of your letter, in which you request us to report on the system pursued by Dr. Frankland in obtaining and recording his analytical results, we have to offer the following few remarks.

Without discussing the question of the general applicability of Dr. Frankland's method of water analysis, which are at present we believe almost exclusively employed by him, we must express our dissent from one of the inferences which he founds upon his analytical results. In particular, we contend that the proportion of nitrogen discovered in water, in the forms of nitric acid, ammonia, &c., is not a trustworthy measure of the extent to which that water has, at some time or other, been contaminated by sewage, inasmuch as the nitrogen compounds existing in a water may, on the one hand, greatly exceed, and, on the other, equally fall short of those which would be furnished by the addition to the water of a given proportion of sewage (using the latter term in the broad sense in which it has been applied by Dr. Frankland), thus, for example, we cannot accept as a correct representation of the relative condition of the East London water (from the river Lee), and that supplied by the Kent Company from deep wells in the chalk, the statement of Dr. Frankland in the Registrar General's Weekly Return for May last (No. 22, page 179) that the former contains 0 parts of previous sewage contamination (estimated) in 100,000 parts of water, while the latter exhibits 3,540 parts of previous sewage contamination in the same amount of water.

It scarcely need be pointed out by us, that the apparently higher results which Dr. Frankland's published analyses record, as to the solid constituents generally existing in water, when compared with those given in the reports of other analyses, are simply ascribable to the circumstance that they are calculated on 100,000 parts of water instead of on the imperial gallon of 70,000 parts, as is the general custom.

In conclusion, we have to express our opinion that no useful results, but the reverse, can be attained by expressing in large multiples, as in tons (see Registrar General's weekly returns), the small proportions of mineral or other constituents, which analysis discovers in potable waters, and by designating as *impurities* perfectly harmless substances which exist, in varying proportions, as normal constituents of nearly all natural waters.

Engineers and others.

185. The Rev. J. C. Clutterbuck:—

1805. You are well acquainted, are you not, with the surface condition of the watershed of the Thames for some hundred miles up?—Yes, all the way.

1806. Is it highly cultivated?—It is highly cultivated, decidedly.

1807. And what, in your judgment, would be the effect upon the water in the rainfall passing through a soil so cultivated?—With reference to the chalk surface, I do not conceive that there would be any great amount of effect produced by cultivation on the water percolating that part of the country, because it would sink through so very much soil.

1810. Looking at that general condition of the surface and at its geological formation, is there in your judgment any objection to that gathering area for water for the purposes of domestic use?—No, I think not, I cannot say that I see any.

Mr. Hawksley:—

2553. The great complaint of London water at present is not the quality of the water itself so much as the polluted district through which it passes?—That, I think, there is the greatest possible amount of misconception upon; there is a great deal of prejudice, not unnatural at all, but still amounting to prejudice, upon that question. I believe, in fact I know, that the water of the Thames at Hampton is very excellent water, very pure, very free from organic matter, and that what little organic matter it does contain is of a very innoxious character.

5076. What quantity of water, as compared with the volume of sewage, is necessary for the purpose of breaking up into its original elements the sewage which has been discharged into it?—Generally about 20 to 1. If the water flows rapidly and is very much disturbed, so as to be continually receiving fresh oxygen, a smaller quantity, even 12 to 1, will effect the process; if it proceeds very tardily it may take a little more; but usually 20 to 1 is perfectly abundant. I could give you very remarkable instances. Take Sheffield: nothing can be fouler probably than the state of the water at Sheffield, whereas if you go down to Doncaster the water is supplied by the waterworks, and is actually drunk in the town. I do not, however, say that it is a desirable thing.

5077. How many miles is Doncaster below Sheffield?—About 20 miles.

5078. Is it a rapid running stream?—No, it is not rapid in summer. In point of fact it is controlled by the weirs set up for the navigation. But take the river Irwell leaving Manchester, receiving the Irk, the Matlock, and all the refuse of the manufacturing population for a great many miles; when it travels down only eight or nine miles to Warrington it is perfectly changed, it ceases, or nearly ceases, in that short distance to be an

offensive river. I do not say that it has become all that it ought to be by any means, because the distance is not sufficient, and the flow is not rapid enough. The river is canalized, which prevents its flowing with all the rapidity it ought to have.

5079. You remember, do you not, the original condition of the river at Leicester after receiving all the sewage of the town into it?—Yes, perfectly well. I happened to be the engineer at Loughborough and also at Leicester. I made the waterworks at Leicester, and I advised the sewage works at Loughborough, and I also was called in to design waterworks for Loughborough, and I had on those occasions to take particular notice of the state of the river at all times, both at Leicester and at Loughborough, Loughborough being about 12 miles below Leicester. At Leicester the water was as black as this ink. I do not mean to say that it was absolutely so thick, but looking at it in a mass it was as black as ink—nothing would live in it, and the smell was abominable,—but by the time it got to Loughborough it was entirely restored to its pristine condition. You could stand on the bridge there and see the fish swimming amongst the beautiful reedy and other plants growing in the water just as in the purest stream. You could see every pebble at the bottom. That is an instance of the effect of oxydization.

5080. The water has symptoms of returning purity, has it not, within four miles of Leicester?—Yes, but not to the same extent as at Loughborough. The water was perceptibly impure at the driest period of the year down as far as Barrow. It could be just perceived there, but at Loughborough it was perfectly restored.

5083. Having regard to the capacity of the Thames watershed to yield a sufficient supply for the metropolis, (and when this system or purification is completed, whether for the sake of removing prejudice or any other purpose, to get rid of filth at all events the water must be improved,) you are of opinion that there is no necessity to seek a supply of water from a distance from the metropolis?—Certainly not. You have very fine water surrounding London in all directions, and it only wants utilizing.

Mr. Beardmore, Engineer to the River Lee:—

3329. What is your opinion as to the quality of the water supplied from those sources for the uses of the public generally for sanitary and domestic purposes?—I think that with proper arrangement of reservoirs the quality may be faultless, always excepting the carbonate of lime, which I regret to see published every week as so many grains of impurity, being merely a solution of pure chalk in the water. It is called in the papers impurity, but setting aside that carbonate of lime you will never get a purer water. In fact the New River is as pure as Loch Katrine now very generally, and with reasonable arrangements you may have the water still purer.

Mr. Leach, Engineer to the Thames Conservancy Board:—

4289. It would of course greatly improve the river if that sewage and other contaminating matter were diverted?—It would improve the condition of the river, but I think that the contamination has been very much exaggerated. In those country towns there is no regular system of sewage generally. The majority of the houses drain into cesspools; and really there is no very large outfall in any case except at Windsor; there a more perfect system of drainage has been carried out, and there is a most offensive outfall.

4290. Still there must be a very large amount of ammonia flowing into the river notwithstanding the cesspools, because of the overflow which you must necessarily catch in the river. A cesspool is very soon filled, and though not filled with solid excreta still there is an overflow, and that must find its way into the river ultimately?—The ground absorbs a good deal of that. I have noticed the outfalls of some of the larger towns, such as Abingdon and Wallingford, and although they are unquestionably offensive, still there is not that volume which would be the case with a similar population in London.

4291. Is the volume of water in the river sufficient to deodorize it?—Yes, it very soon loses any contamination.

4292. Take Windsor for example, where there is a discharge of a considerable amount of sewage out of their drains, have you observed the condition of the river at the point of discharge and also a few miles down?—Yes, I have.

4293. How soon in your observation is the effect of sewage destroyed by its flow and admixture with the water?—At Windsor it is discharged into a most unfavourable point in the river, where there is little or no stream at ordinary times. At times of flood of course there is more stream, but usually there is very little stream there, and the matter which is passed out of the drain floats about in the river there to a very great and very disgusting extent.

4294. Is there an eddy there, or what?—No, there is a weir just immediately below, which deadens the stream sufficiently to deprive it of the force required to take what is floating away. Two miles or even a mile below that I could see no traces whatever of the sewage.

4295. Was it all broken up and destroyed?—Yes, and taken by fish, and so on.

4296. Is it the habit of fish to take up matters of that kind?—Yes, you generally see persons fishing close to the outlet of a drain. I think that the operation of the Act of 1866, which prohibits the discharge of sewage into the river, will have a very beneficial effect. If some such provision had not been passed I can quite understand that as the system of waterclosets was extended and a more perfect system of drainage was carried out, the river would rapidly become much more contaminated; but the powers contained in that Act will, I hope, put an effectual stop to the pollution of the river.

Mr. Simpson:—

4625. With regard to the effect of the London water, which your companies supply, upon the health of the population, do you consider it an unwholesome water?—No, decidedly not. I believe the water to be as wholesome as any water that we can obtain.

4627. Are we to understand that you have heard nothing or seen any returns that would lead you to believe that the water supplied to London is bad in quality and injurious to health?—I certainly have not. I believe that a great deal of what has been stated upon that point is merely assertion without inquiry. I have been in the habit of being consulted by towns not only in England but on the Continent, and I doubt whether any city in Europe is better supplied than the metropolis either in quantity or quality.

Mr. Quick:—

6009. The quality of the water you say is good?—It is very good indeed for all purposes, not only for domestic purposes but for manufacturing purposes. Brewers and tanners, and those people who use large quantities of water for trade, all prefer the Thames water to any other water that they can get.

The following remarks by Mr. Pole (Appendix O.) also bear on this question:—

Below Lechlade the Thames is canalized, the water being held up by locks, weirs, and sluices at intervals, forming successive ponds.

There appears to be no traffic worth speaking of in a large portion of this navigation; but the weirs have, I have no doubt, a very beneficial influence on the quality of the water, as its flow over them causes great agitation and aëration, and so must promote considerably the breaking up and oxydation of the organic matter. This fact I think ought to receive more consideration than hitherto in the discussion of the general economy of the river.

The towns of Cirencester, Cricklade, Lechlade, Fairford, Northleach, Swindon, Highworth, and some other small places, lie in the basin above this point, but as no systematic drainage by sewers (except to a small extent at Cirencester) is carried out in any of them, I think it may be said that the only contamination of importance received by the water is from the tilled land. And from the absorbent nature of the ground over nearly the whole of the district, this will naturally be much less than in places where the waters flow over retentive soils.

Analyses of the Waters of the Thames and its Tributaries made for the Commission.

186. The analyses, by Drs. Frankland and Odling, of the samples collected by Mr. Pole (see Appendices O, and A X 1 and 2) show the difference in the quality of the water of the Thames, in different parts of its course, and of its principal tributaries, together with the character of the water of some of the main springs feeding these rivers. The facts obtained are important, although we see reason to differ from some of the conclusions which one of the chemists has drawn from them.

Dr. Frankland adds to these analyses the following remarks of his own:—

The conclusions arrived at from the foregoing investigation of the waters of the Thames basin may be thus summarised:—

1. The head waters of the Thames and the waters from chalk wells and springs in the Thames valley contain but a very small proportion of organic matter, which is, however, highly nitrogenized. They are very hard, and, with one exception (the Caterham well water), exhibit a high previous sewage contamination. Although markedly superior to the river waters at present supplied for domestic purposes to the metropolis, they are much inferior to the Welsh and Cumberland samples.

2. All the feeders of the Thames (exclusive of the head waters) which have been examined, are, without exception, ill adapted if not utterly unfit for domestic purposes. They are all decidedly inferior to the Thames itself at Hampton, and consequently none of them could be substituted with advantage for any portion of the present metropolitan supply.

3. The head waters of the Thames are polluted by sewage or manure matters soon after leaving their sources, and on reaching Lechlade are contaminated even to a greater extent than the Thames water delivered in London.

4. The precise effect of the flow of a stream, in purifying the water from sewage or manure matters, cannot be clearly ascertained from the foregoing investigation; but the analytical results demonstrate that at no part of its course does the Thames become freed from the soluble animal organic matters with which it is contaminated, although the total amount of these matters becomes diminished as the stream pursues its course.

5. After leaving its head springs, the water of the Thames is purer and better adapted for domestic purposes at Hampton than at any other point in its course.

6. Irrigation, properly carried out, purifies sewage to a great extent, but not sufficiently to render it admissible into potable water without danger; the risk arising not only from the considerable amount of animal organic matters which the effluent water still retains in solution, but also from the absence of any guarantee for the removal of the germs or other noxious suspended matters which are frequently present in sewage.

Dr. Odling adds as follows:—

It may assist the Commission, in interpreting the results of our analyses, to have their attention drawn to the following points:—

1. That unoxydized nitrogen, or nitrogen in the forms of organic substance and ammonia, is the characteristic constituent of animal excretions; and that if the entire daily excretions of the 800,000 persons living above the Thames at Hampton were added at once to 800,000,000 gallons of water, or the daily quantity of water flowing past Hampton (*i.e.*, if the excretions of one average person were added to 1,000 gallons of water), they would give to the filtered water a proportion of unoxydized nitrogen amounting to ·3 part in 100,000 parts.

2. That whereas, in fresh animal excretions almost the whole of the nitrogen exists in the form of organic substance, and but a minute proportion in the form of ammonia, in ordinary town sewage about four-fifths of the dissolved nitrogen has become changed into ammonia, only one-fifth remaining in the form of organic substance; so that if the sewage of 800,000 persons were included at once in 800,000,000 gallons of water, it would give to the filtered water a proportion of nitrogen in the form of ammonia amounting to ·24 part, and a proportion of nitrogen in the form of organic substance amounting to ·06 part in 100,000 parts.

3. That according to the tables of results, the excess of unoxydized nitrogen in Thames water at Hampton, above that in the Head Springs water, is ·015 part, and the entire amount of unoxydized nitrogen in the water at Hampton, but ·024 part in 100,000, the two waters being alike free from ammonia; whilst, of feeders, &c., of the Thames draining sparsely populated districts, the quantity of unoxydized nitrogen amounts in the Kennet above Hungerford, to ·034 part, including ·003 of ammonia; in the Thames below Lechlade, to ·036 part, including ·003 of ammonia; in the stream from Bagshot sands, to ·046 part, including ·003 of ammonia; in the Wey above Godalming, to ·066 part, including ·001 of ammonia; and in the Thame, to ·073 part, including ·001 of ammonia, in 100,000 parts of water.

187. An examination of these analyses shows:—

	Parts.
1. That the solid residue in 100,000 parts of the *waters of the Thames* and of its *tributaries* in the Oolitic and Chalk area varies from	25·58 to 32·95
And from its *tributaries* flowing through or from the Bagshot and Lower Greensand districts from	7·05 to 18·10
2. That the proportion of *lime* (as carbonate of lime chiefly) in this residue varies in the one case from	11· to 15·03
And in the other from	·68 to 5·73
3. That the *springs* in the Chalk and Oolitic districts contain of solid residue from	28·25 to 32·36
4. That the *lime* in these different springs is in nearly equal quantities, varying only from	14·00 to 14·50
5. That the quantity of sulphuric acid (in combination chiefly as *sulphate of lime*) varies in the tributaries of the Chalk district from	·49 to ·54
Ditto, ditto, Oolitic limestone district from	1·62 to ?
Ditto, ditto, clay and mixed districts from	3·68 to 4·28

Of other inorganic substances the quantities are small.

In the whole course of the Thames, from Lechlade to Hampton, the only resulting difference in the quantity of solid residue is ·56, showing a decrease of from 28·63 to 27·87. Part of the lime present in the springs is precipitated, apparently by exposure to river flow, both in the Thames and the Lee, showing a reduction of from about 14·25 to about 11·50 in the 100,000 parts of water.

188. There are great anomalies in the quantities of nitrites and nitrates present in the springs and in the rivers in different parts of their course. All the springs hitherto examined, whether in the chalk or oolitic districts, contain more of these salts than the river waters do, as estimated by the quantity of nitrogen in combination with them, which varies from ·358 to ·422. From ·358, which is the quantity in the head springs of the Thames, it decreases rapidly to ·157 at Lechlade. It rises again to ·277 below Oxford, decreases to ·245 at Abingdon; is ·205 above and ·211 below Windsor, and falls to ·196 at Hampton. Some effect is no doubt partly due to the addition of sewage matter as the river passes these towns, and we had hoped to obtain a measure of the extent of conversion of organic matter into innocuous nitrates and nitrites by the plan adopted of testing the water before and after it had passed the principal towns on the banks of the river; but the change effected by other causes, especially by the influx of the tributaries, is so much greater, that it becomes difficult, or rather impossible, at present to apportion effects to the relative causes. Thus the high figure below Oxford is in greater part accounted for by that of the Cherwell, which, two miles above Oxford, gave ·264, while again the Thames proper had risen from ·157 at Lechlade to ·218 above Oxford, influenced possibly by the smaller tributaries it had received in its 27 miles flow. At Caversham, above Reading, the quantity had again increased to ·286, whereas just below Reading, after receiving the drainage of this town, it fell to ·148; this arises evidently from the influx of the Kennet, which a little above Reading contains only ·029, while nearer its supply springs above Hungerford this tributary gives ·113. The Thame—the hardest and worst of the tributary waters—contained only the small amount of ·080 of nitrates. Again, the Thames at Hampton is affected on the one hand by the Colne with ·302, and the Wey with only ·090.

It would appear, therefore, that the effect produced by the drainage of towns into the Thames is quite subordinate to the changes produced by the flow of the river, the effects of vegetation, and probably by the action of the mud and silt, which in some of the tributaries, where there is a larger proportion of argillaceous matter present, may have a more efficient action in separating the bases of the nitrates and nitrites. The Thame flows chiefly over argillaceous strata, and the Kennet just before reaching Reading receives the several small streams draining the London clay and Bagshot sands of the district. The Wey has a portion of its drainage from the same formations. The fluctuations in the quantity of nitrates seems to us inexplicable upon the hypothesis of their immediate dependence upon recent organic matter. We should be more disposed, looking at the exceptional quantity present above Reading, in the Colne and at other places where the rivers have been largely fed by springs from the chalk, to refer much of it to supplies furnished by these springs. This, however, requires investigation.

189. The organic matter in solution in the waters of the Thames through its 140 miles course exhibits the same general persistence, accompanied by similar though not parallel fluctuations to those of the inorganic matter and the nitrates. In this case, however, the conditions at starting are very different. The quantity of organic nitrogen, taking that as the test of undecomposed organic matter present in the springs, is at its minimum instead of the maximum shown by the nitrates. The following table shows some of the

results of the analyses made for the Commission by Dr. Frankland which bear on this point:

	Organic Nitrogen.	Organic Carbon.
Amwell Well (taking this water to represent the springs of the Lee)	·009	·076
Otter Spring, the Colne, near Watford	·012	·026
Croydon Well (taking this to represent the spring water of the Wandle)	·007	·040
Syreford and other large springs, forming the main sources of the Thames	·009	·014
By the time the Thames has reached Lechlade these quantities have increased to	·033	·133
And subject to a number of fluctuations they stand on the river reaching Hampton at	·024	·260

190. The effects of town drainage, and the diminution of the quantity of organic matter brought about by the flow of the river, are more apparent in these experiments, but are still far from striking. Thus the quantity of organic nitrogen has decreased from ·033 at Lechlade to ·028 in the Thames above Oxford: after passing Oxford it still stands at ·028, but that is accounted for by the junction of the Cherwell with only ·025 of organic nitrogen; at Abingdon it falls to ·026, rises to ·032 at Caversham, increases to ·049 just below Reading, decreases, 5 miles lower, to ·032, decreases to ·028 above Windsor, rises at Windsor to ·029, and then falls to ·027.

191. In a supplementary report, Dr. Frankland and Dr. Odling call attention to the important fact that "the Thames is chemically purer at Hampton than at any other part "of its course." They account for the reduced quantity of mineral constituents by the influx of the Wey at Weybridge, which, draining a tract of Lower Greensand, Bagshot sands, and London clay, brings down less carbonate of lime, as is rendered clear by the results of their analyses, which show the solid residue in each to be—

Thames at Staines.	Colne.	Wey.	Thames at Hampton.
31·40	32·14	18·10	29·90

of which the lime is in the proportion of—

12·63	13·78	5·73	11·85

The nitrates in the same way give a mean result. They remark, however, that the marked reduction of ·003 part of organic carbon and ·044 part of organic nitrogen in the Thames between Staines and Hampton finds no explanation from this series of analyses, and they attribute it to some exceptional cause, such, possibly, as the precipitation of organic matter, which they show may take place when calcareous waters—such as that of the Colne—are mixed with peaty water like that of the Wey. We would, however, observe that the diminution in the quantity of organic nitrogen in the Thames in the five miles below Reading by ordinary oxidation (for there is no influx of any tributary) is ·017 part, while the ·072 part in the Thame water at Dorchester leaves the Thames water at Caversham, after a flow of about 18 miles, at ·032.

192. The fluctuations in the quantity of nitrogenized organic matter, in summer and winter, which their analyses show to take place, are, however, more remarkable, and need further investigation. They are as follows:

	Filtered Thames Water just below the Weir at Staines.		Filtered Thames Water at Hampton.	
	May 2d.	Oct. 28th.	May 4th.	Oct. 28th.
Organic substances in 100,000 parts of each water:				
Organic nitrogen	·027	·097	·024	·057
„ carbon	·304	·304	·260	·263

Compared to these the slight changes in the quantities of organic nitrogen noted in the Thames water in different parts of its course, from samples taken during the months of April and May, are comparatively insignificant.

193. Although these analyses of the Thames waters will require repetition and extension before the exact value of all the facts can be determined, yet as they relate to the river at one season they may be accepted as relatively correct, and they are sufficient to show at least not only the absence of any increase of objectionable matter in the river from

Lechlade to Hampton, but that the variations in the quality which commence at Lechlade, after showing several temporary changes in many parts of the river's course, fall at Hampton in general to a point as low as at Lechlade, and in one respect, viz., the organic nitrogen, to a point even lower.

It is necessary to remark that the river waters were filtered before analysis, but not the spring waters, which were only left to subside. This must be taken into consideration, as the effect of filtration on organic matter, to which reference is made elsewhere, is of great importance.

194. We cannot conclude this part of our Report without making a few observations on some of the inferences attached to the chemical analyses made for the Commission, as well as on some of the same character accompanying the monthly reports of the Registrar General, as they have been much disputed in the evidence, and as the authority these Reports carry is necessarily great. We refer especially to the interpretation put upon the presence of certain salts as indicating what has been termed "original sewage contamination," and on what are really impurities in water.

It is well known that decomposing organic matter is constantly giving rise to alkaline nitrites and nitrates. Dr. Frankland refers them, not simply to organic matter taken generally, but to sewage or manure matter especially; and the quantity of these salts is made the measure of the estimated "previous sewage contamination" of the different waters, for which a separate column is given. This seems to be an inference which can hardly be accepted. It would be perfectly correct if all the nitrogenized matter supplied to the Thames or other waters was, after conversion into nitrates or nitrites, retained in the water, and if also all these salts could be referred to sewage and manure matter solely. But such is not the case. All the analyses show how variable the quantity of these salts is in different parts of the river's course, and that the quantity present at any place is not so much dependent upon the sewage received as upon the removal which has been effected by vegetation and other causes, by the interference of tributaries, and by the addition from springs; so that, even supposing them to originate solely from animal origin, the residue affords no comparative results as to the amount of original contamination. The interfering causes are too numerous to allow us to assign any value to the remainder. We find it therefore difficult to understand the value of the meaning to be attached to "previous sewage contamination" if by that term it is supposed that we are able to recognize the amount of contamination produced in a river by the addition of the sewage of the towns by which it passes.

If the quantity also of nitrates varied in the inverse ratio of the organic nitrogen some more definite conclusion might be formed; but that is not generally the case. It appears that the sources most free from probable contamination, such as the springs forming the head waters of the Thames, contain in 100,000 parts of water, 3·260 parts of nitrates, whereas the Thames just below Lechlade contains only 1·270, and after experiencing various fluctuations as it flows by Oxford, Reading, and Windsor, still contains at Hampton only 1·640 or only one-half of that in the head springs of the river. The Kennet above Hungerford contains ·830, while just above Reading the quantity is 0. The chalk springs at Amwell give 3·740, while the East London Company's water at London shows 1·077. The water in Croydon well has 5·200, and the Wandle at Mitcham 3·704. The excess in the springs has been referred to manured lands, but this seems offered rather in explanation than as an ascertained fact.

Here the sources most free from possible contamination show the larger skeletons, whilst, after the known large additions of sewage matter made to the Thames at Oxford, Reading, Windsor, Henley, and other places, the proportional quantity of nitrates present in the river at Staines is no greater than at Oxford; so that without an *à priori* knowledge of the facts of the case, the analysis would have failed to indicate them. The Kennet, after flowing through Hungerford and Newbury, would seem by the column of "previous sewage contamination" to be as pure as the waters of Loch Katrine or Bala Lake; the river Lee, to become purer the nearer it comes to London; and the river Wandle, so far from suffering from the addition of the Croydon sewage from the Beddington meadows, would show to more advantage than the water at its source.

Nitrogenous compounds are, in fact, not peculiar to animal substances. They are present in a great number of plants. Their decomposition in either case may give rise to alkaline nitrates, and in the latter lead naturally to their introduction into the surface soil. Nitrites and nitrates are not only the result of the decomposition of sewage and other animal matter, but they are also constantly present in the soil and in springs. M. Boussingault, the distinguished French chemist, in his work on "Chimie Agricole," states that he tested for these salts in soils which were never manured, as in the soil of forests, as well as in soils which were slightly and much manured; that one kilogram

of earth from ground never manured, as for example that of the pine forest on the summit of the Liebfrauenberg hills, contained 0·0041 gramme of nitrates, another pine forest gave 0·0014, and the forest of Fontainbleau 0·0020; whilst a vineyard at Liebfrauenberg gave only 0·007, and a hop ground at Sauer 0·0018, both the latter being highly manured lands. Other cultivated lands gave larger quantities,—some very large. Much depends upon the fall of rain. The same able chemist shows also that nitrates are occasionally found in chalk, in some marls, faluns, and in gypsum, while springs equally free from known sources of contamination give very variable results. In lakes he generally found the quantity small. In some wells, on the other hand, he found as much as from half to one gramme per litre.

We cannot help therefore concluding that considerable sewage contamination may take place without indication of its presence by nitrites and nitrates, whilst in other cases these salts may be derived from vegetable matter and from springs which cannot be suspected of having been contaminated with true sewage matter. Their presence in moderate quantity does not indicate with certainty the presence of old sewage matter, nor does their absence prove freedom from such matter. At the same time, where an excess of these salts occurs, as in some wells, they should be regarded with suspicion, and form cause for immediate inquiry; for that they are generated largely by town sewage is indisputable.

Nor can we agree with some eminent authorities in looking at river water in a solely chemical point of view, and speaking of the presence of the 10 to 20 grains of mineral matter in the gallon as *impurities*. So, chemically speaking, they are, but as this seems to be almost a normal condition of river waters, we should not be disposed to consider this term an appropriate one to be applied to substances so constantly present in natural springs and streams.

And further, we cannot but consider it unphilosophical when, in addition to treating as "impurities" substances perfectly harmless even in much larger quantities, the minute quantities present in a gallon, or any other small measure of water, are multiplied by taking masses of water, such as the individual never has to deal with, and given to the public in figures so large as to tend to cause misconception, and perhaps unnecessary alarm in the minds of those not conversant with all the conditions of the case. It would be as just to speak of the small proportion of carbonic acid present in the atmosphere, equally in populous cities and in the Alps, as an impurity, and to startle those unacquainted with the subject by giving in some large figures the total quantity of that gas present in the atmosphere of London.

The question of main and vital importance is not the presence of a moderate quantity of mineral matter, which is of secondary importance, but refers to the presence of organic matter of an objectionable quality. Few waters are free from organic matter, but all organic matter is not objectionable in small quantities.

It is contended, and no doubt with truth, knowing beforehand the probabilities of the case, that although the soft waters of the mountainous districts of England and Wales contain as much organic matter as the Thames water, there is an essential difference in its quality. Still the evidence is by no means conclusive even on this point. Whilst on the one hand there is clearly far less objectionable matter introduced into the former, on the other hand the remarkable power of oxydation possessed by running water, admitted more or less by all chemists, so destroys and removes organic matter that the water regains in a great measure its original purity, either unassisted or else further aided by filtration. It is possible also that the deposition of carbonate of lime, which is known to take place in rivers where the saturation has been in excess of a given quantity, may carry down with it, as it does in Clark's process, a certain quantity of organic matter. The singular fact also noticed by Dr. Frankland and Dr. Odling, of the precipitation of nitrogenous organic matter by the influx of a more peaty water into the Thames is of great interest.

Where a minute quantity only of organic matter escapes destruction, it would seem that chemistry is not yet sufficiently advanced to pronounce authoritatively as to its exact quality and value, and with microscopic living organisms, especially, chemistry is incompetent to deal, and other modes of examination are needed.

Where the organic matter is present in quantities sufficient to diminish the free oxygen in the water, or to tend to putrefactive decomposition, danger is to be apprehended, and considering the nature and scale of the experiment now about to be made with respect to the disposal of the sewage of towns, too much care and watchfulness cannot be exercised in face of the risk which any neglect or oversight might give rise to.

Whatever may be our difference of opinion with respect to some of the conclusions, we

cannot place too high a value on the independent analyses of the water supplied to London, published monthly in the comprehensive and important Reports of the Registrar General.

B.—ON THE FUTURE INFLUENCES LIKELY TO AFFECT THE QUALITY OF THE WATER FROM THE BASIN OF THE THAMES.

195. We must look forward to the prospect of a probable increase of the quantity of sewage coming from the towns, and which if allowed to be poured into the river and its tributaries, would no doubt have a serious effect on the quality of the London supply.

The Chemical Commission of 1851 say:—

"The contamination by sewerage, however, cannot fail to become considerable and offensive with the increase of population, and the more efficient and general drainage of towns. And it appears to be only a question of time, when the sense of this violation of the river purity will decide the public mind to the entire abandonment of the Thames as a source of supply, unless indeed artificial means of purification be devised in the meantime and applied."

And again:—

"The removal of the nuisance complained of, however, can never be complete, but only partial. The contamination from navigation and the river population must be increasing rather than otherwise; while gas-works and other indispensable chemical manufactories, which at present pour their refuse products directly into the river, would necessarily continue to do so, as these products are often of kind not admissible into ordinary sewers."

196. This question, however, has been grappled with by the Rivers Pollution Commission, who in their report on the Thames, March 1866, have treated at considerable length the subject of the purification of the river, not only from house and town sewage, but also from the refuse of manufactories and other pollutions.

In regard to the former they came to a conclusion expressed as follows:—

"That from experiments conducted under the Sewage Commission, and evidence taken on the subject of sewage utilization, and also from our own inspections and investigations, and from the evidence appended to this report, we believe that town and house sewage may be so utilized on land as to preserve the river from the danger of pollution."

They proposed certain changes in the governing body in whom was vested the conservancy of the river, and added the following recommendations:—

"That, after the lapse of a period to be allowed for the alteration of existing arrangements, it be made unlawful for any sewage, unless the same has been passed over land so as to become purified, or for any injurious refuse from paper-mills, tanneries, and other works, to be cast into the Thames between Cricklade and the commencement of the metropolitan sewerage system, and that any person offending in this respect be made liable to penalties to be recovered summarily.

"That it be made incumbent upon the conservators to see to the enforcement of the above prohibitions against pollution of the river, and that for this purpose power be given to them to visit and inspect works, and, after due notice, to close the outlets of sewers, drains, and discharge-pipes into the river within the limits described in the last preceding recommendation.

"That, subject to proper safeguards to prevent abuse, powers be given to local authorities to take land compulsorily for the purpose of sewage irrigation, to an extent not exceeding one acre for every 50 persons whose sewage is to be applied.

"That the conservators be empowered to levy upon all waterworks, taking water for domestic or trade purposes from the River Thames, a rental in proportion to the volume abstracted; the maximum of such rental to be named by Parliament."

197. In consequence of these recommendations an Act was passed in August of the same year (29 & 30 Vict. cap. 89), intituled "An Act for vesting in the Conservators of "the River Thames the Conservancy of the Thames and Isis from Staines, in the county "of Middlesex, to Cricklade, in the county of Wilts, and for other purposes connected "therewith." It altered the constitution of the existing Conservancy Board of the Thames, and considerably enlarged their powers and the extent of their jurisdiction.

The following clauses relate to the improvements affecting the quality of the water of the river:—

"52. The Conservators shall cause the surface of the Thames to be (as far as is reasonably practicable) effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.

"63. From and after the passing of this Act it shall not be lawful for any person to do any of the following things, namely,—

"(1.) To open into the Thames any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter:

"(2.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into the Thames down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose:

"(3.) To open into any river, stream, cut, dock, canal, or watercourse communicating with the Thames at any point within three miles of the Thames, measured in a direct line therefrom, any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage or of any matter aforesaid in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

'(4.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into any such river, stream, cut, dock, canal, or watercourse at any point within the distance aforesaid down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose, in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

"If any person does any act or thing in contravention of this enactment he shall for every such offence be liable on summary conviction to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred.

"64. Whenever any sewage or any other offensive or injurious matter is caused or suffered to flow or pass into the Thames, or is caused or suffered to flow or pass into any river, stream, cut, dock, canal, or watercourse communicating with the Thames, at any point within three miles of the Thames, measured in a direct line therefrom, in such manner that the same is carried or is likely to be carried into the Thames, then and in every such case, whether any such sewage or other matter aforesaid had or had not been so caused or suffered to flow or pass before the passing of this Act, the Conservators within a reasonable time after knowledge of the fact shall and they are hereby required to give notice in writing under their common seal to the person or body causing or suffering the same so to flow or pass, to the effect that they require him or them to discontinue the flow or passage thereof as aforesaid within a time to be specified in the notice, not being in any case less than twelve months or more than three years; provided that the Conservators may, if they think fit, at any time and from time to time extend the time specified in the notice by another notice in writing under their common seal; but nothing in this section shall authorize the Conservators, until the expiration of six months after the passing of this Act, to give to the owner or occupier of any mill or work a notice requiring him to discontinue the flow or passage as aforesaid of any liquid matter produced or used in the manufacture of paper or in any process incidental thereto."

"65. Subject to the provisions of this Act, any person to whom any such notice is given by the Conservators shall, notwithstanding anything in any other Act, within the time allowed by the notice, discontinue the flow or passage of the sewage or other offensive or injurious matter to which the notice refers, and if any person fails to do so he shall be guilty of a misdemeanor, and shall be liable, on summary conviction thereof before two or more justices, or on conviction thereof on indictment, to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred."

In consideration of the improved quality of the water which it was assumed would result from these measures, the five metropolitan water companies drawing water from the river agreed and were bound by clauses 59 to 61 of the Act to pay to the Conservancy Board, each the sum of 1,000*l.* per annum, in addition to certain sums previously agreed to be paid by some of them.

198. We have had before us the chairman, Mr. Thorpe, the secretary, Captain Burstal, and the engineer, Mr. Leach, of the Conservancy Board, and we learn from them that they have served the notices required by the Act, on all the local authorities, from Oxford downwards, to discontinue discharging their sewage into the river.

We are not aware what the result of these notices has been; probably sufficient time has not elapsed to carry out the works necessary, but we presume we may take it for granted that the provisions of the Act will be duly enforced, and that if any difficulties should arise in doing so the subject will receive the attention of the Legislature.

199. Presuming, therefore, the sewage to be used upon the land, it only remains to inquire what amount of benefit may be expected from this measure. It must be borne in mind that the use of liquid sewage for irrigation does not entirely intercept it; for after deducting a certain loss by evaporation and absorption during the irrigation process, the remainder must still flow off into the streams; and hence the question becomes, to what extent will this latter portion be improved in quality over its original state of simple sewage?

200. This question presented itself to the Conservancy Board, and they referred it to three eminent chemists, Drs. Letheby, Frankland, and Odling, desiring them to report— 6851 et seq.

"Whether fluid which has been mixed with sewage can be so purified as to be admissible into the river Thames, and if so, in what manner it may be done; and to fix a standard of purity."

The report given in answer to this question is printed in Captain Burstal's second evidence. The referees examined carefully the application of the sewage irrigation systems

in use at Croydon, Rugby, Carlisle, Worthing, Leicester, and Hertford, and give their opinion that if the process is performed under certain conditions, the defæcated fluid is remarkably improved in quality and may be safely discharged into any running stream. Dr. Frankland, however, adds an opinion as follows:—

"P.S.—The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes. Neither by the processes of purification mentioned above, nor by any others of a practical nature, at present known, can water which has once been contaminated with sewage be, in my opinion, again rendered safe for human use."

The Board referred Dr. Frankland's opinion to the two other chemists, who expressed their dissent from it.

Dr. Letheby says:—

"In reply to your letter of the 5th instant, I have to state that I cannot at all agree with Dr. Frankland that the water of the Thames, after receiving defæcated sewage water, is unfit for domestic use; for after a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage when it is mixed with about 20 times its volume of running water and has flowed a distance of 10 or 12 miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxydation.

"I have stated this in evidence before Parliamentary Committees and Royal Commissions, and I am satisfied that the opinion is well founded."

Dr. Odling says:—

"From many considerations, and especially from the fact that the undefæcated sewage, &c., discharged into the Thames above the source of the present water supply is not recognizable in the water at present supplied, I am decidedly of opinion that the water of the Thames will not be rendered unfit for human use by receiving sewage matter defæcated in the manner described, unless the proportion of such defæcated sewage should become much larger than there is any reason to anticipate."

201. Many able witnesses have given us evidence on this subject.

Mr. Simon says:—

2817. But assuming that the powers given to the Commissioners of the River Thames Conservancy are fully carried out, which amount to an absolute prohibition as to the towns drawing their sewage directly into the Thames, would not that, in your opinion, be an immense advantage in purifying the present supply of London, which is taken now above Teddington lock?—Yes, it would be a very great gain.

2818. Supposing that the prohibition were extended to all sewage going directly into the river at any part of it, and that under the powers which are given to the Thames Conservancy Board, they compelled the towns to distribute their sewage for the purposes of irrigating the land, and consequently that all the water falling on the surface merely came into the river after having passed through the soil, do you think that in that case the Thames water taken above Teddington lock would still be polluted, or should you consider it to be practically free from pollution?—Assuming a sufficient thickness of soil, I should so consider it.

2819. Can you form any opinion at all in that case as to whether the water taken above Teddington lock would still be impure and unwholesome, supposing, for instance, it had travelled exposed to the atmosphere for 15 or 20 miles of river?—I should think it quite a safe water as regards the danger that we are speaking of.

2839. Supposing that those upper towns are driven to deodorize their sewage, or to apply it for irrigation to the land, would the water that must pass off ultimately into the river be sufficiently purified, do you think, so as not to affect the river prejudicially?—A speculative answer is not worth much upon this subject, and I can only give a speculative answer at present. I think it very likely that the water would be harmless, but possibly the result might show that the water could not be deemed quite safe.

Dr. Parkes says:—

3230. Assuming that under the powers of the Act of last session all that sewage will be diverted in the first instance from the Thames and used upon land, would you not consider that the result would be that it would be very much purified beyond what it is at the present moment?—I have no doubt of that at all, but it is impossible to say what the amount of purification would be, because I do not know what the conditions would be of the irrigation of land in proximity to the river, or the amount of water which would pass through the land.

3231. All that would be laid upon the chalk and oolites would be almost entirely absorbed by the land, would it not?—Yes.

3232. But where the sewage is laid upon the clay it would come off more rapidly?—Yes.

3233. Do you think that if that plan were carried out there would be still an impurity in that water sufficient for you to say that it ought not to be used?—I should feel very great difficulty in answering that question.

3234. You seem to say now that from Dr. Frankland's analysis it is what you would call a suspicious water?—I should say so, because there has been certainly organic matter in it derived from sewage, and though that has been oxydized to a considerable extent, still, as showing previous impregnation, and as indicating that there might be a further passage of sewage into the water, and the possibility of a less degree of oxydation at certain times, I should call it a suspicious water.

3235. Then until that purification has taken place which is now in progress, and the water is analysed afterwards, you think that no opinion could be formed upon that point?—I should like to know whether it would be effectual or not in completely diverting the sewage from the Thames, and I should hardly think it possible to form any opinion upon that point.

Dr. Letheby says:—

"I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water

by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome."

Dr. Frankland gives evidence as follows:—

6376. Supposing the sewage were diverted from the Thames in pursuance of the existing law as carried out by the Thames Conservancy Board, would your objections be removed with regard to the Thames water being suitable for the supply of London?—They would be removed so far as the actual sewage was concerned. I should still object, although in a mitigated degree, to the drainage from cultivated land flowing into the Thames. But in speaking of the diversion of the sewage from such towns as Oxford and Windsor, the mere diversion of that sewage so as to throw it upon land, and then allow it to drain or to make its way into the Thames, would not overcome my objection to the water on the ground of the sewage, because I do not think that sewage which has been merely passed over land, or even through land, can be safely allowed to mix with water that is to be employed for domestic use.

6377. Then your gathering ground for the supply of large towns must necessarily be very limited if that view prevailed, that it should pass over no cultivated land, and that the smallest particle of sewage makes it unsuitable for domestic purposes?—If you have no choice of water, of course it would be much preferable to drink water that was contaminated only from the drainage from manured land, as compared with that which was contaminated directly by sewage. But sewage that has been allowed to flow over land, and which perhaps does not sink into the land at all, would, I should think, be much more objectionable than the water drainage from cultivated land, and which is manured principally from animal as distinguished from human manure.

6378. In the case of the 250 acres of land at Croydon upon which the sewage of that town is spread, the water running off into the Wandle is to the eye perfectly pure; have you ever examined any of that water to ascertain whether there is still held in solution that which is prejudicial to human health?—I have examined that particular water which you have mentioned, and also a number of other similar waters running off land upon which sewage has been placed. Those examinations have been recently made by Dr. Odling and Dr. Letheby and myself for the Board of Conservators of the Thames, and I may say that the substantial result, at least what I myself would say was the substantial result, of those examinations is, that about four-fifths of the sewage matter is destroyed under favourable circumstances, but that is all you can calculate upon. So that if you were to have all the sewage which is at present poured in an unmitigated form into the Thames distributed over the land as it is done at Croydon, you would reduce the amount of contamination of the Thames to one-fifth of what it is at present. In other words, if the population increased to five times its present amount, in the Thames basin the contamination would be as great as it is at the present day, after the sewage had passed over the land.

6396. Assuming that the Act of Parliament which was passed last session for preventing the pollution of the river Thames is efficiently carried out, and that no sewage is directly discharged into the river, and assuming also that those companies adopt proper modes of filtration, would not this specially objectionable case be to a great extent met?—With regard to the muddiness of the water, it would completely, but not with regard to the wholesomeness completely. The unwholesomeness of the water would doubtless be mitigated by otherwise disposing of the sewage, or rather, I should say, by passing the sewage over the land before its admission into the Thames; but I do not think that even after that such a proportion of sewage would be innocuous when admitted into the Thames.

Dr. Odling says:—

6443. But are you of opinion that, supposing the Act of last year were faithfully carried out, and the sewage were intercepted from the river Thames, the water on the whole would be a suitable water for the supply of London for domestic purposes?—Yes, I am.

Sir Benjamin Brodie says:—

6992. Are you prepared to express an opinion on the result of the application of sewage to the land, the water being afterwards discharged into a river, whether it would or would not be injurious to health after its filtration through the soil?—No; I think here again the same obscurity prevails, only to a less extent. I think it is certain that the sewage water must be benefited very materially indeed by being filtered through the land, and I have that opinion because I know that in the porous material of the land the processes of oxydization which destroy the injurious sewage matter go on much more rapidly and efficiently than they do otherwise, and not only that, but that the land operates as a filter and stops, mechanically, a large portion of the solid injurious matter of the sewage; but if you ask me whether the water that runs out from the land, although it may be bright and clear, is a good beverage, I do not know how we are to answer that question except by giving the water to human beings to drink, and by long observation of its effects.

6993. Then, although the process of filtration may catch and retain all that is held in mechanical suspension, still in your judgment there may be elements passing off in solution that might be injurious to health?—I think there may be, certainly, and not only in solution, but even not in solution; I mean by that that there may be even solid matters, organic germs, which would be so small that they would pass through the filtering material employed.

6994. And which might be unobservable to the eye?—Unobservable altogether to the senses, and yet which might be extremely detrimental to the health; but here again you cannot say that they are detrimental to the health, you can only say that they may be so.

7039. What course do you consider the most efficacious one to get rid of sewage contamination from the towns on the river?—The best is not to put the sewage with the river at all, that is the best answer I can give, and, indeed, that is really the only course by which you can be certain that you have not got it in. I certainly do think it a very good thing to employ the processes used for the filtration and destruction of sewage, and they are *pro tanto* beneficial. They really help the matter a good deal, but I do not think that they are entirely effectual. There is no known process that I am aware of for, on a large, scale destroying the injurious qualities of sewage.

7040. By throwing it upon the land you absolutely get rid of a large portion of the sewage, and what is left is somewhat improved?—Very greatly improved, but I should not like to take a glass of water and drink it from just the spot where it went into the river, still less to make it one's daily and habitual beverage.

Dr. Angus Smith says:—

7204. Is it your opinion that after the application of sewage to the land the water filtered off and running into the river would be harmless?—If the land or the filter is not overburdened with sewage, that is to say, if no more is allowed to pass through than can be properly oxydized, then complete purification must take place.

7206. Then, as a rule, are you of opinion that it would be safe to apply sewage to land and allow the water to run off into a river which is the main source of supply to a town for domestic purposes?—It is certainly safe to apply some. I am not able at this moment to say how much. I am not able to say, considering the new plans of irrigation proposed, that it would be proper to load the neighbourhood of a large town with sewage, and collect the water from it and use it for the town. I am inclined to think that it would not be safe; but in a thinly populated agricultural country I think we have no reason to believe that any danger can occur. . . . . I therefore conclude that it is a question of quantity, how much sewage can be put upon the land.

Mr. Hawksley says:—

5074. Are you aware that the Thames Conservancy Board are now clothed with power to call upon all the local authorities on the banks of the river, up to and including Oxford, to divert their sewage and other polluting matter from finding its way into the river?—Yes.

5075. Of course the river would be greatly improved if that principle were adopted uniformly up the river?—The river would be very much improved near the towns themselves, but at considerable distances from the towns it would have no effect whatever, because all those matters are exceedingly decomposable in the presence of oxygen and become decomposed entirely by oxydization. There is no such thing as a particle of fæcal matter put into the Thames at Oxford finding its way down to Hampton Court. It is all burnt up in fact by the combustion set up by the oxygen.

Mr. Greaves says:—

5169. Have you seen the report which has just been issued out from the River Pollution Commissioners?—Yes, I have.

5170. They recommend that the same course should be followed in the Lee as had been adopted by Act of Parliament with regard to the Thames, but giving power to a new body to prevent the pollution of the Lee for the future. If that were carried out do you think it would add to the good quality of your water?—I have not the least doubt that it would.

202. During the inquiry our attention had been called to the improvement made in the water of the river Wandle by the sewage irrigation practised at Croydon, and as this example of the process was so accessible, we requested Mr. Pole, when collecting the samples of water from various parts of the Thames basin, to visit these works and to take specimens of the sewage before and after defæcation, and to submit them to Drs. Frankland and Odling for analysis. Mr. Pole's report will be found in Appendix O; he gives a general description of the process, and adds—

When I saw the system at work on the 11th May, although the sewage was foul and dirty when it went on to the land, the water running off was quite bright and clear, without any appearance of foul deposit in the channel. I noticed several fine trout in the river, near the point of discharge, as well as in other places farther down.

It is worthy of remark that the plan here adopted, of allowing the sewage to travel slowly over the land, in constant agitation among the blades and stalks of the vegetation, appears to me peculiarly favourable for the oxydation of the impurities by the action of the atmosphere, which I have no doubt powerfully aids the purifying action by vegetable absorption.

The report of the chemists will be found in Appendices A. X. (1 and 2); it shows that in the diluted condition in which the Croydon sewage is applied to the land, it contains only 11·6 grains more of solid matter (or 43·6 parts in 100,000 parts evaporated to dryness) than the well water of Croydon. In this undecomposed sewage water the ammonia has increased from ·001 to 2·191, and the organic nitrogen from ·007 to 1·156, whilst the nitrogen, as nitrites and nitrates, stands at ·000, whereas the Croydon well water contains ·551. After flowing off the land, the sewage contains only 34·4 parts per 100,000 of total solid residue, the ammonia being reduced to ·002, and the organic nitrogen to ·037, and the nitrogen, as nitrites and nitrates, has increased to ·317. At Mitcham, one mile lower down, the water of the Wandle contains only 31·0 parts of solid residue, or one part less than the Croydon well water, the ammonia has disappeared, the organic nitrogen has decreased to the extent of ·007, and the nitrogen, as nitrites and nitrates, has further increased to ·403. Dr. Frankland considers this amount of purification exceptional, as the quantity of solid impurity in the sewage water, as it flows off the land into the Wandle, would appear to vary according to the rainfall and the season of the year.

According to chemical analysis, the Wandle at Mitcham will contrast fairly with other river waters. The amount of contamination effected by the Croydon sewage, which, however, is weaker than London sewage, almost disappears after the river flow of three furlongs, and a mile lower down all excess of solid impurity has disappeared, the organic nitrogen only being in excess of the quantity existing in the Croydon well water. On the other hand it has to be observed that, notwithstanding the large and constant introduction of town sewage at Beddington, the nitrates and nitrites in the Wandle

at Mitcham are present in less quantities than in the Croydon well water, or than in many of the oolitic and chalk spring waters of the Thames basin. The following table gives some of the comparative results obtained by some of the analyses made for the Commission. It shows the condition of the Wandle 1½ mile below the place where it receives the Croydon sewage, as contrasted with the waters of the Thames and the Lee in places free from town sewage. The quantities are given for 100,000 parts of water.

	River Wandle at Mitcham.	Lee above Hertford.	Thames above Reading.
Total solid residuum	31·0	25·88	32·7
Ammonia	·000	·000	·001
Nitrogen as nitrates	·403	·246	·286
Organic nitrogen	·024	·025	·032
„ carbon	·099	·125	·291
Hardness before boiling	21·1	19·9	21·
Do. do. by Clark's test	14·8	13·9	14·7
Hardness after boiling	9·7	2·1	8·2
Do. do. by Clark's test	6·8	1·5	5·7

WATER FROM THE LEE VALLEY.

203. Our remarks hitherto have been directed principally to the quality of the water from the main stream of the Thames, but they apply also very generally to that from the River Lee.

204. The Rivers Pollution Commission, in their report on the Lee, dated May 1867, point out that the river, above the lowest intake of the water companies, is polluted by the sewage of Luton, Hertford, Ware, Bishop-Stortford, and many other places, as well as by manufacturing refuse of several kinds. In some towns attempts have been made to purify the sewage by different processes before its discharge into the river.

The New River are in the best position as to quality, as they escape the sewage of Hertford, Ware, and all below, and have moreover in their supply a large proportion of pure water received directly from the chalk.

The East London Company's intake is considerably lower, but still their supply is considered wholesome by the Rivers Commission, who report on it as follows:—

"With regard to the quality of the water, the water drawn at Ponder's End is not of course so pure as that taken by the New River Company higher up the stream, because the river in its course over the intervening space has received additional impurities from towns and places, as already detailed under the head of pollution, but this difference is greatly diminished by the fact that between Hertford and Ponder's End the Lee has been reinforced by a large accession of fresh water from the land springs which break out from the chalk into the bed of the river. The result is, as the analyses show, that the East London Waterworks Company are able to obtain a fair wholesome water. The company have gone to great expense to improve the water before it passes to their filter beds, by the construction (under statutory powers) of Catchwater Dyke to intercept sewage of certain towns above the intake, and to deliver it at a point below. In a bill now before Parliament the East London Waterworks Company proposed an extension of this system of intercepting sewers."

The Commission, however, came to the conclusion "that it is expedient that more "stringent measures be adopted to protect from pollution that portion of the metropolitan "water supply which is derived from the river Lee," and they made recommendations with that object.

205. In 1867 the Board of Trade directed an inquiry to be made, through Captain Tyler, into the severe outbreak of cholera which had taken place in 1866 in the east of London, and which had been ascribed principally, if not solely, to the bad quality of water supplied by the East London Waterworks Company. This case has been frequently mentioned in evidence before us, and it appears that by some faulty arrangements at the East London Works the foul waters of the lower part of the river Lee were admitted into the company's reservoirs.

The conclusions arrived at by Captain Tyler are expressed in the following extract from his Report:—

"The disease was, undoubtedly, very fatal during the visitation of last autumn in the metropolis, in the East London Company's field of water supply, and especially in the districts which drew principally from the Old Ford reservoir. There were, on the other hand, other localities, chiefly on high ground and of a better class, such as Stamford Hill, Leytonstone, Wanstead, Woodford, Buckhurst Hill, and Walthamstow, parts of which

are supplied exclusively from that reservoir, which were nearly or quite free from it. Silvertown and North Woolwich were exceptions, the former in the early part, the latter throughout the epidemic. All the houses in these latter places are on constant supply from the North London Company; and the disease was very fatal in certain localities near the East London Company's field of supply, where no water that they supplied could have been an exciting cause. The want of better drainage had, no doubt, much to do with the intensity and duration of the epidemic; but the mortality declined from the 1st and still more from the 9th of August; while the Metropolitan Board of Works commenced their pumping operations to divert sewage from the River Lee and the Limehouse Cut into the northern outfall sewer only on the 24th of August. The Lee must have been contaminated at Old Ford at an early period of the epidemic. The covered reservoirs at Old Ford may have received from the river at different times, as they were partially emptied, some of the poison; and the water supply of some of the districts drawn from those reservoirs may thus at different times have been to some extent infected. Considering this possibility of infection, and looking to the effects which were only too apparent in the general field of supply from Old Ford, a case of grave suspicion exists against the water supplied by the East London Company from Old Ford, and that proximity to absolute proof at which I hinted in commencing this subject has thus been nearly reached. But any poison so distributed would have been in a condition, if it were soluble in water, of considerable dilution, and I am not prepared on that account, as well as in consideration of the deplorable state in other respects of their district, to go so far as the memorialists in asserting that this water was 'the principal if not the sole cause of the fearful mortality from cholera.' I believe, however, that if, as is possible, choleraic poison did find its way into the company's mains, it must have passed directly from the River Lee into the closed reservoirs and I have no reason to believe that it was distributed in the water which was so improperly supplied to the district from the open reservoir."

But whatever may have been the connexion of the East London water with this outbreak of disease, it is clear that the evil arose from an accidental circumstance, and therefore affords no argument against the quality of the Lee water when taken under proper conditions, at the upper part of the river.

206. The House of Commons Committee of 1867, who devoted considerable attention to the Lee, state:—

"Your Committee having received scientific evidence of the present quality of the water supplied by the New River Company and the East London Company, are satisfied that, as far as chemical or other science affords the means of judging, the water is not only wholesome, but compares favourably with that supplied to other places."

The Committee noticed the pollution of the river, and after making some suggestions in addition to the conclusions of the Rivers Pollution Commission, they recommended that a bill should be introduced into Parliament to provide remedial measures.

207. This was done, and on the 31st July 1868 there was passed "An Act to make better "provision for the preservation and improvement of the River Lee and its tributaries, "and for other purposes" (31 & 32 Vict. cap. 154).

The provisions of this Act for excluding sewage and other contamination from the river are generally of the same nature as those enacted for the Thames; making, however, a special exception of the town of Luton, which is allowed to use a chemical purifying process instead of applying the sewage to the land.

WATER OF THE KENT COMPANY.

208. The water of this company is about four or five degrees harder than that of the Thames or the Lee, but in other respects it is fully equal to them, if not superior, on account of its smaller quantity of organic matter. Objection has been taken to the large quantity of nitrates and nitrites in this water, but we have already pointed out that this is not an unusual feature in the water of springs far removed from sources of pollution, as in those of the oolite at the head of the Thames valley, and the chalk.

FILTRATION.

209. It is absolutely essential to the good quality of the Thames water that it be effectually filtered. The Chemical Commission remarked in 1851 that the effect of ordinary filtration through sand was very decided on Thames water, as it appeared to be upon chalk waters in general. The river water, they remarked, could thus be easily obtained, under usual circumstances, entirely free from suspended solid matter or mechanical impurities. More modern experience seems to lead to the belief that filtration also acts, though probably in a way less understood, in improving the quality generally. The analyses in Appendix AG, by Messrs. Letheby, Odling, and Abel, which give the comparative qualities of filtered and unfiltered water, clearly show the advantage gained, as will be seen by the following extract:—

General Results.	Thames Companies.		New River.		East London.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Dissolved matter, per gallon	20·825	19·479	22·402	21·550	24·940	24·360
Of which organic and other volatile matter	1·261	0·976	0·702	0·567	0·915	0·300
Suspended matter, per gallon	0·830	0·034	0·241	0·095	0·561	0·047
Of which organic and other volatile matter	0·173	0·005	0·033	0·014	0·045	0·023
Hardness before boiling (degrees)	14·4	13·3	15·5	13·5	14·4	14·0
„ after „ „	5·3	4·6	4·2	4·0	5·0	5·0
Dissolved gases, per gallon (cubic inches)	13·77	13·85	13·95	12·75	12·51	13·75
Dissolved oxygen, „ (grains)	0·796	0·825	0·906	0·906	0·891	0·752
Oxygen required to oxydise organic and other matter (grains)	0·146	0·134	0·115	0·069	0·090	0·095
Ammonia, per gallon (grains)	0·003	0·002	0·001	0·001	0·004	0·003

Mr. Wanklyn's letter, Appendix AK, says,—

"The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow."

All chemists agree on the importance of filtration.

210. Filtration was made compulsory by the fourth clause of the Metropolis Water Act, which runs as follows:—

"IV. From and after the 31st day of December 1855, every company shall effectually filter all water supplied by them within the metropolis for domestic use before the same shall pass into the pipes for distribution, excepting any water which may be pumped from wells into a covered reservoir or aqueduct without exposure to the atmosphere, and which shall not be afterwards mixed with unfiltered water."

211. All the companies profess to comply with this provision, but the evidence shows that the filtration has been imperfectly carried out. In the Registrar General's annual summary for 1867 occurs this passage:—

"It is much to be regretted that the London waters are not more effectively filtered before distribution. Only on one occasion during the whole year have I obtained a transparent sample of water from the Southwark Company's main. The Grand Junction and Kent Company's waters were turbid four times out of 12, the Chelsea thrice, and the West Middlesex, Lambeth, and East London twice out of the 12 occasions when the samples were drawn for analysis."

In every succeeding monthly report the same complaint has arisen.

212. We call special attention to this neglect to comply with the provisions of the Act. The process of filtration presents no difficulties, all that is wanted being a sufficient area of filtering surface. There seems to be no efficient means of enforcing an observance of this provision of the Act, and the neglect of the companies to comply with it, notwithstanding the repeated attention drawn to the imperfect filtration, shows the necessity for some change in the system of supervision to which the supply of the metropolis is subjected.

GENERAL REMARKS BY THE COMMISSION ON THE QUALITY OF THE WATER FROM THE THAMES BASIN.

213. The evidence before us leads us to the conclusion that the Thames water has many good qualities which render it peculiarly suitable for the supply of the metropolis, and which give it, in some respects, a superiority over the soft waters usually obtained from high gathering grounds. When properly filtered it is clear, bright, colourless, agreeable, and palatable, and the amount and nature of its saline constituents are considered by many to contribute to its general acceptability for drinking. It is well aerated, has good keeping qualities, and is unusually safe as regards action on lead and iron.

On the Organic Impurities.

214. The evidence we have collected on this subject presents great diversities of opinion; but there is one result which, we think, is clearly deducible from the facts before us, namely, that in the present state of chemical science, analysis fails to discover,

in properly filtered Thames water, anything positively deleterious to health. Whatever may be the difference of opinion with respect to the time required for removal of all the objectionable organic matter, all the chemists agree that in Thames water taken from the present source and properly filtered, all such matter has disappeared, and that the resulting compounds, such as nitrates, &c., remaining therein are innocuous and harmless.

Having carefully considered all the information we have been able to collect, we see no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome.

215. The only point raised against the Thames water on the ground of organic contamination is of a less positive character; it is said that water which has been once contaminated with sewage may still contain undecomposed organic matter, which, though inappreciable by the most delicate chemical tests, may still exercise prejudicial effects on the human system.

The strongest form of this objection has reference to some opinions now prevalent, that certain forms of disease, such as cholera and typhoid fever, are propagated by germs contained in excremental matter; and it is conceived possible that when matter of this kind once gets into streams, these germs may escape destruction and long preserve their dangerous character. It is said that no process is known by which such noxious material can be removed from water, and therefore it is argued that water which has at any time been contaminated by sewage is thenceforth unsuitable for domestic use.

These opinions have been advanced by many eminent men of science; they are worthy of respectful attention, and ought to operate as a constant stimulus to the most searching examination of the state of the water; to the improvement of the modes and means of scientific analysis; and to the diligent collection of medical data as to the effect of the waters upon the public health. But we cannot admit them as sufficiently well established to form any conclusive argument for abandoning an otherwise unobjectionable source of water supply.

216. We may also expect that the state of the Thames and the Lee will be very much improved by the exclusion from them of all sewage and other offensive matter, in accordance with the provisions of the Acts of 1866 and 1868. And it is worthy of consideration whether these provisions should not be extended higher up the tributary streams, so as to exclude all possible sources of noxious pollution.

217. We are of opinion that, when efficient measures are adopted for excluding the sewage and other pollutions from the Thames and the Lee, and their tributaries, and for ensuring perfect filtration, water taken from the present sources will be perfectly wholesome, and of suitable quality for the supply of the metropolis.

218. The analyses made specially for us of the waters in the various parts of the Thames basin are, we conceive, of great interest and value, and will be very useful as data for comparisons of the state of the river at future times. The result shown by them that the present point of intake is the best that could be chosen in the whole course of the river, is peculiarly important and satisfactory.

PART V.

REMARKS ON VARIOUS POINTS BEARING GENERALLY ON THE SUBJECT OF THE METROPOLITAN WATER SUPPLY.

Section I.

ON THE QUANTITY OF WATER LIKELY TO BE HEREAFTER REQUIRED FOR THE SUPPLY OF THE METROPOLIS.

219. The quantity of water that is likely to be hereafter required for the metropolis forms a prominent element in the consideration of any plans of supply, and we propose to devote a few remarks to the elucidation of this subject.

This quantity will obviously depend on two elements—

(*a.*) *The estimated future population, and*
(*b.*) *The quantity to be allowed for each individual.*

(*a.*) As to the estimated future Population to be provided for.

220. The population of London embraced within the limits of the Registrar General's district (see map Appendix AW.), was given for the middle of the year 1867 at 3,082,372 persons.

The number of persons estimated to have been supplied by the companies in that year, as given in the table in Part III. of our Report, amounts to 3,100,000. The districts supplied have a somewhat wider range than that of the Registrar General, as they extend farther into the suburbs; but on the other hand, it is probable that some portions of the population may not be included within the companies' returns.

221. In reasoning upon the probable number of persons to be hereafter provided for, Mr. Bateman states as follows:—

"Will you give us, in the first place, the population of the metropolis in the year 1861?—According to the population returns for that year the population within the district of the Metropolitan Board of Works was 2,803,034 persons. 3–4.

"What is the present population?—The present population, taking the rate of increase at which the metropolis in recent years has been increasing, is upwards of 3,000,000 by estimate. Dr. Letheby, in December 1866, gives the population at 3,067,000 in round numbers. The rate of population has been as follows: it has trebled since the beginning of this century, it has doubled itself in the last 40 years, and it is now half as large again as it was 20 years ago; therefore, at the same rate of increase, in 20 years, it will be half as large again as it is now, and will amount to 4,500,000 persons. I believe that that will scarcely represent the whole population which may be expected to reside in the immediate neighbourhood of London at that time, because the suburbs of London beyond the area included in the district of the Metropolitan Board of Works are so rapidly increasing that they may be taken as forming a part of the metropolis, and ought to be considered with reference to any supply of water."

He gives further explanations of his views on this point, and adds:—

"In 1856 the supply was at the rate of 28 gallons per head per day, in 1866 it was at the rate of 31 gallons per head per day, and in 1867 it was at the rate of 32 gallons per head per day. If you take 32 gallons per head per day as the consumption, and estimate the population in 1877, nine years from the present time, at 3,650,000 persons, which it would amount to at the rate of 1·73 per cent., you will want 117,000,000 gallons a day. If you take the increase at the rate of 2½ per cent., you will want 127,000,000 gallons a day at that time; and if you take it at 3 per cent., which with all deference I think ought to be what you should take it at, you will want in nine years from the present time 132,500,000 gallons a day. Judging from the experience of all the places that I know, I think that is about the right amount to take, and my own belief is that when you get water which can be supplied by gravitation, when you include everybody as you ought to do upon the principle which I have laid down, and compel them to pay for water, and therefore give them an inducement to take it and use more than they have done, when you have converted every privy into a water-closet, and when you have water of the softness of Welsh water, in which case you would sell as much again for trade purposes as you do now, that is an under-calculation instead of an over-calculation, and my belief is that before nine years are over you will want more than 130,000,000 gallons a day. However, I have assumed 130,000,000 gallons, because that happens to be the scale on which I devised these works when I first laid them before the Commission, and that seems to me to be the quantity which may be required about the time at which they could now be executed." 6583–6.

In about 12 or 13 years from the present time he estimates that 170,000,000 gallons will be required, and ultimately 230,000,000 gallons; but he extends his estimates to the provision of 300,000,000. 6632–54.