

Discussion.

Mr. Wolfe Barry. Mr. J. WOLFE BARRY, C.B., President, said he had great pleasure

in proposing a hearty vote of thanks to the Authors for their valuable contributions. The record given by Messrs. Worth and Crimp was of great value to the Institution, being, in fact, the history of a gigantic work, and forming a most worthy sequel to the contribution of the late Sir Joseph Bazalgette in 1865.¹ The account of the constructive work since Sir Joseph Bazalgette began the system of the outfalls at Crossness and Barking was a valuable addition to the Papers already possessed by the Institution on that subject. The present Papers brought the subject up to date, and the details, which had been described in a most interesting way, were full of instruction. The importance of the chemical branch of the subject had been shown clearly by Mr. Dibdin, and his Paper was a valuable supplement to his contribution in 1887,² also bringing the history up to date, and giving details of the success that had been attained. The purification of the water of the lower Thames was apparent to everyone who had worked on the banks of the river. He could testify to the marked improvement that had taken place during his career in bridge-building in the Metropolis since 1860. Mr. Dibdin's Paper was full of promise for the future, and removed many of the difficulties in the way of dealing with the sewage of large cities. He thought there was little doubt that the hope expressed in the Paper for greater and better results might be realized. He could speak from observation of the increase of fish life in the lower Thames; and if the same improvement continued, it was not beyond the reach of possibility that Londoners might again see salmon ascending the Thames, as they did before that noble stream was so infamously polluted as it had been in former times.

Mr. Symons. Mr. G. J. SYMONS observed that in the design of the original scheme Sir Joseph Bazalgette had adopted an estimated quantity of rainfall, and some years ago, when there were bitter complaints of the state of the Thames, a Royal Commission was appointed to inquire into the subject, and a good deal of evidence was given respecting it. He found no reference to the subject in the first Paper, nor

¹ Minutes of Proceedings Inst. C.E., vol. xxiv. p. 280.

² *Ibid.*, vol. lxxxviii. p. 155.

indeed was anything said about rainfall, with the exception of the Mr. Symons. account of experiments carried out at Bayswater. Inasmuch as rain-water was admitted into all the sewers, and as many valuable details were given with regard to the pumps, the capacity of the drains and the like, such particulars were desirable. It was stated that heavy rains did not affect the quantity of water which reached Barking Creek. Probably not; the sewers could not carry it there, and the floods escaped by the storm-overflows, which he thought were too numerous. It was stated that the storm-water contained more suspended matter than ordinary sewage, for which reason it was very unsatisfactory that it should be turned into the storm-overflows and sent into the river without treatment. This was proved by the remark of Mr. Dibdin: "These include storm-water, which increases the average amount of suspended matters left in the effluent, as in many instances the quantity found in the dry-weather sewage is considerably lower." He should be glad of further information with regard to the cost; it was given at the date of the opening of the Crossness works, but that was evidently not the cost of the 284 miles of sewers; it was the cost at an antecedent date. The amount was then $4\frac{1}{2}$ millions. He had tried in vain to ascertain how much had since been spent, and the result was not satisfactory. It appeared about £100,000 a page all through the Paper. There were also independent amounts; steamers, for instance, had cost £431,000; Crossness, £144,000; the Isle of Dogs, £317,000. With the addition of the estimate of $2\frac{1}{4}$ millions, the amount reached a very large total, and for it something extremely good was to be expected. Again, in regard to the Effra creek pumping-station, the question of rainfall had been ignored. Reference was made to repeated complaints of flooding in 1878. In that year there were more exceptionally heavy thunderstorms than had occurred in any year since the works had been constructed. Reference was also made to a Report by Mr. Binnie and Sir Benjamin Baker as to what was necessary for the relief of flooding. He thought it should be stated how much of the necessity for that additional relief was due to the original design in regard to the capacity of the sewers, and how much was due to the development of the Metropolis, the increased area built on, and the areas taken in which were not originally contemplated. With regard to the experiments on the north of Hyde Park, it was stated, "When running full, the sewer under consideration can carry off about $\frac{2}{3}$ inch of rain per hour from the area drained by it; and on the occasions referred to was carrying about that volume, which is equal to a rate of about

Mr. Symons. 24 cubic feet per minute per acre." That amount of rain was small compared to the 1878 storm, which had led to the Effra creek development. For a short interval the actual rainfall was at the rate of no less than 12 inches an hour. The original design for the sewers allowed for $\frac{1}{100}$ inch per hour. The quantity of sewage that reached Barking was given in the Paper, but no reference was made to the population or the area that contributed it. He should like to know the quantity per head that the 205 million gallons referred to at the close of the Paper represented.

Lieut.-Colonel Jones. Lieut.-Colonel ALFRED S. JONES, V.C., thought the area of Bayswater supplied exactly the kind of data engineers had long wanted as to the collection of rainfall upon areas which had been fully built over. It contributed a clear warning to preserve and improve all natural water-courses on any land which was ever likely to be built over. His evidence before Lord Bramwell's Royal Commission¹ showed that an approach to the separate system might even yet be adopted to palliate those great evils of the storm-water overflows. He admitted that the appearance of the foreshores and water of the Thames of late years indicated that those evils had been "abated," as was anticipated by the Royal Commission, as a result of the "preliminary and temporary measures" they proposed. Such improvement in his opinion was due mainly to the careful working of the screens, filth-hoists and destructor, eliminating about 5,000 tons per annum of the most offensive refuse which used to disfigure the foreshores. Secondly, he attached importance to the sludge-barges going to sea, but he discounted the great quantity which was annually taken out by the amount of simple water. It contained 90 per cent. of water, and he computed the cost of the freight of those barges at 5s. 11d. per ton for removing about 107,600 tons of filth during the year 1894. He reduced it not only by the water, but divided the remainder by two, on account of the harmless mineral matter, which went to the bottom without injury to anybody. For the last twelve or fifteen years the working of the nitrifying organism in the pores of the soil on land irrigated by sewage had been known, and he thought Mr. Dibdin was one of the first to try to concentrate that action in a filter of more porous material than land. His experiments, like those of the Massachusetts Board of Health, had been conducted in a scientific manner, and were most valuable. The Paper rightly laid stress on the fact that the coke filter was a

¹ Second and Final Report of the Royal Commission on Metropolitan Sewage Discharge, 1884, p. xxxi.

“delicate organism,” and required as much care and attention to keep it in working order as any other piece of machinery. Where, he asked, in this country had that delicate organism, that nice piece of machinery stipulation, been applied to a sewage-farm, which did the same work and in the same way, only not in such a concentrated form? He had had to reclaim a 120-acre farm, which, for fourteen years, worked most perfectly, and then for fifteen years had been absolutely neglected, so much so that it had become a nuisance, and was even now looked upon as a horrible cesspool. He was thankful to say that for the last eighteen months its wheels had been oiled to a certain extent by War Department expenditure, and if it were only given a fair chance he maintained that the farm would regain the position that it had, or even do better than it had before. That was a case of a delicate piece of machinery being absolutely neglected for fifteen years. It was stated that the material for the Barking coke filter was obtained on the spot at the very low price of 1s. 6d. per ton, and nevertheless it cost £2,000 to the acre. But the City Engineer of Manchester had estimated for precisely similar filters at the rate of £5,500 per acre. From the Table giving the averages of daily analyses, it appeared that the experimental acre had been tested at the rate of 1,000,000 gallons per day during three periods—108 days, 13 days, and 148 days respectively, making 268 altogether, with intervals for rest of 37 days and 13 days. It was also said that “the experiments were then concluded, it having been satisfactorily established that with proper care the filter was capable of continuing its work as long as it might be required at an average rate of 1,000,000 gallons a day.” He thought that must be received with caution, or the sanitary authorities, leaning upon the statement that they might go on for ever working that beautiful machine, would get into trouble, and if they had not a tidal river to discharge it into, they might not know what to do with the sewage during the period of rest. With regard to the precipitation, he understood that Mr. Dibdin was content to put on his coke filters the effluent from a precipitation or deposition process, provided it had taken the suspended matter out. He would like to have some data from Mr. Dibdin as to what the difference would be by using chemicals one week and not using them another.

Professor HENRY ROBINSON remarked that many years ago Mr. Melliss and he had, in dealing with the chemical treatment of the sewage at the outfall works at Coventry, utilized copperas, or iron water, as it was termed in the Paper. Their observations had shown

Lieut.-Colonel
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that the sulphate of alumina which possessed a large proportion of the protosulphate of iron had a much better purifying effect. They were glad to find in these later years that the London County Council were utilizing blue copperas at Barking and Crossness. With reference to the works at both these stations, carried out by the late Sir Joseph Bazalgette, he had had several opportunities of closely observing, not only their nature, but also the admirable way in which those works were executed, and that the outfall sewers and outfall chambers below water-level were watertight. He remembered more than 30 years ago having light refreshments with some of the officials in connection with the Metropolitan Board of Works and others in one of the large chambers much below water-level, and there was not only not a drop of water in them, but there was every indication of the splendid manner in which work of that sort could be executed. In his own practice he had often to remedy sewerage systems where the work was carried out in such a way as to cause the leakage of subsoil water into them, bringing about serious trouble and expense at the outfalls, especially where there was pumping. With reference to the general system which was now adopted at the outfalls at Crossness and Barking, when Lord Bramwell's Commission held its inquiry he had been asked to give evidence. At that time the solution of the problem, according to the Commissioners, as was stated by the Authors of the first Paper, was that after chemical treatment the effluent should be purified upon land. Many most influential men pointed to the necessity of obtaining enormous areas of land, and it was owing to that feeling that when he was asked to give evidence before that Commission, he suggested that the solution of the problem of treating the sewage at Barking and Crossness would be by a simple chemical treatment, as was now being done, which would bring the effluent up to a sufficiently high standard to enable it to be discharged into the Thames without the cost of the distribution of the effluent upon land. What Mr. Dibdin had done with filters was of great importance. He believed it was agreed by those who had studied bacteriological matters that there were two organisms which could be brought into play in dealing with the purification of sewage. In one case the organism did not require oxygen, and was called by bacteriologists the anaërobic. Its action resulted in liquefying the solid matter in sewage and bringing it into a shape more capable of the action of the aërobic germ than was possible in putting the sewage upon land or upon

filters without the previous action of the anaërobic germ. The investigations of Dr. Rideal and others had pointed out those two functions of the micro-organism, and he was certain that the time had arrived when those functions had come so much within the range of practical engineering that the days of sewage-farms and the distribution and purification of sewage on large areas of land were over, unless the sewage upon land could be utilized with commercial advantage, which procedure he did not wish to under-value. But in dealing with the purification of sewage those two organisms had now come to the front to a very large extent, and he had successfully used an anaërobic chamber at sewage outfall works that he had designed.

Professor
Robinson.

Mr. ARTHUR ANGELL was anxious that engineers should not conclude that ordinary sewage in smaller flows could be dealt with upon the same lines as they were dealt with at Crossness and Barking. As a general rule, other things being equal, the larger the flow of sewage the more easily it would be treated. He spoke as a chemist; he knew that engineers were desirous of minimizing the daily expenses. As a chemist he watched with something like fear their anxiety to reduce their volume. He would like to have it increased almost *ad infinitum*. That could not be permitted, but at the same time he hoped it would not grow into too concrete an idea that the entire rainfall should always be separated from the sewage, because chemical difficulties occurred. Now the difficulties which occurred were not known at the works described, although he was familiar with them elsewhere. In one district the tanners had possession of the sewers, and had sent their filthy waste down, and that had to be dealt with. In another district it was the brewers who stood in the same situation; in a third it was the laundry; and in the fourth there was the wool-scourer. That proved the problem, chemically speaking, was not such a simple one as it was when the whole was put into hundreds of millions of gallons and made into a uniform mixture. Engineers must not expect to be able to obtain with the same amount of precipitants and with the same simple applications as good results as at the works described. But were those results so remarkably good? They were, inasmuch as they produced the desired effect upon the river. In Appendix I there appeared figures which were somewhat remarkable as representing the purification of sewage so far as regarded the dissolved matters. The tabulated figures represented a great number of results obtained upon the crude sewage and upon the effluent. Taking what, in his opinion, was by far the

Mr. Angell.

Mr. Angell. most important column—although there was a difference of opinion as to whether the albuminoid ammonia, or the oxygen absorbed, was the most reliable measurement—taking the mean amount of albuminoid ammonia as 0·353 at the northern outfall and the remarkable effect of purification was that it was increased to 0·356. That might do, and he believed it did do, well for Crossness, but in view of the comparative paucity of the London sewage, in albuminous matters, he thought 0·3 would be looked upon as a highly noxious effluent to obtain. He was not criticizing what was being done there, except if it were put into operation or imitated elsewhere, where the flow was smaller and the river which was to receive the result was also smaller. A small flow and a great flow, chemically speaking, depended not only upon the absolute amount to be dealt with, but upon the relative amount compared with that of the water to which it was added. At the southern outfall, a purification of 24 per cent. had taken place. If it occurred in the northern outfall he did not know that he should have referred to the figures so distinctly. One of the speakers had referred to nitrification at Crossness. He had tested some of the effluents from the filter-bed at Crossness, and to his astonishment, seeing that they were styled nitrifying beds, had found no nitrates present. It thoroughly coincided with the wide experience he had had with filter-beds, namely, the non-formation of nitrates, but the formation of carbonic acid and ammonia; but he did not say there was no such thing as nitrification. He did not wish to speak against the biological force of those organisms, but at the same time another force was at work, as he had proved by taking the material fresh from a kiln and passing through sewage, sterilized by shaking it up with chloroform. In that way he had obtained a large percentage of purification where no kind of organism could possibly have existed. He was doubtful about the watertight sewers; from a chemical point of view he could not understand how such a poor sewage as that of London could contain such abnormal amounts of chlorine, running up from 10 to 17 parts per 100,000. That tended to prove, that salt water probably found its way into some of the large sewers running down near the banks of the Thames. He did not however think it a matter of great importance if it did. His great anxiety was to stay engineers from believing that they must go to Crossness or Barking for an example of what they were able to do when they came face to face with the enormous difficulties met with in the various outflows of sewage throughout the country.

Mr. G. R. STRACHAN wished to offer a word of congratulation to Mr. Strachan. Mr. Santo Crimp upon two good works he had carried out whilst with the London County Council. In the first Paper the fact was modestly mentioned that by erecting head-walls in the precipitating channels at a cost of £1,890 the output of sludge was increased from 7,300 tons to 23,000 tons per week. He had also designed and constructed the coke-breeze filter which, as shown by the analyses, effected a high purification in the effluent from the chemical tank at the rate of 30,000 persons per acre. The figures were 1,000,000 gallons per day, which would work out in round figures to 30,000 persons per acre. With regard to the main sewerage question he was struck with the small provision made for London compared with the usual practice in provincial towns. As to the quantity taken to the treatment works, the main outflow sewers on the northern side would discharge 45,000 cubic feet per minute. In dry weather the amount of sewage was 13,000 cubic feet per minute, so there was a provision for the rainfall going through the treatment works of two and a half times the dry-weather flow in addition to the dry-weather flow. If such a thing were proposed for a provincial town it would never pass the Local Government Board; it would be condemned as insufficient. The overflows into the river must therefore be brought into action with great frequency. When a heavy rain-storm occurred over the whole of London the sewerage system would be practically resolved into the primitive simplicity of discharging straight into the river. He was also impressed with the meagre capacity of the treatment works. The precipitation-channels, which were not tanks in the ordinary sense, had a volume of 20 million gallons. The quantity of sewage dealt with was 117 million gallons, so that the tank-capacity was 17·1 per cent. of the dry-weather flow. He ventured to think those channels were not well adapted or designed for the continuous process. They were long and narrow, with the result that the sewage in dry weather passed through them when they were all in use at the rate of 4 feet a minute. The lineal velocity generally aimed at with sewage on the continuous principle was 6 inches per minute; and he thought that if the channels were larger and better proportioned, a better result would be obtained. The meagreness of the London system came very prominently into view when the quantities of chemicals used were examined. They might not be insufficient, but 3·7 grains of lime per gallon, and 1 grain of iron per gallon, was about as small a quantity as was used anywhere in England; two to three or even four times those quantities were generally used. As to the results

Mr. Strachan. of the treatment, in Appendix I, Mr. Dibdin had given the analyses of 4,380 samples of sewage, and the same number of samples of effluents from the Barking works on the northern side, spread over the whole year 1894. In the part relating to the northern outfall, the total suspended matter in the sewage was 29·8 grains per gallon; in the effluent it was 7·1 grains per gallon, which was a substantial reduction. The total dissolved matter in the sewage was 60·2 grains; in the effluent 63·2 grains, so that it had been enriched from the treatment. The amount of chlorine was 11·1 grains in the sewage, and 10·8 grains in the effluent. The oxygen absorbed from permanganate in four hours in the sewage was 3·124 grains, and in the effluent it had grown to 3·225 grains. The free ammonia of the sewage was 3·027 grains, and in the effluent 3·137 grains. The albuminoid ammonia in the sewage was 0·353 grain, and in the effluent 0·356 grain. With the exception of the large reduction in the suspended matters, it appeared that the precipitation at Barking in 1894 enriched the effluent. He appreciated that the liming apparatus was not in such a good condition at the northern outfall as at the southern. At the southern outfall the sewage was very much stronger, and there was a good percentage of reduction in the impurities. A sweep who came home dirty, could not be called clean if he took off 50 per cent. of the dirt. The question was, Was the effluent clean? With regard to the Crossness effluent in 1894 the amount of oxygen absorbed from permanganate in four hours was 3·115; the sewage on the north side was 3·124, so that the net result on the south side, taking the effluent (although there was a percentage of reduction in that particular item), was to bring it practically to the standard of the sewage on the northern side in that matter. Again, the albuminoid ammonia in the Crossness effluent was 0·331; on the northern side in the sewage it was 0·353. That was a reduction, but substantially it appeared that in the year 1894 on the northern side, the effluent was about as bad as the sewage, except with regard to the suspended matter, and at the southern outfall the standard of the effluent was raised pretty much to the standard of the northern sewage. By virtue of his position, Mr. Dibdin had been compelled to go to chemical precipitation for the treatment of London sewage. No other system was practicable under those large conditions, and he referred to the "costly" sewage farms. He should like to ask Mr. Dibdin, in his reply, to explain, or rather to criticize, the action of his colleague, Mr. Santo Crimp, with regard to his filter. Sewage farms had been recommended by Mr. Santo Crimp at

Shrewsbury, Waltham, Midhurst, Woking and Stowmarket, when, according to Mr. Dibdin, all he had to do was to dig a hole in the clay and put in coke breeze, and he would get almost as good a result without the cost of the sewage farm. He asked why Mr. Santo Crimp had adopted "costly" sewage farms when he had such a "cheap" method of dealing with the sewage ready at his hand.

Mr. J. LUNT noticed that Mr. Dibdin had pointed to the conclusion that the condition of the Thames in 1887 was due to the manganate treatment having been replaced by the chloride of lime treatment. He thought there were other factors which might equally well account for the condition of the Thames in that year. Referring to Table III, Appendix II, it would be found that in 1887 the mean temperature of the summer months was the highest recorded in the river-water for the ten years which were given, and also that the rainfall for that and the two preceding years was less than at any subsequent time. Therefore there was a minimum of fresh water going into the river, and also a higher temperature, which tended to foster the putrefaction of the polluting matters both in suspension and in solution in the Thames, and so caused its bad condition. On these grounds alone, without contrasting the two processes of deodorization, the condition of the Thames in that year might easily be accounted for. Stress was very properly laid on the amount of dissolved oxygen present in the river water at Crossness as evidence of the purity of the Thames, and Mr. Dibdin had collected a large amount of very valuable material in the Tables. In Table III were a number of analyses, given for the summer months of 1885 to 1895, which were most instructive. The figures seemed to have been taken by Mr. Dibdin with some care, in order to demonstrate the purification of the Thames which had taken place during those years. He particularly referred to the figures stating that in 1887 the amount of dissolved oxygen was 17·4, and in 1894 it had risen to 51·8 per cent. of the saturation quantity. It must be admitted that previous to 1889 the process in daily use at Crossness for the estimation of dissolved oxygen was very imperfect. It had come under the notice of Sir Henry Roscoe and himself in 1888, when they thoroughly investigated the matter. The results of this investigation had been laid before the Metropolitan Board of Works in Reports of that year, and perhaps Mr. Dibdin, after that, had altered his process to one based on more accurate methods. It was certainly significant that in the year 1889 the dissolved oxygen in the Thames water had greatly increased. In the years 1885 to 1887 the figures

Mr. Lunt. were 20, 22 and 17, and in 1888, 24. Then there was a rise to 35, 37, 41, 55 and so on. That would form a good comparison if reliance could be placed on the older figures, and if all the other figures showed a corresponding purification of the Thames. He thought those figures might well serve to show even that during the years 1885 to 1895 no purification of the Thames had taken place. For example, taking 1887 as a "notoriously bad" year as referred to by Mr. Dibdin, the total suspended matters at high water were 2·17, and in 1895, 2·47. The amount of chlorine was not of great importance, because it merely represented the amount of admixture with sea-water. The oxygen absorbed from permanganate in 4 hours was also a good indication of the amount of polluting matters in the Thames, and in the year 1885 the figure was 0·231, whereas in 1895 it was nearly 50 per cent. more, viz. 0·336. In the same way the free ammonia of 1886—when £81,000 were spent in chemicals alone for deodorization—the figure was 0·093, whereas in 1891 it was 0·261, and in 1892, 0·134. The albuminoid ammonia was also a very good indication of the amount of dissolved impurity; in 1886 it was 0·024, in 1892 it was more than 50 per cent. higher, viz., 0·038, and in 1893 0·032, and so on, so that the indications of purification given by the figures for the dissolved oxygen did not seem to be borne out by all the other figures. He asked whether, after the defects in the process used in 1885, 1886 and 1887 had been pointed out, any modification had been made in the method of estimating the dissolved oxygen, because it was previously possible to get a very high result or a very low result at will. The figures for low water might equally be read in the same sense to show that during the years given there was practically no amelioration of the condition of the river, because, taking the low-water figures for 1886, the oxygen absorbed from permanganate in 4 hours then were 0·236, and in 1895 almost 100 per cent. greater, viz., 0·466. The rainfall seemed a very important matter in the purification of the Thames. The figures from 1885 to 1887 were very low for the summer months and the temperature was higher, and those natural influences seemed to be neglected by Mr. Dibdin in drawing his conclusions as to the effects of the artificial treatment adopted.

Sir Leader Williams. Sir LEADER WILLIAMS said, in reference to what had fallen from the last speaker, it had been his good fortune to make a ship-canal in England, and his bad fortune to have it filled with sewage. During wet seasons or even during ordinary rainfall, the Manchester Ship-Canal was in a very fair state, and he did not think anyone could object to travel upon it; but when a drought, like that of

the autumn of 1896 set in, and there was also a high temperature, Sir Leader
he was bound to say it was in a bad condition. He quite appreciated, therefore, that one year's treatment of sewage could not be contrasted with that of another year under different treatment, unless the rainfall and the temperature were the same. The sewage of Lancashire was peculiar; a large variety of manufactures had to be dealt with—there were dye-works, paper-works, and chemical works, and the result of the compound was a sewage very difficult to deal with efficiently; in fact, he did not think worse sewage was to be found. He thought there was a great future before the biological treatment. He had recently been called in by the Corporation of Exeter to look into a matter connected with the River Exe, and he went with the City Surveyor to inspect the sewage works, and found the whole treatment automatic. There were cinder- or coke-breeze filters; the sewage was allowed to flow into the respective tanks full of that breeze for a time. Water was meanwhile slowly trickling into a balance-weight arrangement, which tipped over after a certain time, and the whole of the sewage passed out, and, after a time, it came back again; so that automatic tanks side by side were filled and emptied of sewage. It was a matter of experiment how long the sewage should be kept in and how much time should be given in the filters. He found the appearance of the effluent exceedingly good. There were no precipitation tanks, and the crude sewage, except for some flocculent matter and so forth, was much better than that from the Lancashire towns, and he should hardly like to say that the system would be a great success in those places. It was obvious, however, that in many towns where ordinary sewage had to be dealt with, the treatment laid down in the last Paper might be of very great value.

Mr. H. A. ROEHLING thought that as there could be no finality Mr. Roechling.
in matters pertaining to such a vast drainage-system as that under discussion, it was necessary that any extension of such a large network of drains should be carried out on well-defined and clearly laid down principles. If the Authors, therefore, could state whether, in their opinion, two main outfall stations would have at all times to be adhered to, or whether eventually the now united drainage-area would be split up into smaller independent drainage-areas with separate sewage-purification works, it would be of interest. The sewage of London did not appear particularly concentrated, and was not very heavily charged with manufacturing liquids. The sole difficulty seemed to lie in its vast volume. With regard to Mr. Dibdin's Paper, the system

Mr. Roechling, at present adopted at the outfall works might be called a partial clarification with a sewage farm, and that sewage farm was the River Thames. The difference therefore from the former treatment was simply that a certain percentage of the suspended solids was now extracted. How long a river could be used as a sewage farm depended upon its digestive powers; but at any rate in this country, the Legislature had made it an indictable offence to set up in the river putrefactive changes which discoloured the water and gave rise to obnoxious smells. As to the partial clarification of the sewage at the outfall works, he was sorry to find from the Table for 1894 (Appendix I, Table I) that the removal of suspended solids had been comparatively small, for he found that at the northern outfall in that year only 76·17 per cent. were abstracted, and at the southern outfall at Crossness only 80·32 per cent. This was disappointing, for it meant that during that year there were discharged into the Thames at the outfalls 31,910 tons of suspended solids in a dry state; or expressed in sludge, 339,246 tons with 90·70 per cent. and 91·25 per cent. of moisture. He did not think that from 20 to 25 per cent. could be called a small percentage left in the effluent. The increase in the dissolved impurities which took place at the outfall works ranged between 5 per cent. and 9 per cent. He hardly thought that would account for leaving such a large percentage of suspended solids in the effluent. He should like to ask why the percentage of increase of dissolved impurities at Crossness was 9 per cent. and at Barking only 5 per cent., although at Crossness the quantity of lime used was 26·2 per cent. less, and the percentage of moisture slightly higher than at Barking. He was particularly struck with the very great increase of suspended solids which had evidently taken place in the tanks. In the tanks at Barking it amounted to 65·77 per cent., and at Crossness 31·30 per cent. That meant that every 100 tons before treatment had been increased at Barking to about 166 tons, and at Crossness to about 131 tons after treatment. With regard to the water in the Thames, Mr. Dibdin had given the figures for eleven years—from 1885 to 1895. For convenience of comparison those years might be divided into two periods—from 1885 to 1889, the period during which no precipitation was carried out; and the period from 1890 to 1895, during which precipitation was employed. If the rainfall was first considered, and only the months of June, July and August as the most critical months of the year, excluding the exceptionally wet summer of 1888, it would be found that the rainfall in the second period, in the years from 1890 to 1895, was considerably

larger than in the first period—it might almost be said twice as large. The degree of dilution, therefore, in the second period for the impurities still left in the effluent must have been considerably greater than in the first period. From the contents of the river-water it would be found, as might be expected, that the amount of suspended solids in the second period was smaller than in the first period. But towards the end of the second period—in 1893, 1894 and 1895—the suspended solids had again increased. The treatment would not materially affect the chlorine one way or the other, and therefore he was not surprised that that had considerably increased. The “oxygen consumed,” if the test were applicable at all, showed that in the second period, from 1890 to 1895, the amount of organic impurities held in the river-water was greater than in the first period. If the periods of high and low water were distinguished, it would be found that at high water the amount of free and albuminoid ammonia had slightly decreased in the second period. At low water, however, the amounts had considerably increased in the second period. The Tables therefore showed, especially the dissolved impurities, that a gradual deterioration had taken place during the second period, although it appeared that the degree of dilution had been greater than during the first period. It was a pity that Mr. Dibdin, though no doubt he had determined the number of germs in the river-water from 1885 to 1895, had not given them; because they, generally speaking, afforded a readier and more delicate guide in judging the character of the water than analytical figures. He observed a marked contrast between the dissolved oxygen and the oxygen consumed. From the dissolved oxygen figures a very considerable improvement appeared to have taken place; but he thought the apparent difference in the results should be explained, and how the figures had been obtained. He thought the figures supplied showed that a time would come when the stomach of the Thames would not be large enough to digest all the impurities poured into it. There was no doubt that the agents which carried on the purification of the sewage in the biological filters and on a sewage farm were the same, namely, the bacteria, but the conditions under which they worked in the two media appeared to be different. On the farm the germs found a congenial home—that provided for them by nature; they found, in short, natural conditions. In the biological filter they found the reverse—they found the home provided for them by man—artificial conditions. He had called those biological filters forcing-beds, or forcing-frames, of nature, in which nature was bid to do her work at express speed and under arti-

Mr. Roechling.

Mr. Roechling. ficial conditions; and he thought it was very dangerous to force the hand of nature, especially in a case where so little was known about the very intricate processes by which the decomposition of organic matter was brought about, lest in this attempt they might create conditions which in the end might prove disastrous. It was, for instance, well known that in the process of putrefaction certain highly poisonous substances such as ptomaines, toxins, &c., were formed, and if an effluent containing these was discharged into a small stream, which during very dry weather contained practically nothing else but this effluent, he was not sure whether they would not set up conditions which would prove disastrous lower down the stream. Then, again, there was the great number of germs in the effluent, and they all knew that they reached into millions. He did not so much object to mere numbers, but before establishing filters on a large scale, he should like to be assured that neither the life-products of those germs nor the germs themselves would be able to do any more harm further down the stream. Then, with regard to the working of the biological filters, he would like to draw attention to the remarkable words which Mr. Dibdin used towards the end of his Paper, when he said, "It must not be overlooked, however, that unless the process is carefully watched, the first sign of overwork is noted by careful analyses, and rest is given when required, great risk of failure will be incurred." That was a warning note. It meant that unless those filters were under continual, careful, intelligent supervision, and unless the effluents were frequently analysed, Mr. Dibdin would not guarantee the result. But where in practice would this continual careful supervision be obtained? It was the systematic neglect of sewage-disposal works which had brought especially some sewage farms into disrepute. He had little doubt that of the two the biological filter was the more delicate, and the farm the more robust instrument; and if through neglect, or rough usage, the more robust instrument had failed in places, he had little doubt the more delicate instrument would fail too—and that considerably sooner. If the filters were under intelligent supervision, they had, undoubtedly, a great power for good; but if neglected, they had in the same degree a great power for evil. With regard to the working expenses, Mr. Dibdin gave no figures; but the expense of having a chemical laboratory with chemists superintending the filters, and a staff of labourers, would be considerable. As to the total cost of sewage purification on these lines, there was the first cost of laying down filter-beds and their working expenses, and if to that was added the cost

of erecting precipitation and sludge-disposal works, and the Mr. Roechling working expenses of these works, he was convinced that not very much more would be heard of expensive sewage farms, because, when the figures were balanced, any difference, he thought would be rather in favour of sewage farms. It would be a very interesting task to describe the various phases through which the sewage question had passed during the present century. He thought the historian would have to record that the pendulum had swung back to the position in which it stood at the commencement of the century, which was on the side of the land treatment. At that time—he believed he was right in saying—there was no other method of sewage treatment known but land treatment. Edinburgh, for instance, had used that method since 1750. Then towards the middle of the century came the boom of chemical precipitation. Chemistry and its allied sciences had made rapid strides, and this led experimenters to think there was in sewage a hidden treasure. Immediately that was hinted at, capitalists joined, and feverish energy seized each investigator to be the first to discover this wealth; patent after patent was taken out, and companies after companies were formed. Few were left to tell the tale of how much money they had spent and what small results they had obtained. This failure set scientists thinking again, and to their aid came now Pasteur's ever memorable researches into fermentation and fermentative changes; and at last it began to dawn on the scientific world that those chemical changes in decomposition were not brought about by chemical agencies at all, but by bacteria. Then Koch's discoveries furthered the investigation; and if Mr. Dibdin's experiments proved anything at all he thought they proved that the only rational and natural method of sewage purification was treatment on land. As he had pointed out the pendulum had swung back at the end of the century to where it stood at the commencement, and in future there should be no difficulty in assigning to chemicals their right place in sewage disposal.

Mr. B. BLOUNT congratulated Mr. Dibdin on perceiving that the Mr. Blount. one thing eminently desirable in these cases was to get all the lime to be used as a precipitant in solution. The old practice of adding it as a cream was thoroughly and fundamentally bad. It was never known what quantity of lime was being utilized, and what proportion was being simply sent down as a mass of superficially carbonated particles. A similar precaution should be

Mr. Blount. observed in water-softening processes; but it was not generally realized. It was by no means universally recognized that a mere mixture of lime and water was not lime-water. He would particularly comment on the use of sulphate of iron which had been combined with the use of lime. The sulphate of iron used was ferrous sulphate, whereas ferric sulphate should be used. But, as far as he knew, ferric sulphate could not be obtained cheaply and in large quantities. Nevertheless, it was the proper material, and he thought the manufacturers should supply it. There appeared no chemical reason why it should not be made as cheaply as ferrous sulphate. The ferrous sulphate only attained its full value as a precipitant when the iron which it contained had been brought to the ferric condition. The plan of separating out the coarse solid matter by means of a rough filter and getting rid of it was good; but he dissented altogether from putting it upon land and calling it manure. He thought it was much better to burn it in a destructor. That this refuse was of small value was indicated by the fact that the percentage of nitrogen was only 0·041 per cent. and phosphoric acid 0·11 per cent., calculated on the whole quantity. Again he would congratulate Mr. Dibdin on having recognized the fact that to use the crude sewage for making lime-water and a solution of ferrous sulphate was not a proper arrangement, but that the water should be drawn from a comparatively pure source. It was futile to waste chemicals which were comparatively expensive in precipitating material which would deposit itself in any case, and it was better to use a comparatively clean river-water. It was stated that the quality of the lime was such that about 110 grains per gallon were necessary to make a saturated solution. With pure lime only about 100 grains per gallon were required, so that there was a considerable excess of lime necessary to compensate for that which was not dissolved, and that which was not lime at all; the average commercial lime which was supplied was very far from being as good as engineers had a right to expect. That was a question which was as important in another direction as in sewage, namely, the question of the purification of gas in gas works. There lime was bought and sold on a specification which usually demanded a minimum purity of 90 per cent. Anything between 90 per cent. and 95 per cent. was paid for *pro rata*, and anything below 90 per cent. was rejected. Those who had no direct experience in the matter would be astonished at the difficulty found

in getting lime even of the minimum quality permitted. He Mr. Blount. would like to emphasize the remark which several speakers had made as to the methods Mr. Dibdin had used in determining free oxygen—oxygen which was actually dissolved in the water. Up to a few years ago most of the methods of determining oxygen which were extant were illusory, and it was only recently that it had been known how to determine accurately the dissolved oxygen in water. He would ask Mr. Dibdin to put on record an exact account of the methods he pursued, both in 1885 and at the present time, so that it might be made clear whether the results at the two dates were comparable. Finally, he would echo the comments which had been made on the very feeble purification which had been effected—he meant the purification as set out in Appendix I, Table I. He thought the matter could be summed up in the simplest way by saying that the function of the chemicals which were added to the sewage at Crossness and Barking was, that they acted as a coagulant of the suspended matter in the sewage and enabled the removal of this suspended matter to be effected; but he did not think they improved *per se* the character of the effluent in any important degree.

Mr. C. H. COOPER thought it was to be regretted that in the Mr. Cooper. experiments on coke-breeze filters at Barking there was no record of the performance of the filters with raw sewage. At the suggestion of Mr. Crimp he had taken out the amounts of raw sewage which had been treated on a burnt ballast filter $1\frac{1}{2}$ acre in extent constructed in 1876 at Wimbledon. From 1876 to the end of 1884 this filter received the Sunday and night sewage brought by the low-level sewer, which averaged 68,000 gallons per acre per day. In December, 1884, the Sunday sewage was diverted and had not since run on to the filter, but the night sewage continued to run on till 1893; during these latter years the night sewage treated averaged 117,000 gallons per acre per day, equivalent at the rate of flow to 3,060 persons per acre. Allowance must be made for the night sewage being weak. He did not consider there could be a more troublesome method of dealing with storm-water than that known as the separate system, especially when the storm-water sewer discharged into small streams. During the dry and warm summer of 1893 at Wimbledon only two complaints of smell from ordinary sewers came under notice, whilst over thirty were received in respect of storm-water sewers. The information given in the first Paper respecting the amount of storm-water coming off the area drained by the Counters Creek sewer was very

Mr. Cooper. instructive. Two-fifths of the rain that fell reached the sewers, amounting to 24 cubic feet per acre per minute; it was to be regretted that the rate at which this rain fell was not recorded.

Professor Corfield. Professor W. H. CORFIELD observed that the new artificial filters had caused some purification of the sewage, and that they had not yet become choked. The purification they had effected had been shown by the analysis of average samples of the sewage, and average samples of the water after it had passed through the filters. He asked how those average samples were taken, and also if equal quantities of sewage or of effluent water were taken at various times, and mixed together, and then a sample of that mixture taken. Although that was the usual method, it seemed not a proper one. It had been pointed out by the Committee appointed by the British Association some years ago to investigate the methods for the treatment and utilization of sewage, that average samples of sewage could only be obtained by taking samples of sewage in proportion to the flow at the time, and that it was useless to take equal samples of sewage if it was flowing at different rates and in different quantities at the times when the samples were taken. It was obvious that an average sample of sewage for analysis or for any other purpose, could only be taken correctly in that way. He would like to know if those samples were taken according to that method, but he did not mean that for present purposes it would make a great difference in the results that would be obtained or in the deductions from those results. With regard to the duration of those filters, Messrs. Worth and Crimp made the remark that the filter was "apparently capable of continuing its function for an indefinite time." That seemed a strong conclusion to draw from experiments with a filter that had only been at work for three months. It was stated by Mr. Dibdin that a 1-acre coke-breeze filter, which had worked for three months, and filtered 500 million gallons of effluent, had a quantity of sludge brought down to it during that period "equal to 2,232 tons of sludge of 90 per cent. moisture." In that sludge there were about 110 tons of organic matter. He presumed that meant dry organic matter, although it was not stated, and, therefore, that those 110 tons were really 110 tons out of 223 tons, and not out of 2,232. The 2,232 tons of moist sludge contained 223 tons of dry sludge, and he understood that of this 110 tons consisted of organic matter, the whole of which was oxidized, while the sand amounted to 40 tons. What became of the rest of the mineral matters which were, he supposed, clay and other matters likely to aid in clogging

up filters, was not indicated. It was stated that 40 tons of sand had been carried into the body of the coke, and that at present there was no appearance of any danger of choking arising from that cause. If after 5 years there was no sign of choking that was certainly a strong point. However, 5 years' working did not convince him that after a considerably longer period—for after all 5 years was not a very long time in the life of a filter—choking was not likely to take place. With regard to that system the manurial value of the sewage would all be lost. It had been shown that the manurial value of sewage could be utilized just the same as that of artificial manures. The Committee of the British Association in the experiments on Breton's Farm, Romford, which were continued for 5 years, showed that an average of almost exactly 33 per cent. of the nitrogen brought in the sewage on to the farm was recovered in the crops—a result which would compare favourably with those produced by artificial manures. It was stated that by the adoption of such a system the question of sewage purification “is placed on a different footing, and the necessity of costly sewage farms is entirely obviated.” He could not help thinking that that was very rash advice to give upon what he must regard as an experiment. The strongest argument, however, against the system, would be found in Mr. Dibdin's Paper where he said: “It must not be overlooked, however, that unless the process is carefully watched, the first sign of overwork is noted by careful analyses, and rest is given when required, great risk of failure will be incurred.” And further: “The filter, in fact, is a delicate organism, and requires as much care and attention to keep it in good working order as any piece of machinery.” With such a description as that it could hardly be a system to advise towns to adopt as against irrigation farms. He could not help thinking that if the money which had been spent in trying to purify the sewage of London, by means of precipitation and filtration, had been spent in taking it out further, as had been proposed, to the Maplin Sands, or some other suitable place, and disposing of it by irrigation, that money would have been very much better spent. He thought that would be resorted to in the end, however much money might be spent on experiments.

Dr. DUPRÉ expressed sympathy with Professor Corfield, who had predicted that the river would be more foul after the scheme had been in operation than before. He thought a chemist who could not take a sample was not worthy of the name. It was no doubt generally believed that a sewage-polluted river

Dr. Dupré. was injurious to the inhabitants living on its banks; but it had been repeatedly proved that that was not the case. He did not think there was a single instance to prove that a river polluted by sewage had injured any of the inhabitants living near it. That had been proved during the inquiry of the Royal Commission in London, and it had also been proved in Dublin with regard to the Liffey. He thought it had also been proved with regard to the Clyde at Glasgow, and it had been further proved with respect to the Exe at Exeter, although that river was not nearly so polluted as those just mentioned. The process which the Metropolitan Board of Works adopted was based on a long series of experiments made by Mr. Dibdin and himself. Those experiments had extended over some months on a large scale, the samples being taken by flow and not by quantity. Every process then known was tried, and the result was embodied in the report to the Metropolitan Board of Works. On that report the scheme was based. The Metropolitan Board of Works adopted the scheme, and in spite of immense opposition, stuck to their guns, and by so doing had saved millions of useless expenditure to the Metropolis. The amount of purification in the Dibdin filter was stated by Mr. Crimp to depend upon the length of time the effluent was allowed to remain in the filters, but that was a mistake. First it depended on the biological condition of the filter; and, secondly, it was absolutely essential that the filter should stand empty for a time. He might say that the so-called empty filter contained about half the amount of sewage there was in the full filter, and there was reason to suppose that the purification was proportionate to the time the filter was empty rather than to the time it was full. He asked how long the sewage must be left in the tank to allow perfect settlement to take place. He had listened to Mr. Dibdin's Paper with very great pleasure, remembering that it was only about ten years ago that the plan was called most foolish, a disgrace to civilization and to English science. The analyses had proved that all those anticipations of the opponents were entirely falsified, and he thought the conclusions of Mr. Dibdin and himself, based on the process, were perfectly justified. In his experience the amount of oxygen which remained in the river formed the best means of judging the action of the river. If the river was pure it was fully aerated; if it became foul, the fouler it was the less the amount of aëration, and it was most extraordinary how, by means of the oxygen, every foul stream that came into it could be found. When Mr. Dibdin and he were at Erith they could, after the first day, find out the hour of

the tide by means of the oxygen dissolved in the water, and could find out the sewage stream from Barking by means of the analyses of oxygen absorbed even before the eye noticed it. The oxygen absorbed allowed them, so to speak, to feel the pulse of the river; as long as the oxygen remained about 25 per cent. or 30 per cent. of the possible total there was no fear of any harm. No doubt the counting of the bacteria would also be very good. The counting of bacteria would take 2 or 3 days, whereas the oxygen took 2 or 3 minutes. There was no doubt that Sir Henry Roscoe had shown that the process known as Schützenberger's was not as accurate as was supposed, but the main point was that it was a process which could be performed badly and could also be performed well. Many processes used by chemists could be ill used and could be well used; but in the process as they used it there could be no doubt whatever that the oxygen examinations were correct within 1 per cent. or 2 per cent. of the total possible aëration. The process could, at any rate, show the difference in aëration between sea-water and river-water; the former absorbed less oxygen than the latter. Therefore he thought it might safely be concluded that the oxygen examinations then made were nearly correct. The process which Mr. Dibdin and he had recommended appeared to be even now misunderstood. In the first place they came to the conclusion that no chemical process which could be fairly adopted would, practically, do much more than precipitate the suspended matter. It removed sometimes 10 per cent. or 20 per cent., and sometimes only 5 per cent. of the dissolved matters, but it practically only clarified the sewage. Therefore they came to the conclusion on the next point that the minimum amount of chemicals which would clarify was the proper amount to take. That had another considerable advantage. The former evil effects, which were always found and were predicted with regard to the Thames, were due to the fact that so much chemicals were added that a large proportion remained in the effluent, and instead of doing all the action in the tank, the action went on in the river. By reducing the chemicals, all those injurious after-effects were eliminated. It was never intended to purify the effluent from dissolved matters; the effluent was to be clarified, but not further purified. The next point was that lime should be added in solution. It was only then that it would always be effective with the minimum amount. Fourthly, the natural action of the organism of the river, when once those suspended matters were removed, would effectively deal with the

Dr. Dupré.

Dr. Dupré. dissolved matter. Nobody at that time understood this; they had realized it and built their hopes upon it, and those hopes had not been disappointed. He might point out that the suspended matter had a much more serious effect than at first sight appeared. During cold weather there was very little oxidation of solid matter. The solid matter sank to the bottom, and partly floated about, but it was not much oxidized. When the warm summer weather came, the mud began to putrefy and rose to the surface, being also disturbed by passing vessels, and the result was that the whole of the suspended matter had to be got rid of virtually in three months. The 6 grains of suspended matter left in the sewage would be equivalent to 24 grains during the summer months, when the whole of the suspended matter would have to be disposed of. On those four points the scheme was based; and he thought Mr. Dibdin's analysis had proved conclusively that the scheme was correct, and that all the prophecies made against it had come to naught.

Mr. Binnie. MR. ALEX. R. BINNIE rose to make a few remarks upon the Papers with feelings of considerable diffidence and trepidation. First of all he must omit those terms of courtesy in which the members generally received the Authors of a Paper. He was too intimately associated with them as his colleagues to appear to praise himself by any remarks in that direction. All who rose to speak on that important subject must feel that they were directly or indirectly criticising the great works carried out by his predecessor, Sir Joseph Bazalgette, and if they claimed for themselves any modicum of praise for what in recent years had attended their efforts, they must always remember that it was to the system which Sir Joseph Bazalgette had designed that they were indebted for the means of doing so. After seven years' association with the main drainage of London he could bear his testimony wholly and entirely first to the scheme which Sir Joseph Bazalgette had designed, and secondly to the way in which the works were carried out. Those works were the largest in the world. They had been carried out and constructed in a manner second to none in the records of the profession. They were working to-day as they had been working thirty-two years ago, when Sir Joseph Bazalgette read his Paper¹ before the Institution, and he believed they would continue to work when the whole of the present members of the Institution had passed from this mortal scene. He wished to draw a few conclusions about those

¹ Minutes of Proceedings Inst. C.E., vol. xxiv. p. 280

works as to their extent and design. When those works were initiated, the population of what was now called the County of London amounted to, in 1851, 2,362,000 and in 1861 to 2,600,000 persons; and Sir Joseph Bazalgette had designed the works to accommodate a population of 3,500,000. That was arrived at, as could be seen from his Paper, on the estimate that the County of London would contain a little under 30,000 persons to the square mile. At present the works which Sir Joseph had designed, with the small additions subsequently made to them, were accommodating a population of 4,750,000. The cost of the works executed by Sir Joseph Bazalgette was £6,800,000. Up to date the total cost was £7,750,000, but as £3,500,000 of that had been paid off the present main drainage debt stood at £4,200,000. He wished to refer to some of the fundamental problems with which Sir Joseph Bazalgette had had to deal in designing the main drainage of London. Then, as now, he had been assailed by the desire to separate the sewage from the rainfall. He would read one sentence from the Paper referred to: "Applied to London, it (the separate system) would involve the re-draining of every house and every street in the Metropolis, and, according to a moderate estimate, it would lead to an expenditure of from 10 millions to 12 millions of money, while the interference with private property alone would render such a proposal intolerable."¹ He was afraid after the thirty years that the moderate 10 millions or 12 millions estimated by Sir Joseph would more nearly approach 15 millions or 20 millions. That scheme had been abandoned. Sir Joseph Bazalgette had had to deal, as shown on the map, with an old system of sewers along the valley lines, flowing into the Thames, the lower portions of those sewers in many cases flowing through low-lying land, tide-locked at high water, and consequently becoming sewers of deposit. Many members would recollect the state of the river caused by that system of drainage. Sir Joseph Bazalgette had elected to intercept, as far as possible, the sewage flowing down those old valley lines, and in doing so he fixed on certain fundamental quantities. He had provided for an average flow of sewage in twenty-four hours of 5 cubic feet, or 31¼ gallons, together with a ¼ inch of rainfall in twenty-four hours. But the sewers were constructed (and that was what so many people forgot) to carry one half of that total quantity in six hours of the day. All above that capacity of sewer-discharge was caused to flow over weirs into the previously existing valley lines, which drained

¹ Minutes of Proceedings Inst. C.E., vol. xxiv. p. 291.

Mr Binnie. the Metropolis—storm-water overflows, in fact. In that connection Sir Joseph Bazalgette said :¹ “A quantity equal to the one-hundredth part of an inch of rain in an hour, or a quarter of an inch in twenty-four hours, running into the sewers would occupy as much space as the maximum prospective flow of sewage provided for, so that if that quantity of rain were included in the intercepting sewers, the sewers would, during the six hours of maximum flow, be filled with an equal volume of sewage, and during the remaining eighteen hours additional space would be reserved for a larger quantity of rain. Taking this circumstance into consideration, and allowing for the abstraction due to the evaporation and absorption, it is probable that if the sewers are made capable of carrying off a volume equal to a rainfall of $\frac{1}{4}$ inch per day during the six hours of maximum flow, there would not be more than twelve days in a year on which the sewers would be overcharged, and then only for a short period during such days.” That initiated the various principles on which Sir Joseph constructed the main drainage of London. From the Paper which he had been quoting, he had abstracted certain fundamental facts, and had put them into the form of the following Table:—

SIR JOSEPH BAZALGETTE'S DATA IN RESPECT OF THE MAIN DRAINAGE OF LONDON.¹

Districts.	Sewage per Day of Twenty-four Hours.		Rainfall per Day of Twenty-four Hours.		Total.	
	Cubic Feet.	Gallons.	Cubic Feet.	Gallons.	Cubic Feet.	Gallons.
North of the Thames .	11,500,000	72,000,000	28,500,000	178,000,000	40,000,000	250,000,000
South of the Thames .	5,750,000	36,000,000	17,250,000	108,000,000	23,000,000	144,000,000
Total .	17,250,000	108,000,000	45,750,000	286,000,000	63,000,000	394,000,000

NOTE.—As the rate per head was taken at 5 cubic feet per day, and provision made for a total of 17,250,000 cubic feet of sewage daily, the sewers were constructed to receive the sewage of 3·45 million, say 3,500,000, persons, and made large enough to take half the daily quantity in six hours.

Although Sir Joseph Bazalgette in 1860 had provided for 5 cubic feet or $31\frac{1}{4}$ gallons as the ultimate flow of sewage, it was remarkable that he pointed out that at that time the water-supply of the Metropolis was only between 20 gallons and 25 gallons per head per

¹ Minutes of Proceedings Inst. C.E., vol. xxiv. p. 292.

day. The water-supply of the Metropolis had increased during the last year to $35\frac{1}{3}$ gallons per head per day. In the previous year, 1895, it had risen to a little over 38 gallons per head per day, consequently a population one-and-a-quarter million larger than that for which the works were designed was now being dealt with. The works were providing for 10 gallons per head larger water-supply than that existing at the time of their design, and they were actually coping with 4 gallons per head per day greater water-supply than the ultimate quantity for which Sir Joseph had provided. That led to the consideration of the means of disposing of the sewage. If the river were to be used as a means of disposal, it must be regarded as a stream capable of receiving the sewage. It was a tidal river, and in the summer and drier months depended for its purification and the downward passage to the sea of any matters which were thrown into it, mainly upon the upland river-water. What was found to be the case? That as regards the River Lea during the summer months not a drop of upland water passed into the tidal reaches. So far from that being the case water was pumped from the tidal reaches into the upper reaches to maintain the navigation. In the case of the Thames the same state of things existed, that the total minimum flow over Teddington Weir had fallen on one day in July last to 108,000,000 gallons a day, or only $44\frac{1}{2}$ per cent. of what the natural flow of the river would have been had the water not been abstracted for potable purposes; and during the whole of July of 1896 the total quantity flowing over Teddington Weir only amounted to an average of 188,000,000 gallons a day, or 58 per cent. of what would have been the natural flow. In the future, therefore, a continued increase of sewage poured into the river was to be looked to. Within the next thirty or forty years it might be anticipated that the County of London would contain about 7,000,000 persons and that the Greater London of the Census Commissioners would probably contain 11,250,000. Taking that large increase of population into account, with its increased water-supply, and its increased sewage, the difficulty was encountered that in the summer months the river flow due to the upland waters would be continually decreasing. He would now turn more particularly to those precipitation works at Barking and Crossness which formed the subject of Messrs. Worth and Crimp's Paper. He had no hesitation in saying at once that they were the largest engineering works of the kind in the world. They dealt daily with over 200,000,000 gallons of crude sewage, and over 2,000,000 tons of sludge were sent to sea 20 miles below

Mr. Binnie.

Mr. Binnie. the Nore per annum. That was carried out by means of 1,140 I.H.P. of steam, by the employment of 400 men, and six ships containing a crew of 138 officers and men; and the cost of carrying out the work of precipitation, including the repayment, interest, and sinking fund, amounted to about £150,000 per annum. The President had paid them the high compliment of speaking in terms of approbation of the effect produced on the river by their action during the past few years. He felt that what the President had said would be echoed by all who were acquainted with what the river was in the years 1880 to 1889, and what it was at the present time. When, as was anticipated the direct flow of sewage from 250,000 persons in West Ham was taken out of the River Lea, and diverted into the precipitation works, as well as the sewage which at present passed into the river from what was called North Woolwich, that island which lay between the Victoria and Albert Docks and the river, he thought a still better result would be shown. Those works which had been carried out, and the effect which had been produced, must be studied, and could only be studied by regarding the state of the river as it was up to the year 1888. The works of precipitation at Barking and Crossness were designed and commenced by his predecessor, Sir Joseph Bazalgette. Those works in their design were based very largely, if not entirely, on the data furnished by Mr. Dibdin, who had been then the chemist to the Metropolitan Board of Works, as he was now to the London County Council. At that period it was assumed¹ that the total solid matter in the sewage amounted to 27 grains per gallon, and Mr. Dibdin estimated² that the quantity of sludge to be dealt with would be about 3,000 tons per day. Those works, as was well known, were designed on a system of intermittent precipitation. The region of estimates and analyses had been passed; single gallons and grains were no longer dealt with, but daily millions of gallons of sewage were treated, and thousands of tons of sludge disposed of. The result was that the sewage of the south side of London discharged at Crossness contained about 34 grains of solid matter per gallon, and that at Barking there was, on the northern side of the Thames, about 38 grains per gallon. Nearly 5,500 tons on the average of 365 days in the year were now dealt with, and that without any enlargement of the works designed by his predecessor; but Mr. Crimp and he, at an early period of their association with those works, had made one important and fundamental alteration. They had found the

¹ Minutes of Proceedings Inst. C.E., vol. lxxxviii. p. 156.

² *Ibid.*, p. 170.

works designed to carry on the work by intermittent precipitation, Mr. Binnie and by building weir-walls at no great expense, as described in the Paper, they converted it at once into a continuous system of precipitation. The result was that in the first week after that alteration was carried out the output of sludge at Barking alone increased from 7,000 tons to 23,000 tons per week. The result of his experience during the last seven years' study of this important problem was that it was more a mechanical than a chemical one. No one who had carefully read Mr. Dibdin's Paper could say that any great improvement, chemically speaking, was effected in the effluent water which was sent out from the precipitation works at Barking and Crossness. True, by certain processes a vast amount of suspended solid matter, both organic and inorganic, had been removed from the crude sewage, but he was rather inclined to agree with Mr. Strachan, who had pointed out that the improved effluent at Crossness was to be attributed to the fact that on the southern works the precipitation channels amounted to 30 per cent. of the dry weather flow and at Barking to only $17\frac{1}{2}$ per cent., than to any improved or possible chemical treatment which the sewage had undergone. Passing from the details of those particular works to the general subject, he thought it would be admitted that since the Paper had been read by Sir Joseph Bazalgette, and since the Papers by Mr. Crimp and Mr. Dibdin had been read before that Institution ten years ago, a great change had come over the ideas of engineers. At that time, and even in the Papers then under discussion, allusions were continually seen to some chemical change produced by the oxygen in the water or in the air. Without any chemical treatment whatever, Nature would get rid of dead organic matter, whether it were passed into water or thrown on the land, and would do so without offence, provided that her capabilities were not over-tasked. It was by over-tasking her capabilities that her laws had been offended. The oxygen of the chemist of former years was now appearing quite as important as it was then, only that instead of acting in a directly chemical manner, it was the life-blood and the energy of those micro-organisms which Nature employed to do her wonderful work. From the history of that particular problem, it was found that up to 1888 or 1889 vast masses of filth, too large for Nature to cope with, were being thrown into the river; consequently, the river got into that disgusting state which was so well known. What had been done to remedy that? In the first instance, by mechanical means all the grosser solid floating particles were removed from the sewage. Those were either burnt or taken away for manurial purposes;

Mr. Binnie. they amounted to about 100 tons per week. Then daily there were removed from the sewage in the shape of sludge about 500 tons of dry matter. That was taken away by ships and thrown into the sea, where it was diluted by a large quantity of water, and brought in contact with organisms which rapidly destroyed it. The remaining portion left in the effluent was poured into the river, and, up to the present time, certainly without any great harm to the river, and which was certainly a great improvement on anything that had gone before, although not entirely satisfactory. He did not wish to be misunderstood. The final solution of the problem of dealing with sewage had not been arrived at, and probably would not for many years be arrived at. He believed that the future had in store some very remarkable and useful discoveries, but he was not inclined to go too quickly. Too little was known of the paths about to be trodden, and which were gradually leading away from the purely chemical considerations of the subject into fields of biology and bacteriology which were but unknown lands. The filters which his staff had constructed and were working, to which Messrs. Worth and Crimp on the one hand and Mr. Dibdin on the other had alluded, displayed great promise for the future, but he was not inclined to be quite so sanguine as probably those gentlemen were. He had had in past years to deal with waterworks filters, and he knew that they became clogged very often, not with organic, but with purely inorganic matter, matter which could never be acted upon by any micro-organisms, however energetic. He was anxious that those experiments should be extended on a much larger scale, and over a much longer time than had hitherto been done, lest a great expenditure should be incurred on what might ultimately prove to be fallacious data.

Mr. McDonald. Mr. A. B. McDONALD asked if the difference of level between the discharge weir at Barking, and the invert of the outfall sewer, had any effect upon the retardation of flow in the sewer. There were figures in the second Paper which did not seem to agree with the relative statements made in the first. He observed in Appendix I of Mr. Dibdin's Paper that there was scarcely any elimination of the element of albuminoid ammonia from the effluent as compared with the raw sewage. That perhaps was susceptible of explanation, but it was entirely at variance with their experience in the treatment of sewage at Glasgow. The Glasgow sewage works, which were designed by the late Mr. Alsing, and which had been the subject of high encomium by every professional man who had examined them, gave to-day a result of a very

different kind from anything he had been able to discover in the Mr. McDonald. statements in either of the Papers. The quantity of suspended matter in the Glasgow sewage was very high, amounting to as much as 24·08 grains per gallon. It was also very intractable sewage to deal with, being largely composed of dye stuff and other industrial refuse. From the precipitation-tanks, however, before the sewage went into the filter-beds, a surprisingly good effluent was obtained. The sample he exhibited had been taken from the precipitation tanks between ten and eleven o'clock on the previous morning. It was perfectly transparent, quite free from suspended matter, and it contained only 0·203 grain per gallon of albuminoid ammonia out of an average of 0·406 grain contained in the sewage, which compared very favourably with any analysis mentioned in the Papers. It had to be remarked that this result was attained in face of the circumstance that the works were now being carried on under such pressure that the sewage only received precipitation for a period of 25 minutes, whereas the designer of the works intended that the period of precipitation should last at least 1 hour. The works were now under course of extension, and when, 6 months hence, they were put into operation, with the full period of precipitation then available, it might reasonably be expected that that 0·203 grain per gallon of albuminoid ammonia would be reduced perhaps to a figure as low as that expressed in Mr. Dibdin's analysis of the effluent of the bacteriological filter. At Glasgow the suggestion that bacteriological filtering was necessary in the treatment of sewage was looked upon with apprehension. At present he was engaged in studying the design of new sewage works for the daily disposal of 37½ million gallons at Dalmuir, 12 miles nearer the sea than the sewage works at Glasgow. There the sewage, after being precipitated in tanks, designed upon a scale sufficient to provide ample time for the operation, would be discharged into estuarial water. This effluent it was believed would be altogether innocuous, entirely free from suspended matters, and would contain an amount of albuminoid ammonia scarcely perceptible to analysis. At present in Glasgow the suspended matter was altogether eliminated—24·08 grains in the gallon disappeared. The only thing that was left was a minute trace of supernatant grease, and a little filamental matter which could be caught if desired by screens and intercepted in that way without being put through the filter at all. Only recently it was imagined that sewage sludge was an article not only of no value, but it was alleged that being mixed with

Mr. McDonald. matters which possessed a slight fertilizing property, it deteriorated and sterilized whatever manurial value those substances had. The manager of the Glasgow sewage works had lately adopted a system of drying the pressed sludge, and an astonishingly ready market was found for it at the price of 25s. per ton. Orders had come in for over 2,700 tons of it, and the Corporation had been so stimulated by the result that machinery was being constructed to produce dried sludge in large quantity. There was every reason to expect that a full market would be obtained for as much as could be produced. He looked forward with great apprehension, as he had said, to the suggestion of the filter being an essential process after effective precipitation, and he hoped that the members would sustain him, in face of the reasons which he had given, in the belief that in a position such as that chosen for the new works at Dalmuir to filter sewage which had been so effectually treated as it was now at Glasgow would be superfluous and an extremely unwise expenditure of public money.

Dr. Woodhead. Dr. G. SIMS WOODHEAD had had opportunities of watching, somewhat carefully, filter-beds constructed by Mr. Scott-Moncrieff, and also some filter-beds at Exeter constructed by Mr. Cameron. There could be no doubt that if all the circumstances were favourable, it would be perhaps better to use the ideal method of throwing sewage on to land, but in that matter, as in many others, it was necessary to do what was practicable and not what was ideal. In the question of filtration it might be practicable, in certain cases at any rate, to go half way with each party. He thought the extension-filter experiments had proved that the earlier laboratory experiments as regards the breaking down of solid matter by special micro-organisms had been fully borne out. There could be no doubt that micro-organisms were capable of what was called peptonizing or breaking down nitrogenous or carbo-hydrate material. There were organisms capable of breaking up sugar and substances closely allied to them, and there were also nitrifying organisms, and organisms which had the power of forming nitrous acid. In a series of experiments he had recently carried out, along with his colleague, Dr. Wood, he had taken a quantity of crude sewage from which they had obtained, by plating out, the various micro-organisms present in the sewage. They had, by means of the Pasteur filter, filtered out every micro-organism in a considerable quantity of sewage, and then had taken out those single organisms and put them back one by one into the sterile sewage matter, because it was sterile when they had taken out the whole of the micro-organisms; and in that way they

had been able to prove that several of the organisms had the power of forming both nitric and nitrous acids. These experiments were being continued in connection with other substances, but for the present they could, by adding these organisms to the sterilized sewage, that was, sewage which had been passed through the Pasteur or Chamberland filters, produce fair quantities of both these acids, in varying proportions. They looked upon that as a very important fact, because it showed that the formation of those substances could to a certain degree be controlled. In the filters as described by Mr. Dibdin, there were undoubtedly two processes at work, and Mr. Dibdin had shown clearly that he was attempting to obtain his results by utilizing those two processes. One of the great advances recently made had been the adoption of intermittent filtration; by this means the sewage was brought comparatively slowly into contact with a very large surface of coke breeze, the substance mentioned in that special case; and as that fluid was brought into contact with the coke breeze, the solid particles, the particles which still remained in the sewage, and even some of the material in solution, were kept on the slimy surfaces exposed or presented by the coke breeze, those slimy surfaces consisting of a coating of micro-organisms. The more slowly and regularly the sewage was brought into contact with these surfaces, and the more frequently the fluid came into contact with them, the greater would be the quantity not only of solid but also of matter in solution taken out by the micro-organisms. After that had been done, it appeared, as indicated by Dr. Dupré, that the process stopped to a certain extent; the oxygen was consumed. The process of oxidation stopped there and remained stationary until a fresh quantity of air was brought into the filter, and when the filter was emptied or drained down to the bottom, the process of oxidation again went on much more rapidly, and the process of purification was continued to a higher degree than when the filter was full. Not only that, but the inflowing sewage formed a medium for washing away the products of those micro-organisms which were on the surface of the coke-breeze. This fluid, when run off again, carried with it such waste products. In his experiments with lactic acid, Pasteur had found that if he put the lactic acid organism into milk alone, the formation of lactic acid soon ceased; but if he added sufficient lime in solution to take up the lactic acid, the combined acid was rendered inert, and the organisms could go on producing lactic acid. The same result was brought about in a different way by the fluid washing away the products and leaving the organisms free to continue their work with the next batch of

Dr. Woodhead. sewage presented to them. He looked upon that as an exceedingly important point, and believed that ultimately, the purification being found to take place while the filter was empty, the filters would be slowly filled; they would then be emptied, and left as long as possible filled with air, resting, it was said, but really acting very vigorously. Of course it was not necessary to leave them any longer than the time necessary for the exhaustion of the whole of the oxygen, because as soon as that point arrived, the filter was no longer doing its work. He was not sure that ultimately lime would be used as a precipitant, in the first instance, because it appeared that almost the same results could be obtained by allowing the sewage to stand for a short time in what might be termed an exaggerated cess-pool. It was well known that organisms acted in two ways. There were certain organisms which could only take their oxygen from substances which contained oxygen bound up in them, as it were. They could not take it from the free air. There were other organisms which could take oxygen from the free air. But in a cesspool changes took place in which the anaërobic organisms, or those which did not require free oxygen, were doing a very large amount of work. Although they might not be growing at a very great rate, still they were breaking down forcibly by extracting oxygen and throwing into a nascent condition very complex organic substances found in sewage. In that process, large quantities of very offensive gases were developed, but if the process went on comparatively slowly those gases rapidly became oxidized as soon as they came into the presence of oxygen, after the first breaking-up process had taken place. The great aim was then to oxidize everything which came from that tank, allowing the oxidizing organisms, or those organisms which took the oxygen from the air, to do their special work. By a process of that kind a purification, as tested by the oxygen absorbed, of about 60 per cent. had been obtained, about equal to that mentioned by Mr. Dibdin; and there was no doubt that as that process became more fully understood even better results would be obtained. He would like to mention one or two points in connection with organisms found in sewage, because they played an important part in the process of biological filtration. Even the colon bacilli, which had been vilified so greatly, undoubtedly played a part in that condition. He mentioned that because a considerable number of these colon bacilli had been found which varied considerably in their action upon organic matter. Some produced gas freely, some did not produce

so much. But all colon bacilli which had a [pathogenic action, as Dr. Woodhead. some of them undoubtedly had, died out very rapidly in water; whereas the colon bacilli, which had been accustomed to live in water remained and continued the process of purification, in which process they were assisted by other water organisms for some time after the sewage had left the filtration tank, and had been run into a brook or river. He wished to point out that the limit of the work of those filters had not been arrived at, and if the sewage had to go on to the land, as it might profitably do under certain conditions, there could be no doubt that the process of biological filtration prepared it in a very marked degree to be a much more useful product as a manure than it could possibly be as crude sewage. If the manurial products could be thrown on to the land in a form in which they were more rapidly assimilated by plants, far more could be obtained from them than when the sewage was thrown on in a crude form, clogging the soil or allowing a large proportion of the crude manurial substances to be washed away. He looked forward to the time when biological filtration and preparation would be part of the sewage-farm process, and there could be no doubt that the most perfect conversion would be obtained if the material could be first passed through a controlled filter, and then put on to the land, where a great many of the filtration products were taken out by the various bases in the soil, as had been pointed out by Mr. Warrington and others. It had also been indicated that by this filtration sewage was rendered suitable to be utilized at leisure by the plants. He believed the filters had a great future before them in places where it was impossible to get sewage farms; and in places like London, where enormous quantities of sewage had to be dealt with, there could be no doubt that these filters would come into very general use, although perhaps not immediately. The best results could only be obtained by studying them carefully on accurate biological lines.

Mr. BALDWIN LATHAM observed from the second Paper that the Mr. Latham. quantity of suspended matter in the sewage, estimated in 1887 at 27 grains per gallon, had increased since that period to about 29 grains per gallon. But the large volume of suspended matter, which was actually removed from London sewage by the chemical process, differed enormously from the figures which Mr. Dibdin had given. Referring to the first Paper, it would be found that in the year 1894, the same year which Mr. Dibdin gave in his analysis of suspended matter as 29·8 grains per gallon at Barking, the actual quantity of dry matter carried to sea was 42·8

Mr. Latham. grains instead of 29·8 grains per gallon. Both of the Papers agreed upon the question of the percentage of moisture in the sludge; but in addition to the quantity of solid matter actually carried to sea, there was the quantity which had been taken out, amounting to nearly $1\frac{1}{2}$ grain per gallon, by those screens which had been passed into the destructors, or had been sold to the farmers. Beyond that there was still a quantity, which must be very large indeed, which in times of rain, when the storm-overflows came into operation, was carried direct into the Thames. Added to that the effluent itself contained 7·1 grains of suspended matter per gallon, so that there was in the sewage of London at least double the quantity of solid matter given by Mr. Dibdin as the quantity of solid matter in the sewage shown clearly by the figures in the Papers. In 1887 it had been pointed out that the amount of chemicals which Mr. Dibdin then proposed to use was too small to purify the sewage.¹ The result of the analyses in the Papers clearly proved that so far as the suspended matters in the sewage were concerned, practically no purification had taken place, certainly, on the north side of the Thames. He would like to ask Mr. Worth and Mr. Crimp to give the actual capacity of the tanks which were used, both at Barking and Crossness, as that was a very important point with regard to the removal of the suspended matter. It was stated to be 20 million gallons on the north, and $31\frac{1}{4}$ million on the south; but it was not indicated how much was used at a time. Taking the total capacity, it would be found that the speed at which the sewage passed through the tanks on the north was 3·84 hours, while on the south it was 9·3 hours, so that it was only two-and-a-half times slower on the south than on the north; yet the degree of purification which Mr. Dibdin attributed to the better solution of the lime, might not be due to that cause at all, but really was due to the much longer time the sewage was in the tanks on the south side compared with the north. It was curious that Mr. Dibdin had actually more suspended matter in the sewage on the south than on the north. But on referring to the first Paper, it would be found that that could not possibly be so; because on the north in 1894 it required 34,473 gallons of sewage to produce 1 ton of sludge, but on the south it required 39,058 gallons; showing that the sewage was much more dilute, and must have very much less suspended matter in it than the sewage upon the north. Upon the question of rainfall Mr. Binnie had made some remarks about the plan adopted for the

¹ Minutes of Proceedings Inst. C.E., vol. lxxxviii. p. 194 *et seq.*

Metropolis; but even in the suburbs of London a much smaller amount of rainfall was allowed to be brought into the sewers than $\frac{1}{4}$ inch per day. A gauging was given of a sewer in connection with Counters Creek, which showed that in sewers it was not a rule-of-thumb quantity that had to be dealt with passed into a sewer at a given time, but it was the actual rate at which rainfall flowed off. The actual rate at which rain flowed off in that particular district in time of heavy rain was stated by Messrs. Worth and Crimp to be $9\frac{1}{2}$ inches in that time. In the design of London sewers the length had not been taken into account; and the consequence was that that length deferred the flow of the sewage. The rain which fell in the neighbourhood of the outfalls passed away before the more distant rainfall miles away had come down, so that those sewers would discharge, and did discharge, a much larger quantity than was actually calculated as so much falling upon a given area in a given time. So far as the constructive work was concerned, no possible fault was to be found with the London sewers, but they seemed to be on too small a scale, and the storm-overflows into the Thames took place at much more frequent intervals than was desirable for the purity of the river. The bacteriological treatment of sewage had occupied his attention for many years, and now it seemed to have been taken up by Mr. Dibdin and others. He had in 1883 designed a filter to carry out that bacteriological process. It differed essentially from the process now proposed, which was simply to fill a tank with either coke-breeze or burnt ballast, turn the sewage on to it till it was full, leaving the sewage in contact with the materials in the tank, and, when it had been there for, say, 2 hours, the effluent was drawn off at the bottom, supposed to be perfectly purified. In the Friern Barnet filters, which he had designed in 1883, and which had now been working for 10 years, there was a difference of design. The filtering material was burnt ballast and coke-breeze; but on the top of the filter there were 6 inches of fine sandy soil. Those filters were perfectly ventilated at all times by constructing drains and carrying air-pipes up above the water-line. The object of placing that fine material on to the filter was to restrict the rate at which the sewage passed through. The nitrifying organisms that produced the purification attached themselves to the particles of the filter. The germs did not float about in the water, because if they did, every time the filters were discharged, away went the germs; but they adhered to the particles of the filter, and the more intimately the sewage was brought into contact with the germs the more perfect the purification. In a

Mr. Latham.

Mr. Latham. filter of the Dibdin type the actual capacity was about 40 per cent. of the cubical capacity of the filter; that was, the material occupied 60 per cent. and the liquid 40 per cent. But in a filter of that kind there would be large holes and drainage-channels, and consequently all the sewage would not naturally come in contact with the germ which was attached to the material in the filter. The moment the filter was filled the whole of the air was driven out. In a filter such as he had designed and had been so long successfully at work at Friern Barnet, the sewage trickled slowly through the whole of the material of the filter. The filter was never devoid of air, because it was never flooded. It had always a free movement of air through it, and the difference he found by comparing the effluent at the Friern Barnet filters dealing with the sewage of a population of over 8,000, was that the sample of effluent taken from that filter and kept for an indefinite time in a warm place was perfectly fresh, whereas the first sample of effluent on emptying a filter as described by the Author after a week was very foul. He therefore thought the question as to which was the best form of biological filter—especially after what he had heard from Dr. Woodhead—must be decided in favour of that which he had adopted for over 12 years. That was certainly much more advantageous than a filter such as had been described by the Authors, which really could not be called a filter because there was no filtration—it might be called a contact chamber, as the sewage was simply let into the chamber to take its chance whether or not it came into contact with the organisms. Such a process could never compare with a controlled filter such as those he had constructed at Friern Barnet, and which from the time they had been constructed, had never had a particle of material removed from or added to them.

Mr. Chatterton.

Mr. G. CHATTERTON thought the great work of the late Sir Joseph Bazalgette (whose pupil he had been, and with whom he had worked many years) with regard to the main drainage of London, afforded an example to be followed by all engineers. The intercepting of the main drainage was perhaps the finest work that had been carried out during the present century. As to the purification works, he had, in conjunction with Dr. Günther, of the British Museum, made many experiments with regard to fish-life in the Thames, sinking little boxes or corves, about 1 foot 6 inches square, in different portions of the river between Greenwich and Gravesend. The result showed that in 1880 fish could not live in the river between Gravesend and Greenwich, but they could exist below Gravesend and above Greenwich;

they were suffocated, dying from the want of free oxygen. Mr. Chatter-Greater importance had, in consequence, since been attached to the determination of the amount of free oxygen in the river. A great improvement had resulted, as shown by the fact that the London County Council were now carrying out to sea over 2,250,000 tons of liquid mud per annum, which had had a poisonous effect on the fish. The results of the processes that had been carried out were sufficiently shown by the oral testimony of the watermen, the yachtsmen, the riparian owners and the wharfingers. There could be no doubt that the Thames was an entirely different river from what it was in 1882. He thought that sufficient attention had not been paid to the report¹ of Messrs. Bidder, Hawksley and Bazalgette—one of the most remarkable reports, he thought, ever made on the subject. There was one point in it to which he should like to direct attention. In making provision for the storm-water, Messrs. Bidder, Hawksley, and Bazalgette, and Mr. Glaisher, who had been associated with them in the inquiry, had estimated it at $\frac{1}{4}$ inch in twenty-four hours reaching the sewers, or 0.4 inch falling; and that by means of sewers, since carried out, 95 per cent. of the sewage would reach the ultimate outfalls at Barking and Crossness, and only 5 per cent. would be discharged by storm-overflow into the Thames. That calculation, made probably in the dark in 1858, was one of the most remarkable ever made by those eminent engineers whose names were on the walls of the Institution. He understood that the London County Council had made the most accurate gaugings of the storm-overflows of London, showing that 96 per cent. of the total flow of the sewage of London went to the outfalls.

Dr. RIDEAL thought that in regard to the purification of the Thames, the action of the Thames Conservancy, in compelling riparian owners above London to adopt improved methods for sewage disposal, should be taken into account. That had been attended by enormous expense to the local authorities, to the benefit of the London Water Companies, and the Thames at and below London. It seemed anomalous that London should have been assisted in that way by ratepayers outside the metropolitan area; and credit should have been given by Mr. Dibdin to that assistance in bringing about the improved condition of the Thames. Although sewage purification had undoubtedly been effected, also, by the chemical treatment of the sewage at Cross-

¹ Report . . . upon the Main Drainage of the Metropolis. London, 1858. A copy is in the Library of the Institution.

Dr. Rideal. ness and Barking, it should be remembered that, strictly speaking, that was not purification of the Thames, but a removal of polluting matter from the Thames area. A convenient figure, viz., 10,000,000 tons of sludge, at 4½d. per ton, had been stated by Mr. Dibdin as that removed by the London County Council steamships. The chief lesson to be learnt from the sludge precipitation, as practised by London, was the advantage of what might be called the homœopathic chemical treatment over the former, and, even now, in other places, the present extravagant use of chemicals. It had been shown that the cheapest chemicals, viz., lime and sulphate of iron, in minimum doses, could effect the removal of suspended matter as efficiently as chemicals at higher prices and in greater quantities. Practically no soluble matter was removed except phosphates. It was gratifying to find that the results achieved had shown the fallacy of regarding land treatment or a sewage farm as a *sine quâ non* in dealing with the sewage problem. It was to be hoped that the Local Government Board would be more ready to lend a favourable ear to those modern schemes in which land treatment was omitted now that the statistics of the largest sewage problem in this country had been summarized and made available for use by other authorities. He regarded the sewage problem as capable of division under three distinct headings, viz., (1) the removal of solid suspended matter; (2) the destruction of soluble organic matter; and (3) the removal of nuisance and smell from the effluent. The latter might be called "the finishing process," and was most important. In London, the first of these processes had been accomplished by so perfect a chemical treatment and sludge removal that no treatment of the effluent had been necessary except that occasionally a "finisher" had been used. That deodorization had been effected at various times by bleaching-powder and by manganate of soda. Credit was due to Mr. Dibdin for establishing the superiority of the latter in the face of much opposition. Except in cases like London, where a large quantity of river-water acted as a diluent and natural oxidizer, a chemically treated effluent, without other treatment, obviously required for satisfactory purification a correspondingly larger quantity of deodorant than where the chemical effluent had been further treated by land or filter-beds. Even when filters were used, a deodorant was in many cases desirable and necessary. In land-treatment and in filter-beds the oxidation was effected by atmospheric oxygen, which was obviously the cheapest chemical to employ, but acted only under the influence of bacteria. It seemed that for deodorant purposes a cheap oxidizer

was wanted, and manganate of soda and bleaching-powder might Dr. Rideal, not be so cheap eventually as oxidized sea-water, or ozone obtained directly from the atmospheric oxygen by cheap electric energy. The problem of deodorization therefore resolved itself into a comparison between the cost of controlling bacteria, and the cost of generating electrical energy for rendering the oxygen in air or water available. Theoretically, the conversion of free atmospheric oxygen into ozone should be cheaper than the electrolysis of water or brine; but the convenience or utilization of the procurable oxygen necessarily conditioned the economy. As a finisher, he had recently suggested in regard to filtrates from filter-beds in which the amount of soluble organic matter was small, that probably the cheapest method would be complete aeration and exposure to sunlight in a shallow tank or open water-course. A convenient name for such a finisher would be an "insolator." In this way oxidation was effected by the aid of sunlight and chlorophyl-bearing organisms, algæ, confervæ, duckweed, and possibly watercress. The latter part of Mr. Dibdin's Paper dealt with the results obtained by his well-known experimental acre filter-bed upon chemically treated sewage. He had elsewhere¹ objected strongly to the use of the term "filter" in connection with that subject, as in Mr. Dibdin's experiments the effluent had been freed from nearly all suspended matter by chemical sedimentation. The bacterial change, although called nitrification, was something more than that, as it was certain that, besides the conversion of ammonia into nitric acid, there was also the conversion of soluble organic matter into nitrites, nitrates, carbonates, and water, simultaneously going on; carbonification or production of carbonic acid, as he had shown elsewhere, took place to a very considerable extent. This he had proved by determinations of the increase of CO₂ in the effluent and in the circumambient air, whilst it was also shown by the reduction in the amount of oxygen absorbed from permanganate. The improvement in the albuminoid ammonia in the so-called filter-beds also established the fact that organic nitrogenous soluble matter was destroyed. He had been able to corroborate Mr. Dibdin's experiments that the material for such filter-beds had little effect upon the results, and in that conviction it was noteworthy that the recommendations of the Local Government Board for many years in favour of a polarite filter-bed, which it was no secret was what Mr. Dibdin called the "proprietary

¹ Journal of the Sanitary Institute, 1897.

Dr. Rideal. material," must now be abandoned in favour of any properly constructed arrangement for ensuring the growth of the organisms which effected that change. These, as already mentioned, were not only the nitrifying organisms, but they were a variety of aerobes, living on organic carbon and nitrogen compounds in presence of air. In the experiments on the Exeter filters, referred to by Dr. Dupré and Dr. Sims Woodhead, which were similar in type to those of Mr. Dibdin, it had been shown that the bacterial oxidation took place during the period of rest, or, rather, when the filter was empty, not full. This anomaly was due to the fact that the dissolved oxygen in an effluent, even if fully aerated, was not sufficient for complete oxidation. When a filter was apparently empty, it contained, like a sponge, a very large percentage of the last dose, and the sewage matters, in contact with the air and resident organisms, were then destroyed. When the filter was full of liquid, the free oxygen was quickly consumed, so that only a short full period was necessary. Determinations of the free oxygen in a full filter-bed would indicate the time when such filter-bed should be discharged, as a longer period caused the organisms to die from drowning. By construction with sufficiently porous material, it ought to be possible to arrange a filter in which the volume of oxygen was so adjusted to the volume and strength of sewage, that by the time the available oxygen was consumed, the sewage was completely destroyed; this complete oxidation seldom obtained in practice, which necessitated insolation, further filters, land treatment and deodorant, or admixture with a large volume of river-water containing free oxygen, in which self-purification could proceed. The importance of increasing the rate of filling and shorter periods of rest had been referred to. He thought the quick removal of the liquid from the filter was wanted rather than rapid filling, and longer empty periods instead of shorter ones. The possibility of doing away with chemical treatment altogether and replacing it by a bacterial process had not been referred to by Mr. Dibdin. In a recent Report to the Sutton District Council, Mr. Dibdin had described such a process, and took credit for presenting to the community at large, in the year of Her Majesty's Jubilee, the solution of a problem, the monetary value of which he reckoned at not less than £60,000,000 sterling. He ventured to think that although the London County Council seemed apparently to undervalue Mr. Dibdin's services to them, such a boon to the nation would be appreciated by the Institution. In reference to the new process mentioned by Professor Henry Robinson, the disappearance of solid faecal

matter by natural agencies was well known to take place in Dr. Rideal's broad irrigation and in cesspools. When controlled and localized it seemed a rational method of dealing with such solids. Several processes had been proposed in recent years which were modifications of that idea, but in many of them it seemed to have been forgotten that the initial change or conversion of organic solids into soluble compounds did not involve oxidation. Cesspools were covered, manure was dug into the ground, so that absence of air and absence of light were favourable to the change. An upward-filtration tank filled with flints was used by Mr. Scott-Moncrieff; Mr. Cameron used at Exeter a closed tank with a very slow current of sewage passing through; Mr. Dibdin at Sutton used a ballast open downward filter identical with those he had used for oxidizing at Barking. The results in all these processes were the same, viz., disappearance of the sludge, formation of soluble organic compounds, evolution of carbonic acid, hydrocarbons, and sulphuretted hydrogen. The oxygen of such carbonic acid was not derived from the air, but was part of the combined oxygen existing in the organic matter. Open tanks were liable to smell, and therefore he was inclined to favour the closed form adopted by Mr. Cameron for practical working. In Mr. Dibdin's open form an anaerobic condition obtained below the surface, whilst on the surface there might be aerobic growth which tended to diminish any nuisance; but, as he had said in connection with his effluent oxidizing filters, it was a delicate organism, and required as much care and attention to keep in good working order as any piece of machinery. Although those questions were bacterial, the results were chemical, and could only be judged by chemical analysis. As mixed breeds of organisms did the work efficiently, their isolation and identification had only a scientific interest. Proper relation of the supply of sewage to that of air in the case of the oxidizing filters seemed to be the principal condition, while in the sludge liquefying or dissolving tank, time and absence of air were the principal factors. He had already pointed out that in many cases bacterial effluents had to be finished off before final disposal when Conservancy Boards or riparian owners below were very exacting. What was a satisfactory effluent? An increase in the amount of albuminoid ammonia might under certain circumstances be looked upon as a good sign in a partially treated sewage as it shows that the nitrogenous organic matter is in process of dissolution. Any conversion of solid nitrogenous matter into soluble forms obviously increases the amount of albuminoid ammonia in the liquid. He had elsewhere stated that he agreed

Dr. Rideal, with the contention that an effluent was good if, when mixed with sufficient ordinary water containing free oxygen, the ammonia and organic nitrogen were converted into nitrates. The percentage relation of oxidized nitrogen to unoxidized nitrogen and the amount of available oxygen in the stream were therefore the standard by which an effluent should be judged.

Mr. Ward. Mr. HENRY WARD spoke as a member of the Main Drainage Committee of the London County Council, and he should have been glad if that Committee had received severer criticisms than any that had been offered. He doubted whether any engineering work in the world had been better designed and carried out than the main-drainage system of London. He had been many times into the sewers, and the various work connected with them during the last six years, and he had never seen a bit of bad work. With regard to the design, the fact that it had been taken as an example in many other towns, not only in England, but throughout a large part of the world, said much in its favour. He thought the County Council and its predecessor, the Metropolitan Board of Works, had also been ably served by its chemists. They really appeared to have carried out the works without having made a single serious mistake. In reference to Mr. Strachan's criticisms that a larger provision was not made originally for storm-water, and that the sewers had a capacity of two and a half times the flow in dry weather, whereas most other towns had sewers of a capacity equal to six times the dry-weather flow, he would advance two points. A very large reservoir was constituted in the great length and extent of the sewers. When the London County Council first took over the works, it was found that many of the low-lying sewers had not been kept pumped down under ordinary circumstances, especially the one running along the Thames Embankment down to Abbey Mills. Larger pumping power had been installed, with the result that the main sewer, extending as it did many miles, was now kept almost dry; at any rate, it was well pumped down. Again, the storm rainfall, over the very large area of London often differed very much both in time and quantity. When it was considered that the district extended from Willesden in one direction to Plumstead and Crossness in the other, a distance of nearly 20 miles, it would be seen that there was an area in which it was quite possible to have a severe storm at one place and no storm at another, so that by extending the area they required less sewer capacity than if they had to do with a comparatively small district. Still, it was early recognized by the Council that this was their weakest point, and the matter had been referred in 1891

to Sir Benjamin Baker and Mr. Binnie to report on. The result Mr. Ward was that those gentlemen suggested that a further sewers should be provided at an expenditure of something like £2,000,000. That proposal had been followed only to a very small extent; but the Main Drainage Committee had in 1896 brought up strong recommendations to the Council that a very large expenditure should be made in that direction. Unfortunately, they were unable to persuade the Council of its necessity. That was largely due to the fact that the improvements in the Thames had been so indisputable that opponents again and again said that while the river was in such a splendid condition, large sums of money should not be asked for to improve it still further. As to the work of the overflows, exact records were kept of the number of hours in which each overflow worked per annum, and despite the natural increase of population, and therefore of the sewage, the number of hours that the overflows worked was less than it had been for some years past. Some speakers had expressed their doubt as to the actual purification, but he did not think that the point could be contested. There were so many authorities among those who had been opponents of the main-drainage system in times past who were now ready to recognize the greatly improved character of the river. At the site of the Barking outfall, where there was once a huge bank of mud, there might be seen, at a little below high-water mark, a considerable area of what was more or less shingle beach. That, he thought, was a sufficient proof of the state of purification. Then there were many reports as to fish being caught as high as Greenwich. There was perhaps one great difficulty which the public did not appreciate in reference to the drainage of London, namely, that so large a part of the area lay under high-water level. Along both sides of the Thames, on part of the land which had been marsh-land at one time or another, the water could only be kept out by the river wall. Under those circumstances it was difficult to get rid of the storm-water when a storm occurred at the time of high-water. The storage capacity of the sewers and, to a small extent, the pumping power had to be relied upon. There was not sufficient pumping power to deal with the whole of the storm-water; but no serious complaints had been made on that score. Under the new Building Act the Committee could prevent houses being built on land lying below high-water mark; still they had a difficulty with regard to houses built below that level in times past. The fact that the main-drainage rate all over

Mr. Ward. London was only $3\frac{1}{4}d.$ in the £ appeared to show that they could construct excellent works, pay interest on them, and also repay the capital—the whole capital would be repaid in a period of 60 years—as well as pay working expenses at a very small cost to the ratepayers. He thought many of the provincial towns would like to be able to show so low a rate as that paid in London.

Mr. Taylor. Mr. G. MIDGLEY TAYLOR noticed in Appendix I, referring to the effect of chemical treatment on the sewage of the northern and southern outfalls, that there was considerable improvement in the effluent of the southern outfall over that of the northern. That result had been attributed by Mr. Dibdin mainly to the improvement in the addition of lime-water, and Mr. Strachan had suggested that that was probably due to the increased capacity of the tanks at the southern outfall, and the opinion was corroborated by the eminent authority of Mr. Binnie. He would venture to suggest an additional reason. It would be found on p. 84, that the lime-water at the southern outfall was made with comparatively pure Thames water, and that the quantity of river-water pumped for that purpose was between 2,500,000 gallons, and 4,000,000 gallons per day, which, on the 76,000,000 gallons daily flow of sewage, amounted to about 5 per cent. He therefore thought that dilution alone would largely account for a great deal of the purification. At the same time, the river-water contained a large amount of dissolved oxygen. He would ask Mr. Dibdin if he had examined the effluent from the southern outfall, to ascertain if the dissolved oxygen had further purified the sewage, or whether it was still coming out as dissolved oxygen. In reference to the subject of upward filtration his firm had constructed filters for the upward filtration of crude sewage for some years past, and the average of three analyses of the effluent from one typical installation, made in January 1894, showed that the suspended matter was reduced to $3\frac{1}{2}$ grains per gallon; that the albuminoid ammonia was reduced from 0.44 grain to 0.3 grain per gallon, and the oxygen absorbed from 1.56 grain to 1.4 grain. The general result being, that this treatment was practically as effective as a chemical process for clarifying sewage. He agreed that a filter constituted a delicate piece of machinery. It was not every sewage works that had the advantage of such an eminent chemist as Mr. Dibdin to keep its filters in order, and he feared that if the filters were placed about the country to deal with sewage effluents for the purposes of purification without Mr. Dibdin at their head, there would be numerous failures. In regard to the cost of filtration, it would be seen that in 1894 the

cost was at the rate of £2 9s. 6d. per million gallons, and in 1895 Mr. Taylor. £1 15s. 1d. It was a pity that 1896 was not included; possibly the Authors might supply it. At any rate it would be seen that the process was expensive, and his experience led him to believe that when it was attempted to purify sewage at anything like the rate of 1 million gallons per acre per day, the cost became excessive. He therefore thought that unless there were very strong reasons for the adoption of that system of filtration, engineers would be well advised to continue the system of purification by land.

Mr. WORTH, in reply, said the population contributing to the Mr. Worth. disposal works, including those outlying districts which had the privilege of draining to London under certain conditions of payments, was 4,750,000, as nearly as could be estimated, at the end of 1896. That, calculating on the dry weather flow, gave 38 gallons per head per day. The rateable value at the end of the same year, 1896, was £37,049,886, which also included the outlying districts; 3¼d. in the £ on the rateable value was the sum required to repay the principal and interest on the capital outlay and defray all the working expenses of the main drainage of London. The remarks of Mr. Strachan with regard to the works were correct; he was also correct in stating that provincial towns would require a larger proportion of tank accommodation to the daily flow of sewage than was provided for London. He had, however, overlooked the fact that the analogy was not quite the same, as London discharged its effluent into a tidal river. Also the discharges from the various storm-overflows were not so large or so frequent as in former times, now that the pumps at the various stations had been brought and kept in the highest state of efficiency. He could only say, in reply to Mr. Roechling, that no suspended matter was manufactured at either of the outfall works. The chemist gave it, without doubt, as he found it, but it was not as ascertained by other and more reliable means; it had now reached beyond the experimental stage into a practical one: there was the bulk to be dealt with, and that could not possibly be wrong. With regard to the chemist's results, they depended on the position that the various samples were taken in the flow of the sewage, the sample might be taken too high—*i.e.*, near the surface of the flow to get an average one and so miss the heavier suspended matters which passed along nearer the invert of the outfall sewers. He thought the samples were taken somewhat as stated by Dr. Corfield—equal samples of sewage, rather than taking them in proportion to the

Mr. Worth. volumes, because it varied considerably, both as to the rate of flow and the quantities during the day. The ratio of the samples to the flow was about 1 to 115 millions; for that was the average flow passing daily at the Barking Outfall Works. The mode adopted, which he considered a more reliable and practical one, was as follows:—Records were taken during the past three years, from 1894 to 1896 inclusive, of the output of sludge taken from the sludge-settling channels before discharging from them into sludge vessels for conveyance to sea; then, having given the sludge as above indicated, with the percentage of moisture and the quantity of sewage coming down to the Outfall Works, it resolved itself into a simple arithmetical sum to obtain the suspended matter per gallon. When this was obtained, and the number of grains that passed away in the effluent added to it, deducting the number of grains per gallon of chemicals that were put into the sewage for precipitation operations, together with a proportional increase due to the carbonate of lime. In that way during the past three years it had actually ranged between 37 grains and 40 grains of suspended matter to the gallon of sewage. That result entirely ignored the 500 tons of grit and other débris which were annually dug out of the precipitation channels, and put on the spoil bank, and also 5,000 tons annually taken from the cages or screens, representing practically another 2 grains to the gallon. Turning to the sludge vessels, they had a total capacity of 6,223 tons, reckoning the sludge at 65 lbs. to the cubic foot; this gave an average to each boat of 1,037 tons, and from actual tests carefully gauged from the overhead tanks extending over a long period, the average showed a deficiency of less than 3 per cent., so that in adopting the standard of 1,000 tons, shown in the Tables in the Appendixes, pages 74, 75, and 76, it was a deficiency of $3\frac{1}{2}$ per cent., which was a fair allowance and would therefore give the maximum quantity of sludge sent away from the Barking Outfall Works, while that obtained from the sludge-settling channels gave the minimum, so that 37 grains to 40 grains, or say an average of $38\frac{1}{2}$ grains of suspended matter in the sewage as coming to the outfall from the north side of the Thames could be accepted as the minimum. The difference therefore between the result of the sludge-settling channels and the sludge steamers was less than 3 per cent. He submitted on page 159 a Table of the tests of the sludge vessels taken during 1896–97 from the overhead tanks. In the admirable remarks of Mr. Binnie, which all would appreciate, were given some valuable facts and figures which left him very little to say in reply. At the Barking precipitation channels,

SLUDGE VESSELS.

Mr. Worth.

	Bazalgette.	Barking.	Binnie.	Barrow.	Belvedere.	Burns.	Totals.	Average for each Vessel.	Adopted Standard for Cargoes.
Cubical capacity in feet . . }	37,885	36,560	34,961	34,979	35,069	34,993	214,447
Tons . . }	1,099	1,061	1,015	1,015	1,018	1,015	6,223	1,037	
Average of ten tests . }	1,083	1,012	984	991	992	986	6,048	1,008	Tons. 1,000
Deficiency, per cent. . }	1.46	4.61	2.99	2.36	2.56	2.95	2.81	2.81	3.58

NOTE.—Sludge, 65.0 lbs. per cubic foot; 34.5 cubic feet to the ton.

the tank capacity to the level of the weir-walls was 3,250,548 cubic feet, and at Crossness 3,454,900 cubic feet, or practically 17 per cent. and 30 per cent. of the day-weather flow at each station respectively. He had found that about one-sixth could be taken as the proportion for those not in use during the process of decanting the effluent and removing the sludge from the floors of the precipitation channels. It must also be remembered that at Barking there was still the old reservoir which could be used as storage, having a capacity of 35 million gallons, which was provided for the purpose of enabling the sewage to be discharged into the river as far as practicable on a falling tide previous to the construction of the precipitation works. It could still be used in respect to storing the effluent after precipitation operations for a certain time before and after ebb-tide if desirable. The cost of the 1-acre filter-bed was £1,494 2s. 5d. The particulars of working at Barking for the year 1896 were as follows:—

	Gallons.	£	s.	d.	£	s.	d.	
Precipitation	45,407,471,000	cost	40,177	18	11	= 0	17	8.36 per mill. galls.
Filtration .	192,942,111	„	226	13	11	= 1	14	1.25 „ „
Sludge (land cost) . . }	Tons. 1,410,000	„	11,730	11	8	= 2d.		per ton.
Sludge (sea cost) . . }	1,410,000	„	19,832	6	0.84	= 3.376d.		per ton.
			£71,967	10	6.84			

Mr. Worth. The following Table showed the cost of filtration of the effluent for three years :—

	£	s.	d.	
1894 . . .	2	9	6.65	per million gallons.
1895 . . .	1	15	1.39	„ „
1896 . . .	1	14	1.25	„ „

In conclusion, he thought credit was due to the Main Drainage Committee for the energetic and painstaking manner in which they had grappled with this gigantic question since the dissolution of the late Metropolitan Board of Works in 1889. Their earnest desire had been, and was, to have a purer Thames, free from all noxious substances, and the present condition of the foreshores and reaches at low water bore testimony to the success which had resulted from their efforts.

Mr. Crimp. Mr. SANTO CRIMP, in reply, thought the significance of the Table on p. 63 relating to the Isle of Dogs storm-overflow, one of the most important in London, because it was in direct communication with the invert of the northern low-level sewer, was not appreciated. It would be seen that in 1889, before the machinery at Abbey Mills was put in order, the overflow was in operation for 11 per cent. of the total time, which meant the discharge of an enormous quantity of sewage into the Thames. After the machinery had been repaired the average was $2\frac{3}{4}$ per cent. of the total time; and subsequently, when the northern outfall sewer was duplicated as far as Bromley, and the second pumping-station at Abbey Mills was provided, the storm-overflows amounted to only 0.6 per cent. of the total time. That was a matter of great importance from a sanitary point of view. Another important point was the effect of flooding in the Isle of Dogs. The poorest population of London was there congregated, many of the houses were 3 feet or 4 feet below the level of the roads, and he had seen upwards of four hundred such houses filled to the road-level with storm-water and sewage. He submitted that no work could be of greater importance from a sanitary point of view than that carried out by the London County Council for the prevention of that flooding. In order to reduce the offensiveness of the storm-overflows, the London County Council had spent £60,000, during his term of office, in constructing new inverts in the old sewers and in improving them in other respects, and the vestries had spent large sums in the same work; in fact, the whole of the old main sewers were in course of gradual reconstruction. With regard to the separate system, he thought that, so far as London was concerned, it was dead; Mr. Binnie had shown

that it was impracticable. No responsible person would ever come forward with the suggestion that the separate system should be adopted in London. He had known surface-water taken from the street outside the Institution during periods of slight rainfall, when storm-overflows were not in operation, to be eleven times as rich in albuminoid ammonia as average sewage. He would ask those who advocated the separate system whether they would like to discharge that into the river under existing conditions. The sludge liquor, far from being simply water, was the essence of sewage. Filter-pressing had been tried both at Crossness and Barking with a view to reducing its bulk, but it was cheaper to take it to sea. It certainly was better from a sanitary point of view. As the bulk could not be reduced, it was useless to refer to the percentage of liquid in the sludge. Alluding to the cost of the filter at Barking, Colonel Jones had said that for precisely similar filters at Manchester the estimate was £5,500 per acre. He had had the honour of being associated with the City Engineer of Manchester in framing the estimates, and was in a position to state that the filters did not bear any similarity whatever to those at Barking; they differed in many material respects. London equalled a hundred provincial towns rolled into one, and, as a result, the conditions were very different. It was not true that when a rain-storm came over London, the drainage system would be simply resolved into its original state, and discharge straight into the river. The most important overflow was at Old Ford; 52,000 cubic feet per minute could be brought to that point, and 30,000 cubic feet per minute could be taken away. The storm-overflows were so arranged that they could not be brought into operation until the flow was increased sixfold. When it was increased seven times six-sevenths of the sewage was still going on to Barking, and one-seventh escaped at the overflow. He knew from details he had obtained in connection with the overflow that it was in operation for less than 1 per cent. of the total time, and he believed that about 99·8 per cent. of the sewage arriving at Old Ford was conveyed to Barking. With regard to the meagre tank-capacity, he confessed that at one time he had thought that the bad effluent at Barking was due to that cause. He thought that when the works at Crossness were brought into operation better results would be obtained. At Barking the tank-capacity was 16 per cent., but at Crossness 39 per cent. of the average flow of 1895, approaching in fact the tank-capacity provided in provincial towns. It was stated by Mr. Dibdin that the chemicals were applied in a better way, and

Mr. Crimp, that was correct; but the average amount of suspended matter in the effluent at Barking for 3 years was $7\frac{1}{4}$ grains, and at Crossness $5\frac{3}{4}$ grains per gallon, and he confessed he was disappointed with the result. Mr. Strachan had asked why he had recommended sewage-farms, seeing he had had experience of filters. He had begun to make artificial filters when he was in Mr. Baldwin Latham's service in 1878, and since that time he had made upwards of 50,000 square yards of artificial filters for sewage.¹ He had not only made filters, but during the 8 years that he had been at Wimbledon, from 1882 to 1890, he had—what was more important—practical experience of their working, and working side by side with the filters was the well-known sewage-farm. It was because he had had that experience that he now recommended the sewage-farms referred to by Mr. Strachan, and had recommended upwards of thirty in addition. He did not wish, however, to say a word against filters. He had only just completed a small installation, and they were doing their work satisfactorily. He believed that both sewage-farms and filters had their own peculiar field. As to the details of the storms referred to as yielding $\frac{2}{3}$ inch of rain per hour to the sewers, on the 10th August, 0·54 inch fell in 16 minutes, and 0·60 in 34 minutes. In the first storm of the 6th September, 0·38 inch fell in 9 minutes, and in the second 0·49 in 18 minutes, and 0·56 in 26 minutes. With regard to the effect of deferred flow, there were self-recording gauges at Old Ford, and he found from one observation that he had made of a typical storm that when $\frac{9}{10}$ inch fell in less than 2 hours, the whole of the water had not run off at the end of 21 hours, when another storm occurred. The second storm ranged from 0·18 to 0·25 inch in depth, and of that only 42 per cent. had passed off at the end of 9 hours. Of that 42 per cent. 6 per cent. ran off during the 1st hour, 33 per cent. in the 2nd, 20 per cent. in the 3rd, 15 per cent. in the 4th, 11 per cent. in the 5th, tailing off to 1 per cent. in the last hour. As to the effect of length of time, he had spoken from experience, and he found that in passing the sewage quickly through artificial filters practically no purification was effected, but by passing the same sewage slowly it could be purified to practically any extent. The time the sewage must be left in the tank to allow perfect settlement to take place, depended on the amount of the chemicals used. Some suggestive information had been given in the Paper as to the effect of very light doses

¹ Minutes of Proceedings Inst. C.E., vol. lxxvi. p. 317.

at the outfalls in London. He agreed that the effect of chemicals Mr. Crimp. was simply to clarify the sewage. A considerable volume of sewage at Wimbledon had been dealt with by upward filtration, constantly and not experimentally, since 1876, and he was therefore familiar with the subject. Although the capacity of the filter-tanks referred to was only one-third of the dry-weather flow—less relatively than at Crossness—the suspended matter in the effluent was really less; and there was a substantial reduction in the dissolved impurities, the process being, in fact, as effective, if not more so, than the examples before the meeting. As stated by Mr. Taylor, his firm were constructing many of these tank-filters in England. He believed the proportion of tank capacity in operation at the same time at Barking and Crossness was about five-sixths; and the proportion of sewage discharged at the outfalls now approached 97 per cent. Considering the meagre details which the engineers who designed the scheme had to work upon, they were remarkably near in their calculation. He would say, in conclusion, that knowing the main-drainage system as he did, he thought that the younger engineers who were fortunate enough to be associated with it had an extremely good field for adding to their experience; whether regarded from a constructional point of view, or from the point of view of design, he believed it reflected the highest credit on the three eminent engineers responsible for it, and formed an enduring monument to their great abilities and scientific attainments.

Mr. W. J. DIBDIN, in reply, thought the original intention in Mr. Dibdin. treating the sewage at the Northern and Southern outfalls, by the plan he had submitted to the Royal Commission in 1884, and clearly set out on p. 80, was not remembered by many of the speakers. The absence of any material degree of purification of the matters in solution was there explained. Certain points in regard to the Barking results especially had been criticized by Mr. Strachan, but his Paper distinctly stated that it was contemplated, after considerable discussion, to spend £60,000 on a new liming-station. On pp. 86 and 87, the comparison between the estimated and actual cost was shown, and following the table on p. 87 the comparisons of various competing schemes, which were strongly supported by Sir R. Rawlinson, Sir Henry Roscoe and others, showed that these purification works had been accomplished for an expenditure of £1,000,000 as against various proposals of between £4,000,000 and £12,000,000. With regard to Colonel Jones's observations, efficient filters, suitable for all requirements, had, at his suggestion, been constructed at

Mr. Dibdin. Sutton at an expense of only £1,000 per acre. Misapprehension appeared to prevail upon the question of filter construction; he had even heard it stated that a filter would do much more if it was only "properly constructed." The construction of the retaining walls would have no effect upon the amount of work accomplished by the bacteria residing in the bed, and granite walls and marble columns would make no difference. He had recently conducted experiments at the Sutton Works in continuation of those at Barking and Sutton on sewage effluent, the results of which were embodied in his Paper. In October, 1896, a filter had, at his suggestion, been built at Sutton of burnt ballast, and the crude sewage had been turned on, to ascertain how far it was possible to induce the bacteria to dispose of the solid matters or sludge. The system had been working most efficiently for the past 4 months, and he was working out improvements on the method. He was convinced the biological treatment of sewage, without the aid of chemicals, precipitation tanks, sludge presses, etc., was an accomplished fact, and he hoped soon to be in a position to invite those members who were interested, to inspect the system, which would be so designed as to practically obviate all but the minimum of working expenses. He had used iron and lime in the manner suggested for sewage treatment 20 years ago, before he had the pleasure of knowing of Professor Robinson's work in this direction. The effluents were regarded with suspicion by Mr. Angel because the matters in solution were not attacked, but earlier in his remarks Mr. Angel had said he did not know why Mr. Dibdin should go further than merely to remove the sludge. As to the presence of nitrates, he was astonished Mr. Angel should challenge the results of hundreds of analyses by that of one sample which, he was informed, had been taken just before the filter was shut off for rest, it having shown signs of over-work. Under these circumstances he should have been astonished if nitrates had been found. Unquestionably there was another force at work besides the biological one. The action, commonly called catalytic, or contact action, was well instanced in the case of solutions of alkaloids which might be removed by a suitable filter until the filter was saturated; when, on passing pure water through the filter, portions of the alkaloids would be washed out. This showed the power of a filter to remove organic matter in solution without the aid of bacteria; but when once the filter was charged with organic matter, under suitable conditions the action of the organisms would come into play and destroy that organic matter,

and so act as a constant purifier. With regard to the erection of Mr. Dibdin. certain weir-walls at Barking, by which the output of sludge had been increased, the loss of sludge had been ascertained to be in consequence of the rate at which the effluent poured down the telescope weirs, setting up such a rapid action that it washed the sludge away. The analyses of the sewage showed approximately how much sludge should be obtained, and when this was not realized it was evident that a large quantity was escaping, although samples of the effluent taken from the tanks, when in a quiescent condition, before the opening of the telescope weirs showed a most satisfactory effluent. It was, therefore, clear that the sludge was first of all taken out of the sewage by the process, and it became perfectly clear that the whole of the sludge was not collected. When this position was clearly established to the satisfaction of the Committee, the proposals to build such weir-walls immediately received attention, and the weirs were ultimately built, with the result that since they came into action the quantity of sludge had increased to the amount previously estimated. The original telescopic weirs were of insufficient emptying capacity, and caused a rush of water to a small opening, stirring the sludge and carrying it away. The filter had been admirably built under the direction of Mr. Crimp, but he did not think the success of the biological treatment of sewage was due to the builder of the filter. After the suggestions made some years ago by Dr. Dupré and himself, nothing was heard of this method of treating sewage until the State Board of Health of Massachusetts carried out their well-known experiments, which he had further continued on a working scale, with the result that the question was now practically solved in regard to the treatment not only of effluent, but of crude sewage. In bringing about these results, he had had to depend entirely upon his staff of chemical assistants. He thought the main point at issue was—had the river been purified? If so, the more meagre their works the more economically it had been effected. The explanation of the difference of the dissolved matters in the sewage at Barking and Crossness was that the use of crude sewage and sludge liquor for making lime-water in one case and that of the use of river-water in another would increase the amount of dissolved matters. There was no doubt that objectionable effluents had been discharged from Barking. But it was to be hoped this would, in the near future, be entirely obviated, whether by the erection of a new liming-station or by what, he thought, under the conditions of present knowledge would be far more efficacious—

Mr. Dibdin. increased facilities for filtering the effluent or, better still, the crude sewage. It had never been proposed to entirely clean the sewage; if so, what degree would be admitted as sufficient? The effluent was clean enough to prevent nuisance when discharged into the river, and the purifying capacity of the river was quite equal to the present circumstances. It was no more than was intended. With regard to the modification made by Sir Henry Roscoe and Mr. Lunt in the Schutzenberger process, for estimating the quantity of oxygen dissolved in the water, in the Author's hands sufficiently good results were obtained to indicate those differences which practically were effective. Isolated tests under exceptional circumstances might give misleading results; but when the process was used carefully and an average of the tests taken, it could be relied upon to give very close approximations to the truth. He had, however, always relied, in his estimations of dissolved oxygen in water, upon the absolute or gasometric method. The dissolved oxygen was boiled out of the water in vacuo, collected over mercury, and the quantity present ascertained either by explosion with hydrogen or by absorption with pyrogallic acid, both methods being employed from time to time. This process was in use in his laboratory at the time Sir Henry Roscoe and Mr. Lunt were making their experiments with the Schutzenberger apparatus, and their Paper¹ upon the question had been without effect upon the results obtained before or since, as even they had to employ the gasometric method in order to standardize their new modification. The low-water value was the more indicative of the effect of the sewage in the river, and showed that in 1887 the suspended matters were 8.9 as against 5.5 in 1895. The quantity of oxygen absorbed from permanganate was regarded by Mr. Lunt as a fair measure of the quantity of organic matter. How much of that oxygen had been absorbed by the living organisms in the water? If the organisms were first killed by the process and then oxidized, the quantity of oxygen absorbed could not be taken as the measure of the dissolved impurity or actual putrifying matter in the river. He could not see why Mr. Lunt took the values in 1885, when manganate of soda was used, instead of 1887, when Sir Henry Roscoe was using chloride of lime, and when the figure was 0.377 instead of 0.231. In dealing with the free ammonia, Mr. Lunt omitted to say that in 1886 the river was kept in good condition for half the cost of the present system, there

¹ Journal of the Chemical Society, vol. Iv. p. 552.

being no cost for works, ships, &c. In 1886, with an expenditure of only £81,000 for chemicals, and no expense for works, the free ammonia was maintained at a quantity less than in any subsequent year except 1895, when the expense, including repayment of capital, was exactly double that in 1886. In 1887, the chloride of lime year, the ammonia (Table III, Appendix II) was 0·258 against 0·093 in the permanganate year, and 0·058 in 1895, the year in which the whole of the sewage was precipitated, and after the river had had several years in order to recuperate from its previous bad condition. With reference to the cost of the treatment and the satisfactory condition of the river in 1886, an expenditure of £81,000, with no outlay on works, sludge-ships, &c., to keep the river in a satisfactory condition, could not be called extravagant by advocates of an expense of £12,000,000, the interest on which alone would be four times the expense for chemicals used in that year. He had throughout fully appreciated the influence of rainfall. The Table on p. 91 showed that the annual rainfall for 1895 was the lowest on record for the previous period of ten years, being 18·83 against 19·8 for 1887. As for the summer rainfall, between 1886 and 1887, the permanganate year and bleach year respectively, there was practically no difference, being 4·05 in 1886 against 3·79 in 1887. He thought the figures in Table III spoke for themselves and required no further explanation. With reference to Mr. Roechling's remarks, he had pointed out that the increase of solids was due to the river-water at Crossness and the sludge liquor at Barking. The dissolved solids in the river-water at high tide and especially in the dry season was very much higher than that in the sewage. He thought Mr. Roechling confused the suspended solids in the river with the effect of the effluent. In order to increase the quantity of suspended matter in the river-water to the extent of only 1 grain per gallon, the effluent discharged from Barking and Crossness would have to contain as much as 200 grains per gallon, therefore slight differences in the quantity of suspended matter such as those shown in the Tables are not due to the few grains in the effluent. He had shown that the suspended matters in the river afforded but slight indication of the effect of the effluent upon the river. With reference to the question of dissolved oxygen, Mr. Roechling pointed out that in future it was not impossible that the stomach of the Thames would not be large enough to swallow and digest the impurities poured into it. This was the crux of the whole question, and the way to test this was to watch the aeration. If this was well maintained there need be no fear; but when it fell below a

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Mr. Dibdin, certain point an objectionable condition might be apprehended. When London was double its present size, and manufactures and shipping increased, possibly the conditions might be different, and it was always well to have additional safeguards. He hoped, however, to see the whole of the sewage of London treated in the near future by the biological process, when the Thames would be able to employ itself entirely in dealing with the refuse turned into the river in so many points other than those at Barking and Crossness. He did not fear the process of forcing the hand of Nature, as Mr. Roechling termed it, in connection with the biological treatment, any more than he was afraid to endeavour to make his garden yield a plentiful crop of vegetables instead of letting it lay waste and be covered with weeds. A properly adjusted and worked biological filter was more robust than any system of sewage farming. While tens and hundreds of thousands of pounds are being spent throughout the country upon the installation and up-keep of farms, precipitation processes and schemes of various kinds—and their cost was a most grievous burden upon the ratepayer—the properly adjusted biological process, even if burdened with the expense of a few analyses, would come to the relief of the ratepayer, and would effect a settlement of the whole of this question of sewage treatment. In his Paper of 1887 he had specifically pointed out the utility of using lime in solution in the form of lime-water. Until his specification for lime to be used at Barking and Crossness was drawn up by himself some years back, so far as he was aware, no similar specification existed. It was not until he had an opportunity in connection with other work to point out to a large gas company the absurdity of their methods of buying lime, and to suggest to them that they should adopt the system which he employed, viz., to buy lime on specification, that it came into general use. He agreed it was unfortunate that in the experiments on coke-breeze filters at Barking there was not some record of what the filter would do with raw sewage. At the time that he suggested the experiments he had referred to at Sutton, he suggested the same thing to the London County Council, but so far as he was aware, up to the present moment, no stone had been turned towards a trial of the experiments; so that, while London had been sleeping, they had been working at Sutton with the most satisfactory results. He did not agree that the best possible way of dealing with sewage had not, and probably for many years would not be arrived at. His biological investigations had shown that the problem was very nearly, if not entirely settled. Water-

works filters would not be used for this scheme; and if, in the course of years, they became clogged with inorganic matter (the Barking system had been working five years) the cost of re-sifting, or even of renewing the filtering material would be but a trifling item in comparison with the present system. If Mr. Baldwin Latham had been using biological filters in 1883, it was curious he was silent when, in his 1887 Paper, the biological question was pointed out and well discussed. He greatly regretted that he did not have the opportunity of meeting Mr. Baldwin Latham when he had taken a sample from experimental works under his direction. He agreed that the improvement of the Thames was largely due to the cessation of considerable sources of pollution higher up the Thames, and he felt satisfied that the evidence he had placed before the Royal Commission on Water Supply in 1892 had contributed largely to the improvements which had been made. By the direction of the Main Drainage Committee of the London County Council he had for some time an inspector under his charge, collecting samples from various factories and works on the Thames and Lea, which were carefully analysed and the results submitted in a printed report by that Committee to the Lea and the Thames Conservancy respectively. He agreed as to the definition raised by Dr. Rideal of "filter," or "bacteria bed;" he had endeavoured for some time past to get rid of the word "filter." It was applied to the process largely in consequence of the use of that expression by the Massachusetts authorities. In Sutton he spoke, for distinction, of one method as a "bacteria tank" and the other as a "coke-breeze filter," but a convenient expression to define the method, and yet not leave upon the mind an impression that it was a process of ordinary filtration, was still wanted. A word had been suggested by Dr. Rideal, but he ventured to think "carbonification" was too long and would be equally misleading. He thought Mr. Thudichum's experience in the question unique, in that he resided on the works from the time of their first being opened for some years; and in connection with the work personally measured the capacities of the various tanks. The results agreed with those of very careful observations made by himself in conjunction with his former colleague, Sir Joseph Bazalgette, and others. He regarded his estimate in 1883 of the quantity of suspended matters in the London sewage being under 30 grains per gallon as a remarkably close approximation to the truth, while those of Mr. Baldwin Latham and Dr. Tidy, of from 50 grains to 60 grains per gallon, and that of Dr. Frankland, of 110 grains per gallon, were baseless and extravagant. In conclusion he desired to thank the

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Mr. Dibdin. Institution for the opportunity for discussion of the Paper which he had had the honour to place before it, and which recorded the fact that, with the co-operation of Sir Joseph Bazalgette and Mr. Binnie and their respective staffs, he had been able to bring to a satisfactory conclusion a task which, ten years ago, had been declared impossible.

Correspondence.

Mr. Fairley. Mr. WILLIAM FAIRLEY thought the Tables appended to Mr. Dibdin's Paper showed very clearly the comparative purity of the River Thames before it entered the metropolitan area, and testified to the efficient manner in which the removal of pollution from the river had been accomplished by the sanitary authorities having districts adjacent to the river, under the superintendence of the Thames Conservancy. It would appear that it was only after the river had entered into the area under the London County Council that serious pollution occurred. By Table IV, Appendix III, the organic matter in suspension, in March 1894, was 0·41 per cent. at Hammersmith Bridge, rising gradually to 2·05 per cent. at Barking; while dissolved oxygen by Table III was 91·1 per cent., and 48·5 per cent. at the same places. The removal of the suspended matter from the sewage at the Outfall Works at Barking and Crossness had undoubtedly greatly assisted in removing pollution from the lower river, and there could be no doubt that within the past few years there had been a very great improvement in its sanitary condition at all states of the tide. The effluent water discharged at Barking and Crossness, judging from the analyses given in Table I, was still sewage in the ordinary sense of the word, and would undoubtedly create a serious nuisance if discharged into a river much smaller in volume than the Thames at Barking or Crossness. The analyses showed no reduction of the organic matter in solution. This might be expected when the very small amount of chemicals added to the sewage was taken into consideration, together with the fact that the tank accommodation provided was much too small, being approximately 50 million gallons of storage to 200 million gallons of flow, or approximately 25 per cent. He understood Mr. Dibdin considered that the chemicals were only necessary to assist in the clarification of the sewage, and that no reduction of the organic matter could result from their use. This was not in keeping with experience gained in many parts of the country,