PURIFICATION

OF

WATER-CARRIED SEWAGE

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DATA FOR THE GUIDANCE OF
CORPORATIONS, LOCAL BOARDS OF HEALTH
AND SANITARY AUTHORITIES

BY

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PREFACE.

ALTHOUGH sanitary authorities are more or less acquainted with the various systems employed for the treatment of water-carried sewage, they are generally perplexed when they have to apply their knowledge to the place under their immediate care, and frequently find that it is proposed to employ a system, unsuitable to the special circumstances of the case, on the ground that the same plan has succeeded at another place where the surrounding conditions were peculiarly favourable to it, but which are wanting in the locality under consideration. Such a course has led to an increase of the rates, which might have been avoided if some of the simplest rules which govern the case had not been disregarded. This arises less through pure ignorance than through the advocates of a particular system having gained sufficient influence to carry out their hobby irrespective of such rules.

The present appears to be a suitable time to take stock of, and to record impartially, what has been done in regard to the treatment of water-carried sewage, and

to reduce to a practical and useful form the mass of information and experience that is now available.

The importance of this subject is now well recognised throughout the country, both in its sanitary and financial aspects; and although it is surrounded with difficulties, these have been produced to a great extent by the pertinacity with which the broad scientific principles which apply to sewage treatment have been, and are still, disregarded.

In 1874 the Corporation of Rochdale collected, and published in a tabular form, what had been, and what was being, done by other towns. During the session of 1875 a return of a similar kind was called for in the House of Lords by Lord Rosebery, and it was published in March of the following year.

Almost simultaneously with this action on the part of Lord Rosebery, the Society of Arts held a Conference on the Health and Sewage of Towns, in May 1876, the results of which, embracing much useful information, have been embodied and published in the form of a pamphlet.

The report of a Committee appointed in June 1875, by the Local Government Board to enquire into the several modes of treating town sewage, has recently appeared, and a considerable amount of information has been collected by this Committee.

Valuable as is the matter brought together in these publications, it is not in a form which can be utilized by sanitary authorities.

The object of this work is to review and to arrange concisely the results thus obtained, and, aided by the

authors' own experience on the subject, to draw conclusions for the guidance of those who have to deal with the purification of water-carried sewage.

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7 WESTMINSTER CHAMBERS, LONDON, S.W.
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WATER-CARRIED SEWAGE.

PART I.—GENERAL CONCLUSIONS.

WATER-CARRIED sewage (which is the refuse of communities conveyed by the aid of water) varies both in quantity and quality with the density of the population, the number of water-closets in use, the volume of water supplied to the inhabitants, the number and nature of the manufactories which drain into the sewers, the amount of subsoil water which leaks into them, and the proportion of rain or surface water which is admitted into them.

It will doubtless become desirable in time to classify different qualities of sewage, but for the present it is sufficient to consider it under the heads of domestic and manufacturing, the former implying the absence of manufacturing refuse, which is present in the latter. Water-closets do not add very much to the volume of sewage, inasmuch as a water-closet contributes only about five or six gallons daily; but their use increases the value of sewage, as the average annual value of the excreta of a human being has been computed at 10*s.*

It has been proposed to diminish the amount of sewage dilution by adopting a duplicate set of sewers, one for sewage proper, the other for rain and storm water; but the advantages of this plan appear chiefly where sewage is disposed of by irrigation, and where it is abso-

lutely necessary to lift it by pumping. For irrigation it appears desirable to have sewage as concentrated as possible; but when pumping is unnecessary the dilution of sewage within certain limits is not detrimental, as the subdivision of solid matter by an admixture of water brings it into a better condition, for chemical treatment. A duplicate or separate system would involve a greater cost than a single system, whether it be in a town already sewered, or in one about to be sewered. A separate system would exclude from the sewers street and road washings which, especially after dry weather, are unfit to be admitted into streams. It would also prevent that natural flushing of sewers and branch drains by a heavy rainfall, by which solid accumulations are removed.

A careful investigation of the various systems for treating sewage leads to the conclusion that water-carried sewage has never yet yielded a profit, when all things are taken into consideration, and that it is a nuisance that must be got rid of at the expense of ratepayers, or, as recently remarked by Sir Henry Cole, K.C.B., 'towns must pay to be clean.' Local authorities have to pay for the efficient purification of their sewage, taking care to adopt a system suitable to their special circumstances, by which that cost may be minimised.

The Executive Committee of the Society of Arts Conference, in 1876, arrived at the conclusion, 'That, as a rule, no profit can be derived at present from sewage utilisation. For health's sake, without consideration of commercial profit, sewage and excreta must be got rid of at any cost.'

Mr. Rawlinson, C.B., C.E., in speaking at that Conference, said: 'To come back to the several modes of dealing with sewage, towns should look not to profit, but to the cheapest mode of dealing with it. After investigating all the best methods, he knew of none by which

a town would be benefited commercially by dealing with its sewage. These things being so, the result was, that precipitation, where you could not possibly get land for irrigation, was the best process, not to make profitable manure, for, in his opinion, profit was not to be made out of the matter deposited from sewage; at all events, he knew of no process that came within any range of profit. He had analyses from Dr. Voelcker of samples of sewage mud taken from several towns, and in no instance did he give the value with the chemical ingredients, as far as he recollected, at 20*s.* per ton; and it must be remembered that he made his analyses by drying the manures which he had tested to an extent greater than was ever done in practice. Whether farmers would give that sum, 20*s.* per ton, he was not prepared to say; but there was this great fact staring one in the face, that whatever the value of the manure might be, it did not find a ready sale. When he was at Rochdale, he saw thousands of tons which the farmers would not take away. It was evident, therefore, that whatever the value might be, at the present time the price asked did not offer sufficient inducement for farmers to buy it. 'Towns, therefore, must be content to clarify their sewage at the expense of the rates.'

Water-carried sewage should, in order to secure proper sanitary results, be dealt with within twenty-four hours of its formation, as after that period, decomposition sets in, offensive and dangerous gases are generated, and its defecation is more difficult. This is referred to in the Report of the Local Government Board Committee in 1876, p. xiv. It was also pointed out by Dr. Hofmann, who said, in giving evidence before a Select Committee on Sewage of Towns, in 1862: 'The offensiveness of sewage will depend of course upon the season of the year; but on the whole I believe that those who examine

sewage at the outfall of a sewer for the first time, will be surprised at the comparatively inoffensive character which it presents; it is only after some time, when kept in cisterns, in a state of stagnation, that it becomes offensive.' Professor Way at the same time remarked, 'Sewage is a large quantity of liquid which must be disposed of day by day, as it will not admit of accumulation.' This shows that, excepting where some process is used for the purpose of defecating the sewage, the plan of storing it in or passing it through depositing tanks is objectionable. It may be found convenient and economical to store Sunday and night sewage, but whatever mode of treatment is adopted, it should involve dealing with the sewage before decomposition sets in.

Pumping should be avoided as much as possible on account of the cost, and where unavoidable, should be reduced to the smallest possible limits. It is chiefly necessary where irrigation is adopted, as in many cases a considerable lift and horizontal distance are required to command the necessary land. Where precipitation is employed, pumping as a rule is either unnecessary, or a lift of only a few feet will suffice.

The presence of manufacturing refuse adds to the cost of dealing with sewage, but local authorities now have the power under the Rivers' Pollution Act to meet the expense thus incurred by requiring manufacturers to pay for putting their refuse into the sewers..

Litigation is almost certain to occur where large areas of land are required for irrigation purposes, as opposition arises which, although founded only on a sentimental objection, has to be met.

Ten years ago the Rivers' Pollution Commissioners pointed out, in their second Report, 1867, the danger of litigation, and said in reference to the Valley of the Lee :—

'The Lee exemplifies the evils inevitably entailed by absence of river government. Left without control, towns naturally take advantage of running water to get rid of their sewage, regardless of the fact that the process is simply a transfer of the nuisance from themselves to their neighbours lower down the stream; litigation follows; but litigation besides being expensive and breeding ill-will is unsatisfactory. Courts of law are, in fact, incompetent to deal with the difficulty, and too frequently the party proceeded against may not possess either the legal power or the pecuniary means to provide by permanent works a good and sufficient remedy. The town authorities of Luton are under a perpetual injunction obtained against them by a wealthy landed proprietor in the neigbourhood, which prohibits them from casting their sewage into the river unless it has been first treated by lime. The people of Luton have carried out the injunction strictly, and have remained safe. The New River Company, which subjects the Hertford sewage to the same process, and in a still more careful manner, is nevertheless complained of and threatened with litigation by the authorities of Ware. But in both cases the result is the same; large sums are annually spent in vain, the effluent water remains to all purposes sewage, and, except to the eye, the Lee receives both from Luton and Hertford almost as much sewage pollution as if that process had never been performed. In point of fact, if a river is really foul, it is safer that it should look so.'

Hitherto, the sewage question has been made the subject of jealous rivalry on the part of enthusiasts endeavouring to carry out either irrigation or precipitation under all conditions. It is now clearly established that each place must be dealt with according to the circumstances peculiar to it, and that it is unsafe to conclude that because some

plan of sewage disposal has succeeded in one district, it is equally certain to succeed in another. This was pointed out in 1876 by the Executive Committee of the Society of Arts Conference, thus: 'It was conclusively shown that no one system for disposing of sewage could be adopted for universal use; that different localities require different methods to suit their special peculiarities.'

The best way of dealing with water-carried sewage of villages adjoining each other is, when possible, to unite several together for sewerage and sewage purposes with works common to each group.

It is incorrect, as is sometimes alleged, that sewage is capable of being purified by the flow of the river into which it is cast, because the solid matter becomes deposited, and in the summer and dry seasons, causes a nuisance. This is evidenced by the carefully conducted experiments recorded in the first Report of the Rivers' Pollution Commissioners, pp. 18 to 22.

Although experience in treatment of sewage by precipitation is not so extensive as that by irrigation, and although the false expectations that were held out, as to the value of the resulting manure, have greatly retarded progress, yet sufficient advancement has now been made to show that an efficient precipitation process will sufficiently defecate and purify sewage for admission into streams, that it can be carried on without nuisance, and that a resulting manure can be produced which has a market value (according to Dr. Voelcker, F.R.S.), somewhat above that of farmyard manure. Further, that the purification of water-carried sewage by this means can be effected at a cost to compare favourably with the average cost of disposing of it by land alone.

In reference to this mode of treating water-carried sewage, the Rivers' Pollution Commissioners, in 1858,

came to the following conclusion:—'That considered merely as the means of mitigating a nuisance, these precipitating processes are satisfactory, that the cost of them in any case is such as town populations may reasonably be called upon to meet; that the necessary works need not, if properly conducted, be a source of nuisance, and that by modifications of the existing methods, even the slightest risk of nuisance may be entirely obviated,' and this opinion is endorsed by the Local Government Board Committee in their Report of 1876, pp. 116, 121.

The Executive Committee of the Society of Arts Conference also arrive at the following conclusions:—'With regard to the various processes based upon subsidence, precipitation, or filtration, it is evident that by some of them a sufficiently purified effluent can be produced for discharge, without injurious result, into water-courses and rivers of sufficient magnitude for its considerable dilution; and that for many towns, where land is not readily obtainable at a moderate price, those particular processes afford the most suitable means of disposing of water-carried sewage. It appears, further, that the sludge in a manurial point of view is of low and uncertain commercial value; that the cost of its conversion into a valuable manure will preclude the attainment of any adequate return on the outlay and working expenses connected therewith, and that means must therefore be used for getting rid of it without reference to possible profit.'

Manures produced from water-carried sewage by precipitation processes, where a considerable amount of useless matter (in a manurial sense) is added with the chemicals employed in treating the sewage, are almost valueless; but where the materials used in the process are small in bulk and increase rather than diminish the worth of the manure, it has a moderate value. Dr. Voelcker, in the Report on the Birmingham Sewage Inquiry in 1871,

says, at p. 47 : 'The smaller the amount of foreign matter having little or no fertilising value which is introduced into the deposit, the greater the chance will be of its finding a sale.' Agriculturalists as well as chemists differ widely as to the merits of water-carried sewage manures. Some assert that they are less stimulating than guano and such-like manures, that they are longer in their action, and that they show a greater value than the chemist assigns to them.

In the Report of the Local Government Board Committee, 1876, p. lxii, Dr. Voelcker says: 'The estimated money value of sewage and night-soil manures, as has been stated already, does not fairly represent their real commercial value. The bulk of all the samples submitted to me for analysis, consists of matters which occur in abundance in almost all soils, and which at any rate have no commercial value, or rather have a negative value, inasmuch as carriage has to be paid for them, and the application of bulky manures necessarily is more expensive than that of concentrated manures such as guano or bone-dust. It is, therefore, manifestly practically wrong to estimate the money value of such bulky and poor manures by the same standard of prices at which the commercial value of guano, bone-dust, sulphate of ammonia, and similar concentrated artificial manures are estimated. A more rational and correct estimate of the true value of sewage and night-soil manures is obtained, by comparing them with ordinary farmyard manure, and the price which is paid for the latter. Good farmyard manure,' Dr. Voelcker says, 'has a money value in round numbers of 15*s.* and a market value of 5*s.* to 7*s.* 6*d.* per ton.'

At page lxiii, he compares the values of sewage manures produced by various processes with that of farmyard manure, and it would appear from the figures there given

that a farmer would be a gainer by purchasing the best of them in preference to farmyard manure, as he would save both in carriage and labour of spreading, and that sewage sludge should find as ready a market as farmyard manure.

Another mode of dealing with sewage sludge is by fortifying it with fertilising elements so as to enable it to bear carriage to a distance.

It is not at all unlikely that midden or pail stuff may eventually be so treated as to be used for fortifying manures obtained from water-carried sewage.

The use of lime alone as a precipitant does not appear to afford satisfactory results, and the addition of some other chemical to act as a deodorant and a disinfectant is therefore requisite. General Scott, F.R.S., has lately stated that 'an effluent would be improved by the addition of either sulphate of alumina or sulphate of iron'; and Captain Flower recently says, 'Even as long ago as May, 1868, Dr. A. S. Taylor said something more than lime was necessary. My experience certainly proves he was right.'

Phosphates are not economical precipitants, as chemists seem agreed that a great amount of the derived phosphate in the manure has but little fertilising value, owing to its not being in the right form for assimilation by plants. Phosphates are, besides, costly materials to employ, and as sewage during treatment must be kept acid, there is a risk of loss from the phosphate passing off in solution with the effluent water.

It is stated by Mr. Crookes, F.R.S., that processes using phosphates as precipitants have the objection of causing the effluent to contain phosphoric acid, which produces the low confervoid growth commonly called sewage fungus.

Chemical processes do not remove all the fertilising elements from sewage, therefore the effluent water may be

used for irrigation where practicable so as not to lose those elements which remain in it. Dr. Letheby has said: 'The right way of dealing with the subject is first to defecate the sewage by means of one or other of the best precipitating processes, and then to use the clarified water upon land, if it be desirable; and if not, to discharge it into a neighbouring watercourse. By this means all desirable results may be secured; for not only may the necessary disinfection be so accomplished that the effluent water may be either used upon the land, when the season permits, or discharged into an outfall channel, but the precipitated matter may be so treated as to destroy the vitality of parasitic ova.'

It appears desirable to defecate all sewage previous to its application to land.

Colonel Hope, V.C., whose experience in sewage irrigation gives force to the opinion which he expressed at the Society of Arts Conference, says: 'The spreading of a quantity of solid matter in suspension over the surface of land in which crops are growing has a tendency to choke the pores of the soil; and, further, if the land to which the sewage is applied is in a populous neighbourhood, or surrounded, as it often is, with villas, spreading undissolved sewage matter over land is objectionable to the nose, and possibly to health; therefore, for all these reasons, it ought to be taken out before the matter in solution is distributed over the surface by irrigation.'

The solution of the sewage difficulty will, without doubt, be found in a large number of cases in a combination of precipitation with irrigation. The former for the purpose of deodorising the sewage, and removing the solid parts, and the latter for the purpose of obtaining, where necessary, a high standard of purity in the effluent water.

The conditions that it is essential to secure for the

disposal of water-carried sewage on land, apart from chemical treatment, are as follows:—

The power to acquire, without heavy parliamentary, legal, or similar expenses, sufficient land of suitable contour and quality (loam, sand, or gravel); the average quantity used in practice appears from a table given at page 32 to be not less than 389 acres to every million gallons of sewage per day to be dealt with. That the price should not exceed about 100*l.* per acre for purchase, or 3*l.* 10*s.* per acre annual rental. That the land should be situated at a moderate distance from the town, so as to avoid the heavy cost of very long outfall sewers. That it should be accessible to the sewage without the aid of pumping if possible, if not that the vertical lift should be small. That there should exist an outlet for the sale of the farm produce. That additional land should be available for the necessary extension of the farm to meet the growth of populations and the consequent increase in volume of sewage.

Where these conditions can be strictly complied with, irrigation would seem to be the best means of purifying sewage, but no profit must be expected.

The Executive Committee of the Society of Arts Conference in 1876 came to the conclusion that 'in certain localities, when land at a reasonable price can be procured, with favourable natural gradients, with soil of a suitable quality, and in sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage. It is essential, however, to bear in mind that a profit should not be looked for by the locality establishing the sewage farm, and only a moderate one to the farmer.'

The Committee of the Local Government Board, on the disposal of sewage, in 1876, arrive at the following conclusions at p. xiii of their Report:—

'That town sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes, where local conditions are favourable to its application, but that the chemical value of sewage is greatly reduced to the farmer by the fact that it must be disposed of day by day throughout the entire year, and that its volume is generally greatest when it is of the least service to the land.'

'That land irrigation is not practicable in all cases; and, therefore, other modes of dealing with sewage must be allowed.'

At page xxxvi of their Report the Committee say:—'Disappointment has therefore been expressed at the poor financial results of sewage farms. Agriculture is never a specially lucrative business, and during the last few years it is probable that strictly accurate accounts would prove that very little profit has been derived from the ordinary cultivation of arable land. Farms to which town sewage is applied have invariably many unfavourable circumstances to contend with. The rent, except where the local authority has land of its own, is certain to be extravagant; the application of sewage is often too costly; the management is frequently changeable and faulty, and the prejudice against the produce of the farm is, in some districts, obstinate and widespread. But where a fair rent is charged for suitable land, the sewage is cheaply and regularly delivered, and a good market is close at hand, there is no reason to doubt that the return for capital judiciously expended upon sewage farms will produce a higher rate of interest than the money invested by the majority of the tillage farmers throughout the country.'

Experience has, however, proved that the opinion here expressed is not in practice realised.

In the present work reference is made to seventy-nine places where, during the last quarter of a century, irrigation has either been carried out or the idea entertained. Of these one is where the system is only being discussed, nine are where, for some reason or another, it has been abandoned, seven are where it has been partially carried out for agricultural purposes only, nine are where exceptionally favourable circumstances exist, nineteen are where the operations are either incomplete or upon a small scale, and of which no information has been published, four are where the works are not yet completed, and three illustrate only the quantity of land requisite for irrigation purposes. The remaining twenty-seven represent the most important instances of the irrigation system in this country. Omitting one of these, from which full information has not been obtained, twenty-six show that the average cost of disposing of sewage by this mode is 7*l.* 16*s.* 4¼*d.* per million gallons, 1*s.* 10½*d.* per head of the population per annum, or 5$\frac{27}{32}$*d.* per pound of the rateable value, details of which are given in a table at page 28. There are eight instances, if Wrexham is included, showing a moderate loss, viz., Wrexham, Cheltenham, Rugby, Bedford, Bishops Stortford, Altrincham, Banbury, and Kendal. The first of these shows a small profit, but inasmuch as nothing is included in the accounts for the skilled management bestowed upon it, it is scarcely right to regard the small balance which it shows in such a light. It will be observed that in the eight instances last referred to the conditions necessary to sewage irrigation are favourable. Wrexham has exceptionally good land and skilful management. Cheltenham has the willing co-operation of the adjoining landowners, and Bedford has a good outlet for the produce of the farm. The others will be found more or less

weighted with heavy charges; some with the cost of pumping, as Leamington, Kidderminster, Warwick, Norwich, and Crewe; others, such as Blackburn, Northampton, Harrogate, Merthyr Tydfil, Tunbridge Wells, and West Derby, with heavy legal and other expenses incurred in the acquisition of land, &c. At Leamington, however, notwithstanding the heavy cost, no land has been purchased. At Doncaster the land employed belonged to the Corporation. At Merthyr Tydfil the character of the soil is exceptionally favourable, and so is the character of the sewage. Still, the cost at these places is very high, owing to want of compliance with one or more of the several conditions which are necessary to enable sewage irrigation to be adopted *per se*. At many of the above places the necessity for obtaining additional land already exists, thus showing that it is almost impossible to form a correct estimate of what will be the ultimate cost of sewage farming.

The Committee of the Local Government Board recognise this, and in their recent Report (p. xxxiii) say: 'A very limited experience soon teaches us that the purification of a constant flow of sewage, and which is frequently greatest when least wanted on the farm, must bring certain difficulties in its train. The cultivation of sewaged land, for instance, requires more than double the amount of manual labour which is usually employed upon arable land, and more horses must be kept than upon an ordinary farm. The amount of capital, even where the produce is sold off as soon as grown, must be greatly in excess of that required for the general ordinary cultivation of the soil; while to properly stock and work a sewage farm upon which the main produce is consumed, quite five times the usual amount of money will be needed.'

The necessary expenditure to meet growth of population and increasing volume of sewage, would seem to be

greater in the case of irrigation than precipitation, as the cost of acquiring additional land under such circumstances, even where possible, would be more uncertain than the cost of enlarging precipitating works.

It may be well now to review some of the practical difficulties that pertain to sewage treatment, where irrigation *per se* has been adopted. The insufficient amount of land with which it has been sought to conduct irrigation works has proved at the outset a source of great practical difficulty. From an average of 32 places where irrigation has been employed, it is found that 389 acres of land are requisite for a daily flow of one million gallons of sewage, as will be seen by the table at pages 31 and 32.

Even where an adequate quantity of land is at first available, it is sometimes erroneously assumed that money advanced by the Public Works' Loan Commissioners at $3\frac{1}{2}$ per cent., to be repaid in 30 years at 5*l.* 8*s.* 9*d.* per cent., will pay off the debt incurred by a sewage farm in that period of time. Not only, however, is some of the money used for this purpose borrowed from other sources at a higher rate of interest, but it is a fact that long before 30 years have expired additional expenditure of capital will be required for an extension of the farm. Statistics show that populations will have nearly doubled in that time, and that, with advancing sanitary improvements, the flow of sewage will be largely increased. Already, at Croydon, additional land is requisite to meet the growing population, and in that neighbourhood the price will doubtless be high. At Warwick and Cheltenham more land is required and cannot be obtained. At Northampton the land acquired is already found to be insufficient. At Blackburn as much as 150 years' purchase has recently been paid for additional land. At Bedford it has been found necessary to increase the area of land from time to time. At Wolverhampton an instance occurs of an entire block in

this direction, parliamentary powers having been obtained for the acquisition of 900 acres of land for sewage purposes, but at no reasonable price can the Corporation obtain more than 283 acres, consequently the works remain incomplete. For the above reason, it has been preferred in this work, in arriving at the financial results of sewage works, to adopt 5 per cent. as an annual charge on all capital expended.

In order to meet the difficulty in obtaining sufficient land for irrigation *per se*, the laboratory experiments of Dr. Frankland, F.R.S., which were made some years ago for the Rivers Pollution Commissioners, have been applied to the treatment of sewage by what has been termed 'Intermittent Downward Filtration.' Dr. Frankland calculated from his experiments that one acre of land of suitable quality, deeply drained and properly prepared, would purify the sewage of 3,300 persons; but he did not calculate how long it would continue to act, neither did he consider the effect of varying qualities of sewage in his experiments. The following objections were advanced against this system by the Rivers Pollution Commissioners themselves (1st Rep. pp. 62–70):—

'1st. It is entirely unremunerative; the amount of sewage applied to a given area of land being probably, in such a case, too great to permit of the growth of any ordinary agricultural crop.

'2nd. The whole of the manure ingredients of the sewage would be absolutely wasted.

'3rd. The collection of solid fæcal matters upon the surface of the soil, with no vegetation to make use of them, would probably give rise to a formidable nuisance, especially in hot weather.'

The plan was first put into practice at Merthyr Tydfil, where, in 1870, twenty acres of land were prepared by Mr. Bailey Denton. It is thus described by Sir

Joseph Bazalgette, at p. 53 of his evidence before Sir John Hawkshaw's Commission on the Purification of the Clyde: —'There is another process which is very much in favour at this moment, because it helps to get rid of what I may call the land difficulty, and that is the intermittent downward filtration system, which Mr. Bailey Denton has started at Merthyr Tydfil, based upon the experiments of Dr. Frankland, who showed, by experiments which he made, that the sewage from 3,000 people could be filtered through an acre of land, drained two yards deep, so as to purify it entirely. Based upon that theory, Mr. Bailey Denton laid out a farm at Merthyr Tydfil, and he drained it two yards deep, and poured the sewage, for a short time, of 1,000 people per acre, upon that land; and then, based upon that experiment, it is proposed that all over the country where there is a difficulty about obtaining sufficient lands for sewage farms, to fall back upon intermittent downward filtration, and to put the sewage of 1,500, or 2,000 people, to an acre of land, regardless of the soil. That proposition rendered it necessary that I should go, about two years ago, to Merthyr Tydfil to see what was done, and there I found that there was a gravelly soil 50 feet in depth, an admirable opportunity of drainage, and circumstances more favourable than could be obtained almost in any other place, and that they did for about six months, under those favourable conditions, apply the sewage of 1,000 people to the acre without causing any nuisance; but that the engineer who had charge of it, a very intelligent engineer of the name of Harpur, came to the conclusion that even under those favourable conditions you could not apply the sewage of more than 500 people to an acre safely and permanently. The plan for this process which they adopt is to take three acres to begin with; they divide it into three, and they irrigate one acre for one year and leave the other two acres at

rest. Next year they turn the sewage upon the second acre, leaving the acre which has been under sewage for the former year, two years to purify itself again. Now, that calculation means that before the year was out for some time, and for some time after the year was out, the land has been charged very heavily with sewage, and therefore cannot have been in a proper state for purifying sewage. Then they divide the acre which is in use into three parts also, and they pour the sewage for eight hours upon one part, eight hours on another, and for the remaining eight hours upon the remaining third; therefore, if there are 1,000 people to the acre, there is going on a portion of the land for a year, the sewage of 3,000 people —that is 1,000 people upon one-third of an acre, which is equal to 3,000 per acre. The theory is, and it is a very good theory, that the sewage should be allowed to go through land well drained and well aerated, and coming in contact with the air it is oxydised and purified; but, if it is allowed to be upon the land for any length of time, it gets clogged, and the sewage is not purified; and therefore they apply it intermittently, and they allow time for the air to pass through it. It is a very useful plan, as are all other modes of dealing with sewage under certain conditions; but it is very apt to be taken up as most of those theories are, and applied too extensively, which must only end in great disaster.'

In practice, filtration of crude or untreated sewage has not been successful. Mr. Crookes says, in evidence before Sir John Hawkshaw's Commission on the Purification of the Clyde: 'Sewage is the most difficult thing possible to filter. You cannot filter it through filtering paper; it contains a kind of glutinous papier-maché stuff which clogs up any filter.'

What is true of other filtering media is true of land, and also equally true of intermittent downward filtra-

tion. Mr. Crookes says, in reference to this plan: 'I would expect those filters soon to fill up; they must not be so open that the solid matter in the sewage will pass through, and they will be then so close that they will soon clog up. Filters might probably answer very well for a few years.'

Dr. Frankland stated that one acre of land was sufficient to purify the sewage of 3,300 persons. It was afterwards put at one acre to 1,000 persons, and more recently at one acre to 500 persons. The Report of the Local Government Board Committee states (p. 24), that at Merthyr Tydfil 'the land-filter-beds have since 1872 been treated as ordinary irrigation ground, and are now so used, together with 230 acres of the other portions of the land, as a sewage irrigation farm.'

In a Paper recently read before the Institution of Civil Engineers, by Mr. C. N. Bazalgette, it is stated that Dr. Frankland's experiments, 'instead of having been confirmed, have been refuted by subsequent practice,' and that the true facts at Merthyr are, 'that for five months the sewage was applied in the proportion of 1,000, or, at most, 1,250 persons to an acre, then of 500 persons to an acre, and afterwards permanently of 229 persons to an acre. That though the formation necessary for downward filtration has been preserved, to all intents and purposes the filters are performing the permanent functions of an ordinary sewage irrigation farm.'

Had such a plan succeeded in economising the use of land, it would have done so at Merthyr Tydfil, as the sewage and soil are both favourable. At Kendal also the circumstances are exceptionally favourable to filtration; but it appears from the Report of the Committee of the Local Government Board (p. 32), that there also the filtering area has recently been doubled.

Intermittent downward filtration has been tried at

Wellingborough, unsuccessfully. At Wrexham it was given up. It was tried at Cheltenham, but very little was said about it there. At the Lodge Farm, Barking, it was extensively and carefully tried under Mr. Morgan's supervision, and completely failed. (Soc. Arts, p. 73.)

At Nottingham, it has recently been suggested that 500 acres can be made to treat a daily flow of 5,000,000 gallons of sewage of a manufacturing character, but this would be at variance with practical experience now gained elsewhere.

Proper skilled supervision, though rarely obtained, is absolutely necessary, not only in an agricultural but also in a sanitary point of view, in conducting a sewage farm, as the sewage must be dealt with continuously both in dry weather, when it is required, and in winter and during wet seasons when it is not required.

Dr. Carpenter, in giving the result of his experience in sewage irrigation, at the Society of Arts' Conference, states that if the men employed upon the farm neglect their duty the sewage is apt to flow over the land without going through it. He further says, that at Croydon sewage farm, 'mischievous people often break down the carriers and other works and let the sewage run where it ought not to go; in that way it might get into the effluent water.'

The mismanagement of some sewage farms has brought discredit upon the system. This was pointed out in a Paper read before the Society of Arts, December 1, 1875, by the late Dr. Smee, F.R.S., in which also various rules for the management of sewage lands are suggested.

Most of the published information about sewage farms deals with the agricultural value of sewage, and states that, by its application to land, large crops of a certain kind can be grown; but the conditions of applying the sewage, the limited variety of crops, and their cost, have been too much

lost sight of, and the sanitary aspect of the question which now confronts local authorities has been less fully considered.

M. Depaire stated, at the Brussels International Congress (an account of which appeared in the 'Standard,' October 7, 1876), 'that he believed the question of the utilisation of sewage was about to receive a definite and satisfactory solution.' 'A large collection of splendid vegetables was at the same time exhibited. These were grown on the plain of Gennevilliers, near Paris. They were shown as examples of the crops grown in fields irrigated by the sewage of Paris.' The only fact, however, proved by the exhibition of those vegetable productions, was, that they were grown with sewage, but, nothing was stated as to the cost of production.

The limited variety of crops that can be grown with sewage was stated in evidence before the Select Committee on Sewage of Towns, in 1862, when it was shown that sewage is not suitable for wheat, corn or green crops, as they will not allow of a daily regular application of liquid; but that crops of a succulent nature only, such as Italian rye-grass, osiers, and mangold-wurtzel, can be grown under sewage irrigation in this country.

In respect to this, the Committee of the Local Government Board, in 1876 (p. xxxii of Report), say: 'The continuous application of town sewage to all soils is by no means an unalloyed benefit; as in some cases and seasons and especially upon clay-land it may be rather injurious than otherwise. Very few crops are actually benefited by the direct application of sewage upon a stiff and retentive soil; indeed, Italian rye-grass, cabbage, and mangold-wurtzel seem to be the only crops that persistently flourish upon any soil, heavy or light, under continual doses of town sewage.'

Considerable difficulty arises in disposing of sewage-

grown produce. The Birmingham Sewage Inquiry Committee, in 1871 (p. xvii of Report), referred to this practical difficulty, and, in reference to a suggested farm of 4,800 acres of land for the disposal of their sewage, they said: 'Local experience renders it manifest that such an area could not be used with advantage, for the rye-grass now grown upon part of the 140 acres of the Corporation Sewage Farm, at Saltley, can scarcely be disposed of, and how much greater must the difficulty of disposal become, supposing the requisite quantity of 4,800 acres to be employed for the growth of such crops as those above described.'

Mr. Chalmers Morton, who has given a good deal of attention to sewage agriculture, also states, in a work called 'Half-a-dozen Sewage Farms:' 'One of the greatest difficulties which have to be encountered in sewage farming is that of finding a market for its produce.' It is not uncommon to see ricks of rye-grass (too coarse in quality to attract the attention of farmers in the neighbourhood) stand from season to season on a sewage farm, as well as quantities of mangolds remaining unsold after the season is over.

Where a farm is not favourably situated as regards a ready market for the produce, stocking it has been resorted to, by which the produce is consumed on the premises; but this necessitates the employment of additional capital with the attendant risks of dealing with cattle.

Difficulty arises generally where sewage farms are let upon lease. In dry weather a farmer desires to have sewage, and in wet weather he does not, and as the farmer's interest and that of the sanitary authority responsible for the purification of sewage are not identical, the farmer preferring the condition of his crops to that of the river, local authorities run a risk of their sewage not being

purified. The Select Committee on Sewage of Towns foresaw this in 1862, and pointed out (as stated also in the Report of the Committee of the Local Government Board in 1876, p. 128), the necessity for local authorities keeping the control of sewage in their own hands.

Where land is taken on lease for a sewage farm, difficulty is likely to occur in its renewal at the expiration of the term. In reference to this, at Croydon, where the lease of the land expires in the year 1892, Dr. Carpenter said, at the Society of Arts Conference, 'before that time is out, I trust, the utilisation of sewage will be so understood as to render it unnecessary for a renewal of the leases upon the present onerous and unsatisfactory basis.'

The length of time that land will continue to take raw sewage will depend upon the quantity placed upon it, and the amount of vegetation grown thereon; but, under ordinary sewage-irrigation as practised in England, it is by no means certain how often a complete change of land may be necessary. The irrigated fields at Milan are sometimes quoted as an illustration of sewage-farming, but there the sewage is not always applied to the same land, an arrangement existing by which it is provided that the sewage shall not be applied to the same spot for more than six or seven years continuously.

In respect to this, the Committee of the Local Government Board state (Rep., p. xxxvi): 'We have been assured by a gentleman of vast experience that the long-continued application of sewage to the same land fails to produce the like beneficial effect as when it was first used.'

It should be observed that sewage cannot be sufficiently purified by flowing *over* instead of *through* land. As far back as 1862 an injunction was granted against the Local Board at Croydon for allowing sewage to pass into the Wandle unpurified. In this case, though the sewage was clear in appearance, it went *over* and not

through the land, as stated by Professor Way in evidence (First Report, Committee on Sewage of Towns, 1862, p. 38).

Although it has been sought to attribute disease to sewage-irrigation, none as yet has been decidedly traced to it. Sewage-irrigation, without previous chemical treatment, may, however, be attended with insanitary effects, owing to offensive emanations, the percolation of sewage into subsoil water, and thence into springs and wells, or to the distribution of undefecated sewage charged with disease-germs. The Rivers Pollution Commissioners (at p. 87 of their First Report, 1868,) pointed out that odours do arise from land irrigated with sewage day after day for years, especially with limited areas.

It is improbable that the high standards of purity laid down in the Reports of the Rivers Pollution Commissioners will be practically insisted on, and the inspectors of the Local Government Board, with whom, under the Rivers Pollution Act, this point rests, will doubtless vary the standard to meet different conditions.

Although no known chemical system *per se* will render sewage perfectly pure, there are chemical combinations for the treatment of sewage which, at a moderate cost, produce an effluent water pure enough for all practical and sanitary purposes, and, if supplemented by irrigation or filtration of the effluent water on a small amount of land, are quite capable of complying with the highest standards of purity.

A suggestion made by Mr. Crookes (Soc. Arts, pp. 80, 81) for a standard of purity to be adopted, from a common-sense way of looking at it, was this, 'that any effluent should be better than the water of the river into which it was put. If that process were adopted universally, it would tend to purify the river naturally. The manufactories at the top of the river would of course have the highest standard of purity to

work up to, those lower down would for some years have the standard very low, but it would go on increasing as they found the means of purifying the water they threw in. In that way, by making the river itself the standard of purity, the thing would work itself round; until at last you came to this point, that nobody could put anything into the river, because, from one end to the other, it was as pure as the mountain stream which gave it birth. Then would come the time for chemical analysis.'

He also said: 'There were one or two points connected with the effluent from precipitation processes which ought to be borne in mind. In the first place, you must not have an alkaline effluent, because wherever there was alkalinity there was a tendency to putrefaction, as had been proved over and over again. Where you could keep the effluent acid you were safe, and if it were neutral the carbonic acid of the atmosphere would make it safe.'

The disposal of sewage by discharging it into the sea does not hold out the hope of a solution of the difficulty in that direction that is claimed for it. At Brighton the cost would appear to amount to upwards of 5*l.* 10*s.* per million gallons of sewage. No possibility of any revenue exists, and the authorities have now to face difficulties in the shape of sewer gas and ventilation of sewers, with the attendant risk of disease. The scheme proposed for dealing with the sewage of Glasgow by casting it into the sea involves a cost for interest on capital alone, exclusive of pumping, maintenance of works, supervision, &c., of 4*l.* 5*s.* 7*d.* per million gallons. This sewage could be dealt with at Whiteinch by precipitation for less than that amount, because the standard of purity required in an effluent water to discharge into a river of the size of the Clyde at that point (three and a half miles below Glasgow) need not be very high.

Considerable expense and difficulty attend the proper

ventilation of long lines of outfall-sewers into the sea; and in addition there is the risk of serious leakage of subsoil water.

Such a plan is wasteful, inasmuch as whatever fertilising elements sewage may contain are entirely thrown away.

It may not effectually dispose of the sewage which may be brought back by the sea and deposited on the shores and continue to be a nuisance.

The Committee of the Local Government Board, at page xiii of their Report, carefully point out that such a plan can only be allowed 'provided no nuisance is caused.'

Discharging sewage into tidal rivers or estuaries is likely to involve the cost of dredging. This was pointed out by the Rivers Pollution Commissioners (2nd Rep., 1867, p. xiii) in referring to the river Lee. They said: 'Large sums of money are spent in dredging out sewage mud, which has accumulated in the bed of the river.'

In dealing with the cost of sewage farms in this work, the valuation of material upon the farms has not been included, it being preferred to take an average of two or three years' expense of working and sales of produce. This, it is considered, would afford more accurate results, as in some instances the produce is unsaleable, and it would be misleading to take it into account. For the same reason it has been omitted to take into consideration the value of manure produced by precipitating processes.

The populations given in the present work are those of the last census, excepting in a few instances where a proportionate addition has been made to meet a more than usually rapid increase.

TABLES

SHOWING COST OF TREATING WATER-CARRIED SEWAGE, AND PROPORTION OF LAND USED FOR IRRIGATION PURPOSES.

TABLE SHOWING COST OF TREATING WATER-CARRIED SEWAGE.

BY IRRIGATION.

Including all Charges and 5 per cent. on Outlay, and deducting Receipts for Sale of Produce.

Town	Population	Daily flow of sewage in gallons	Annual cost	Cost per head of the population per annum	Cost per million gallons of sewage	Annual rateable value	Annual cost in the pound	Remarks
			£ s. d.	£ s. d.	£ s. d.	£	£ s. d.	
Wrexham .	8,537	300,000	—	—	—	32,000	—	The published accounts show an average annual profit of £244. 15*s.* 5*d.*, being 6¾*d.* per head of the population, £2. 4*s.* 8½*d.* per million gallons of sewage, and 1 13/16*d.* per pound of the rateable value. But no allowance is made for the skilled supervision of Colonel Jones.
Cheltenham	41,923	1,250,000	132 0 0	0 0 0¾	0 5 9½	217,849	0 0 0 1/7	Exclusive of cost of management.
Rugby . .	8,400	400,000	262 0 0	0 0 7½	1 15 10	45,000	0 0 1½	
Bedford .	16,851	700,000	599 0 0	0 0 8½	2 6 10½	65,000	0 0 2 1/5	
Bishops Stortford .	6,250	500,000	533 0 0	0 1 8¼	2 18 4	27,000	0 0 4 11/32	
Altrincham	9,000	250,000	281 0 0	0 0 7½	3 1 7	42,558	0 0 1 9/16	
Banbury .	11,718	320,000	412 0 0	0 0 8½	3 10 7	34,104	0 0 2 7/8	
Kendal . .	13,442	500,000	658 0 0	0 0 11¾	3 12 2	44,600	0 0 3 17/32	
Doncaster .	18,750	700,000	1,000 0 0	0 1 1	3 18 3¼	68,721	0 0 3½	Exclusive of cost of management.
Croydon .	57,000	3,000,000	4,311 0 0	0 1 6	3 18 9	275,000	0 0 3¾	
Reigate .	15,916	480,000	754 0 0	0 1 0	4 6 1	89,114	0 0 2 1/32	
Chorley .	18,000	500,000	784 0 0	0 0 10½	4 5 11	54,407	0 0 3 7/16	
Warwick .	11,000	700,000	1,667 0 0	0 3 0	6 10 5¾	43,339	0 0 9¼	

Kidderminster	19,463	1,120,000	2,880	0	0	0	2	$11\frac{1}{2}$	7	0	11	53,196	0	1	$0\frac{31}{32}$	Exclusive of cost of management.
Leamington .	24,000	800,000	2,086	0	0	0	1	$8\frac{3}{4}$	7	2	$10\frac{1}{2}$	113,400	0	0	$4\frac{13}{32}$	
West Derby .	24,100*	723,000	2,176	0	0	0	1	$9\frac{1}{2}$	8	4	11	163,000	0	0	$3\frac{1}{8}$	
Merthyr Tydfil .	48,500*	1,200,000	4,500	0	0	0	1	$10\frac{1}{4}$	10	5	$5\frac{1}{2}$	135,000	0	0	8	
Northampton	45,000	1,000,000	3,805	0	0	0	1	$8\frac{1}{4}$	10	8	6	117,089	0	0	$7\frac{25}{32}$	
Blackburn .	83,000	1,500,000†	6,296	0	0	0	1	6	11	10	0	235,127	0	0	$6\frac{13}{32}$	
Harrogate .	12,000	210,000	993	0	0	0	1	$7\frac{3}{4}$	12	19	$1\frac{1}{2}$	50,000	0	0	$4\frac{3}{4}$	
Epsom . .	6,276	104,000	546	0	0	0	1	$8\frac{3}{4}$	14	7	8	30,571	0	0	$4\frac{9}{32}$	
Norwich .	84,000	—	12,763	0	0	0	3	$0\frac{1}{2}$		—		225,000	0	1	$1\frac{19}{32}$	
Swindon New Town .	7,628	300,000	1,643	0	0	0	4	$3\frac{3}{4}$	15	0	1	37,443	0	0	$10\frac{17}{32}$	
Crewe . .	20,000	900,000	5,368	0	0	0	5	$4\frac{1}{4}$	16	6	$9\frac{3}{4}$	59,705	0	1	$9\frac{9}{16}$	
Tunbridge Wells .	23,000	650,000	4,144	0	0	0	3	$7\frac{1}{4}$	17	9	4	142,914	0	0	$6\frac{3}{4}$	
Eton . .	3,000	80,000	770	0	0	0	5	$1\frac{1}{2}$	26	7	5	15,500	0	0	$11\frac{5}{8}$	
Average						0	1	$10\frac{1}{2}$	7	16	$4\frac{1}{4}$		0	0	$5\frac{27}{32}$	

* Proportion of population contributing to sewage. † Three-fourths of daily flow.

BY PRECIPITATION.

Including all charges and 5 per cent. on outlay, but allowing nothing for sale of manure except where stated.

Coventry .	40,000	2,000,000	3,446	0	0	0	1	$8\frac{1}{2}$	4	14	$4\frac{3}{4}$	101,438	0	0	$8\frac{1}{8}$	This is a case where the whole sewage of a town has been continuously (having been in operation 3 years) and satisfactorily treated. This cost includes interest on capital, management, treating sewage, and artificially drying sludge.

BY PRECIPITATION—*continued.*

Including all charges, and 5 per cent. on outlay, but allowing nothing for sale of manure except where stated—*continued.*

Town	Population	Daily flow of sewage in gallons	Annual cost	Cost per head of the population per annum	Cost per million gallons of sewage	Annual rateable value	Annual cost in the pound	Remarks
			£ s. d.	£ s. d.	£ s. d.	£	£ s. d.	
Coventry *contd*	40,000	2,000,000	2,614 0 0	0 1 3½	3 11 7½	101,438	0 0 6$\frac{5}{32}$	Less market value of manure produced, as fixed by report of Local Government Board Committee.
Bradford .	163,056	8,000,000	9,456 0 0	0 1 1¾	3 4 9¼	745,671	0 0 3$\frac{1}{25}$	Does not include artificial drying of sludge.
Birmingham	350,000	12,000,000	22,460 0 0	0 1 3¼	5 2 6½	1,229,844	0 0 4$\frac{2}{5}$	The treatment is incomplete as regards purification of the sewage, and dealing with the sludge.
Bolton . .	93,000	5,000,000	2,349 0 0	0 0 6	7 14 5½	311,563	0 0 1$\frac{4}{5}$	One half of the sewage only treated, and that for only 57½ hours, instead of 168 hours a week and exclusive of drying sludge or management.
Leeds . .	245,000	9,000,000	Too incomplete at present to ascertain what is the cost, but it will apparently amount to about £5 15s. per million gallons of sewage.					

BY DISCHARGING INTO THE SEA.

Brighton .	About 100,000	2,500,000	5,000 0 0	0 1 0	5 9 7	450,000	0 0 2$\frac{5}{8}$	Exclusive of cost of maintenance, ventilation, and removing silt.

Table showing Proportion of Land used for Irrigation Purposes to a Daily Flow of One Million Gallons of Sewage at 32 of the Principal Places where that System has been adopted.

Locality	Proportion of land to a daily flow of one million gallons of sewage	Population	Character of sewage	Character of soil	Remarks
	Acres.				
Altrincham . .	220	9,000	Domestic, 250 w.c.	Moss soil.	
Banbury . .	431	11,718	Chiefly domestic, w.c. universal.	Clay and sandy.	
Barking . . .	571	—	Domestic.	Light gravelly.	
Bedford . . .	261	16,851	„ 3,300 w.c.	Gravel.	
Bishops Stortford .	194	6,250	„	Gravel and loam.	
Blackburn . .	378	83,000	Manufacturing. Pails in general use.	Sand and clay.	
Broadmoor Lunatic Asylum . .	950	600	Domestic.	Gravel and sand.	
Bury St. Edmunds .	177	14,928	„ 300 w.c.	Gravel and sand.	
Cheltenham . .	369	41,923	Chiefly domestic, 10,000 w.c.	Clay.	
Chorley . . .	266	18,000	Partly domestic. „ manufacturing.	Clay and loam.	
Crewe . . .	285	20,000	Domestic, 60 w.c.	Strong clay.	
Croydon . . .	175	57,000	„ 11,000 w.c.	Gravel.	
Doncaster . .	374	18,750	„ 500 w.c.	Sand and gravel.	
Epsom . . .	577	6,276	„	Gravel.	
Eton . . .	375	3,000	„ w.c. general.	Sand and gravel.	
Harrogate . .	857	12,000	„ 1,620 w.c.	Clay and sand.	
Kendal . . .	130	13,442	Partly domestic. „ manufacturing, 500 w.c.	Sand, loam, and boulders.	Exceptionally favourable formation of land and *very* dilute sewage.

Table showing Proportion of Land used for Irrigation Purposes to a Daily Flow of One Million Gallons of Sewage at 32 of the Principal Places where that System has been adopted—continued.

Locality	Proportion of land to a daily flow of one million gallons of sewage	Population	Character of sewage	Character of soil	Remarks
	Acres.				
Kidderminster	152	19,463	Domestic.	Light gravelly.	
Leamington	469	24,000	„ 8,000 w.c.	Loam and gravel.	
Malvern Link	332	2,000	„ 100 w.c.	Gravel and marl.	
Merthyr Tydfil	287	48,500	„ 4,000 w.c.	Sand, pebbles, &c.	Exceptionally favourable formation of land.
Northampton	327	45,000	Manufacturing, 7,000 w.c.	Sand and gravel.	
Reigate	228	15,916	Chiefly domestic, w.c. universal.	Clay.	
Romford	334	6,335	Partly domestic. „ manufacturing.	Light sand and gravel.	
Rugby	195	8,400	Domestic.	Loam, clay, and gravel.	
Stafford jail	1,000	1,300	„	Peaty.	
Swindon New town	350	7,628	„	Clay.	
Tunbridge Wells	335	23,000	„ 5,635 w.c.	Part sandy and part clay.	
Warwick	203	11,000	„ 2,400 w.c.	Clay.	
Watford	1,090	4,000	„	Loam and gravel.	
West Derby	265	24,100	„	Part sandy and part clay.	
Wrexham	280	8,537	Partly domestic, partly manufacturing, w.c. used by 30 per cent. of population.	Gravel and loam.	

Average 389 acres to a daily flow of one million gallons.

PART II.—PRECIPITATION.

PRECIPITATION, or chemical treatment of water-carried sewage, requires consideration in four different sections, viz. :—

I. Mechanical straining so as to remove the larger portions.
II. Chemical treatment and subsidence.
III. Disposal of the precipitated matter.
IV. Filtration of the effluent water.

I. Mechanical straining becomes necessary where the sewage contains much garbage, paper, rags, corks, solid fæcal matter, hops from breweries, &c., as the sewage is thereby brought into a better condition for chemical treatment, and solid matters are prevented from accumulating upon the surface of the tanks, and there forming a nuisance. The necessity for including or omitting straining in the construction of sewage works depends on the character of the sewage, and there are various methods by which it may be accomplished. Ordinary fixed iron or wire gratings are objectionable, because they soon become choked, and require constant watching and cleansing, involving labour and consequent expense. Latham's self-cleansing mechanical strainer, is a simple appliance for this purpose.

II. Chemical treatment and subsidence both disinfect, deodorise, and cause precipitation of the organic substances contained in the sewage. The conditions which

are essential to success in this portion of the process, are to employ chemicals, which are disinfectants as well as precipitants, which are readily obtainable in large quantities and at moderate prices, and which can be used in solution so as to add the least possible solid matter to the sludge. Unless these conditions are strictly complied with, the result will either be insanitary, or else too costly. Besides the erroneous expectations that a profit would accrue from the manufacture of a manure, many processes have failed because one or more of the foregoing conditions have not been complied with.

III. The disposal of the precipitated matter or sludge is essentially necessary in all works. Not only must it be reduced to a portable form, but some plan for its continuous removal has to be kept in view. This residue does not form a manure of sufficient value in its natural state to command a ready or a continuous sale, therefore the following conditions demand attention in order to ensure success in this respect :—I. That the smallest possible amount of sludge be produced. II. That the chemical or fertilising value of the sludge be kept as high as possible. These two results are regulated chiefly by the bulk of the chemicals added to the sewage, and show plainly the necessity in practice for conforming to the conditions already pointed out. Hitherto, in laboratory experiments made to produce a good effluent water, practical difficulties in regard to the disposal of the sludge have been very much lost sight of. The quality of sludge will fluctuate slightly according to the quality of the sewage from which it is produced, but it will vary chiefly according to the chemicals used for treating the sewage. Under the most favourable circumstances a dry manure has never yet been produced from water-carried sewage, showing a greater theoretical value than about 35*s.* per ton, except when chemicals have been added

with a view to fortifying the resulting sludge. The quantity of sludge produced will vary with the bulk of chemicals which are added. This is illustrated by a comparison between Birmingham and Coventry. The sewage of both places is of a manufacturing character, and, although different in chemical composition, is near enough allied for this illustration. At Birmingham, from 12,000,000 gallons of sewage a daily result of 300 or 400 tons of sludge is obtained. At Coventry, from a flow of 2,000,000 gallons of sewage a daily result of about 25 tons of sludge is obtained. Having once reduced the sludge to a minimum bulk and a maximum value, there are various modes by which it may be disposed of after it is brought into a portable condition, viz. :—I. As a dry powdered manure. II. In a semi-dry condition similar to farmyard manure. III. Fortified by the admixture of phosphates, ammonia, or other fertilising agents, to bring it up to a higher standard as an artificial manure. IV. If it contains a large percentage of lime it may be burnt according to General Scott's process into cement. The success of this, however, depends greatly upon the chemical constituents of the sludge. V. It may be converted into fuel by admixture with other waste products. VI. It may be used for the production of gas.

Any of the above processes may be conducted without nuisance. A good cement has at times been manufactured on a small scale from the sludge at Birmingham, but its quality, owing to the acid character of the Birmingham sewage, is variable. The process is, however, about to be carried out by Scott's Sewage Company upon an improved plan, at Burnley, in Lancashire. Experiments have been conducted for the conversion of sludge into fuel and into gas at Coventry, but the odours arising from the burning of the fuel itself were objectionable, and in the latter the illuminating power

of the gas was small, although its heating power was considerable.

IV. Filtration of the effluent water is not essentially necessary, and where it flows into the sea, or into a tidal or large river, may be dispensed with. On the other hand, where the effluent water is required to be of a high standard of purity to enter small streams or rivers affording a supply of water for drinking purposes, filtration, either through a *small* area of land, or through artificially prepared filter beds, is necessary after chemical treatment. The former mode of filtration is preferable, where land both of suitable quality and character, and under favourable conditions is available, because the fertilising elements remaining in the effluent water may be utilised thereon, but where land cannot be obtained, and artificial filter beds are required, they may be constructed in a somewhat similar manner to those used for filtering water for domestic purposes. The area of land required for this purpose is about one fortieth of that required for irrigation or filtration of raw and untreated sewage.

With the foregoing prefatory remarks, the principal precipitation processes which have been practically tried will now be referred to, and the results that have attended them recorded.

I. *Processes which employ Salts of Alumina as the chief Precipitating Agent.*

The COVENTRY PROCESS is based upon a patent taken out in 1869 in connection with the General Sewage and Manure Company Limited, which was formed in the year 1872 to work it. They entered into contracts with the Local Board of Health of Nuneaton and the Corpora-

tion of Coventry, in Warwickshire, for the purification of the sewage of those places. These contracts were both based upon the erroneous assumption that the manufacture of manure from water-carried sewage would be remunerative without any subsidy from the towns. They spent a considerable sum of money in acquiring patents, erecting works for developing those patents, experimenting and treating the sewage of these two towns for several years, but they discovered the unprofitableness of their efforts, and the fact that they had entered into contracts for a long period involving an annual heavy loss proved fatal to them. This failure, however, does not affect the sanitary works which they have been the means of carrying out. The first contract entered into was for Nuneaton, but inasmuch as the process has been more fully developed at Coventry, a reference to it will be made in the first place. Coventry contains a population of about 40,000 inhabitants. It has 4,510 water-closets, and its sewage has for many years poured into the river Sherburne at a spot situated a mile to the south of the city. In this locality the river is not more than 10 feet wide, and being very shallow, the flow of sewage, amounting to 2,000,000 gallons in twenty-four hours, frequently increased its volume two or three-fold. This sewage being extremely foul, and coloured by refuse dye thrown into the sewers from the numerous silk-dyeing works, varnish works, &c., in the town, very soon converted the river into a large, open, and extremely offensive sewer, which, in conjunction with another small river called the Sowe, entered the river Avon, and finally contributed towards the supply of drinking water to the town of Warwick. It was not, therefore, a matter of surprise that when sanitary matters took hold of the public mind, the Coventry authorities experienced a troublesome time of it. They had fulfilled

what was considered a generation ago to be all the requirements for draining the town, and conveying the sewage to the nearest natural carrier, in the shape of a running stream. After, however, doing this, they had to encounter an Injunction from the Court of Chancery, which was obtained by some of their neighbours, to restrain them from allowing it any longer to enter the river. Having previously used filtration, lime treatment, &c., and found them to fail, the difficulties of their position led them to endeavour to obtain a sewage farm. Accordingly, they purchased 282 acres of land for a sum of 28,500*l.*, but the estimate for preparing it amounted to a sum larger than they were willing to expend, and the result appeared uncertain.

The estimated cost of carrying out irrigation at Coventry is as follows :—

	£
282 acres of land already purchased . . .	28,500
Requisite quantity of land for a flow of 2,000,000 gallons of sewage per day would be 780 acres. Additional cost of 498 acres at above price	49,800
Preparation of land for irrigation at the minimum price of 50*l.* per acre	39,000
Cost of outfall works, pumping station, rising main, to lift 2,000,000 gallons a day 150 feet; taken at less cost than those at Kidderminster. . .	15,000
Total	132,300

Assuming the farm to pay its working expenses, the annual cost would therefore amount to—

	£
Five per cent. interest on capital . .	6,615
Cost of pumping	1,000
Total	7,615

or at the rate of 10*l.* 8*s.* 6*d.* per million gallons of sewage,

or 3*s.* 9*d.* per head per annum of the population, exclusive of the cost of management.

The cost would, moreover, undoubtedly be heavier, if the opinion of the Local Government Board Committee were adhered to (Rep., p. xxxii), viz.: that no growing crop, save natural grass, should be sewaged during the winter. This would involve having 780 acres of grass land for winter use in addition to arable land.

The General Sewage Company undertook to purify the sewage at their own expense, and constructed works which were put in operation on the 30th April, 1874, and since that time have been continuously at work purifying all of the sewage.

The sewage (an analysis of which is given in the Appendix) flows to the works by gravitation, and is first mechanically strained through Latham's extractors, so that the largest solid matters in suspension are separated. The materials thus extracted consist of fæcal matter, garbage, dead rats, and, occasionally, some rather remarkable elements, amongst which have been seen living fish and frogs, silver-mounted meerschaum pipes, walking sticks, and, more rarely, spoons and forks. The strained sewage is then mixed with a dose of a solution of sulphate of alumina, prepared in a cheap way by treating shale with sulphuric acid. The necessary engine-power, boilers, mixers, and other machinery are provided both for the admixture of the chemicals with the sewage, and also for the manufacture of some of the chemicals themselves. The sewage next receives a charge of milk of lime, and then flows to four precipitating tanks, which are worked on the continuous principle. These when full allow the effluent water to pour over weirs at the extreme ends of the tanks and in a fair state of purity.

The effluent water from the tanks is next conveyed to filter beds comprising nine acres of land. These beds are used intermittently, so that when one requires rest or

repair, another is ready to replace it. The effluent water finally passes into the River Sherburne at the rate of about 80,000 gallons per hour, and in a condition as shown by the analysis in the Appendix.

The tanks are periodically stopped, and the sludge removed for drying. The amount of sludge is about 25 tons a day, containing 85 per cent. of moisture.

The sludge in the first place is filtered (by passing through a drum filter) to 65 per cent. of moisture. It is then passed through Milburn's drying machines and exposed to a low heating process, by which the moisture is reduced to 60 per cent. It is then stacked in its heated state, when moisture continues to be given off until it is dried down to from 10 to 15 per cent., in which condition the day's precipitate would amount to $4\frac{1}{2}$ tons of manure, at a cost for drying of about 6*s.* or 7*s.* per ton.

The sludge, when reduced to a portable condition, is disposed of in three ways :—I. In a dry, powdered state, as a manure, the theoretical value of which is about 35*s.* per ton, according to Dr. Voelcker's analysis, given in the Appendix; II. After drying by the admixture of phosphate of lime and other fertilising agents, so as to form an artificial or fortified sewage manure, at an average chemical value of 4*l.* to 5*l.* per ton; III. In a semi-dry condition, for manuring grass and arable lands.

The chemicals used per day at Coventry are as follows:

	Tons	cwt.	qrs.	lbs.	
Crude sulphate of alumina manufactured on the works[1] . .	2	0	0	0	For two million gallons of sewage.
Lime	0	10	0	0	

The cost of these ingredients is 3*l.* 8*s.*, or 34*s.* for one million gallons of sewage. The sewage of Coventry containing a great amount of dye, requires a larger

[1] This is dissolved in water, the solution only being allowed to pass into the sewage, the solid residuum to the extent of two-fifths of the weight being removed by subsidence.

proportion of materials to purify it than would be wanted in cases where manufacturing refuse is absent. The cost in those cases would, therefore, be considerably reduced, according to the quality of the sewage, and the quantity of land employed as an auxiliary to the process.

The cost inclusive of rent of land, interest on capital expended in works, management, labour, and materials, for the months of August, September, October, 1876, as taken from the books kept at the works, and fairly representing the continuous cost of the process, is as follows:—

	£	s.	d.	£	s.	d.
Coal				115	9	10
Sulphate of alumina				218	12	6
Lime				27	9	8
Labour on works and filter beds				218	16	6
Incidental expenses, repairs, &c.				68	5	1
Rent of land for works and filter beds	13	0	0			
Interest at 5 per cent. on 12,000*l.*, cost of works	150	0	0			
Cost of management	50	0	0			
				213	0	0
Total for three months				861	13	7

The entire annual cost at Coventry is therefore 3,446*l.* 14*s.* 4*d.*, or 4*l.* 14*s.* per million gallons, or 1*s.* 8½*d.* per head of the population.[1]

If the market value of the manure (as fixed by Dr. Voelcker in the recent report of the Local Government Board) is realised, the cost would be reduced as follows:—

	£
Annual cost	3,446
Receipts from manure	832
Loss per annum	2,614
or 1*s.* 3½*d.* per head of the population.	

[1] Care should be taken in using these figures for other places, as they include cost of works and cost of management, neither of which increase or decrease in direct proportion, and also include the price of chemicals requisite for treating *manufacturing* sewage where nine acres of land only are employed for filtration.

The sales of manure, according to the books, have been at rates varying from 4*s.* a ton for sludge, containing about 65 per cent. of moisture, to 40*s.* a ton for dried manure, containing 10 per cent. of moisture. Some has been sold in a fortified state at 5*l.* or 6*l.* per ton. This latter price represents more than the extra cost of the fortifying materials added to the chemical value of the sludge.

The sale of a manure of so low a value as that from water-carried sewage will, however, be slow and uncertain, and, in the first instance, but little consideration should be bestowed upon it as a source of revenue or profit.

The Coventry works have been under investigation by the Committee appointed in 1875 by the Local Government Board. In their report, at page 46, an account of the process is given. At page 49 an analysis of sludge containing 47·36 per cent. of moisture is given, and at pages lxi and lxiii. this analysis is compared with other sewage manures containing only 15 per cent. of moisture. A similar reduction of moisture in the Coventry manure would show it to be worth more than is there stated.

Towards the end of 1876 the Town Council of Coventry appointed a Committee to investigate various modes of dealing with town sewage, with a view to consider the advisability or not of continuing this process, and came to the following conclusion: 'That the system for treating the sewage of this city by precipitation having been in use since the 30th of April, 1874 (a period of nearly three years), this Council are well satisfied with its sanitary success, and that the same be certified under the common seal, and given to The Rivers Purification Association (Limited), with a statement appended thereto that this Council have entered into a contract with them to continue to carry on the said system of purifying the

sewage of this city, in consideration of an adequate annual subsidy to the said Association.'

The Association here referred to has been formed to carry out the requirements of the Rivers Pollution Act by the most suitable methods. It has acquired the original and recent patents for the Coventry process.

The process is employed also at NUNEATON, which has a population of 7,399, but where there are no water-works and only a few water-closets in use, the sewage being chiefly derived from fellmongers' works situated on the outskirts of the town. In the year 1872 the Local Board of Health constructed precipitation works for dealing with 127,000 gallons, the estimated daily flow of sewage. The works, in an incomplete state, were handed over to the General Sewage and Manure Company in that year, with a condition that the Company should complete them, pay rent for the same, and purify the sewage at their own cost. The Company completed them, but the volume of sewage from the fellmongers' works, and from leakage of subsoil-water into the sewers, having increased to 300,000 gallons a day, the pumps and machinery had to be enlarged. This, however, had scarcely been done when, at times (in wet weather especially), the flow of the sewage still increasing reached as much as 400,000 to 500,000 gallons a day, and, as all this had to be lifted 40 feet at the Company's expense, it necessitated a further enlargement of the works. The Company being reluctant to continue so losing an undertaking, in the early part of the year 1875 the Local Board of Health applied to the Court of Chancery to compel them to pump the whole of this volume, and also to make the necessary additions and enlargements to the works for the purpose of treating it. The Court of Chancery ruled that the Company, under their agreement, must do this, and issued an Order ac-

cordingly, under penalty of sequestration if the Order were not complied with. The Company did comply with this Order, and having enlarged the works they were put in operation in November, 1875. The treatment of sewage was renewed, and continued with satisfaction to the Court of Chancery up to August, 1876, when the Company stopped, and the works came into the hands of the Local Board. The effluent water at Nuneaton was filtered through two acres of land, and in most respects the process carried on was similar to that at Coventry. The yield of manure was about a ton a day; and the working expenses were (exclusive of pumping the sewage, which cost 300*l.* a-year) as follows:—

	Per week. £	*s.*	*d.*
Labour and management	4	6	0
Coal	1	0	0
Alumina	1	10	0
Lime	1	5	0
Contingencies	0	5	0
Total	8	6	0

This, together with interest on capital expended on works at 5 per cent., made it about the same as that of Coventry, viz.: 1*s.* 8*d.* per head per annum of the population, exclusive of any revenue from sale of manure. The sewage of Nuneaton is of a very offensive character, owing to the presence of a large quantity of manufacturing refuse.

THE NATIVE GUANO, OR A B C PROCESS, patented in 1868 by Messrs. Sillar and Wigner, consists mainly in the use of alum, blood, and clay. One of the first trials with it was made at LEICESTER, in 1868, by the Rivers' Pollution Commissioners (under the superintendence of the patentees), where it was tested in comparison with treat-

ment by lime. The constituents used under the patent at that time for ordinary sewage were as follows:—

	Parts.	
Alum	600	About 4 lbs. of this mixture were added to 1,000 gallons of sewage, or 1 ton 15 cwt. 80 lbs. per million gallons; and the sediment or sludge treated with a small quantity of sulphuric acid was dried into a manure.
Blood	1	
Clay	1,900	
Magnesia	5	
Manganate of potash	10	
Burnt clay	25	
Chloride of sodium	10	
Animal charcoal	15	
Vegetable charcoal	20	
Magnesian limestone	2	

Although no account of the cost of manipulation is recorded, the other results of these experiments are thus given:—[1]

'I. The Sillar and Lime processes remove to a great and nearly equal extent the suspended matters contained in sewage.

'II. Sillar's process increases the amount of dissolved solid matters in sewage, but reduces the quantity of putrescible organic matter. The Lime process reduces both the amount of dissolved solid substances and the quantity of putrescible organic matter; the reduction of the last being about the same as that effected by Sillar's process, viz.: rather more than one-half.

'III. Both processes fail in purifying sewage to such an extent as to render it admissible into running water.

'IV. For the manufacture of solid manure from sewage, Sillar's process is greatly superior to the method of treatment by lime, although it fails to extract from the liquid more than a very small fraction of its valuable constituents.'

The removal of organic matter from the sewage did not appear to differ much in both processes, and the

[1] 1st. Rep. Riv. Pol. Com., 1868, pp. 53, 55.

chemical value of the resulting manure was put as follows:—

	£	s.	d.
Manure from lime process . . .	0	13	6½ per ton.
„ Sillar's process . .	1	13	0¾ „

In the year 1869 the process was in operation at LEAMINGTON; filtration of the effluent water through animal charcoal was added, and the Rivers' Pollution Commissioners again inspected its working. The weather on that occasion being most unfavourable, the Commissioners did not obtain any results, but did so upon a subsequent inspection, when the specification was varied, and the constituents used were as follows:—[1]

	Cwt.	qrs.	lbs.	
Alum	1	2	0	About 7·3 lbs. of this mixture were added to 1,000 gallons of sewage, or 3 tons 5 cwt. 20 lbs. per million gallons.
Sulphate of alumina . .	0	3	7	
Clay	8	0	0	
Animal charcoal . . .	0	2	0	
Clay and blood, containing 5½ pints of blood . .	0	1	12	
Mixture of potash, carbonate of potash, and carbonate of soda	0	0	6	
Previously manufactured manure	0	0	14	
Strong solution of perchloride of iron . . .		1 pint		

At a further inspection by the Commissioners at Leamington, on the 10th May, 1870, the specification was again varied, and the ingredients used were as follows:—

	Cwt.	qrs.	lbs.	
Ammonia alum . . .	3	0	0	About 8 lbs. solid of this mixture were added to 1,000 gallons of sewage, or 3 tons 11 cwt. 48 lbs. per million gallons.
Clay (moist) . . .	6	0	0	
Animal charcoal . . .	0	0	15	
Vegetable charcoal . .	0	0	20	
Epsom salts . . .	0	0	20	
Blood in a pailful of clay-magma . . .	0	0	4	
River water . about 1,135 gallons				

[1] 2nd Rep. Riv. Pol. Com., 1868, pp. 10-13.

The cost of these ingredients is said to havebeen 15*l.* 18*s.* per million gallons of sewage.[1] Analyses of the results of these experiments are given in the Appendix.

The process was eventually given up at Leamington, and arrangements entered into with the Earl of Warwick for disposing of the sewage upon land.

The next practical test of this process was at CROSSNESS, where the Native Guano Company obtained a concession of sewage from the Metropolitan Board of Works, and erected works at the Southern Metropolitan outfall, capable of treating 500,000 gallons of sewage daily. In order that the results should be unquestioned, the works were placed under the immediate superintendence of the engineer and the chemist of the Metropolitan Board, whose reports thereon were published in January, 1873.[2] From them the following facts are gathered. The working extended over eighty days (nights and Sundays being excluded), and during that period 11,672,737 gallons of sewage were treated with upwards of 166[3] tons of A B C mixture (which differed from that which had been employed at Leicester and Leamington), and was as follows:—

	Parts	
Sulphate of alumina	2·5	32 lbs. of this mixture were added to 1,000 gallons of sewage, or 14 tons 5 cwt. 80 lbs. per million gallons.
Charcoal . .	14·5	
Clay . . .	13·0	
With a little blood and occasionally lime.		

The yield of dry manure at the conclusion of the experiments was 142 tons, of which it is calculated that about 61 were obtained from the sewage and 81 added in

[1] Proc. Inst. C.E., vol. xlv., p. 159.
[2] The *Standard*, Jan. 23, 1873.
[3] Containing only 81 tons of *dry* material.

the A B C mixture; in other words, a million gallons of sewage yielded 5¼ tons of manure, exclusive of the mixture added for its precipitation, and 12⅓ tons inclusive of that mixture. There was no nuisance attending the process, the effluent water was clear and good. The cost of the ingredients was 24*l.* 9*s.* 8*d.* for one million gallons of sewage. The cost of production of the manure is given as 6*l.* 6*s.* 4*d.* per ton, exclusive of rent, interest on capital, depreciation of plant and other incidental items, being equivalent to a cost of 76*l.* 6*s.* per million gallons of sewage.[1] This heavy cost has been clearly shown by the Company to be due to exceptional circumstances, and cannot therefore be regarded as a fair test of the expense. The analysis of the manure produced shows that it contained 0·929 per cent. of ammonia, and 0·760 per cent. of phosphoric acid: hence its chemical value was barely 20*s.* per ton.

Experiments with the process have also been tried at TOTTENHAM, but they were on a small scale, and were abandoned without any data as to results having been published.

A branch Company was formed for treating the sewage of HASTINGS by this process, and very complete works were erected for that purpose, and although some of the manure found a market in the hop-growing districts of the south-east of England, the undertaking fell into liquidation and was abandoned.

At BOLTON, *Lancashire*, the process was tried, in 1872–73, for thirty-two months. This place has a population of about 93,000, and at that time had an average daily flow of manufacturing sewage amounting to 2,500,000 gallons.

In 1870 the Corporation entered into an agreement

[1] For details of these expenses, which include the cost of pumping the sewage, *see* Proc. Inst. C. E., vol. xlv., p. 146.

with the Native Guano Company, whereby they contracted to erect works at a cost of £16,578, and the Company undertook to defecate and purify the sewage. The Corporation agreed to pay the working expenses of the process, and to deliver to the Company one-fourth of the manure made at the works. A portion of the sewage only was dealt with, and the following is given as the particulars of treating a daily flow of 1,035,000 gallons for a period of 57½ hours.[1] The chemicals used were as follows:—

	Tons	cwt.
Sulphate of alumina	3	11
Clay	6	12
Carbon (waste product of prussiate of potash manufacture)	4	1
Blood, a small quantity		
	14	4

The cost as follows:—

	£	*s.*	*d.*
Labour	11	7	3½
Chemicals	8	12	9½
Coal	3	0	0
Miscellaneous	0	18	0
	23	18	1

The process has been given up, it is stated, on account of its great expense,[2] and another, which is referred to elsewhere, has been substituted.

At SOUTHAMPTON, with a population of 55,800, and a domestic sewage, the Native Guano Company entered into a contract to deal with the sewage. About 10,000*l.* were spent in preparing tanks and connecting sewers, and it was estimated that the cost of the works when completed would be 21,000*l.*, exclusive of 1,500*l.* for the purchase

[1] Loc. Gov. Bd. Rep., p. 37.
[2] Roseb. Ret. p. 18; also Soc. Arts, p. 4.

of land, and the rental of other land taken upon lease.[1] The sewage was to have been dealt with at two outfalls, but when the works at the Belvidere outfall only had been partially constructed, the contract was cancelled, and the undertaking abandoned. No results have therefore been obtained at this place, where the sewage flows as before untreated direct into the Southampton Water. These contracts appear to have been entered into upon the erroneous supposition that a profit would be derived from the manufacture of sewage manure.

At LEEDS, this process has been more fully developed than at any other place. The borough of LEEDS contains a population of 291,580. The district at present sewered comprises the townships of Leeds, Hunslet, Holbeck, and St. John's, Wortley, an area of about 4,900 acres, containing a population of 245,000. There are about 8,500 water-closets in use, and the sewage, which amounts to an average daily flow of 9,000,000 gallons,[2] contains a large quantity of manufacturing refuse from cloth dyers, tanners, and curriers' factories, &c. Having abandoned the use of lime and the idea of irrigation, both of which are referred to elsewhere, and being under legal pressure to purify the sewage, the Corporation of Leeds, in August, 1870, entered into an agreement with the Native Guano Company as follows :—'The Corporation to purchase the land required for the works, and grant a lease to the Company for twenty-four years. The Corporation to construct works capable of purifying 2,000,000 gallons of sewage per day, the cost of these works not to exceed 6,000*l.* exclusive of land; and afterwards, if the purification is successful, to extend the works, to enable the Company to purify 12,000,000 gallons per day, at a

[1] Roch. Ret. p. 28.

[2] *Description of the Leeds Sewage Works*, &c., by Alfred W. Morant, C.E., 1876.

further cost of 14,000*l.* If the Company made any profit then, they pay to the Corporation 5 per cent. upon the cost of the works, exclusive of land; beyond this if any profit remained, 15 per cent. to be handed over to the Corporation. The works to be carried out from the plans and specifications provided by the engineer to the Native Guano Company, and the Company to be paid 2½ per cent. for such plans and specifications.' The Corporation at once purchased the land, and performed their part of the agreement by erecting experimental works, by which, in October, 1871, the Company were able to commence the treatment of about 1,000,000 gallons of sewage daily. The chemicals or mixture used on this occasion appears to have been as follows :—

	Tons	cwt.	qrs.	lbs.	
Alum	2	13	1	0	This quantity was used per million gallons of sewage.
Carbon (animal carbon, being refuse from prussiate of potash works)	2	0	0	0	
Clay	3	6	2	12	
Blood mixture	0	0	2	0	
Lime	0	1	2	18	
Total	8	2	0	2	

The cost of these ingredients is said to have been 7*l.* 5*s.* After carrying on these trials for some time, the Company gave notice on the 14th of March, 1873, that they were not in a position to continue their operations at Leeds. The Corporation thereon agreed to release the Company from their contract, upon condition that they were allowed to use all or any of the Company's patents free of royalty, and took possession of the works on the 1st of June, 1873, and invited other patentees to make experiments.

In the meantime, the Corporation were proceeding

with the construction of the permanent works for dealing with the whole of the sewage according to their original agreement with the Native Guano Company. These works were designed and erected specially for the A B C process, and a description of them has recently been published.[1]

The cost of the construction of these works up to the present time has been 57,543*l.* 18*s.* 2*d.*

The Native Guano Company, learning that others could purify the sewage in the new works at a cheaper rate than in the old experimental works, were desirous of trying the A B C process in the former to ascertain if they could cheapen it. They obtained permission to do this, and accordingly, in June, 1875, commenced working, again altering the proportions of the ingredients of the A B C mixture by reducing the quantity of alum, and using a very much larger quantity of lime.

The materials used per day of twenty-four hours (on an average of nine days and nights) on this occasion were as follows:—

	Tons	cwt.	qrs.	lbs.	
Lime	7	2	3	2	2 tons 14 cwt. 7 lbs. of this mixture were added to a million gallons of sewage.
Animal carbon	6	1	0	4	
Norris's alum	3	12	0	12	
Clay	7	10	1	20	
Carbolic sulphite	0	0	0	27½	
Total	24	6	2	9½	

The cost of these ingredients was 21*l.* 19*s.* 5*d.*, or at the rate of 2*l.* 8*s.* 10*d.* for one million gallons of sewage.[2]

In a subsequent trial made for a week in January, 1876, the following ingredients were used upon the average per day of twenty-four hours:—

[1] *Description of the Leeds Sewage Works*, &c.
[2] *Ibid.*, and Soc. Arts, p. 38.

	Tons	cwt.	qrs.	lbs.	
Lime	6	13	3	20	3 tons 14 cwt. 1 qr. 6 lbs. of this mixture were added to a million gallons of sewage.
Carbon	8	6	0	24	
Spence's alum	5	6	1	4	
Clay	11	2	1	4	
Carbolic sulphite	0	0	0	5½	
Total	33	8	3	1½	

The cost of these ingredients was 29*l.* 11*s.* 9*d.* or at the rate of 3*l.* 5*s.* 9*d.* for one million gallons of sewage.

An error appears to have crept into a certificate given by the Sewage Committee of the Leeds Corporation (and printed in Health and Sewage of Towns, Society of Arts, 1876, p. 40), as to the cost of the chemicals per million gallons. It is stated to be 1*l.* 17*s.* 0*d.*, but this was reckoning the flow of sewage to be between twelve and fourteen instead of nine million gallons per day.

Analyses of the effluent water and of the manure produced from this trial are given in the Appendix.

The Company having made these experiments, were allowed to continue working for a while, the results of which have not yet been published. Opportunities were then given to other patentees to try their processes on the new works, and the one now under trial is referred to elsewhere.

The following report of the manure produced from the A B C process at Leeds, is published:—'Sixty gentlemen have made trials of one or two tons each of the dried manure from the A B C process, and the effect on turnips, potatoes, general garden produce, and grass, is reported upon favourably by forty of them, and unfavourably by twenty,' but some of these latter remark that the season was 'too dry for a fair trial to be obtained.'

The A B C process is at present being worked at

AYLESBURY, *Buckinghamshire* (having a population of 6,962), with the following ingredients:—

	Tons	cwt.	qrs.	lbs.	
Alum	1	17	0	0	This quantity is added to a million gallons of sewage.[1]
Clay	2	14	1	0	
Blood	0	1	0	14	
Charcoal	1	4	0	0	
Lime	0	4	1	19	
A small quantity of carbolic sulphite					
Total	7	0	3	5	

The results of working at Aylesbury have not yet been published.

THE PHOSPHATE SEWAGE PROCESS, patented in 1870, by Mr. David Forbes and Dr. Astley Paston Price, consists in the use of phosphate of alumina and lime, the former being an expensive chemical, and one chiefly imported from foreign countries. The object of using phosphate of alumina is, that by employing as a precipitant a material of a high fertilising or manurial value, a richer and more marketable manure will be obtained than is derived from precipitants having a less recognised manurial value.

The precipitant or phosphate of alumina is mixed with sulphuric acid to render it soluble, after which, it is added to the sewage, together with a certain quantity of lime to aid precipitation. About three years ago the process was experimentally in operation for a few months at the Lodge Farm, BARKING, where small quantities of the Metropolitan sewage were treated by it. It is stated that the manure produced from this sewage contained an average of about 2½ per cent. ammoniacal matter, and 22

[1] *Description of the Leeds Sewage Works, &c.*

per cent. precipitated phosphate.[1] It was advertised at 4*l.* per ton in railway trucks, but no results of these trials in a financial point of view have been published, and they have been abandoned.

At HERTFORD the process has been in operation for about two years, but at what cost to the Company working it is not stated. The Corporation of Hertford have, however, every reason to be satisfied with the favourable arrangement they have been able to make.

Hertford has a population of 7,169. Water-closets are in general use, and the sewage contains refuse from breweries. As this town is situated on the River Lee, from whence the New River Company draws its supply of water, that Company spent 28,000*l.* in the construction of requisite sewage works, and further pay the Corporation 600*l.* a year to deal with the sewage, so as to prevent the pollution of the river.[2] For sixteen years, from 1858 until 1875, the lime process was used, at an annual working cost of 410*l.* a year, and was then given up as being both expensive and unsatisfactory,[3] and, further, because the Phosphate Sewage Company offered to lease the sewage works, paying 100*l.* a year rental, and receiving 300*l.* a year for the treatment of the sewage, thus leaving the Corporation a clear profit of 400*l.* a year. The Company evidently rely upon the sale of the manure to cover their expenses and make a profit, as 7*d.* per head of the population is an inadequate allowance for carrying on an efficient process. The results to the Company have not yet been published, but chemists seem to be of opinion that phosphates, when used in this manner, become deteriorated, and that being put into the sewage in a soluble form, they come out in the sludge in a more or less insoluble condition; therefore, the value of the manure is not increased to the extent anticipated. It is

[1] Soc. Arts, p. 37. [2] *Ibid.*, p. 9. [3] Roseb. Ret. p. 14.

also stated to be a fact that some of the fertilising elements in the chemicals added to the sewage flow away in the effluent water, and, therefore, are not returned in the sludge as manure. These two practical results are unfavourable, however satisfactory the sanitary results of the process should prove to be. There is an opinion that effluent waters from phosphate processes must be filtered in order to sufficiently purify them. In reference to an effluent water containing phosphate of lime, Mr. Crookes has recently stated: 'Another point proved many years ago by Professor Heisch was this, that you must not have phosphoric acid in the effluent, or there would be a great tendency to produce the low confervoid growth, commonly called sewage fungus, that was a great difficulty with any process which had any phosphate in it.'[1]

BIRD'S PROCESS employs what is called sulphated clay. This is a simple mixture of sulphuric acid and common clay, in the proportion of 4 to 9 parts by weight of the latter to 1 of the former. It has been tried at CHELTENHAM, previous to the adoption of irrigation there, but was not found to be satisfactory.[2] It has been for some time, and is at present, in use by Bird's Sewage Company at STROUD, *Gloucestershire*, with a population of 8,000, and sewage of a manufacturing character containing refuse from cloth mills, &c., amounting to an average daily flow of about 640,000 gallons; the proportion being 1 ton 15 cwt. 40 lb. of mixture per million gallons of sewage, the whole of the solids being added to the sewage. In 1868 the Rivers' Pollution Commissioners investigated these works, when from 150,000 to 200,000 gallons of sewage were treated with

[1] Soc. Arts, p. 80.

[2] Roseb. Ret., p. 13; Roch. Ret., p. 7.

6 cwt. of pulverised clay, to which 120 lbs. of sulphuric acid had been added, forming the so-called sulphated clay. At that time the effluent water was filtered through coke. They reported as follows[1] (analyses of average samples are given in the Appendix):—'It is evident, first, that the sewage was very weak; and, second, that the effluent liquid, though much improved, was still not of the degree of purity which would render it admissible without nuisance into a clean river. Moreover, if stronger sewage were treated, the effluent water would doubtless be still more objectionable. It was always somewhat turbid, but nearly inodorous.'

In the year 1875, the proprietors of this process applied to the Court of Chancery to grant an injunction restraining the proprietors of the Coventry process from continuing the works at that place, upon the ground that the Coventry process was an infringement of their patent. After a long trial in the Rolls Court and a subsequent appeal to the Lords Justices, in both instances it was ruled that the Coventry process was not an infringement of Bird's patent.

STOTHERT'S PROCESS, patented in 1852, employs lime, sulphate of alumina, sulphate of zinc, and charcoal. To each gallon of sewage is added 73½ grains of sulphate of alumina, 3½ grains of sulphate of zinc, 73½ grains of moderately-fine charcoal, and 22 grains of slaked quick lime.

It does not appear that this process has been practically in operation at any place. It has been said of it: 'The result differs from that of the lime process only in that the clarification is more complete, that the phosphoric acid is all precipitated in the form probably of

[1] First Rep. Riv. Pol. Com., 1868, p. 58.

phosphate of alumina, and that the manure contains much more worthless matter derived from the precipitating mixture.'[1]

II.—*Processes which employ Lime as the chief Precipitating Agent.*

HILLE'S PROCESS, patented in 1870, employs lime, tar, salts of magnesium, or other chemicals, and the products arising from the calcination of lime, the effluent water being afterwards filtered, either through artificial filters or through land, or it may be used for irrigation purposes. The patentee starts with the following common-sense and commendable assertion: 'I do not propose to manufacture from sewage, water fit for drinking purposes, or a highly valuable artificial manure. But I do profess to produce by my process an effluent water, at a reasonable cost, which is good enough, for all practical and sanitary purposes, to be discharged into any river, and a sewage deposit which is perfectly harmless and inoffensive.'[2]

The process is in operation at the following places:—

EDMONTON, *Middlesex*, with a population of 15,000, and an average daily flow of about 800,000 gallons of sewage of a domestic and dilute character. The sewage is pumped to a height of 27 feet. The Local Board possess about 114 acres of land, purchased for a farm, which is used as an auxiliary to the process. It is stated that 26,200*l.* have been spent on sewage works, and that the cost of carrying them on with this combined process during four months was at the rate of 750*l.* per annum,[3]

[1] *Treatment and Utilisation of Sewage*, by M. H. Corfield, M.A., M.B., 1870, p. 211.

[2] Pamphlet by F. Hille, 1876.

[3] Roseb. Ret., p. 28.

but the details of this sum are not given, and the complete cost of treatment has not elsewhere been published, excepting as stated by Mr. Eachus, that 'the results of six months trial at Edmonton were found to be that both irrigation and a precipitation process, that known as Hille's, had cost the Local Board in each case about the same, namely, 6*l.* per million gallons treated, or 1*s.* 2*d.* per head per annum, inclusive of interest on capital expended for the two systems.'[1]

The materials are added to the sewage in the form of a thick fluid compound in the proportion of 3 tons 7 cwt. to a million gallons; but the proportion of moisture in this fluid mixture is not given. The residue from each day's sewage is stated to be 3 tons, and its theoretical value to be 26*s.* per ton.[2]

TOTTENHAM, *Middlesex*, with a population of 23,000; about 5,000 water-closets are in use, and there is a domestic sewage (the refuse from India-rubber mills being now kept out of the sewers)[3] amounting to an average daily flow of about 1,200,000 gallons. The process has only recently been put in operation. It is stated that upwards of 11,000*l.*[4] have been expended on sewage works, and that the cost of carrying on such works during the year 1875 was 1,979*l.*[5]

GRANTHAM, and also at TAUNTON, the process has been experimentally in operation, and is about to be adopted at the latter place.

WIMBLEDON, *Surrey*, with a population of 12,500; the process was tried here on temporary works for six years, and gave sufficiently favourable results[6] to induce the local authorities to adopt it, and to construct permanent works. In these works provision has been made

[1] Proc. Inst. C.E., vol. xlv. p. 199.
[2] Pamphlet by F. Hille, 1876. [3] Roseb. Ret., p. 29. [4] *Ibid.*
[5] Roseb. Ret. and Soc. Arts, p. 16.
[6] For analyses of effluent water and manure, *see* Appendix.

for an increase of population to 45,000. Fifty acres of land have been acquired (forty of which are for filtration of the effluent water) at a cost of 15,550*l.* The tanks, pumping station, and other necessary works, have cost 20,550*l.*, and, inclusive of 28,500*l.* spent upon sewers, the entire works are estimated to have cost 72,000*l.*[1]

No further details of the complete cost of this process or of the weight and value of the products are as yet published, but, according to a report of Capt. Flower, engineer to the Lee Conservancy Board, the process appears to have afforded satisfaction in the Lee Valley.[2]

MARSDEN AND COLLINS' PROCESS employs lime, carbon (a waste product of prussiate of potash manufacture), house ashes, soda, and perchloride of iron.[3] It is in operation at BOLTON, *Lancashire*, where it was first employed about two years ago after trial of the A B C process. Bolton has a population of about 93,000, and there are about 758 water-closets in use. The sewage contains manufacturing refuse from bleach works, dye works, tanneries, and paper works. It is estimated that when the sewers are completed the average daily flow of sewage will amount to 5,000,000, at present the flow amounts to about 4,000,000 gallons a day, but about 3,500,000 gallons have as yet been intercepted, and only 2,500,000 gallons flow to the sewage works, 1,500,000 going direct into the river Croal. The amount spent upon the works is stated to have been 16,578*l.*, and upon the intercepting sewers 10,286*l.*, making a total of 26,864*l.*[4] The sewage is treated only from 8 A.M. to 6

[1] An account of these works is given in the *Standard*, Oct. 18, 1876.
[2] Soc. Arts, p. 41.
[3] Soc. Arts, p. 3; and Loc. Gov. Bd. Rep., p. 38.
[4] Roseb. Ret., p. 18; and Loc. Gov. Bd. Rep., pp. 37 and liii.

P.M. on week days, and not at all on Sundays, or for only 57½ hours, instead of continuously for 168 hours in every week. During the remainder of the time it flows direct into the river. Therefore only a small portion of the whole is dealt with. The sludge from this, which amounts to about 70 tons per fortnight, is not dried, but is thrown into heaps at the sides of the tanks.

The following is given as the cost of chemicals and labour per week:—

	Tons	cwt.	
Lime . . .	7	3	About 1 ton 13 cwt. of this is added to 1,000,000 gallons of sewage.
Carbon . . .	2	15	
Salts, &c. (not stated) .			
Total . .	9	18	

The cost of the above was 8*l.* 3*s.* 9*d.* or about 1*l.* 7*s.* 3*d.* per million gallons of sewage.

The cost of labour, &c. for the same was 11*l.* 3*s.* 6*d.* or 1*l.* 17*s.* 3*d.* per million gallons of sewage.

To this would have to be added cost of drying sludge, management, repairs, and interest on capital expended on works.

The cost of dealing with about one-sixth of the whole sewage (303,000,000 gallons a year) is, therefore, exclusive of drying the sludge and management, but inclusive of 5 per cent. interest upon capital, about 2,349*l.* per annum, or at the rate of about 7*l.* 14*s.* 5½*d.* per million gallons, or about 6*d.* per head of the population.

Analyses of effluent water and manure resulting from this process are given in the Appendix. The latter (containing 15 per cent. of moisture) is stated to be theoretically worth 1*l.* 1*s.* 1*d.* per ton, and to have a market value of 7*s.* to 10*s.* 6*d.* per ton.[1] The sludge not being dried prevents the cost of producing the manure from being ascertained. There is a difficulty in disposing of

[1] Loc. Gov. Bd. Rep., pp. 41 and lxiii.

this stuff to the farmers. Some of it has been mixed with refuse from middens and sold at 1*s.* per ton. The effluent water it will be observed is not filtered, and is not particularly good.

HOLDEN'S PROCESS employs sulphate of iron, lime, and coal-dust (clay being also mentioned in the patent). It was tried at BRADFORD, in 1868, on a portion of the sewage, amounting to 130,000 gallons a day, and was investigated by the Rivers' Pollution Commissioners, who state that, 'while it separated the whole of the suspended matters, it not only failed to remove the putrescible organic matters in solution, but actually (as measured by the organic nitrogen contained in these organic matters) increased their quantity. This it does by causing some of the putrescible organic matter in suspension in the original sewage to pass into solution. The effluent water could not, therefore, be admitted into rivers without causing pollution.' The Commissioners also say, 'It further appears that the amount of sulphate of lime in the effluent water is so great as to give it a very objectionable amount of permanent hardness. As to the manure produced, it is obvious, without any analysis of it, that it does not contain much valuable matter; in fact, 100 parts of it only contained ·555 of organic nitrogen, ·004 of ammonia, and ·3 of phosphoric acid; a manure of the above composition must be considered as practically worthless.'[1]

FULDA'S PROCESS, which has been recently patented, employs principally lime and sulphate of soda. It has been tried on a small scale at Messrs. Pratt's cloth mills,

[1] First Rep. Riv. Pol. Com., 1868, p. 60.

Yeadon, near Leeds, and at the Bramley Union Workhouse, and in September and October, 1873, it was tried on some of the sewage of LEEDS at the experimental works there. The results of this trial are not given, but it was not continued. It is said that the effluent was not satisfactory, and that the patentee did not fully reveal the process.[1]

BLYTHE'S PROCESS, patented in 1858, employs superphosphate of lime with magnesia and lime. It has not been practically put into use, but was investigated by the Sewage Commissioners, who reported upon it unfavourably in its results, and as being the most costly of all the plans that have been proposed, as stated in Corfield's work on sewage, p. 209.

WHITTHREAD'S PROCESS, patented in 1872, employs a mixture of dicalcic and monocalcic phosphate (the latter being added as commercial superphosphate), and also a little milk of lime, the object being to recover in the manure the whole of the phosphoric acid. An experiment was tried with it on a small scale on Colonel Hope's sewage farm at ROMFORD, and he (speaking at the Social Science Congress in 1872) referred favourably to those experiments. It was next tried in 1874, at LUTON, *Bedfordshire*, with a population of 17,316, but the authorities there disapproved of it, and it was not adopted.[2]

In the same year an experiment was made on a portion of the sewage of ENFIELD with the view of making a valuable manure out of the sludge. It is stated by Capt. Flower that this trial was more satisfactory than irrigation, and that apart from the smell of the sludge and the

[1] Soc. Arts, p. 38; and Roch. Ret., p. 27. [2] Roch. Ret., p. 26.

cost, it was an improvement upon the lime process; it appears, however, to have been considered very expensive, and was not continued.[1]

Towards the latter part of the same year a private company, called the Rivers' Protection and Manure Company, Limited, was formed for the purpose of working an agreement with the Local Board of TOTTENHAM for the treatment of the sewage of the town.

Tottenham has a population of 23,000. There are about 5,000 water-closets in use, and the sewage is purely domestic, refuse from the india-rubber works in the locality being now kept out of the sewers.[2] The daily flow is said to amount to the unusually large quantity of 1,200,000 gallons. The result of several months' working of the process at this place is thus given:[3]—2 lbs. of dry chemicals were added to 1,000 gallons, or 18 cwt. per million gallons of sewage. The cost of these chemicals was 3*l.* 2*s.* 0*d.*

The sludge was dried partially in tanks and finally in Milburn's machine, and the manure produced, when dried, bagged, and loaded for sale, was estimated to cost per ton, as follows:—

	£	*s.*	*d.*
Chemicals	1	14	2
Coals for drying	0	14	0
Labour	1	0	7
Total	3	8	9

The quantity produced was equal to about 32 tons per week. By analysis it contained—

About 2 per cent. of ammonia,
8 „ „ phosphoric acid in precipitated phosphates,
equal to 17 „ „ tricalcic phosphate,
5 „ „ potash,

[1] Soc. Arts, p. 42. [2] Roseb. Ret., p. 29.
[3] Proc. Inst., C.E., vol. xlv. p. 157.

and the value assigned to it was 4*l.* 3*s.* 6*d.* per ton ; it is also said that it appeared to meet with a ready sale.

Very conflicting reports of the quality of the effluent water have been given. It has been stated in one place that it was satisfactory, and in another that it contained more phosphoric acid than the filtered sewage, so that there was a positive loss in that respect.[1] The Company subsequently went into liquidation, the sewage works reverted to the Local Board, and another process has been adopted, to which reference is made elsewhere.

CAMPBELL'S PROCESS, patented in 1872, employs phosphate of lime in a soluble state. This is added to the sewage, and then precipitated by a further addition of lime. It was worked for six consecutive days in July, 1872, at TOTTENHAM, and the results are stated[2] to have been that 3,500,000 gallons of sewage were treated with the following chemicals :—

		Tons	cwt.	
Superphosphate of lime	Bone ash	6	10	9·76 lbs. of these were added to 1,000 gallons, or 4 tons 7 cwt. 16 lbs. to a million gallons of sewage.
	Sulphuric acid	4	15	
Lime		4	0	
Total		15	5	

The cost of these chemicals was 57*l.* 2*s.* 6*d.*, or 16*l.* 6*s.* 5*d.* per million gallons of sewage.

The yield of manure was 22 tons, the chemical value of which was estimated to be about 5*l.* a ton; analyses of the manure and the effluent water are given in the Appendix.

The experiments at the Tottenham Sewage Works were then discontinued, and small works, capable of

[1] Paper read at Soc. Arts, by W. Thorpe, F.C.S.
[2] Proc. Inst. C.E., vol. xlv. p. 149.

treating a maximum quantity of 5,000 gallons in twenty-four hours, were erected under one of the arches in the viaduct of the London, Chatham, and Dover Railway, and permission obtained from the Metropolitan Board of Works to pump sewage, for the purpose of experiments thereon.[1]

The experiments on these works commenced in September, 1873, and between that date and May, 1875, thirty-one trials were made—155,000 gallons of sewage were dealt with, and it was eventually found that to produce a good effluent water the following chemicals were required:—

Superphosphate of lime	10 lbs.	This was added to 1,000 gallons, or at the rate of 5 tons 16 cwt. 8 lbs. per million gallons of sewage.
Lime	3 „	
	— „	
Total	13 „	
	—	

The first experiment was with 5,900 gallons of sewage, the chemicals used being—

Superphosphate of lime	56 lbs.	These were used in the proportion of 5 tons 9 cwt. to a million gallons of sewage.
Dry lime	16 „	
	—	
Total	72 „	
	—	

The chemicals cost 4*l.* 2*s.* per ton, or 22*l.* 6*s.* per million gallons of sewage.

The dry manure obtained was 112 lbs. and was valued at 4*l.* 9*s.* per ton.

The second experiment was with 3,358 gallons of sewage, the chemicals used being—

Superphosphate of lime	32 lbs.	These were used in the proportion of 5 tons 11 cwt. 1 lb. to a million gallons of sewage.
Dry lime	9¾ „	
	—	
Total	41¾ „	
	—	

[1] Proc. Inst. C.E., vol. xlv. p. 151.

The chemicals cost 4*l.* 2*s.* per ton, or 22*l.* 15*s.* per million gallons of sewage.

The dry manure obtained was 56 lbs., and was valued at 4*l.* 17*s.* 4*d.* a ton.

The third experiment was with 3,724 gallons of sewage, the chemicals used being—

Superphosphate of lime	36 lbs.	These were used in the proportion of 5 tons 12 cwt. 77 lbs. to a million gallons of sewage.
Dry lime	11 „	
Total	47 „	

The chemicals cost 4*l.* 2*s.* per ton, or 23*l.* 2*s.* per million gallons of sewage.

The dry manure obtained was 80 lbs. 8 oz., which was valued at 3*l.* 15*s.* per ton.

It will be observed that in none of these trials has the cost of labour, coals, interest for outlay on works, &c., been added. It has been assumed to be 1*l.* 8*s.* 10*d.* per ton of the manure produced, and that this, added to the cost of the chemicals, would show a small profit on the manufacture of the manure. There would be, in addition to the risk of much of the valuable chemicals passing off in the effluent water and being lost, the risk of those which are precipitated undergoing a change from a soluble to an insoluable form, and thus losing much of their value for manurial purposes.

Hanson's Process, patented in 1875, employs lime, black ash, and red hæmatite treated with sulphuric acid. The black ash used in this process is said to be soda or tank waste, consisting essentially of the sulphides of calcium and sodium, a refuse from alkali works,[1] and obtainable

[1] Soc. Arts, p. 82.

in considerable quantities. The process was recently tried in the experimental works at LEEDS; at first it was not successful in removing dye from the sewage, but by the addition of hæmatite this was overcome [1] in a subsequent attempt in the permanent works (the authorities at Leeds being engaged in ascertaining by various trials whether this or the A B C is the cheapest). Hanson's process succeeded in obtaining a good effluent [2] with the following ingredients during twenty-four hours:

	Tons	cwt.	lbs.	
Lime	20	0	0	2 tons 16 cwt. 1 qr. of this were added to 1,000,000 gallons of sewage.
Black ash . . .	4	0	0	
Red hæmatite and double brown oil of vitriol .	1	6	2	
Total . .	25	6	2	

The cost of these materials was 20*l.* 11*s.* 2*d.* or 2*l.* 5*s.* 8*d.* for one million gallons of sewage.[3]

The process was discontinued at the Leeds Works in April last, so that lime alone might be tried, an experiment which is referred to elsewhere. The patentee of this process hopes to reduce its cost by changing the chemicals and ingredients employed, viz., by dispensing with the use of the hæmatite.

GOODALL'S PROCESS, which has been recently patented, employs lime, animal carbon, ashes, and an iron liquor called sesqui-persulphate of iron. After experiments tried at LEEDS, a company called 'The Leeds Clarifying and Utilisation of Sewage Company' was formed to work this process. In 1875, the Corporation of Leeds agreed that this Company should try it for three months.

[1] Soc. Arts, p. 38.

[2] For analysis of effluent water and residuum produced, *see* Appendix.

[3] *Description of the Leeds Sewage Works, &c.*

During this trial the process is said to have produced a good effluent water with the use of the following ingredients during twenty-four hours :—

	Tons	cwt.	
Lime	21	15	5 tons 3 cwt. of this were added to 1,000,000 gallons of sewage.
Carbon	13	15	
Ashes	10	14	
Iron liquor . . .	0	4	
Total . . .	46	8	

The cost of these materials was about 19*l.* 16*s.* or 2*l.* 4*s.* for one million gallons of sewage.[1]

No analysis of the effluent water from the above trial has been made. From a previous experiment, in December, 1873, when 800,000 gallons of sewage were treated with—

Lime	15 cwt.
Carbon	15 „
Iron liquor	1 carboy

An analysis of the effluent water as well as the residuum is given in the Appendix

This process completely failed to come within its estimated cost, viz., 7*s.* 6*d.* per million gallons for chemical ingredients. With the experimental works at Leeds, it reached 4*l.* 6*s.* 6*d.*, and with the permanent works it proved to be 2*l.* 13*s.* 4*d.*[2]

The LIME PROCESS has been under trial for upwards of thirty years, the earliest attempts to purify sewage by precipitation being with lime alone. It being a material comparatively cheap and abundant, sanitary authorities have somewhat clung to its employment, notwithstanding that in no instance has it been successful either in a

[1] *Description of Leeds Sewage Works, &c.*
[2] Soc. Arts, p. 38.

financial or a sanitary point of view. The following facts with reference to it have now been ascertained :—

I. When the cost of disposing of the large quantities of sludge produced by lime treatment is taken into consideration in conjunction with the necessity of producing a good effluent water, it is not a cheap process.

II. Lime does not purify but only clarifies sewage. This is stated by the Rivers' Pollution Commissioners, and is the experience at many places where it has been used.

III. It produces a nearly valueless manure.

Seventy-five years ago a patent was taken out by M. Lewis James Armand Estienne for treating sewage with lime. In the year 1841 a patent was obtained by Dr. Clark for softening and purifying water for domestic purposes, and thirty-three years ago Dr. Clark and Mr. John Graham used it for the purpose of purifying refuse water from the Mayfield Print Works at Manchester, it being also employed at the same time for the purification of the river Medlock at the same town. In the year 1846, Mr. William Higgs obtained a patent for treating sewage with hydrate of lime, and in 1851 Mr. Wicksteed obtained a like patent for treating sewage with milk of lime, and manufacturing manure from the residue or sludge. These latter two patents were put into operation on a large scale, the former at Tottenham, and the latter at Leicester. The works at Tottenham and at Leicester were built in an expensive manner, the object in view being more commercial than sanitary, and every preparation was made for the manufacture at both places of sewage manures, otherwise known as 'Tottenham sewage guano' and 'Leicester bricks.' It was not long, however, before the promoters of these undertakings found that the product they were manufacturing was valueless, and in the year 1858 the Leicester works reverted to the Corporation. The commercial part of the under-

taking having failed, attempts were made to continue the process for sanitary purposes, but even in this respect it has been given up at Tottenham, where another process has taken its place, and it is also about to be abandoned at Leicester for some more sanitary mode of dealing with the sewage.[1]

In 1858, the Rivers' Pollution Commissioners reported in favour of the lime process as carried on at Leicester, Tottenham, and Cheltenham, as 'a method likely to be made available in many other places with advantage;'[2] but in 1867 and 1868 the Commissioners alter this opinion by condemning the treatment of sewage with lime at Leicester, Luton, and Tottenham, as well as at Hertford.[3]

A more recent report by Captain Flower[4] on the treatment of town sewage in the valley of the Lee, records very fully the insanitary results of the lime process at some of these places, and it appears that at Birmingham also it is not successful, as it entails there as heavy a charge upon the town as a more sanitary process would. The analysis of the effluent water given in the Appendix shows that the purification of the sewage is not complete. The accounts also state that heavy compensation was recently paid to an adjacent landowner on account of fouling the stream. It is also the case that the large amount of sludge demands an increased area of land for the purpose of burying it, and that such cannot be obtained without heavy expense.

At Worksop and at Southborough, injunctions against the process have recently been granted, and out of thirty places where it has been used it has already been given up at sixteen; the remaining fourteen cannot be said to

[1] Proc. Inst. C.E., vol. xlv. p. 194; and Soc. Arts, p. 82.

[2] Loc. Gov. Bd. Rep., p. 117.

[3] Second Rep., 1867, pp. xi. xii. xiii.; First Rep. Riv. Pol. Com., 1868, p. 52.

[4] Soc. Arts, p. 41.

be satisfactory. These facts are sufficient to show that simple lime treatment has not been successful.

The average amount of lime generally used appears to be one ton per million gallons of sewage, and the cost of the process, exclusive of the cost of works, to be about 5*l.* for the treatment of the same quantity.

Lime treatment is in operation at the following places:—

ALTON, *Hampshire*, with a population of 4,192. Lime treatment has been in use for about thirteen years, but not being found effectual in purifying the sewage, perchloride of iron is added on very hot days. Shortly after the introduction of this system, a bill was filed in Chancery against the Local Board of Health.[1]

BALSALL HEATH, *Worcestershire*, a suburb of Birmingham, with a population of 14,000, and a domestic sewage. Lime treatment, with filtration through gravel, is in use, but is not effectual, the Birmingham and Warwick Canal Company having recently threatened the Local Board with legal proceedings for silting up the canal into which the effluent water flows.

BLACKBURN, *Lancashire*, with a population of 83,000; a small quantity of lime is used as an auxiliary to irrigation. Ten years ago the Corporation treated the sewage with lime, in consequence of an injunction being granted against them, but it did not remedy the nuisance, and gave rise to an action against them for the recovery of 20,000*l.* damages.[2] The Rivers' Pollution Commissioners report as follows:[3]—'At Blackburn, especially the river below the outlet of the limed sewage was in a most offensive condition of putrefaction, our note made at the time of our visit being as follows:—'Horribly offensive turbid blackish stream, disengaging most offen-

[1] Roch. Ret., p. 24. [2] Loc. Gov. Bd. Rep., p. 10.
[3] First Rep. Riv. Pol. Com., 1868, p. 52.

sive gases with black masses of putrid mud floating on the surface.' Analyses of the sewage and effluent water are given in the Appendix.

BIRMINGHAM may be regarded as the head-quarters of the lime process. Although the town of Leicester adopted it some eighteen years earlier, the authorities there have come to the conclusion that some other and more efficient method must take its place. Attempts to utilise the sewage of Birmingham were made nearly forty years ago, and for some time it was endeavoured to dispose of it by irrigation. Various experiments with land were made on a more or less limited scale, but eventually in 1859 the town authorities were compelled by legal proceedings to construct tanks for the reception of the sewage. In these several modes of filtration were tried, but found to be ineffective. In 1861, the Corporation purchased 28¼ acres of land for 8,000*l.*, and, in 1867, took on lease 128 acres of land at a yearly rent of 855*l.*, when irrigation was again tried, and the land prepared at a cost of 11,250*l.*, but it was not successful, and, in 1870–71, efforts were made to obtain power to acquire some 2,000 to 2,500 acres of land near Kingsbury, but without success. The costs incurred on this account amounted to 10,644*l.* The Corporation then purchased twenty-four acres of land that had been held on lease, for the sum of 8,000*l.*, and an additional 101 acres for the sum of 29,400*l.* In 1872, the lime process was resorted to at a cost for works of 58,880*l.*, notwithstanding that Mr. Hawksley advised the use of sulphate of alumina and lime.[1] At the present time Birmingham contains a population of about 350,000, with about 8,000 water-closets in use, and discharges by gravitation through two main outlet sewers at Saltley, an average daily volume of 12,000,000 gallons of sewage, containing a very large quantity of manufacturing refuse

[1] Birm. Sew. Enq., p. 87.

from a variety of metal works. To this sewage is added in the sewers about a third of a mile away from the tanks a dose of milk of lime, thirteen tons of lime being used daily for this purpose. It then flows into the tanks, the solid matter being allowed to deposit while the effluent is allowed to flow direct into the river Tame.

This effluent is by no means purified, as its analysis given in the Appendix shows, but is simply clarified sewage, and in a sanitary point of view is inadmissible into a stream or river. The authorities are now making arrangements for conveying it on to land for irrigation and filtration, it being expected that by such means a more complete purification of the polluted water will be effected.[1] The solid matter or precipitate, which is increased at least 25 per cent. in bulk by the use of lime, amounts to near 400 tons per day.[2] It is pumped from the tanks, conveyed a long distance in troughs, allowed to partially dry, and is then buried in the land, about one acre a week being used for this purpose. The land is made to conceal as much as it possibly can of this practically valueless deposit. It is still uncertain how many years must elapse before it will assimilate with the soil sufficiently to admit of the same land being again used to receive another deposit. The Corporation possess 258 acres of land (153 being freehold and 105 held on lease), which is used for this purpose, its surface being to some extent cultivated. The total expenditure upon these works up to the present has been, inclusive of a sum of 6,000*l.* recently paid to Sir Charles Adderley as compensation, 132,174*l.*[3] In addition to this the average annual cost of carrying on the process, during the years 1873–75, has been, after deducting sales of produce, and exclusive of supervision,

[1] Loc. Gov. Bd. Rep., p. 34.
[2] Proc. Inst. C.E., vol. xliii. p. 211.
[3] Loc. Gov. Bd. Rep. p. 33.

15,154*l.* 11*s.* 5*d.*;[1] if to this be added 5 per cent. interest on capital expended, the total average annual cost amounts to 22,460*l.*, involving a charge of 5*l.* 2*s.* 6*d.* per million gallons of sewage, or 1*s.* 3¼*d.* per head of the population. In the face of this cost Birmingham can scarcely be held up for imitation in respect to the disposal of its water-carried sewage.

Sir Joseph Bazalgette has recently said:[2] 'The sewage of Birmingham was now being utilised by the lime process, under the able direction of Mr. Hawksley, past President, Inst. C.E., and it was being carried out as well as it possibly could be; but he thought Mr. Hawksley himself would admit that it was only a palliative, and that it was not such a process as could be applied to most towns.' This opinion will be endorsed by all who consider that the system costs the ratepayers about 1,871*l.* per annum for each 1,000,000 gallons per day of sewage treated, and that it is not a sanitary success. There are other difficulties also, created principally by the use of this process, which the Corporation of Birmingham sooner or later will be called upon to meet, and which tend to show that as a system it is not complete. The enormous quantity of sludge produced by the lime process will in time require more land in which to dig or bury it, and unless a system for lessening the quantity be adopted, the cost of extra land, even if it can be obtained at all, must prove a very heavy addition to the rates of the borough.

The trial on a small scale of General Scott's system for converting sludge into cement is in operation at Birmingham sewage works, but the composition of the sludge there does not appear to be very favourable to this mode of disposing of it.

[1] General and detailed financial statements of the borough of Birmingham for 1873–75.

[2] Proc. Inst. C.E., vol. xliii. p. 211.

Had Birmingham acted on the advice given by Mr. Hawksley in 1871, and since, and adopted alumina in conjunction with lime, by this time some 18,250 tons less of lime would have been used, and 109,500 tons less of sludge would have been formed. The quantity of sludge produced at the Saltley works would also be lessened by some 80 tons per day.

BROMLEY, *Kent*, with a population of 12,000. Tanks for the reception of the sewage of about 200 houses (or 800 persons), and for its treatment by lime and filtration through gravel, have been in use three years and a half. The amount spent upon these works has been 891*l.*, and the cost of carrying them on during the year 1875 was 149*l.*[1]

BURTON-UPON-TRENT, *Staffordshire*, with a population of 20,378, and 232 water-closets in use, has a manufacturing sewage, containing refuse from breweries. The sewage is very foul, and the spent hops from the breweries decompose along the sides of the river, and cause a terrible nuisance. It is stated that 7,121*l.* have been spent on the works for treatment of the sewage, and that the cost of carrying them on during the year 1875, was 1,279*l.*[2] It is elsewhere stated that about one ton of lime is used to one million gallons of sewage, and that the cost of materials and labour amounts to 45*l.* per week.

Notwithstanding this outlay, the pollution of the river is very great, and it was stated in 'The Field' of September 2, 1876, that 'eight or nine dead salmon were seen in the Trent, at Weston, supposed to be due to the sewage of Burton-upon-Trent.'

BRADFORD, *Yorkshire*, with a population of 163,056, has about 4,050 water-closets in use, and an average daily flow of 8,000,000 gallons of sewage of a manufacturing character, containing refuse from wool-combing,

[1] Roseb. Ret., p. 15. [2] *Ibid.*, p. 34.

spinning, manufacturing, dyeing and dressing works. In 1868, the sewage poured into the Bradford Beck, and an injunction was granted against the Corporation. In the same year the Peat Engineering and Sewage Filtration Company attempted to filter the sewage through peat charcoal. Arrangements were entered into and works erected by the Corporation at a cost of 60,000*l.*; but the undertaking failed, because the sewage choked the filters, the Company losing upwards of 30,000*l.*[1] In 1875 the following process was commenced:—The sewage is first dealt with by screening, then precipitation by milk of lime, and, finally, filtration through coke screenings. For this purpose the works were altered, and altogether 63,618*l.* have been spent on them. The proportion of lime used is one ton per million gallons of sewage.

The cost for the year 1876 is given as follows:—

	£
Management	300
Labour	2,710
3,000 tons of lime	1,875
2,000 tons of breeze for filters	125
Fuel	642
Miscellaneous	624
Total	6,276[2]

This, together with 5 per cent. interest on capital, amounts to an annual cost of 9,456*l.* or at the rate of 3*l.* 4*s.* 10*d.* per million gallons of sewage, or 1*s.* 1¾*d.* per head of the population; but this does not include drying or in any way disposing of the sludge, which it is said amounts to about 22 tons per day; there is no sale for it, it accumulates at the works, and the Corporation propose to adopt artificial means for drying it.[3]

[1] Roseb. Ret., p. 46. [2] Loc. Gov. Bd. Rep., p. 44.
[3] Loc. Gov. Bd. Rep., p. 43.

No analysis of the effluent water is published; that of the manure (containing 15 per cent. of moisture) is given in the Appendix. It is in this condition said to be chemically worth 1*l.* 0*s.* 1½*d.* and to have a market value of 6*s.* 8*d.* to 10*s.* per ton.[1]

CHESTER, with a population of 35,232, and from 600 to 700 water-closets in use, has a domestic sewage amounting to an average daily flow of 1,500,000 gallons. A part of the sewage is used for irrigation, and as the effluent flows into a tidal river, the Dee, treatment of the sewage is only partial. It is stated that 4,200*l.* have been spent on the works.[2] The sewage is only pumped when the tidal water is above the height of the gravitation outfall into the river. A small amount of lime is used (viz. 6 cwt. per million gallons of sewage), and the sludge deposited in the tanks is taken by farmers whose land adjoins the works. It is stated that the working expenses amount to 800*l.* a year, about one-fourth of which is spent on the lime treatment; but it should be observed that the conditions for dealing with the sewage here are more favourable than those which generally occur.

EALING, *Middlesex*, with a population of 9,959, has a domestic sewage. About 11,500*l.* have been spent in works for the artificial treatment of the sewage, including the purchase of land for irrigation.[3] In the southern district lime treatment is used, and the effluent water flows by a brook communication into the Thames; the sludge mixed with house refuse is used for farming. In the northern district it is intended to adopt lime treatment also, and to use the effluent water for irriga-

[1] Loc. Gov. Bd. Rep., pp. 45 and lxiii.

[2] Roseb. Ret., p. 5; in Soc. Arts, p. 5, it is stated that 22,000*l.* have been spent in the construction of intercepting sewers and outfall works.

[3] Roseb. Ret., p. 28.

tion before it passes into the Brent. Lime treatment has been in operation for the former during ten years, and the cost is stated to be about 375*l.* a year.[1] Three years ago it was stated that no nuisance had arisen from this mode of treatment,[2] but no further information on this point appears since to have been published.

HARBORNE, *Staffordshire*, with a population of 5,105, and a domestic sewage. Lime is used to a small extent in conjunction with filtration through gravel, coke, and charcoal. No reports as to results have been published.

LEICESTER, with a population recently increased to 115,000, has 6,500 water-closets in use, and a manufacturing sewage containing refuse from dye, india-rubber, fellmongers', and soap works. Twenty-five years ago, Mr. Wicksteed proposed to utilise the sewage by treating it with lime, and manufacturing the residuum or sludge into manure. The subject was approached more as a commercial than a sanitary work, but it was intended to serve both purposes. It was believed at that time that the manure resulting from this treatment of sewage would be worth 5*l.* per ton, and Mr. Wicksteed formed a company, who erected works at Leicester for this purpose at a cost of about 30,000*l.*, but only to discover that the product was next to worthless. The consequence was, that after three years, according to agreement with the Corporation, the whole of the works fell into their hands free of cost, the company having failed to carry out their undertaking. The Corporation continued lime treatment. The works and process were investigated by the Rivers' Pollution Commissioners in 1868, who state that, 'the machinery employed is very perfect and efficient, but the method obviously failed in the purification of the sewage to such an extent as to render it admissible into a river'; and, further, 'that it was a

[1] Roseb. Ret., p. 28. [2] Roch. Ret., p. 27.

conspicuous failure both as regards the manufacture of valuable manure, or the purification of the offensive liquid.'[1] The product was theoretically valued at 13*s.* 6½*d.* per ton, but failed to realise that price, and even when given away the farmers do not care to have it,[2] and it accumulates at the works at the rate of 5,000 tons per annum.[3] The Corporation at present spend 2,116*l.*[4] a year in pumping and treating the sewage, but the works are not always in operation, and the sewage is only dealt with partially and imperfectly.[5] The process is reported as offensive, and giving rise to a nuisance,[6] and the undertaking is virtually abandoned, the authorities having in contemplation some other mode for purifying the sewage of the town.[7]

LEYTONSTONE, *Essex*, with a population of about 5,000. Lime treatment is reported as not satisfactory, though it is stated that no formal complaints have been made.[8]

LUTON, *Bedfordshire*, has a population of 17,316, and a sewage containing large quantities of chemical matter used in bleaching and dyeing straw-plait. The town is situated in the valley of the Lee and close to the source of that river. The sewage is treated with lime, and the effluent water passes over a bed of stone, gravel, and charcoal. The process has been in operation eighteen years. A sum of 7,000*l.* has been expended on the necessary works, and the cost of carrying them on during the year 1875 was, exclusive of interest on outlay, 650*l.*[8] The undertaking does not, according to the Rivers' Pol-

[1] First Rep, Riv. Pol. Com. 1868, p. 52. Analyses of sewage and effluent water are given in Appendix.
[2] First Rep. Riv. Pol. Com., 1870, p. 56; Soc. Arts, p. 82.
[3] [6] [8] Roch. Ret., p. 27.
[4] Roseb. Ret. p. 26; Soc. Arts, p. 82. [5] Soc. Arts, p. 10.
[7] Proc. Inst. C.E., vol. xlv. p. 194; also Soc. Arts, p. 82.
[8] Roseb. Ret., p. 3.

lution Commissioners, bear a good sanitary character. They say: 'The sewage is clarified by a liming process.' 'The effluent water, more or less clarified, flows direct into the stream of the Lee.' 'This process of clarifying sewage improves it in so far as the solids are removed, but the fluid remains sewage, and if allowed to stagnate will become putrid and offensive.'[1] A more recent report by Capt. Flower says: 'These works being of a temporary nature, cannot be called satisfactory, though the discharge of fluid from them, in consequence of the care with which they are carried on and the enormous dilution of the fluid by subsoil water, is at times fairly admissible into the river. Although clarified, however, it is not purified sufficiently to be passed into a river of small volume from which drinking water is drawn.' The sludge at Luton is said to be 'like all lime deposit, very filthy.'[2]

ORMESBY (NORTH), *Yorkshire*, with a population of 6,000. Treatment with milk of lime and filtration through coke were in use in 1874, and had been for six years, during which time no nuisance had arisen.[3] No recent information has, however, been published.

Lime treatment has been tried and given up at the following places:—

BANBURY.—First, carbolic acid and lime, and, second, perchloride of iron and lime, were tried and failed previous to the adoption of irrigation.[4]

COVENTRY.—Previous to the system now in operation, treatment with lime was tried and abandoned.[5] It has also been recently tried in the present works, but with insanitary results.

CHELTENHAM.—Previous to the adoption of irrigation,

[1] Second Rep. Riv. Pol. Com., 1867, p. xi.
[2] Soc. Arts, p. 41. [3] Roch. Ret., p. 28.
[4] Soc. Arts, p. 2; and Roch. Ret., p. 4.
[5] Soc. Arts, p. 36; also Roch. Ret., p. 24.

for some ten or twelve years lime treatment was used, and for three or four years perchloride of iron and Bird's process were adopted, but they were all abandoned as inefficient and unsatisfactory.[1]

HALIFAX.—Three years ago lime treatment was in use, and new additional works were being constructed,[2] but at the present time the sewage is not treated at all.

HERTFORD.—The average daily flow of sewage amounts to about 1,640,000 gallons. Water-closets are in general use, and the sewage, which is very dilute, in consequence of leakage of subsoil water into the sewers, also contains refuse from breweries. The Rivers' Pollution Commissioners in 1867 report as follows:—'By an Act passed in 1854 the New River Company obtained powers to lay down intercepting main sewers through the town, to construct works for treating the sewage by the liming process, and to convey the effluent water past the New River head into the Lee above the town of Ware. The New River Company have completed these sewage and outlet works at a cost of about 22,000*l.*, and maintain them. They also subject the sewage to a liming process at a further cost of about 700*l.* per annum, sparing neither trouble nor money. The effluent water usually passes away clear, but being, as it is, the sewage of nearly 7,000 persons, it cannot be otherwise than a nuisance, and it is, according to the evidence, a constant cause of complaint to the people of Ware.'[3] The Commissioners also say that 'the lime process does not purify the sewage even when carried out most carefully by the New River Company as at Hertford.'[4] The cost to the New River Company for the works during the years 1858 to 1875 was 28,000*l.*,[5] and for sixteen years lime treatment was

[1] Roseb. Ret., p. 13; also Soc. Arts, pp. 65, 105.
[2] Roch. Ret., p. 26.
[3] Second Rep. Riv. Pol. Com., 1867, p. xii.
[4] *Ibid.*, p. xiii. [5] Soc. Arts, p. 9.

used for the sewage. It appears latterly, however, that the Company allow the Corporation 600*l.* a year to carry on this work.[1] The sewage flows by gravitation to the works, and in the year 1867 was treated with about fourteen bushels of lime, and one bushel of chloride of lime per day, making together a dose of 3·76 grains per gallon, or 4 cwt. 79 lbs. per million gallons of sewage.[2] The effluent water, after filtration through coarse gravel, is described as being a little turbid, but soon became clear. An analysis of it is given in the Appendix. The annual cost of carrying on this work is stated to have been 410*l.*[3] The following is from a report in 1876 by Captain Flower of the sewage operations at this place:—'An attempt was made to purify the sewage by liming it. Here again, as at Luton, the effluent, although clear, was not pure, and the adjoining town of Ware lower down the stream was constantly complaining of the nuisance caused by secondary decomposition which is invariably set up by the lime effluent. I believe it is a fact that the most dangerous kind of organic impurity is organic matter in process of change or putrefaction. This change is set up and continues in the effluent after discharge from the works. The condition of the channel between the works at Luton and the stream, and the river at Ware is evidence of this, and thus in the lime effluent there exists the worst condition of sewage. It is not the presence of organic matter in its original state which is so objectionable in sewage, but those matters which are undergoing change or putrefying.'[4]

It is scarcely surprising, therefore, that in 1875 lime treatment was abandoned, and another process employed, to which reference is made elsewhere.

[1] Soc. Arts, p. 78.
[2] The Sew. Quest., 1872, p. 56.
[3] Roseb. Ret., p. 14.
[4] Soc. Arts, p. 42.

HITCHIN.—The sewage passes through a liming-house into a tank, and is supposed to be deodorised before entering the stream; but the present local board are preparing for the disposal of it by irrigation.[1]

LEAMINGTON.—Lime treatment was tried previous to the A B C process, and the adoption of irrigation. The annual expense of the process was 500*l.*, but it completely failed to purify the river, and was discontinued by order of the Court of Chancery.[2]

LEEDS.—Lime treatment was tried prior to the year 1873, but was not continued.[3] It was also tried in April, 1876, on the Permanent Sewage Works; fourteen to fifteen tons of lime per day were used on this occasion, but 'it did not remove the colour from the dye waters contained in the sewage,' and 'the effluent water was frequently mahogany-coloured.'[4] It was, therefore, discontinued.

NEWCASTLE-UNDER-LYME.—The sewage flows into three depositing tanks after mixing with quick lime, and is then passed through three filtering beds. The nuisance arising from the tanks has recently given rise to complaints and legal proceedings by the Corporation of Stoke-upon-Trent.[5]

OVER DARWEN.—Lime is mixed with the sewage, it is then passed through charcoal and straw boxes, and finally flows in a conduit for about a quarter of a mile, and then into the river Darwen. The use of lime was commenced in 1872, but the whole process gives rise to a nuisance, and the local board are about to adopt an alumina process.[6]

[1] Roseb. Ret., p. 14.
[2] Roseb. Ret., p. 41; Soc. Arts, p. 10; and Loc. Gov. Bd. Rep., p. 19.
[3] Roch. Ret., p. 27.
[4] Soc. Arts, p. 84; also *Description of Leeds Sewage Works, &c.*
[5] Tried at Stoke Police Court, April, 1876.
[6] Roseb. Ret., p. 23; and Roch. Ret., p. 28.

OXTON.—Lime with chloride of lime has been tried, but arrangements have since been made with the districts of Birkenhead and Tranmere to discharge into their outfall sewers, and thence into the Mersey.[1]

ST. MARY CHURCH.—Lime treatment, with carbolic acid, and filtration through coarse gravel and sand was tried, but gave rise to a nuisance. Complaints arose, and arrangements are being made with Torquay for an outfall into the sea.[1]

SOUTHBOROUGH.—Lime treatment was in use until an action was recently brought by an adjacent millowner against the local board for fouling and silting up a mill pond through the discharge of lime effluent from the sewage works. This resulted in the granting of a perpetual injunction against the board to discontinue their pollution of the stream.

TOTTENHAM.—Higgs' patent for treatment of sewage with lime, and the manufacture of the sludge into a manure, was put into operation here in 1856; at first, the results appeared satisfactory, but the product was found to be worthless in a commercial point of view. The undertaking was therefore in this respect abandoned, and the costly works erected by Mr. Higgs were sold at an almost nominal price to the local board, who continued lime treatment with a view to purify the sewage, but the board appear to have drifted into a costly litigation with the conservators of the Lee, for polluting that river. In 1867, the Rivers' Pollution Commissioners stated: 'The sewage at Tottenham is limed and the solids precipitated, but the effluent water retains so much sewage matter, that the Lee trustees, as protectors of the navigation and of the health of those employed upon it, have recently obtained from the Court of Chancery an injunction to prevent the Local Board of Tottenham from

[1] Roch. Ret., p. 29.

casting their sewage into the river so as to create a nuisance.'[1]

In a later report, the Commissioners state that the undertaking has proved a failure.[2] Lime treatment has therefore been abandoned as unsatisfactory to the Lee Conservancy Board, and other processes have been tried to which reference is made elsewhere.[3]

It is stated that above 11,000*l.* have been spent on the necessary works at this place, and that the cost of dealing with the sewage during last year amounted to 1,979*l.*[4]

WEST HAM.—Tanks for precipitation have been constructed, and lime treatment was tried for three months, but abandoned on account of its cost and the large accumulation of the sludge. At present (1876) the sewage is pumped into the River Lee at Bow Creek. The amount expended on the works is stated to have been 7,700*l.* and the cost of pumping, &c., during the year 1875, 1,740*l.*[5]

WORKSOP.—The sewage, which amounts to a daily average flow of 300,000 gallons, and is domestic in character, has milk of lime added to it; but constant complaints have been made by an adjoining landowner, who says that the lime injures the fish in the river, and an injunction has recently been granted against the local board, who are, in consequence, about to adopt some other means of dealing with the sewage.

[1] Second Rep. Riv. Pol. Com., 1867, p. xii.
[2] First Rep. Riv. Pol. Com., 1868, p. 52.
[3] Roch. Ret., p. 29. [4] Roseb. Ret., p. 29. [5] *Ibid.*, p. 12.

III.—*Processes in which salts of iron are used as precipitants.*

Salts of iron have been used for more than a century for disinfecting night soil and foul waters, and have formed the subject of various patents for the treatment of sewage, but in practice they are found to be too expensive.

At NORTHAMPTON, chloride of iron in conjunction with lime was tried with the sewage of 40,000 people, about six gallons of chloride of iron and twelve bushels of lime being added to each million gallons of sewage. The effluent water was then filtered upwards through a stratum of calcined iron ore, eight inches thick. It then flowed along a culvert for a mile and a half, in which it mixed with about one-sixth of its volume of spring water, an analysis of which is given in the Appendix. The results were, however, not successful, as in 1870 the Court of Chancery granted an injunction against the Corporation, and the system was abandoned.

At CLIFTON, sulphate of iron and lime were tried and given up.[1]

Previous to the adoption of irrigation, experiments on a small scale were made at CHELTENHAM with perchloride of iron, but were not satisfactory.[2]

IV.—*Miscellaneous Processes.*

Experiments on a small scale have been made with various processes—such as HIGGS', DALE'S, AND DIMSDALE'S, at CROYDON, and have been reported on unfavourably.[3]

[1] Roch. Ret., p. 24. [2] Soc. Arts, p. 105. [3] Roch. Ret., p. 7.

LENK'S PROCESS was tried on a small scale experimentally, and with good sanitary results, at TOTTENHAM, but it was very costly.[1]

Experiments have also been made with hydrate of lime, chloride of lime, and alum, at NEW SHOREHAM, *Sussex*, with a population of from 3,500 to 4,000, and a domestic sewage. A sum of 5,000*l.* it is stated, has been spent upon works and land, but little information has been published as to results.[2]

There are many other patent processes for treatment of water-carried sewage by precipitation, but none of them have been put into practical use.

[1] Birm. Sew. Enq., 1871, p. 47. [2] Roch. Ret., p. 28.

PART III.—IRRIGATION.

THE application of water-carried sewage to land for agricultural purposes has in this country had a trial extending over a quarter of a century, and upon reviewing what has been done in this direction, it must be admitted that it has, both in an agricultural and a commercial point of view, failed to fulfil the expectations entertained of it, and less confident opinions are now expressed of the value of sewage farming. At first an impression gained considerable hold upon the public mind that the manurial elements contained in water-carried sewage could be easily turned to account by its application to land, and that by so apparently simple a method, the refuse from towns could be converted into farm produce, and food for man and beast. This seemed a natural view of the matter, as the various practical difficulties which experience has since revealed were not then foreseen, or, perhaps, were disregarded, and the agricultural view of the case, irrespective of other considerations, has been persistently kept in view. Had some of the simplest data suggested by early sanitarians been borne in mind, some portion of the heavy expenditure on unsuccessful sewage farming might have been avoided.

The Rivers' Pollution Commissioners were so impressed with the agricultural features of the case and the prospect of reducing the rates by profits arising from the utilisation of sewage on land, that they failed to grasp the difficulties which surrounded the subject, but

which, through recent experience, are now well recognised.

From the amount of matter published upon this subject (much of which being expressed long ago is lost sight of), it may not be out of place to repeat some of the conditions which should govern the disposal of sewage by irrigation.

In 1862, Dr. Voelcker stated in evidence before a select committee on sewage of towns, 'that liquid manure may be applied with great advantage on light porous soils and all soils resembling more or less in character such land; but on heavy clay land it cannot be applied with advantage, especially when the land is so cultivated as to produce in dry weather large cracks, through which the liquid manure necessarily will flow.'[1]

At the same time Professor Way stated, 'that though valuable materials were contained in sewage, they were coupled with a condition which obliged you to limit your use of them'; also, 'there is no doubt that if you laid iron pipes over a farm and told me that I might have the sewage when I liked to apply it, I should be very glad of applying it when it was there, and I should be still better pleased if I could take it when I liked and could leave it when I liked.'[2]

Further, he said: 'I believe that under given conditions the sewage is of immense value merely as water, and that under other conditions the water is so objectionable that you would rather lose the manure than be obliged to have the water.'[3]

On the same occasion, Mr. Mechi said he was of opinion that sewage could only be applied to grasses, particularly Italian rye grass, and that 8,000 tons an acre per annum of sewage cannot be used without nuisance to the neighbourhood, or without nuisance to the running streams of

[1] Report, p. 58. [2] *Ibid.*, p. 36. [3] *Ibid.*, p. 40.

the neighbourhood. He further said, '200 or 300 tons per acre in his opinion would constitute a very excellent dressing for a cereal crop';[1] he, however, only applied 48 or 50 tons per acre, thinking that to be a sufficient stimulus, though he used 100 tons per acre for irrigating grass. His opinion was, also, that it would not be free from nuisance if more than 1,000 or 2,000 tons of sewage per acre per annum were applied, and even this proportion must be upon artificially underdrained land.

These statements from one so experienced in agriculture, and also in sewage agriculture, as Mr. Mechi, are valuable; they show: 1st, that sewage ought not to be applied to land for agricultural purposes in a proportion so large as a daily flow of 1,000,000 gallons to 200 acres; 2nd, that a proportion of 1,000,000 gallons to 33,000 acres is sufficient for cereal crops; 3rd, that a proportion of 1,000,000 gallons to 16,393 acres is sufficient for irrigating grass; and 4th, that it would not be safe generally to apply it in a greater proportion than 1,000,000 gallons to 1,000 acres. The true proportion of sewage to land for economical purposes is here pointed out, but, unfortunately, in practice, the limit laid down by Mr. Mechi has been enormously overstretched, and in this lies one of the chief reasons of non-success in sewage farming.

The Rivers' Pollution Commissioners, after an enquiry into the Croydon, Norwood, Worthing, Carlisle, and Edinburgh examples of irrigation in 1866 (Report, pp. 13, 15), came to the following conclusions:—

'Sewage irrigation requires to be undertaken and conducted with strict attention; the site must not be too near to dwellings, adjoining wells should be watched, and, if the soil be very porous, disused; the sewage must be supplied fresh and over a sufficient area of land. There may be difficulty in some cases in finding land available

[1] Report, pp. 56, 57.

for sewage irrigation, but with the exception of lands liable to be flooded, there seems to be no soil that will not serve the purpose.'

'Sewage can be pumped any height, and carried any distance. Its conveyance, therefore, to a given point is merely a matter of cost.'

'If a farm be large enough, there is no time when some portion of the land may not be capable of receiving the sewage.'

'Sewage must be dealt with continuously as time itself. This is a matter of first importance, regard being had to the necessity that sewage, as soon as produced, should be removed from the town and be applied whilst fresh.'

'In the selection of a site for irrigation due regard should be had to economical considerations. The cost of conveying the sewage depends partly upon the distance, but still more upon the height to which it is to be pumped.'

'The irrigated fields should be at least one mile from the town, and, if possible, in the direction of north or east.'

'The extent should not be less than in the proportion of one acre to every 150 inhabitants whose sewage is to be applied.'

'The carriers should be so constructed as to contain as little residuum of the sewage as possible.'

'Care should be taken so to appropriate the land as to leave for each day a sufficient area available for irrigation.'

The Commissioners, in 1867, state (2nd Report, pp. 14, 16): 'A sewage farm requires special and peculiar management, and not only requires a peculiar mode of cultivation, but also special management in dealing with the produce.'.

Dr. Voelcker has expressed the following opinions:—

'Nowhere have experiments on agricultural subjects been more extensively tried than in England; and, seeing the great success of irrigation with liquid manure in Flanders, where the soil is almost barren, men have thought that the system ought to be equally successful in this country, and have perseveringly tried it. Sometimes the results have been advantageous, but generally they have been a complete failure, and have been abandoned.' 'A principle,' he says, 'like that which informs us that fertilising matters produce their maximum effect in liquid form, may be true in the abstract, or with reference to particular kinds of plants, or in certain climates, or with reference to soils of a particular character; but in other climates or other soils there may be operating causes which render it by no means advisable to administer manuring matters in a state of solution.'

Had these foregoing opinions been kept steadily in view there is reason to believe that much of the expenditure upon sewage farming in this country might have been saved, impracticable and costly schemes might have been avoided, and some other mode of meeting the difficulty been sought for.

The unsuitability of the English climate for irrigation purposes has been too much disregarded in considering this subject. The favourable results with irrigation in India, and on the continent of Europe, where the climate is totally different from that of England, have frequently been advanced in support of its being successful in this country.

'In Spain, Northern Italy, and British India, irrigation on a large scale has proved highly useful. In Piedmont, about $1\frac{1}{2}$ million of acres are so treated, and in Lombardy, nearly six millions. The soil in both these countries is composed of deep beds of gravel overlaid with light sand. The volume of water annually used

amounts to from 5,000 to 12,000 tons per acre.[1] The atmospheric mean temperature is about 75° Fahr., the maximum 90°, and in some places, at Mantua and Milan, for instance, even 98°. Those regions have on an average 200 clear days of burning sunshine, 125 cloudy days, and but 40 of rain. At Brescia, for two-thirds of the entire year, the rays of a fierce sun are unchecked by clouds.

'These facts, viz., a torrid climate and a light sandy soil go far to explain the splendid results obtained by the application of large volumes of fertilising water in those countries.'[2] In England, however, where it rains on an average for 150 days out of 365 with a moist cloudy atmosphere generally prevailing, these conditions are altogether changed. Moreover, many lands in England require constant drainage instead of additional moisture and, excepting in dry summer seasons, which are rare, bear no comparison even with the irrigated, arid, sandy plains of Gennevilliers near Paris, or the sandy wastes employed for the sewage of Dantzic.

Neither of these latter instances of sewage irrigation can serve as a guide in this country, not alone because of difference in climate, but because a portion only of the sewage in each case is dealt with. Paris has a population of 1,857,792, and a daily volume of about 77,000,000 gallons of domestic sewage, one-tenth of which is used on the land, the remainder flowing direct into the river Seine. About four years ago the municipality of Paris induced the authorities of Gennevilliers to consent to the construction of an outfall in that commune. Accordingly, about 400 acres of the hot and dry plain of Gennevilliers, with an arid sandy soil on a gravelly subsoil of considerable depth, capable of absorbing any quantity of sewage, were devoted to the experiment. Under such favourable

[1] Equivalent to 191 acres for a daily flow of 1,000,000 gallons.
[2] Krepp on Sewage.

conditions of climate and soil, luxuriant vegetation was produced. This induced the municipality to try and extend the operations, which brought about powerful opposition from a large number of the owners or occupiers of the land, who, while admitting the agricultural results obtained, objected to taking the sewage, stating as their reason that during the experiment, 'The level of the land had already risen two metres since 1872, that the imperfectly purified water, instead of flowing into the Seine, has polluted the wells, penetrated the cellars of houses, the graves of the cemetery, and the quarries, spreading pestilential odours, and producing fevers, previously rare and almost unknown. The contemplated extension, they urge, would create an immense marsh, pestilential not only to Gennevilliers and Asnières, but to Paris itself.'[1]

The sanitary results of this trial are not satisfactory, but that the *agricultural* results are successful there is no doubt.

Experience with the sewage of Dantzic gives no better solution of the sewage difficulty. There the climate differs much from that of England. In 1871, some twenty acres of land were brought under irrigation, and, in 1874, extended to 330 acres. The character of the land is described as 'mostly pure dune-sand, the surface of which is so light that it is blown about by the wind.' The daily supply of sewage from the city is 4,428,900 gallons, from a population of 80,000; a portion only of it is used, which is pumped on to the land, and as no results of the cost have been published it affords no practical data for a guide. As regards the sanitary aspect of the work, it is said: 'The health of the neighbouring inhabitants is found to be in nowise affected by the proximity of the sewage farm, and beyond this no

[1] The *Times*, Sept. 1, 1875.

nuisance or annoyance, except a faint odour on very hot days, is ever found to proceed from the utilisation of the sewage in irrigation. In reference to the financial aspect of the undertaking, it is said: 'The present rental from the land is 20 thalers per morgen, or about 3*l.* per morgen, or 4*l.* 10*s.* per acre, and as the average is about 330, the annual rental is 1,440*l.* When the acreage is doubled, the results will repay expenses; but it is intended, eventually, to quadruple the present acreage.'[1] From the experience at Dantzic, therefore, nothing more is gathered than that good crops have been raised upon a sandy soil, but no account of the cost of dealing with town sewage is made out.

Too frequently has this subject been viewed from one or two points only, to the exclusion of others which claim equal consideration. Either the agricultural, the commercial, or some other element has been made a prominent starting point of inquiry, and in many reports upon sewage disposal, one leading idea can be traced throughout, irrespective of others equally important and necessary. The subject is one that should be carefully considered from many points of view, taken in conjunction one with another, before a sound opinion can be arrived at, and if this is not done, conclusions must be more or less practically misleading and worthless. Sewage disposal should be carefully weighed in the following aspects:—

I. Sanitary.
II. Engineering.
III. Chemical.
IV. Agricultural.
V. Commercial.
VI. Economical.
VII. Local circumstances
- I. Price of land.
- II. Position of land.
- III. Character of its surface.
- IV. Character of subsoil.
- V. Composition of sewage.

[1] *Engineering*, April 14, June 23, Oct. 13, 1876.

A strong feeling hitherto appears to have existed between advocates of irrigation and advocates of precipitation, which has stood very much in the way of sanitary progress. On the one hand there has been a determination to irrigate with sewage under any circumstances, while on the other hand, there has been a strong effort made to employ precipitation; in some cases filtration alone has been advocated, and so rival feelings have striven together, not to solve the difficulty, but to gratify self-opinion.

The sooner this ceases to be the case the better it will be for all parties; for the treatment of water-carried sewage requires one system as much as the other to effect its purification.

There are other reasons why sewage treatment has not made more progress. The Rivers' Pollution Commissioners advocated sewage farming and irrigation as the means to be employed, and the fact of large crops of mangold wurtzel, rye grass, cabbages, &c., being raised under sewage irrigation, was taken as sufficient reason for this mode of treating sewage, regardless of cost.

In 1865, the Rivers' Pollution Commissioners in their third Report state, 'that the right way to dispose of town sewage is to apply it continually to land, and it is only by such application that the pollution of rivers can be avoided.' In the same Report the Commissioners say 'The financial results of a continuous application of sewage to land differ under different local circumstances. Where local circumstances are favourable, and undue expenditure is avoided, towns may derive profit, more or less considerable, from applying their sewage in agriculture. Under opposite circumstances there may not be a balance of profit; but even in such cases a rate in aid, required to cover any loss, need not be of large amount.'

Twelve years' further experience reveals not only that

profit is not to be obtained from the application of sewage to land, but that, on the contrary, in most cases, a considerable rate has been necessary to meet the disposal of sewage by such means.

The Committee of the Local Government Board, in their recent Report, endorse these opinions of the Rivers' Pollution Commissioners in favour of irrigation. At page 116, they say that 'they have as much value now as at the time they were made.' In their own conclusions (p. xiii), however, they are careful to point out 'that town sewage can best and most cheaply be disposed of and purified by the process of land irrigation for agricultural purposes when local conditions are favourable to its application;' and that it 'is not practicable in all cases.'

The Committee of the Local Government Board (Report, p. lix) state that 'the difficulties and excessive charges in obtaining land very much retard local improvements, and tend to throw the question of sewage irrigation back; it is, however, only a repetition of opposition which every improvement in civilisation has had to fight through.'

Much care should be exercised in interpreting this statement, because some of the difficulties where they exist can never be cleared away. Unfortunately, opposition will ever continue, for the small value of water-carried sewage as a manure is now so well known to farmers and landowners, that only in exceptional instances will they be willing to co-operate with town authorities in the matter.

Land irrigation, with undefecated sewage, from a sanitary point of view, is a question that in these pages it is not intended to discuss. It has been argued that sewage farms 'need not be a nuisance.' This appears to be true, but in order to accomplish this end, a better, and

a more costly, supervision than in most cases towns supply, is necessary. That some of the sewage farms which are noticed in this work are not in a proper sanitary condition is true, as the sewage runs off almost as foul as it goes on to the land, and in others it ponds on the surface and putrefies.

The sanitary state of sewage farms is likely to vary much from time to time. It must by no means be considered conclusive that those against which no complaints are made are in every respect what they ought to be as sanitary works, frequently from the over-drenching with sewage or some other mismanagement, or the quantity of land being inadequate to the flow of sewage, a nuisance does occur, but the absence of complaint doubtless arises from the forbearance of riparian owners, who see that efforts have been made, and sometimes at heavy cost, to abate the nuisance.

Captain Flower, after experience of various processes in the Lee Valley district, says: 'Irrigation farms, whereon sewage pure and simple is discharged, is not a mode of disposing of sewage which commends itself for universal adoption.' 'Although sewage may be purified by a farm or a filtration ground if passed without deodorisation on to them, there is an unmistakable odour which, healthy or not, is by no means pleasant to the senses.' 'Specially in my own watershed, I think irrigation farms in the low-lying districts of the Lee Valley are particularly to be deprecated. Sewage constantly poured into a water-logged stratum must in time become a nuisance. The farms at Ponders' End and Rye meads are examples.'[1]

From the instances of sewage-farming which follow, it is evident that sewage irrigation can only be successfully practised under special and peculiar circumstances, viz., where land can be obtained in sufficient quantity, where

[1] Soc. Arts, p. 43.

it is sufficiently far from human habitations, where it can be obtained at a reasonable price, where there would be no difficulty in increasing the area, where the soil is so porous as to admit of free and almost unlimited percolation, where the sewage can reach the land without the aid of pumping, or very long and expensive carriers, where the produce of the land will find a ready sale, and where the farm is under good management. On the other hand the disadvantages of sewage irrigation, as it is now practised, are very numerous and very formidable. In the first place, it often happens that the sewer outfall is so much below the level of the land, that costly pumping power and expensive conduits are required for transport of the sewage. The necessary quantity of land (389 acres, at least, for every million gallons of sewage daily) is not always to be obtained at a reasonable price, within a reasonable distance; for the land must be porous, with a moderately level surface, a proper outfall, and not liable to subsoil pollution. There is the difficulty of obtaining extension of land to meet the increase in volume of sewage. In all cases the ground must be thoroughly levelled and thoroughly drained, and otherwise prepared for the reception of the sewage. There is the difficulty of disposing of sewage in wet weather, when the quantity is larger than usual, and when the ground is already loaded with moisture; also in winter, when vegetation is very sluggish, and at night, when there are no crops to which it can be applied. There is the pressing necessity for continually, systematically, and thoroughly defecating the sewage so as to produce at all times an effluent water which can be freely admitted into the neighbouring watercourses without the danger of polluting them.

There is the serious disadvantage of the non-applicability of sewage to any other crop than osiers, Italian

rye-grass, and mangold-wurtzel, the latter of which can only be used profitably for dairy purposes.

Ordinary agriculture, to be thoroughly successful, demands knowledge and acquirements of no inconsiderable kind, but for sewage farming still higher intelligence and education are needed.

The prejudice which exists against sewage-grown produce, whether it be well-founded or not, operates very much against its sale. This difficulty is experienced on many sewage farms, and very recently it has been stated that at West Derby Sewage Farm, the onions, after being refused in the market, were consigned to the dung-hill, the cabbages were scarcely fit for cattle, and for the most part did not pay for the plants.[1]

Sewage irrigation, it is stated by Mr. Morgan, was found at the Lodge Farm, Barking, not suitable for market gardening, inasmuch as the produce does not come into the market quite so early, because sewage water did not force the plants during the early cold weather as much as farmyard manure.[2]

The subsoil water, if not properly diverted, is apt to reach the neighbouring wells, and render them unwholesome.

In irrigation, sewage is always liable to escape through cracks or rat-holes in the soil to some well or watercourse without being purified. An instance bearing upon this has been quoted as follows (Soc. Arts, p. 73): 'Typhoid fever broke out in the small town of Basle; the excreta went into a stream which was used for irrigating the land. A mile away on the other side of the hill, was the town of Lausanne, where typhoid fever also broke out; the springs were more than a mile from the irrigated land, but they had certain relations to it, because

[1] Local Board Sewage Farming, by G. Ferme, 1876.
[2] Soc. Arts, p. 73.

it was noticed that they sensibly rose when irrigation took place. The suggestion arose that the typhoid material somehow got through the land into the springs, especially as it only occurred in houses where that particular water was used. The next question was—Was there any communication between the irrigated land and the springs? and to test this, a large quantity of salt was mixed with the water, and the result was, an enormous increase of chlorine was found in the springs, showing that there was a connection between the irrigated land and the springs. Then to ascertain whether there was a direct channel, or if it arose from filtration, a large quantity of flour was mixed with the water, but this did not pass, and the conclusion, therefore, was that it filtered through the earth, and caused the spread of disease in that particular neighbourhood.' It can scarcely be said that this evidence was conclusive as to the spread of typhoid poison; but it shows that, at the distance of a mile, sewage from an irrigation ground did escape into a spring of water used for domestic purposes.

These circumstances would tend to a conclusion that the present method of distributing crude sewage upon land is not satisfactory, and point rather to the necessity for dealing with it, first by defecating it with one or other of the best precipitating processes, and then to use the clarified water upon land if it be thought desirable. In this manner, the purification may be so conducted as to suit the special requirements of the case; for if the effluent water is to be employed for irrigation purposes, there is no need of such a careful and perfect disinfection of the sewage as when the water is to be at once discharged into a neighbouring stream. By this means a smaller area of land will suffice, and not only may the necessary disinfection be so accomplished that the effluent water may be either used upon land when the season

permits, or discharged into an outfall channel, but the precipitated matter may be used as a manure. That irrigation, or any one process in itself, is insufficient, is clearly evidenced by the fact that many of the objections which exist to an individual process disappear when two or more processes are taken in combination with each other.

Sewage Farm showing (exclusive of management) a profit.

WREXHAM, *North Wales*, has a population of 8,537, and water-closets are used by 30 per cent. of the inhabitants. The sewage contains refuse from leather manufactories and breweries, and amounts to an average dry weather daily flow of 300,000 gallons, which, along with storm water, is conveyed by gravitation to a farm of 84 acres in extent, having a gravelly and loamy soil. It is held on lease by the Corporation at an annual rental of 320*l.* For two years the local authorities greatly mismanaged the farm, and, in February, 1872, it was sublet (for 350*l.* a year)[1] with the sewage, to Lieut.-Colonel Jones, V. C. who, residing on the spot and devoting his whole energy and skill to managing the undertaking, has achieved a fair amount of success. The sewage is first of all allowed to subside in tanks, and about 600 tons of sludge per annum is in this way removed from it, and sold at 1*s.* 6*d.* per ton.[2] The character of the soil being suitable, the expense of underdraining it, with the exception of mains, has thus been saved. Storm water is not excluded from the sewers, but the flow of liquid sewage on to the farm in wet weather is limited to 500,000 gallons a day, or about one-half the flow after 24 hours' rain. All surplus liquid over and above that quantity in

[1] Roch. Ret., p. 17. [2] Soc. Arts, p. 27.

wet or stormy weather is discharged directly into a neighbouring brook.[1] The land is used in the proportion of 280 acres to a daily flow of 1,000,000 gallons of sewage; 'about two acres of this farm were prepared and used as filter beds, on the Merthyr plan, during the first year; but it has subsequently been found unnecessary to waste any of the liquid sewage by such means, as it can always be used to greater advantage in wide irrigation.'[1] The Corporation of Wrexham, by this arrangement, appear to obtain a return sufficient to cover the interest on the outlay of 1,000*l.*[2] on the necessary works in connection with this undertaking. Colonel Jones, after working the farm for three years, published his accounts,[1] which are not given in full, but state 'that although the first year showed a loss of 22*l.* 8*s.* 6*d.* the second, third, and fourth year's working have each shown a considerable profit; thus, in 1873, after deducting for rent at 5*l.* per acre, interest on capital at 5 per cent. and 5 per cent. on cost of permanent improvements, to form a sinking fund calculated to repay the amount expended on such works within the term of lease, a profit of 186*l.* 3*s.* 3*d.*; in 1874, 276*l.* 4*s.* 6½*d.*; and in 1875, 271*l.* 18*s.* 6½*d.* In this last year twenty additional acres were added to the farm, but six acres were out of the reach of the sewage by gravitation.'[1] These figures show a profit of 2*l.* 4*s.* 8½*d.* per million gallons of sewage, or 6¾*d.* per head per annum of the population. It should be noticed, however, that in these accounts Colonel Jones makes no allowance for his own time and supervision, which require to be estimated for. The Mayor of Wrexham speaking recently in public, said:—'The result of Colonel Jones' taking the farm has been to enable him to make a profit out of it; but it must be

[1] Soc. Arts, p. 27. [2] Roseb. Ret., p. 51.

remembered that he was a gentleman who had an indomitable will and energy in the management of anything he took in hand. If anyone else wished to succeed in the same way, they would have to follow his plan of getting up at four o'clock in the morning, and regulating everything for themselves.'[1]

Sewage Farms showing a moderate loss.

CHELTENHAM, *Gloucestershire*, has a population of 41,923; the sewage is almost entirely domestic in character, containing refuse from 8,500 water-closets, and but little manufacturing refuse from a few breweries and skin yards, and amounts to a daily flow of 1,250,000 gallons. It is first received in subsidence tanks, where the deposit is mixed with ashes, and sold as manure at the rate of 2*s.* a cubic yard; it then flows by gravitation to a farm, about two miles distant, comprising 131 acres of chiefly clay land (purchased in 1870); but, in addition to this, along the route which the sewage travels, there are 330 acres of land belonging to adjoining proprietors, which are also irrigated with it.[2] The price paid for the farm (which, it should be observed, is insufficient in size, and requires the co-operation of the adjoining proprietors of land to make it answer) was 10,500*l.* The cost of the outfall sewers from the tanks to the land, and laying out the land (this is only partially drained), has been 7,500*l.*, making a total of 18,000*l.*[3] The undertaking has been in operation for five years. The land is divided into five or six parcels, and let annually to the neighbours at the yearly rental of about 7*l.* per acre, making a total of 800*l.*, men being kept by the authorities to attend to the irriga-

[1] Soc. Arts, p. 72. [2] Rep. Ass. Pres. Riv. Scot., 1875.
[3] Roseb. Ret., p. 13; Roch. Ret., p. 6.

tion. Many of the conditions here appear to be favourable, although the quality of the land is not so, and the farm is situated at some distance. Heavy legal expenses have been avoided, and the price paid for the land was moderate, viz., 80*l.* an acre; but the chief element of success appears to be in the adjoining landowners' co-operation, and their willingness to pay a high rental for the sewage land. The financial accounts show a loss of 132*l.*[1] for the year 1875, which is stated to be a fair average annual loss,[2] or at the rate of about 5*s.* 9½*d.* per million gallons of sewage, or ¾*d.* per head of the population; but this does not include supervision, and when the practical and sanitary aspects of the case are considered, the difficulties cannot be said to be permanently surmounted, inasmuch as the quantity of land is insufficient,[3] and the difficulties in obtaining more cannot be foreseen. The adjoining parishes of Leckhampton and Charlton Kings, with part of Prestbury, are about to be united with Cheltenham for sewerage purposes, which will bring up the total population to 50,000, or thereabouts; already it is said that 'it would be more convenient if they had a larger area of land, and they were trying to obtain some more for the purpose';[4] so that when these additions are all made, it is evident that more land must be acquired if the present system is adhered to. The Medical Officer of Health for the district states, that 'he had known the place for nearly forty years, and comparing its former state with what it was now, he could trace a wonderful improvement. A sewage farm would occasionally give rise to insufferable odours; but the land was chiefly under grass, that being found the most convenient way of applying the sewage.'[5]

[1] Soc. Arts, p. 66.
[2] This cost is given in Roseb. Ret., p. 13, as 400*l.*
[3] Rep. Ass. Pres. Riv. Scot., 1875.
[4] Soc. Arts, p. 67. [5] *Ibid.*, p. 66.

The proportion in which the land is now used is 369 acres to a daily flow of 1,000,000 gallons of sewage.

As an instance of merely passing the sewage *over* and not *through* the land, it has been stated that at this farm, when the irrigation was absolutely confined to the surface, though the weather was fine at the time, the effluent came off as weak sewage.[1]

RUGBY, *Warwickshire*, has a population of 8,400. The Rugby sewage farm dates from 1853, and is famous in the annals of sewage irrigation. It was selected fifteen years ago as the seat of experiments on the value of town sewage for agricultural purposes, by the Royal Commissioners appointed to investigate the matter. These experiments were carried on during the years 1861–63, by Mr. Lawes, on the part of the Commission of which he was a member. They resulted in the growth of crops of rye grass and other sewage vegetation of fair quality. A great deal of information on this head is given in the Commissioners' Report.[2] In a financial point of view, however, the undertaking has not succeeded, and the tale of Rugby farm is told thus: 'It was laid out in a most approved fashion, and was managed by Mr. Campbell, who had studied the operations at Edinburgh, but after eleven years of experience he abandoned it, and said, in a letter to the 'Times' of November 18, 1864, that he had used the sewage of Rugby ever since the formation of the works, but he was sorry to say in a pecuniary point of view it had been altogether unremunerative. After this it was taken in hand by Mr. Congreve and Mr. Walker, but they also abandoned it, and then it fell into the hands of the local authorities.'[3] The farm has since that been let to a tenant for 429*l.*

[1] Trans. Inst. Sur., 1872.
[2] First Rep. Select Com. on Sewage of Towns, 1862.
[3] The Sew. Ques., 1872, p. 145.

per annum. It now comprises seventy-eight acres of loam and gravel land, lying upon a clay subsoil. It is situated about a mile to the west of the town, and is held on lease by the Local Board of Health for thirty years, at an annual rental of 344*l.*, or about 4*l.* 10*s.* per acre. The board has expended, inclusive of 1,139*l.* 18*s.* 5*d.* paid to lessee of old sewage works, a sum of 6,937*l.* 18*s.* 7*d.*[1] upon it, and on the necessary works in connection with it. Taking 5 per cent. on this outlay, and adding the difference between the present rent and that paid by the local board, the annual charge is 262*l.*, or 1*l.* 15*s.* 10*d.* per million gallons of sewage, or 7½*d.* per head of the population. In addition to this, the tenant shows a loss on the farm for the year 1874, of 24*l.* 2*s.* 8½*d.*[2]

There are 1,400 water-closets in use, and the sewage amounts to an average daily flow of 400,000 gallons, and is purely domestic in character. It passes by gravitation on to the farm, where it is first strained through perforated boards placed in depositing tanks.

The proportion of land used is 195 acres to a daily flow of 1,000,000 gallons of sewage proper. Four years ago the condition of this farm was said to be insanitary.[3]

BEDFORD, *Bedfordshire*, has a population of 16,851, and 3,000 water-closets in use. The daily flow of sewage amounts to 700,000 gallons, which is purely domestic in character, containing no manufacturing refuse. It flows about a mile, and is then pumped to a height varying from 10 to 20 ft. on to a farm which originally was 130 acres in extent, but an additional quantity of land (53 acres) has since been acquired, making the total area of the farm 183 acres, of which 27¾ acres belong to the Corporation, and the remainder is held on lease for twenty years at an average annual rental of 5*l.* per acre. The

[1] Roch. Ret., p. 12. [2] Loc. Gov. Bd. Rep., p. 26.
[3] The Sew. Quest., 1872, p. 11.

gravelly and loamy character of the soil is most favourable. The amount expended on the pumping station, preparation of the land, &c., has been 9,200*l.*[1] The average annual working expenses for the years ending December 31, 1874–75, inclusive of rent, and the cost of pumping, has been 2,560*l.* The average annual return from sale of produce during the same periods has been 2,421*l.*,[2] so that, inclusive of 5 per cent. interest on the capital, the annual expense amounts to 599*l.*, or 2*l.* 6*s.* 10½*d.* per million gallons of sewage, or at the rate of 8½*d.* per head of the population. The farm is distant only about 1,000 yards from the town, and almost all circumstances here are favourable to the undertaking, including the rent, which is moderate. The character of the soil is so suitable, that, with the exception of mains, it has not been found necessary to underdrain it, and the cost of its preparation has not exceeded 15*l.* an acre. The farm is, moreover, situated in a locality well suited for the sale of produce, and no difficulty is experienced on this point. It has been in operation seven years. The proportion of land used is 261 acres to a daily flow of 1,000,000 gallons of sewage.

Bishops Stortford, *Hertfordshire*, has a population of 6,250, and a daily flow of about 500,000 gallons of sewage proper (the flow, owing to large quantities of subsoil water getting into the sewers, is about double), containing no manufacturing refuse. This is an instance of a sewage farm which, having been in operation four years, in a sanitary point of view is spoken well of: 'The sewers have a very large quantity of infiltrated subsoil waters, and the sewage is very weak. This being the case, and to save pumping, about four or five hours of the night-flow is filtered through gravel and charcoal,

[1] Loc. Gov. Bd. Rep., pp. 7 and xxxviii.

[2] Published accounts for borough of Bedford Irrigation Farm, 1874–75.

the rest being pumped daily, Sundays included, on to the farm.'[1] The character of the soil (gravel and loam) is in this instance suitable, and other circumstances are favourable to irrigation; the sewage has to be conveyed to the farm by an outfall sewer, 1,500 yards in length, and lifted by pumping to three different levels. The farm consists of ninety-seven acres, of which eighty-one acres are freehold, purchased at a cost of 6,675*l.*, and sixteen acres are held on lease for thirty years at an annual rental of 3*l.* per acre. A sum of 1,000*l.* has been spent on works. The cost of pumping the sewage is 468*l.* a year, the working expenses of the farm during the year 1875 were 508*l.* and the return by sale of produce for the same period, 877*l.* Therefore, the actual annual charge to the ratepayers, inclusive of interest at 5 per cent. on the capital invested, but exclusive of supervision by town authorities, amounts to 533*l.*, or at the rate of 2*l.* 18*s.* 4*d.* per million gallons of sewage, or 1*s.* $8\frac{1}{4}$*d.* per head of the population. The quantity of land used is in the proportion of 194 acres to a daily flow of 1,000,000 gallons of sewage. The price of the land purchased was at the rate of 82*l.* per acre.

ALTRINCHAM, *Cheshire*, has a population of about 9,000, and about 250 water-closets in use. There is a farm of fifty-five acres of suitable land (chiefly moss soil, originally forming part of Carrington Moss) for the disposal of the sewage, which amounts to 250,000 gallons per day. The sewage contains no manufacturing refuse, and is delivered at a distance of two miles on to the farm by gravitation. The land has been secured at a reasonable rental of 4*l.* per acre upon a lease for twenty years. The farm has been in operation five years. The necessary works have cost 3,000*l.* The average annual loss on the working of the farm during the years 1873,

[1] Soc. Arts, p. 43.

1874, and 1875, is said to have been 131*l.*, so that, if 5 per cent. interest on the capital spent be added, the total annual loss is 281*l.*, or 3*l.* 1*s.* 7*d.* per million gallons of sewage, or at the rate of 7½*d.* per head of the population. The land is used in the proportion of 220 acres to a daily flow of 1,000,000 gallons of sewage. It should be borne in mind that all the conditions here appear favourable to the system adopted.

In the year 1864 an injunction was granted against the local board of BANBURY, *Oxfordshire*, for polluting the river Cherwell, and, subsequently, a sequestration order was issued. The board constructed tanks for the reception of the water-carried sewage of the town, with a view of diverting it from that river, and about ten years ago obtained a farm of 138 acres. This farm, with an additional 100 acres of land, was afterwards purchased for a sum of 23,500*l.* In laying out the land, and constructing pumping station, tanks, and necessary works, a further sum of 5,500*l.* was expended, making a total of 29,000*l.*[1] 138 acres of this land, which is described in character as a sandy clay soil, not very porous, the greater part stiff and tenacious, with a clay subsoil, underdrained to the depth of three feet, is used as a sewage farm. The remaining 100 acres, with the farm-buildings thereon, are let at 3*l.* 5*s.* per acre. The sewage from a population of 11,718, where water-closets are in use to the number of about 2,400, amounts to a daily flow of 320,000 gallons, and contains a small amount of manufacturing refuse from a tweed manufactory. It is received into tanks, where it is allowed to subside, and is also strained. The deposit in these tanks is generally mixed with town sweepings, &c., and sold for manure; this being carried on in the town, is very objectionable. The sewage is pumped from the tanks,

[1] Roch. Ret., p. 4; and Loc. Gov. Bd. Rep., p. 4.

a height of 21 ft. and a distance of about a mile, on to the farm. The average annual working expenses during the two years, 1875 and 1876, inclusive of pumping, has been 657*l.* The average annual return by sale of farm produce, manure, rent, &c. during the same periods, has been 1,695*l.*[1] If, therefore, 5 per cent. interest on the capital expended be added, the total annual cost, exclusive of supervision, is 412*l.*, or at the rate of 3*l.* 10*s.* 7*d.* per million gallons of sewage, or 8½*d.* per head of the population. The land has been purchased at a moderate price, viz., 99*l.* per acre, and it is used in the proportion of 431 acres to a daily flow of 1,000,000 gallons of sewage.

KENDAL, *Westmoreland*, has a population of 13,442. The plan adopted is that of irrigation, aided by subsidence and straining in tanks of the fæcal matter, heavy detritus, &c., and filtration through land. About 450 water-closets are in use, and the sewage contains refuse from woollen manufactories, tanneries, &c. It is exceedingly weak and dilute in character, owing to extensive percolation of springs and subsoil water into the sewers, and amounts to the large daily flow of 1,750,000 gallons. The farm to which it flows by gravitation is sixty-five acres in extent, of a sandy loam upon a gravel bed. Eleven acres of this are used for irrigation, five acres are used for filtering beds, and the remaining forty-nine acres are used for the disposal of the solid matter and sediment from the tanks. This composite system has been in operation for about three years. The amount paid for the land was 16,371*l.* 14*s.* 5*d.*, or about 252*l.* an acre. The cost of levelling sixteen acres was 400*l.*, or 25*l.* an acre, and the cost of preparing five acres for filtration was 1,400*l.*, or 280*l.* per acre, which, together with 700*l.* spent upon the farm-buildings, makes a total outlay up to

[1] Published Accounts of Local Board, &c.

the present time of 18,871*l.*[1] The Corporation are, however, now preparing a double quantity of land for filtering purposes, five acres not being found sufficient.[2] The filtration areas are cultivated, and the average annual working expenses during the years 1874 and 1875 have been 223*l.* and the average annual returns by sale of produce, &c., during the same periods, have amounted to 512*l.*[3] If, therefore, 5 per cent. interest be added for capital expended, the annual charge would amount to 658*l.*, or, exclusive of supervision, at the rate of 3*l.* 12*s.* 2*d.* per million gallons of sewage, or 11¾*d.* per head of the population.

In reference to the financial results of this undertaking, an authority recently says: 'The rye grass and meadow grass pay fairly well. The filtration area about repays the cost of labour in applying the sewage, the rent of land and interest on the cost of levelling and farming the land being lost, being in fact the cost at which the sewage is purified.'

The circumstances are all so favourable in the case of Kendal, that it is quite exceptional as an instance of sewage irrigation, and caution must be exercised in taking its results as a guide for any other place. It is true that a high price has been paid for the land, but the bulk of it has been let at a very good rental, which compensates for this outlay. The proportion of land used (inclusive of the forty-nine acres upon which the deposit is utilised) is 130 acres to a daily flow of one million gallons of *sewage proper*, and exclusive of that it is thirty-two acres to the same flow. The quality and formation of the land is so suited both for irrigation and intermittent filtration of

[1] Abstract of Accounts for Borough of Kendal, 1875, p. 21; and Loc. Gov. Bd. Rep., p. 32.

[2] Loc. Gov. Bd. Rep., p. 32.

[3] Abstract of Accounts for Borough of Kendal, 1874 and 1875.

sewage as to be quite unique. It is described by an authority well acquainted with the works, thus: 'Probably there could not be a better adapted natural filter found anywhere than this piece of land. It is for a depth of from 2½ to 4 feet a fine sandy loam, lying on a bed of sand gradually increasing in size to the boulder class, at a depth of from eight to ten feet, and so porous that the sewage passes right through it and, we find, leaves the whole of the impure matters within the first three inches of the top.'

The condition of the sewage dealt with is also eminently favourable for intermittent filtration. The sewage proper from the town amounts to a daily flow of only 500,000 gallons, and is diluted with about 1,250,000 gallons of spring water before it arrives at the land upon which it has to be dealt with.

Sewage Farms showing a considerable loss.

DONCASTER, *Yorkshire*, has a population of 18,750. The sewage is of a domestic character, and almost free from manufacturing refuse. There are about 500 water-closets in use, and the average daily flow is about 700,000 gallons. In 1870, an injunction was granted against the Corporation for polluting the river Don. The sewage is pumped, to a distance of 2⅛ miles, and a height of 52 feet, on to a farm belonging to the Corporation. The farm comprises 262 acres, chiefly of sand and gravel, a small portion of it being clay. The works have been in operation about three years. The capital expended upon the necessary works, pumping station, rising main, &c., has been 20,000*l.*[1]

The authorities pay the cost of pumping the sewage,

[1] Roseb. Ret., p. 46.

&c., which amounts to 450*l.* a year.[1] The farm is let for fourteen years, at an annual rental of 800*l.*, the increased rent of which is about equal to the working cost of the undertaking, leaving the interest of the 20,000*l.* to be met by the rates;[2] this at 5 per cent. would involve a charge, exclusive of supervision, of about 3*l.* 18*s.* 3¼*d.* per million gallons of sewage, or 1*s.* 1*d.* per head per annum of the population. The proportion of land used is at the rate of 374 acres to a daily flow of one million gallons of sewage. The Corporation had not to purchase the land for this purpose, and possess a larger quantity than is at present used.

CROYDON, *Surrey*, is very illustrative of the great labour and difficulty imposed upon a sanitary authority by a sewage farm. The anxieties of management have here been realised to a full extent, and after experiencing various vicissitudes, the farm is again thrown on the hands of the local board and its officers. As far back as the year 1857, the authorities of Croydon, under pressure from the Court of Chancery, sought the purification of the sewage of the town by its application to land. They commenced with fifteen acres to utilise two-thirds of the sewage, but this resulted in the creation of a serious nuisance.[3] Three years subsequently, 300 acres of land (known as the Beddington meadows) were taken on lease. This farm is well suited for the purpose, being accessible to the sewage by gravitation, and having a very porous soil, upon a deep bed of gravel. It was laid out for irrigation, and sublet at the same amount of rent paid by the board, and also 1*l.* per acre per annum, for the use of the sewage. This appeared to be a most satisfactory arrangement, and the Rivers' Pollution Commissioners reported:[4] 'The success of sewage irrigation

[1] Soc. Arts, p. 6. [2] Roseb. Ret., p. 46.
[3] Select Com. on Sewage of Towns, 1st Report, 1862, p. 94.
[4] Rep. Riv. Pol. Com., 1868, p. 87.

here as a deodorising and cleansing process is complete.' The principal crops grown were grass, mangold-wurtzel, and water-cresses; of these latter the Commissioners say: 'Water-cresses, too, have proved here an excellent crop for sewaging, not only from the profit derived from them, but from their cleansing powers upon the dirty liquid.' These water-cresses find their way to the London market, and have been complained of by the late Dr. Smee, F.R.S., as carriers for disease germs.[1] This apparently satisfactory arrangement was, however, destined not to continue, for an attempt being made very soon after to raise the rent of the farm, the sub-tenant declined to continue it, and in the year 1871, a joint stock company was formed to work it, additional land being acquired to meet the growing population of the place. The efforts of 'The Croydon Sewage Farming Company' were not attended with success, and in three years' time the farm again fell into, and still remains in, the hands of the local board for management. The burden of a sewage farm to local authorities is set forth as follows by Dr. Carpenter, a gentleman who has devoted great attention to the subject. He says, in reference to the accounts of this farm: 'It will be seen that a local board labours under very great disadvantages in carrying on a business like a farm. The wages sheet alone will prove this, for there is no one whose pecuniary interest it is to keep down the expenses. Idle hands are retained, and every man's hand is against the local board, and in favour of the private individual, whilst the managers themselves, as soon as they become aware of the work that is before them, make violent enemies of those men whom they have prevented from fattening on the rates. But they make few active friends among the better class of the community, who decline to take part in local politics. The result is that at the next

[1] Journal of Soc. Arts, Dec. 3, 1875, p. 37.

election the management is changed, and most of the advantages of former experience are lost.'[1] The constant anxiety also to provide additional land to meet a rapidly increasing population, and with it, a greater flow of sewage, is heavily felt by the Croydon authorities. The population of Croydon including South Norwood is at present about 57,000. The sewage is in character purely domestic, there being 11,000 water-closets in use, and no manufactories. It is extremely weak, owing to leakage of subsoil water into the sewers, and amounts to an average daily flow of about 3,000,000 gallons. This flows in two directions, for there are now two farms, the Beddington Farm, containing 465 acres of very porous gravelly soil, and the Norwood Farm, containing 60 acres of a less favourable soil or stiff clay. The solids are extracted from the sewage by means of Latham's extractors, and mixed with town refuse, and the liquid sewage flows on to the land by gravitation in both cases. The chief portion of the land, viz., that at Beddington, is leased at the moderate annual rental of 4*l.* per acre; that at Norwood, which has been acquired at a more recent date, is rented at 10*l.* an acre. The expenditure upon the necessary works is stated, inclusive of the Norwood Farm, to have been 29,214*l.*;[2] an average of ten years' working expenses has been given,[3] but the farm has passed through too much mismanagement and too many changes, during that period, to admit of this result being a fair guide. Its average yearly working expenses during the two years 1875-76 were 9,856*l.* 19*s.* 4*d.* The average annual receipts from sale of produce during the

[1] Soc. Arts, p. 22.

[2] Roch. Ret., p. 6. This amount is given in Roseb. Ret. as 21,740*l.*; and in a report published in the *Leamington Chronicle*, Dec. 4, 1875, as 51,188*l.*

[3] Soc. Arts, p. 20. Apparently the cost of the Norwood farm is not

same period were 7,008*l.*,[1] thus showing an annual loss (if 5 per cent. interest on the capital spent be added) exclusive of supervision of 4,311*l.* or about 3*l.* 18*s.* 9*d.* per million gallons of sewage, or 1*s.* 6*d.* per head of the population. The proportion of land, which is chiefly of the best quality for the purpose, used, is 175 acres to a daily flow of 1,000,000 gallons of sewage. Croydon farm does not bear an unblemished sanitary character,[2] and although it has been stated that the effluent water from it passes off in a very satisfactory condition, on the other hand it has been stated that the sewage as it enters upon the land is very dilute, and consequently so free from organic impurities as scarcely to be recognised as sewage at all.[3]

Analyses of the sewage and of the effluent waters from both farms, taken from the first Report of the Rivers' Pollution Commissioners, 1868, p. 84, are given in the Appendix.

REIGATE, *Surrey*, has a population of 15,916. Water-closets are in universal use, and the sewage contains a small amount of manufacturing refuse from tan-yards. The daily flow is about 480,000 gallons. Irrigation commenced upon forty-three acres of land, which were prepared to receive the sewage of Redhill and the eastern side of the borough, and 7¾ acres of meadow land. In 1872, an additional farm, comprising 58¾ acres was added, making the total about 110 acres. Upon these works 3,463*l.* have been spent in preparing the first acquired area for irrigation; a sum of 1,229*l.* for the purchase of 7¾ acres of meadow land, and 8,387*l.* for the purchase of the latter farm; making a total up to the present time of 13,079*l.* The excess of expenditure on the farm over

included in these figures; if not, the loss upon the whole, collectively, will be higher than what is here stated.

[1] Soc. Arts, p. 20.

[2] The Sew. Quest., 1872, p. 20.

[3] Trans. Inst. Sur., 1872–73, pp. 296, 283.

the amount received for produce during the year 1875, was 104*l.* 9*s.* 7*d.*,[1] so that with 5 per cent. interest on capital, the total annual expenditure so far amounts to 754*l.*, or about 4*l.* 6*s.* 1*d.* per million gallons of sewage, or 1*s.* per head of the population.[2] The land is chiefly of clay soil, and is used in the proportion of about 228 acres to a daily flow of one million gallons of sewage.

The sanitary aspect of this work hitherto appears not to have been satisfactory, for, in 1873, it was stated that the Sewage Committee of the British Association had examined it on three occasions, and condemned it.[3] It was also described as 'swamped and saturated,' not being underdrained, and that the effluent water was but weak sewage.[4]

CHORLEY, *Lancashire*, has a population of 18,000, with 200 water-closets, contributing an average daily flow of 500,000 gallons of sewage, including subsoil drainage rainfall, manufacturing refuse from calico print works, logwood dye works, and bleaching works. In 1867, an injunction was granted to prevent the sewage polluting the river Yarrow. There is one farm of eighty-seven acres, and a second farm of forty-six acres in extent. The nature of the soil is partly a stiff clay subsoil, and partly an adhesive loam and sandy subsoil. The sewage is delivered by gravitation, and the farm has been in operation for six years. Here the circumstances are favourable to irrigation with two exceptions, viz., the land is of unsuitable quality, and it is distant a mile and a half. The price paid for the larger farm was 6,995*l.*, and the cost of its preparation for sewage, 3,994*l.* That paid for the smaller farm was 5,000*l.*, and the cost of its improvement, 400*l.* The latter farm was purchased two

[1] Soc. Arts, p. 14. [2] The works are not yet completed.
[3] Trans. Inst. Sur., 1872–73, p. 291. [4] Trans. Inst. Sur., p. 312.

years ago. It is let at an annual rent of 90*l.*, and is only used for sewage to the extent of ten acres. The cost of working the farm in the year 1875, was 906*l.*, and the receipts for the same period, 847*l.*[1] If, therefore, interest be charged at the rate of 5 per cent. on the capital spent, the total annual charge upon the ratepayers, exclusive of supervision by town authorities, amounts to 784*l.*, or at the rate of 4*l.* 5*s.* 11*d.* per million gallons of sewage, or 10½*d.* per head of the population.

It appears from the foregoing that the quantity of land used is in the proportion of about 266 acres to a daily flow of one million gallons of sewage. That the price paid for land was in one instance about 70*l.* per acre; and in the other, 108*l.* per acre; and that the cost of preparing the land for receiving the sewage has been altogether 40*l.* per acre.

WARWICK is an instance of sewage disposal by irrigation where, excepting that the land has been obtained at a moderate rental, most of the conditions necessary to success are wanting. It has a population of 11,000, contributing an average daily flow of 700,000 gallons of almost entirely domestic sewage from about 2,000 water-closets, with only a small amount of manufacturing refuse from gelatine works. In 1868, legal proceedings were threatened on account of the pollution of the river Avon, and a sewage farm obtained about 1¼ mile distant from the town; it contains 135 acres of stiff clay and clayey subsoil land, a character most unsuitable for sewage irrigation. It is held on lease for twenty-one years from 1866, at a yearly rent, for the first five years, of 404*l.*, and for the remainder of the term at 471*l.* 10*s.*[2] The sewage is pumped a distance of three-quarters of a mile, and to a height of 65 feet, on to the farm. The cost

[1] Roseb. Ret., p. 19. [2] Loc. Gov. Bd. Rep., p. 29.

of the pumping station, necessary preparation of the land, &c. has been 11,000*l.*[1] The average annual cost of working the farm, inclusive of rent and the cost of pumping, during the years 1873–75, has been 2,065*l.*[2] The average annual return by sales of produce during the same period has been 948*l.*[3] If, therefore, interest be charged on the capital spent at the rate of 5 per cent. the total annual charge falling upon the town, exclusive of supervision, is 1,667*l.*, or 6*l.* 10*s.* 5¾*d.* per million gallons of sewage, or at the rate of 3*s.* per head of the population. Notwithstanding this heavy charge the sewage is not completely purified, a large quantity of it passes only *over* and not *through* the land, and runs off almost in the same condition as it flows on.[4] The farm has hitherto been worked by the Corporation, but in consequence of its non-success in their hands, a private company was formed, in 1875, who took a lease of it at the same rental as that paid by the Corporation. The proportion of land to sewage is at present about 203 acres to a daily flow of 1,000,000 gallons, but it is quite insufficient for the purpose, and great difficulty is experienced in obtaining more.

KIDDERMINSTER, *Worcestershire*, has a population of 19,463, and a daily flow of 1,120,000 gallons of sewage, containing manufacturing refuse from carpet factories and dye works. It is received in large tanks, and is disposed of on a farm of 170 acres, the soil of which being light and gravelly, and described as of a hungry sandy nature, is well suited to the purpose. Other circumstances are also favourable; but the fact that the sewage has to be pumped a distance of four miles and a height of about

[1] Roseb. Ret., p. 41.
[2] Published Abstracts of Accounts of Local Board.
[3] *Ibid.* [4] The Sew. Ques., 1872, p. 9.

100 feet, imposes a heavy cost upon the town as will be seen by the following figures:—

Cost of Works.

	£	s.	d.
Pumping station	11,816	0	0
Rising main	1,402	7	6
Engines and boilers	4,409	4	6
Site for pumping station	1,088	0	3
Miscellaneous	167	10	8
Engineer's charges	1,000	0	0
Compensation	583	8	6
Expenses in raising loans	382	18	8
Sewage farm	15,971	11	9
Laying out ditto	1,931	11	1
Pipes for ditto	96	13	11
Total	38,849	6	10[1]

The farm has been in operation about three years. During two years of that time it was managed by the Corporation, and in the year 1873–4 the cost of working it, inclusive of 361*l.* for pumping the sewage, was 2,249*l.*[1] The return by sale of produce during the same period was 1,311*l.*[1] So that inclusive of 5 per cent. interest on the capital expended, but exclusive of supervision, the total annual cost to the town was 2,880*l.*, or at the rate of 7*l.* 0*s.* 11*d.* per million gallons of sewage, or 2*s.* 11½*d.* per head per annum of the population. During the year 1875, however, the Corporation obtained a tenant for the farm at an annual rental of 510*l.*, which reduces this charge upon the ratepayers to 1*s.* 10*d.* per head per annum of the population. The expenses connected with this work appear to be heavy, although the land which is suitable was acquired at the reasonable price of 94*l.* per acre, and the cost of its preparation to receive the sewage does not appear to have exceeded 12*l.* per acre. The

[1] Abstract of Accounts of Borough of Kidderminster, 1874.

quantity of land used is in the proportion of 152 acres to a daily flow of 1,000,000 gallons of sewage.

LEAMINGTON, *Warwickshire*, has a population of 24,000, and the sewage amounts to a daily average flow of 800,000 gallons. It is purely domestic, there being about 8,000 water-closets in use, with no manufacturing refuse. In 1861, the authorities constructed tanks and outfall works at a cost of 8,000*l.*, and used the lime process; but an injunction was granted against them in 1866 for polluting the river, and, as proper steps were not taken to abate the nuisance, in 1867 an order of sequestration was issued. Lime treatment was then abandoned, and, after a trial of the A B C process in 1868, an offer made by the Earl of Warwick was accepted. During that year, however, the authorities spent 1,500*l.* in improving the condition of the river, and also a sum of 5,000*l.* in legal expenses. The authorities of Leamington have acquired no land, but have the privilege of pumping the sewage on to the Earl of Warwick's farm at Heathcote, near Warwick, not only without payment, but his lordship pays the Corporation 450*l.* a year for doing so. This arrangement has been entered into for a term of thirty years from 1871. The cost of the necessary works for pumping the sewage on to Lord Warwick's land, a distance of $2\frac{1}{4}$ miles and a height of 120 feet, has been 16,239*l.*, making a total expenditure of 30,739*l.* The working expenses for pumping are about 1,000*l.* a year, so that, inclusive of 5 per cent. interest on the capital expended, and deducting the payment made by Lord Warwick, the total annual cost to Leamington amounts, exclusive of supervision, to 2,086*l.*, or at the rate of 7*l.* 2*s.* $10\frac{1}{2}d.$ per million gallons of sewage, or 1*s* $8\frac{3}{4}d.$ per head of the population. Lord Warwick publishes no report as to whether he derives any benefit

from this sewage or not. The farm upon which it is pumped is a well managed one, and is, perhaps, the best instance of sewage farming to be met with; but this is undoubtedly due in a very large measure to the following facts: The farm upon which the sewage is delivered comprises 375 acres of a loamy, sandy, gravelly soil, of the most suitable quality for the purpose, and it is supplemented by Lord Warwick's tenantry, who at times take some of the sewage, making altogether an area of 1,000 acres available for receiving it. This large proportion of land of the best quality, upon which the sewage is delivered at small cost to Lord Warwick, and under good management, accounts for the favourable agricultural results attending the Leamington Sewage Farm. Although the Corporation of Leamington have not purchased or leased any land, the disposal of the sewage, as shown above, is attended with considerable cost, and there is this disadvantage, that in twenty-five years the present arrangement will come to an end; and as the Corporation of Longton, in Staffordshire, pay the Duke of Sutherland 500*l.* a year for a similar privilege, it is not improbable that Lord Warwick may decline to continue it on the same terms.

The proportion of land available for treating the sewage of Leamington is 1,250 acres, that of the farm upon which it is delivered, 469 acres, to a daily flow of 1,000,000 gallons.

West Derby, *Lancashire*, has a population of 31,400, of which 24,100 only at present contribute to the sewage farm. The sewage from the remainder of the population discharges into the Liverpool sewers. There are about 3,220 water-closets. The sewage amounting to a flow of 723,000 gallons per day, is domestic in character without manufacturing refuse. It is delivered without pumping on to a farm of about 207 acres, fifteen of

which are not under irrigation, being detached from the remainder by the river Alt. The chief portion (about 150 acres) is of a sandy soil, the remainder of a clay subsoil. The works, which have been in operation three years, have cost up to March, 1876, as follows:—

	£	s.	d.
Purchase of land	30,325	2	0
Compensation, &c.	3,916	1	9
Laying out land	8,934	9	8
Engineering, legal, and other expenses	18,697	12	4
Estimated amount required to complete farm works	1,476	14	3
Total	63,350	0	0[1]

The cost of carrying on the farm for the year ending March 25, 1875, was 2,334*l.*, and the receipts from the sale of produce during the same period, 3,349*l.*[1] So that, inclusive of 5 per cent. interest on the capital expended, but exclusive of supervision, the annual cost of this work amounts to 2,176*l.*, or 8*l.* 4*s.* 11*d.* per million gallons of sewage, or at the rate of 1*s.* 9½*d.* per head of the population contributing to the sewage dealt with. The legal expenses incurred by an injunction appear to have been large, and although other circumstances seem favourable, a very heavy charge upon the ratepayers is the result. The land is used in the proportion of 265 acres to a daily flow of 1,000,000 gallons of sewage. The price paid for the land has been about 166*l.* per acre, and the cost of laying it out about 43*l.* per acre.

MERTHYR TYDFIL, *South Wales*, has a population of 54,500, but of these, 6,000 are on the mountain sides, and in isolated groups beyond the range of the sewers, so that only 48,500 contribute to the sewage. There are about 4,000 water-closets in use, and the sewage is purely domestic, containing no manufacturing refuse. The daily

[1] Loc. Gov. Bd. Rep., p. 30.

average flow amounts to 1,200,000 gallons. In 1868 an injunction was granted to prevent the pollution of the river Taff, and the local board obtained parliamentary powers to acquire 400 acres of land for dealing with the sewage. In the following year, a plan was adopted for irrigating 375 acres, situated at from 8 to 11 miles from Merthyr; and, in 1873, the extensive outfall sewers to this land were completed; but whilst they were in progress the authorities, being hastened into immediate action by order of the Court, adopted a temporary expedient in the preparation of 20 acres of the land for filter beds by deep underdraining. For a few months, (viz. from January to May, 1871), the sewage (from some 20,000 people) was applied to these 20 acres, but after that date one-half of the sewage was conducted to the land prepared for irrigation, and during the years 1871 and 1872, one-half of the daily sewage went to each of the two remedial areas of land, being at the rate of 22,500 gallons per acre on the filtration area, and about 8,000 gallons per acre on the irrigation area.[1] These filters were worked up to the year 1872, and though retained, have since been treated as ordinary irrigation ground,[2] and the local board has found it necessary to continue the preparation of nearly the whole of the land. The chairman, in May, 1875, writing to Mr. Baily Denton, who constructed these filters, says, 'I also desire to disabuse your mind that the board contemplates the abandonment of the filtration areas. It contemplates nothing of the kind, but looks upon them as being that which cannot be described better by any other term than the one you use, namely, a safety valve.' He further writes, 'I may also add that we have it in view, if the land we

[1] Extract from Report to the Local Government Board by Mr. Arnold Taylor, dated Nov. 8, 1872. *Vide* Rep. Ass. Pres. Riv. Scot., 1875.

[2] Loc. Gov. Bd. Rep., p. 24.

shall have acquired be found to be too limited for wide irrigation, to lay out a set of filter beds on the Park Newydd Farm, which we have just bought.'[1] The experience at Merthyr Tydfil shows that these filtration areas or beds are only useful to a certain extent, and are not sufficient for dealing with the whole of the sewage. The formation of this land is the very best that can be found for the purpose, and is in this respect almost exceptional. It is the delta of the river, a bed of fine friable loam or coarse gravel, 50 feet deep.[2] It is drained 7 feet deep at intervals of 40 yards.

The whole work has now been in operation four years, and its cost up to March, 1876, is as follows:—

	£	s.	d.
Purchase of land (including Park Newydd Farm, recently acquired for 9,170*l.*)	27,860	18	11
Constructing outfall sewers	16,002	9	10
Legal expenses	10,721	19	9
Miscellaneous, including engineering expenses, &c.	1,142	0	4
Preparation of land, including Park Newydd Farm	13,893	10	11
Compensation	538	10	9
Total	70,159	10	6[3]

The sewage flows by gravitation on to the farms.

The average annual cost of working the farms during the years 1873, 1874, 1875, and 1876, was 2,506*l.* 12*s.* 1*d.*[4] and the average annual return by sale of produce during the same periods was 1,511*l.* 6*s.* 3*d.*,[5] so that, inclusive of interest at 5 per cent. on the capital, the total annual cost, exclusive of supervision, amounts to 4,500*l.*, or at the rate of 10*l.* 5*s.* 5½*d.* per million gallons of sewage, or 1*s.* 10¼*d.* per head of the population.

[1] Soc. Arts., p. 25. [2] Proc. Inst. C.E., vol. xliii. p. 210.
[3] Published Accounts of Local Board of Health for 1873, 1874, 1875, and 1876. [4] *Ibid.* [5] *Ibid.*

The quantity of land acquired at present amounts to 344 acres, of which 72½ acres are held on lease at an average annual rental of 5*l.* 14*s.* per acre, and 271½ acres are freehold, and have been purchased at an average price of about 100*l.* per acre.[1] The Park Newydd Farm, which the authorities have recently found it necessary to obtain, as additional land for the treatment of the sewage, is, however, not yet fully prepared or in operation; the proportion of land used is 287 acres to a daily flow of 1,000,000 gallons of sewage.

The Merthyr Tydfil sewage arrangements have, after a careful examination, been thus described: 'The quantity of effluent water was nearly double that of the sewage in all cases; and from that circumstance it was inferred that a very large quantity of fresh water got mixed with the water which came away from the irrigation beds. The circumstances of the case, however, were peculiar, the whole valley being the former bed of the river Taff. The land acted as a sieve, the subsoil consisting of pebbles, sand, and a little clay, so that water passed down six or seven feet into the pipes with the greatest ease. It was difficult with the admixture of so large a quantity of underground water to judge to what extent the effluent water was clarified by the process.'[2]

Much care must therefore be exercised in taking any guide from this place, because of the exceptional quality of the land, and the fact that the effluent water, which shows a favourable analysis, is very largely mixed with pure water by leakage into it before it reaches the outfall.[3]

NORTHAMPTON has a population of 45,000. There are about 7,000 water-closets in use, and the sewage, which amounts to an average daily flow of 1,000,000

[1] Soc. Arts, p. 12. [2] Trans. Inst. Sur., 1872-73, p. 292.
[3] Soc. Arts, p. 77.

gallons, contains manufacturing refuse from tanneries, &c. It flows into tanks in the town, where a portion of the solid matter subsides, and is mixed with ashes and burnt bones from the town, and sold at 9*d.* a ton. The sewage flows thence by gravitation, a distance of four miles, on to the farm which comprises at present 327 acres. The land is suitable, being a sandy loam, with a gravelly subsoil. Hurried into action by legal proceedings five years ago, the authorities at that time had no alternative but to obtain an Act for the acquisition of some 900 acres of land for a sewage farm. About one-third of that quantity has been purchased, and the total expenditure upon the whole undertaking, inclusive of 12,000*l.* legal expenses, amounts, up to the present time, to 80,000*l.*[1] The average annual working expenses of the undertaking during the years 1873–74, amounted to 1,447*l.*[2] The average annual return by sale of produce for the same periods amounted to 1,642*l.*[3] So that, inclusive of 5 per cent. interest on capital, but exclusive of supervision, the total annual cost of this work amounts to about 3,805*l.*, or 10*l.* 8*s.* 6*d.* per million gallons of sewage, or 1*s.* 8¼*d.* per head of the population. The land is used in the proportion of 327 acres to a daily flow of 1,000,000 gallons of sewage, but the area is too small, and additional land is required.

Although, as it will be observed, most of the conditions are favourable to sewage farming, in this case some of the practical difficulties are forcibly experienced. Owing to the position of the farm away from a town, a market, or even a railway station, the produce remains on hand, and in the month of March, 1876, 2,000 tons of mangolds were on the farm, unable to be sold. This

[1] Roseb. Ret., p. 30.

[2] Abstracts of Receipts and Payments for Borough of Northampton, 1873–74. [3] *Ibid.*

has suggested the idea of feeding stock upon the farm, but, if carried out, additional capital to the already heavy expenditure will be required; nor must it be overlooked that additional capital is now required for the purchase of more land as well as for the erection of cottages for the workmen employed on the farm, as it appears that the prejudice against the farm in the surrounding villages is great, and the residents object to the farm men living amongst them.

BLACKBURN, *Lancashire*, has been a great sufferer, and is in an unenviable position in the attempts to dispose of water-carried sewage by irrigation, in consequence of a Bill filed in Chancery in 1865 to prevent it from polluting the Darwen. It has a population of 83,000, with a daily flow of about 2,200,000 gallons of sewage, about three-fourths of which, or 1,500,000 gallons, only are dealt with. The sewage contains manufacturing refuse from dye works, and liquid refuse of cotton and woollen manufactories, but the storm water has been excluded from all the recently made sewers. There are 730 water-closets in use, and 10,547 middens which drain into the sewers. Treatment by lime having been abandoned, the Corporation in 1870 obtained parliamentary powers for acquiring 1,090 acres of land for irrigation. Two years later, 179 acres of land were taken on lease for twenty years, at an annual rent of 484*l.*, the outfall sewer was extended thereto, and ninety acres of it prepared for irrigation. In 1875, the Corporation, in order to extend operations, purchased 475 acres of land, and proceeded to underdrain it, the drains being placed four feet deep and eighteen feet apart.[1] The land already acquired comprises 568 acres, the chief part of which has a light loamy soil upon a gravelly subsoil, and is situated six miles from the town.[2] As the

[1] Loc. Gov. Bd. Rep. p. 10. [2] Soc. Arts, p. 73.

works are incomplete it would be impossible to ascertain at present the exact charge that will be thrown upon the rates. It has, however, already amounted to a very heavy sum, as follows :—

	£
Costs in Chancery suit, law proceedings and damages	12,000
Parliamentary expenses	6,500
Outfall sewers and laying out land	11,600
Purchase of land (475 acres)	69,500
Estimated cost of outfall sewer	7,650
Preparation of (475 acres) not yet known	
	107,250[1]
Construction of tanks	9,000[2]
Total	116,250

In some instances the price paid for the land has been as high as 150 years' purchase of the rental,[3] and so excessive has been the outlay already upon this scheme, that at a meeting of the Corporation, in 1875, 'Mr. Councillor Beads carried a motion calling the attention of the Home Secretary to the manner in which the Blackburn Corporation has been imposed upon in carrying out the irrigation scheme. The ex-Mayor said that the prosperity of the town had been blighted through excessive expenditure and heavy rates. 200,000*l.* had been spent. In every instance the Corporation had had to pay three times the value of land taken. A searching inquiry ought to be instituted, and the way in which the Mayor and Corporation of Blackburn had been oppressed ought to be represented.'[4] The sewage is received in tanks, and previous to irrigation is treated therein with a small quantity (four or five cwt.) of lime; it then flows by gravitation to the land. The sludge from the tanks is sold, if possible, but there is a difficulty in disposing of it. It

[1] Loc. Gov. Bd. Rep., p. xxxix.
[2] Roseb. Ret., p. 17.
[3] Soc. Arts, pp. 73, 74.
[4] The *Times*, April 5, 1875.

is three years since this undertaking was commenced, and it will be another year or two before full particulars and information concerning its working and its cost can be given. In the meantime, during the year 1875, the cost of farming ninety acres has been 6,523*l.* 2*s.* 9*d.*, and the receipts for the same period were 5,781*l.* 6*s.* 10*d.*;[1] assuming that when the larger farm is in operation, its sales of produce will balance the expenses of working, an annual loss of 5 per cent. interest on the capital and rent alone, or upwards of 6,296*l.* will have to be borne, or at the rate of 11*l.* 10*s.* per million gallons of sewage, or 1*s.* 6*d.* per head of the population. It does not appear, however, that this will be the final charge on account of this work, and it is to be feared that, under such unfavourable circumstances, the ratepayers of Blackburn will find, when the sewage scheme is completed, they will have a still heavier burden to bear. The proportion of land used when the new farm is in operation will be 378 acres to a daily flow of 1,000,000 gallons of sewage.

HARROGATE, *Yorkshire*, has now an average population of 12,000.[2] There are 1,620 water-closets in use, and the sewage, which is purely domestic, amounts to an average daily flow of 210,000 gallons. In 1867, the authorities were threatened with legal proceedings on account of the pollution of a stream by the sewage, but compromised the matter by payment of 580*l.* and an undertaking not to discharge more sewage into the stream. In 1869, a lease of forty-seven acres of stiff clay soil, situated a mile from the town, was taken, and it was intended to deal with the sewage upon it. In the construction of subsidence tanks, the preparation of the

[1] Loc. Gov. Bd. Rep., p. 10.

[2] Resident population about 8,000, increasing in the summer to about 16,000.

land, &c., a sum of 1,150*l.* was expended. This attempt to purify the sewage was, however, so futile, that in 1875 an injunction was obtained against the authorities. This act of the Court of Chancery was appealed against, but it was confirmed by the Lords Justices, and in the latter part of the same year, the Court, upon the application of the plaintiff in the case, issued a sequestration order. In order to meet these difficulties, the authorities, in the same year, purchased land at a cost of 2,200*l.*, and took on lease for a term of twenty years, at an annual rent of 300*l.*, a farm of 247 acres (120 acres only of which are available for irrigation). These works are now in operation, the estimated cost of laying out the land and conveying the sewage to it being 3,216*l.* The legal expenses in this case have amounted to 3,920*l.* To prevent the sewage of High Harrogate from polluting the streams in the neighbourhood, the authorities have also purchased 13½ acres of land, at a cost of 1,000*l.*, which has been made available, and laid out at a further cost of 3,484*l.* for the utilisation of about 42,000 gallons per day of the sewage from that portion of the town. This land, with the sewage, has been let at a yearly rent of 52*l.*

These works, though not yet completed, have cost up to the present, as follows:—

	£
Purchase of land	3,200
Outlet works and preparation of land	7,850
Compensation and legal expenses	9,500
Total	20,550[1]

The sewage flows on to the land by gravitation. Forty-seven acres only were employed for irrigation in the year 1874, when the expenses, inclusive of rent, were 282*l.* 10*s.* 5*d.*, and the return by sale of produce during the same period was 562*l.* 11*s.* 1*d.*[2] Therefore,

[1] Loc. Gov. Bd. Rep., p. xlii.

[2] *Ibid.*, p. 18.

inclusive of 5 per cent. interest on capital, and rent, but exclusive of supervision, the annual charge at present amounts to 993*l.*, or at the rate of 12*l.* 19*s.* 1½*d.* per million gallons of sewage, or 1*s.* 7¾*d.* per head of the population.

It is proposed to irrigate about 180 acres, thus giving a proportion of 857 acres to a daily flow of 1,000,000 gallons of sewage.

EPSOM, *Surrey*, has a population of 6,276. The sewage is purely domestic. The flow amounts to 104,000 gallons a day. Subsidence in tanks takes place, the solid matters so deposited are mixed with ashes for a manure, and the liquid sewage flows partly by gravitation, and is partly pumped to a height of 10 feet, on to a farm of 327 acres, chiefly of gravel formation. The local board has a lease of this farm for twenty-one years, from 1868, and pays an annual rental of 591*l.*;[1] about sixty acres of it are under irrigation. The land is sublet for a much shorter period, viz., three years, at the annual rental of 516*l.*;[2] so that, with the cost of pumping and distributing the sewage over the land, averaging 290*l.* a year,[3] and 5 per cent. interest on 3,626*l.*[4] capital spent on the necessary works in connection with the pumping station and farm, an annual charge, exclusive of supervision, of 546*l.* falls upon the rates, or about 14*l.* 7*s.* 8*d.* per million gallons of sewage, or 1*s.* 8¾*d.* per head of the population. This arrangement has been in operation four years. The quantity of land used is in the proportion of 577 acres to a daily flow of 1,000,000 gallons of sewage; but it will be observed that the authorities possess land sufficient for a proportion of 3,144 acres to the same quantity.

NORWICH has a population of 84,000. The sewage

[1] Published Accounts of Local Board of Epsom for 1873, 1874, and 1875.
[2] *Ibid.* [3] *Ibid.* [4] Roseb. Ret., p. 38.

contains refuse from 3,500 water-closets, and from breweries, mustard and starch works. It is extremely dilute, through the leakage to a very large extent of subsoil water into the main sewers. In consequence of this the pumps are inadequate to lift the whole of it, and a portion only is pumped on to the farms, a height of 150 feet; the remainder goes direct into the river Wensom. The farms consist of 1,300 acres, 500 acres of which have been purchased for 27,500*l.*, and the remainder taken on lease at 3*l.* 5*s.* per acre.[1] The cost of the necessary works has been altogether 113,300*l.*;[2] 150 acres of the land only are at present under irrigation. The average annual working expenses of this undertaking, including pumping and rent, for the years 1873-74, were 12,621*l.* 2*s.* 10*d.*; and the average annual return, by sale of produce during the same period, was 5,523*l.* 17*s.* 4*d.*[3]; so that, inclusive of 5 per cent. interest on capital, the annual cost amounts, exclusive of supervision, to 12,763*l.*, or 3*s.* 0½*d.* per head of the population. Owing to its incompleteness, it is not possible, at present, to draw any practical conclusions from this undertaking.

Swindon New Town, *Wiltshire*, has a population of 7,628, which is rapidly increasing. There is a farm of 105 acres of a clay soil. A sum of 14,434*l.*[4] has been expended in acquiring the farm, and on the necessary works connected with it. The sewage is purely domestic in character, and amounts to an average daily flow of about 300,000 gallons. The undertaking has been four years in operation. The average annual working expenses during the years 1873, 1874, and 1875, were 1,902*l.*, and the average annual revenue for the same period was 834*l.*;[5] so that, inclusive of 5 per cent. interest on capital ex-

[1] Roch. Ret., pp. 10, 11; and Roseb. Ret., p. 30. [2] *Ibid.*
[3] Abstract of Accounts for City of Norwich, 1873–74.
[4] Roseb. Ret., p. 42.
[5] Accounts of Local Board of Health for 1873, 1874, and 1875.

pended, but exclusive of supervision, the annual charge amounts to 1,643*l.*, or 15*l.* per million gallons of sewage, or (if the population be taken at its present rate of about 9,000) 4*s.* 3¾*d.* per head. The proportion of land used is about 350 acres to a daily flow of 1,000,000 gallons of sewage.

The sewage farm at CREWE, *Cheshire*, is one of the most costly undertakings of the kind. The population is 20,000. The sewage is chiefly domestic. There are, however, only about 60 water-closets in use. The farm comprises 257 acres of land, described as being of a very strong clay character, twenty or thirty yards deep, commencing at six inches from the surface; sixteen acres have been purchased, and 241 acres taken on lease for twenty years, at a rental of from 3*l.* to 4*l.* per acre per annum; 45,000*l.*[1] have been expended on the purchase of the sixteen acres of land, the construction of two and a half miles of outfall sewer, sewage tanks, engines, pumps, delivery mains, and on preparation of the land. Much opposition was experienced to this undertaking from the adjacent land-owners, and the legal expenses were heavy. The farm has been in use two years. The sewage, amounting to a daily flow of 900,000 gallons, is pumped, a height of sixty feet and a distance of half a mile, on to the land. The cost of carrying on this work, during the year 1875, is stated to have been, inclusive of interest on capital, 5,368*l.*,[2] or, exclusive of supervision, at the rate of 16*l.* 6*s.* 9¾*d.* per million gallons of sewage, or 5*s.* 4¼*d.* per head of the population. The land is used in the proportion of 285 acres to a daily flow of 1,000,000 gallons of sewage.[3]

[1] Roseb. Ret., p. 6.

[2] *Ibid.* Detailed statements of expenditure on this work have not been published.

[3] In the *Builder*, Nov. 25, 1876, the Crewe Sewage Farm is stated to have cost altogether near 70,000*l.*

TUNBRIDGE WELLS, *Kent*, has a population of 23,000, and 5,635 water-closets in use. There is a daily flow of 650,000 gallons of a purely domestic sewage, containing no manufacturing refuse. In 1865, an injunction was granted to prevent the pollution of the Calverley Brook. The sewage flows by gravitation into subsidence tanks, and thence to two farms, one containing 165 acres of a light sandy soil, the other 120 acres of a clay soil, together comprising 285 acres; but the sewage is applied only to 218 acres. These farms have been in operation about four years, and have cost, together with legal expenses and the necessary preparation, 87,243*l.*[1] The average annual working expenses of these farms during the years 1873, 1874, and 1875, has been 3,274*l.* 17*s.* 11*d.* (that of the larger farm being 2,095*l.* 4*s.* 10*d.*, and that of the smaller, 1,179*l.* 13*s.* 1*d.*); and the average annual return by sales of produce, during the same periods, has been 3,493*l.* 11*s.* 2*d.* (that from the larger farm being 2,061*l.* 17*s.* 9*d.*, and that from the smaller, 1,431*l.* 13*s.* 5*d.*);[2] so that, inclusive of 5 per cent. interest on capital, but exclusive of supervision, the annual cost amounts to 4,144*l.*, or at the rate of 17*l.* 9*s.* 4*d.* per million gallons of sewage, or 3*s.* 7¼*d.* per head of the population. The proportion of land used is 335 acres to a daily flow of 1,000,000 gallons of sewage.

ETON, *Buckinghamshire*, has an average population all the year round of 3,000, including the school, and a daily flow of 80,000 gallons of domestic sewage. There is a farm of 54 acres, 30 of which are used for irrigation. Notwithstanding that the quality of the land is most suitable, having a depth of 1 to 3 feet of vegetable mould, overlying a fine alluvial sand and gravel

[1] Roseb. Ret., p. 16. This sum appears by Loc. Gov. Bd. Rep., p. xlv, not to include the cost of the Chancery suit amounting to 3,000*l.*

[2] Statement of accounts, Tunbridge Wells Local Board, 1873, 1874, and 1875.

subsoil, the fact that the sewage is pumped to a distance of $1\frac{3}{4}$ miles, and to a height of 20 feet, imposes a heavy charge upon the inhabitants, as will be seen by the figures presently given. The character of the sewage being non-manufacturing, an attempt has been made to deal with it on the separate system, by the exclusion of surface and storm water from the sewers; but it has been found impracticable to shut out all subsoil water. The works have been in operation 5 years, and the chairman of the local board, recognising one of the practical difficulties in the disposal of sewage by such means, says: 'It is found very difficult to distribute the sewage evenly in winter, when no growth has taken place, as also in summer, with the root crops a large proportion of the sewage must escape root action, and descend to the subsoil unpurified, except by filtration through the soil and gravel. What then becomes of it is a problem of great importance, although in the comparatively small quantity dealt with at Eton farm on so large a surface, the question hardly arises yet, as towns in the Thames valley seem to be for the most part adopting the system of sewage irrigation,[1] and in consequence of the disappointing results financially of sewage farming, local boards will probably be disposed to put as large a quantity of sewage as possible on a small surface of land.'[2] The total amount expended on the pumping station and works has been about 10,000*l.* The average annual cost of working the farm during the years 1873, 1874, and 1875, inclusive of rent, and 330*l.* for pumping, has been 851*l.*, and the annual average return by sale of produce during the same periods, 581*l.* Therefore, with interest at 5 per cent. on capital spent, the total annual cost to the town,

[1] Lieut.-Colonel Ponsonby Cox, R.E., has recommended attention to be given to chemical treatment for the Thames Valley towns, situated below the water-intakes.

[2] Soc. Arts, p. 23.

exclusive of any charge for supervision, is 770*l.*, or at the rate of 26*l.* 7*s.* 5*d.* per million gallons of sewage, or 5*s.* 1½*d.* per head of the population. The land here is of very suitable quality, and is used in the proportion of 375 acres to a daily flow of 1,000,000 gallons of sewage.

East Barnet, *Hertfordshire*, has a population of 2,924. A farm of 52 acres of land of a clayey character, with occasional strata of heavy gravel, has been acquired for the disposal of the sewage; 37¼ acres of this land have been purchased for 11,317*l.* 10*s.* (about 300*l.* per acre); the remainder of the land has been taken on lease for 21 years, at 58*l.* 14*s.* per annum (about 4*l.* an acre), and about 6,000*l.* has been spent upon the necessary works.[1] No account of the expenses are given, and it is not stated if the latter sum includes the cost of sewers or not. Still, even under favourable circumstances, there will be a burden of 900*l.* or 1,000*l.* a year thrown upon the rates by this undertaking.

Sewage Farms from which partial information only has been published, including some that are reported insanitary, and others where the population does not exceed 5,000.

Ashby-de-la-Zouch, *Leicestershire*, has a population of 4,200; 28 acres of loam and clay-land are used for the sewage. The land is leased for 20 years, at an annual rental of 200*l.* and it has been in operation 5 years.

Bodmin, *Cornwall*, is a small place of 4,672 inhabitants, where the sewage is purely domestic, containing no manufacturing refuse, and where there are 200 water-closets. It is used to irrigate grass land.

Braintree, *Essex*, has a population of 4,790; 47

[1] Roch. Ret., p. 6.

acres of principally loamy gravelly land are used for the utilisation of the sewage, it being first dealt with by filtration and precipitation; 25 acres of the land are private property. A sum of 3,000*l.* has been spent in purchasing the land and laying out the works.

BURY ST. EDMUNDS, *Suffolk*, has a population of 14,928. Irrigation has been practised for 8 years on 26½ acres of land, 16 of which consist of gravel and the remainder of mild clay. There are about 300 water-closets in use, and the sewage, amounting to a daily flow of 150,000 gallons, is purely domestic in character. The land is held on lease for 21 years, at a rental of 4*l.* per acre; it is not underdrained, the amount expended on the necessary works, including tanks, pumping station, and laying out the land, has been 2,800*l.*[1] The farm is situated 1¼ mile from the centre of the town, and the outfall sewer is 3 miles in length. The sewage is pumped by the local authorities to a height of 50 feet at an annual cost of about 292*l.*, and the farm is sublet for 150*l.* a year. The excess of rent in favour of the local authorities amounts to 44*l.* per annum; deducting this from the cost of pumping, and taking 5 per cent. interest on capital expended, the total annual cost amounts to about 432*l.*, or 7*d.* per head of the population. The proportion of land used is 177 acres to a daily flow of 1,000,000 gallons of sewage. This proportion is, however, too small, and as complaints are occasionally made, the sanitary results obtained are doubtful.[2]

ENFIELD, *Middlesex*, has a population of 16,054. Here there is a sewage farm of 162 acres of gravel and clay land, which has been in operation five years. It is private property, and the owner to whom the sewage of the town is given, has agreed to take it all for 25

[1] Roch. Ret., p. 5.

[2] Birm. Sew. Enq., 1871, p. 189.

years. He farms 60 acres of the land himself, and lets the remainder with sewage, to the Enfield Chemical Manure and Irrigation Company, at 8*l.* per acre per annum.[1] The effects of letting the control of the sewage go altogether out of the hands of the authorities are here apparent, and added to the fact that the land is very little above the water-level of the district, has resulted in this undertaking being described as not only becoming a pestilential swamp,[2] but a nuisance as well.[3]

HARROW, *Middlesex*, has a population of 5,010. Seventeen acres of clay land have been purchased, and the outlay thereon with the necessary works has been 4,324*l.* The sewage is first allowed to subside in tanks where the solid matter is removed, and then it flows on to the land which is let with the sewage.

HATFIELD, *Hertfordshire*, has a population of 4,500. The sewage is disposed of by passing it on to land, and it is said that no pollution reaches the river.[4]

HOOLE, *Cheshire*, has a population of 1,750. A combined system of filtration through charcoal, sandstone, rubble, and gravel in tanks, with irrigation on 25 acres of clay land, has been in use for nine or ten years. 3,000*l.* has been expended on the necessary works, and the land is let on lease.

MAIDENHEAD, *Berkshire*, has a population of 6,173; irrigation is carried out on 16 acres of a very porous soil, which is leased for 14 years, at an annual rent of 5*l.* per acre.

MALVERN, *Worcestershire*, has a population of 5,693, and an arrangement was made to irrigate 60 acres of private land, the soil of which is clay, marl, and gravel, but it has ended in a disagreement between the proprietor of the land and the Local Board of Health.

[1] Roch. Ret., p. 9.
[2] Soc. Arts, p. 42.
[3] Roch. Ret., p. 9.
[4] Soc. Arts, p. 42.

MALVERN LINK, *Worcestershire*, has a population of 2,000, and 100 water-closets in use. The sewage is purely domestic, and is utilised on 20 acres of gravel and marl land, which is held on lease for 33 years, at the moderate rental of 2*l.* per acre. 2,000*l.* have been spent in laying out the works, mains, &c.[1] 95*l.* per annum is stated to be the cost of dealing with the sewage,[2] or about 1*s.* per head of the population exclusive of supervision. The average daily flow of sewage being about 60,000 gallons, the land is used in proportion of 332 acres to a daily flow of 1,000,000 gallons.

ORMSKIRK, *Lancashire*, has a population of 6,127. There are 186 water-closets in use. Here there is a farm of 68 acres of clay and black soil, 40 acres of which are irrigated. The land is held upon lease, and is sublet, but complete information as to cost has not been published.

ROMFORD, *Essex*, has a population of 6,335. The sewage farm here is well known as the seat of the labours of Lieut.-Colonel Hope, V.C., who has done so much in the cause of sewage agriculture.

About eight years ago, the Local Board of Health purchased a farm of 119½ acres, of a light sandy soil overlying gravel, and erected a pumping station, at a cost of 19,816*l.*[3] In 1869, Colonel Hope took a lease of the farm for seven years, at the annual rental of 2*l.* 10*s.* per acre, and 600*l.* a year for the sewage, equivalent to a total annual rental of 898*l.* The sewage containing refuse from breweries, and amounting to an average daily flow of 360,000 gallons, flows by gravitation to tanks situated two miles distant from the town, and is then pumped up to the farm, a height of about 25 feet, by the local board, at a cost of 450*l.* a year. Colonel Hope has not given a balance sheet by which an opinion

[1] Roch. Ret., p. 11. [2] Soc. Arts, p. 11. [3] Roch. Ret., p. 12.

could be formed as to the results of his operations,[1] but has demonstrated upon many occasions the value of sewage for agricultural purposes. He says, 'Here surely are facts strong enough and broad enough to put an end to all doubts on the sewage question. What more can the Government, or the sewage minister, or municipal authorities, or ratepayers desire? I pay the town of Romford the full rent that the farm which they purchased is worth, and buy their sewage from them at the annual price of 600*l.*'[2] Without knowing facts as to the cost of disposing of the sewage on this farm, it is impossible to accept as satisfactory what may be (and appears to be from the results) a case where too high a value has been placed on the sewage, and too little account taken of the cost of dealing with it. A disagreement arose between Colonel Hope and the local board, which resulted in litigation, extending over three or four years, until the lease expired in September, 1876, when the board once more had the farm and the sewage difficulty on its hands.

The land, which is of most suitable quality, has here been used in the proportion of 334 acres to a daily flow of 1,000,000 gallons of sewage, and this has evidently been found inadequate, because it is stated that Colonel Hope considered the land insufficient, and was at one time negotiating for an additional 80 acres.[3]

SWAFFHAM, *Norfolk*, has a population of 3,700. Three acres of gravel and chalk land have been purchased for 2,151*l.*[4] and the sewage, after filtration through flint stones, is used thereon; the land and sewage together are let for a short term at 8*l.* a year.

SWINDON, OLD TOWN, *Wiltshire*, has a population of 4,092. The sewage was for a while utilised on 70

[1] Trans. Inst. Sur., 1873.
[2] Trans. Inst. Sur., p. 267.
[3] Birm. Sew. Enq., 1871.
[4] Roch. Ret., p. 12.

acres of clay land, but the nuisance created was so great as to compel the local board of health to take on lease an additional 130 acres of tertiary land containing boulders overlying Kimmeridge clay.[1] There have been no recent additional reports of this undertaking published.

TAVISTOCK, *Devonshire*, has a population of 7,725. 90 acres of land, consisting of loam with a subsoil of pebbles, are used for sewage purposes, but no information concerning the undertaking has been published.

WALTHAM ABBEY, *Essex*, has a population of 5,000. The sewage is treated by 'nothing more than simple subsidence, assisted by a dose of lime very minute in quantity. It is then pumped on to the town mead, on low-lying land close to the river, where it soaks away, and no pollution is apparent.'[2]

WARE, *Hertfordshire*, has a population of 5,000. Captain Flower, engineer to the Lee Conservancy Board, says: 'The sewage which contains refuse from maltings, is discharged far below the town on to an irrigation farm, close to the historically famous Rye House. It was intended that the sewage should be treated by precipitation before it was applied to the land, but that action was abandoned. The farm is on very low-lying ground, and in flood time a large area is under water. I do not think the sewage of Ware can be said to be satisfactorily disposed of in the Rye Meads; still it soaks away somehow, and until the land becomes supersaturated, I suppose it will not be easy to discover pollution. I question very much whether sewage, pure and simple, should be permitted to be discharged on to the land which surrounds a place of popular public recreation, where thousands of hard-worked Londoners go for a little fresh air, and to spend, perhaps, their only single day's holiday in the course of the year in the country.'

[1] Roch. Ret. p. 12. [2] Soc. Arts, p. 42.

The amount expended on this undertaking is stated to be 578*l.*,[1] and the cost of carrying on the work during the year 1875, 690*l.*[2]

WINDSOR CASTLE has a small sewage farm of 18 acres in connection with the new drainage works which were carried out in 1873. The cost of the pumping machinery, tanks, land for the farm, &c., was 42,000*l.*[3] and the cost of levelling and preparing the land was 80*l.* an acre.[4] The object of this farm was to divert the sewage from the Thames.

Sewage farms where exceptional circumstances, including private assistance, are favourable.

LONGTON, *Staffordshire*, has a population of 19,748. The arrangements for receiving the sewage are as yet incomplete; but it has been agreed that the Duke of Sutherland takes the sewage for 21 years, the Corporation paying him 500*l.* per annum.[5]

LEEK, *Staffordshire*, has a population of 11,478; and the sewage is given to landowners in the neighbourhood, who use it upon 100 acres of a porous sandy soil. This arrangement has been in operation for some years.

LICHFIELD, *Staffordshire*, has a population of 7,347; and the sewage is to be given for 20 years to Lord Lichfield, who commands an unlimited quantity of land of a gravelly character for its use.

MANSFIELD, *Nottinghamshire*, has a population of 11,824. The sewage is discharged into the River Man, and afterwards, by works executed at the expense of the Duke of Portland, it is used for irrigating his meadows at Clipston, consisting of about 500 acres of a light, sandy soil.

PENRITH, *Cumberland*, has a population of 8,317. The

[1] Roseb. Ret., p. 14. [2] *Ibid.* [3] *Engineering*, March 27, 1874.
[4] Trans. Inst. Sur., 1873, p. 315. [5] Roch. Ret., p. 11

sewage has been given to a private landed proprietor, who uses it on 50 to 60 acres of his land, which is of a porous light loam; but it is not stated if the whole of the sewage is dealt with.

PLYMPTON, ST. MARY PARISH, has a population of 3,400, the sewage from 2,267 of which is utilised by the Earl of Morley upon some of his grass lands, having a very porous sandy soil. 1,000*l.* have been laid out by the local authority on the necessary works.

SOUTH MOLTON, *Devonshire*, has a population of 3,978. The sewage is let to a private landowner, who pays 71*l.* 10*s.* per annum for it, and utilises it upon 30 acres of his land, which is clay and heavy loam and partly soft rock.

SWINTON and PENDLEBURY, *Lancashire*, has a population of 20,000, half of which only contribute to the sewage. There are about 12 water-closets in use. The sewage is filtered through tanks, containing several beds of sand and charcoal, and is then utilised on 32 acres of clay land; but as the system appears to be only partial, and the land was given, laid out, and the cost of working borne by the trustees of the late Duke of Bridgewater, it is impossible to derive any practical data from this case.

RUGELEY, *Staffordshire*, has a population of 3,374. The sewage has been let to a private landowner, who utilises it on 30 acres of loamy, gravelly soil, and pays 30*l.* per annum for it.

Sewage farms in which the agricultural element has been the chief consideration.

At ABERDEEN the population is about 88,189, and there are 5,500 water-closets in use. The sewage contains little manufacturing refuse, and only a limited quantity of it is utilised. This is sold to a neighbouring

proprietor of land, who uses it upon 50 acres, and pays the town council 5*l.* for every acre that he irrigates, to the extent of 1,000,000 gallons per acre. The whole of the remainder (being the greater part) of the sewage flows direct into the mouth of the river Dee without any treatment.

ALDERSHOT CAMP, *Hampshire*, has a domestic water-carried sewage of 7,000 adults, amounting to about 200,000 gallons a day. This is leased, and employed to irrigate 80 acres of a very porous sand, with a ferruginous subsoil situated at a distance of nearly 2 miles from the camp, and which has been in operation for 14 years. Notwithstanding that the land is of the best quality for the purpose, and is in proportion of about 400 acres to a daily flow of 1,000,000 gallons of sewage, it is stated by the authorities that, although no nuisance has arisen from the effluent water, complaints have been made.[1] The cost of working cannot be ascertained, and although it is quoted by Mr. Chalmers Morton[2] as an instance, he believes, of an agriculturally profitable farm to the tenant, its results, from a sanitary point of view, do not appear to be satisfactory, as may be gathered from the following statement of Mr. Eggar, who says:—'Having the Aldershot sewage farm under his observation from day to day, he was able to speak confidently as to its being the most perfect success, in an agricultural point of view, of any in the kingdom. That was simply because the sewage was of the most concentrated character, and was only used about two days out of the seven on an average; every other day it ran straight into the Blackwater, which was constantly silting up in consequence. Not long ago, an inspector from the Local Government Board came down to inspect it, and after going over the

[1] Roch. Ret., p. 5.

[2] Report to the Nottingham and Leen District Sewerage Board, 1876.

farm with him, he said there was nothing which anybody could complain of, except what arose from the cause he had mentioned, that the sewage was flowing directly into the river. Some time ago they were told that the effluent water was so pure, that the people broke down the fences to get it to drink; but it was based on a misapprehension, the fact being, the water referred to ran from a drain with which the sewage had no sort of connection, and, therefore, when it was analysed by Professor Abel, it was no wonder if it was found to be pure. There was a new system now being adopted, of which the public were not aware, whereby the sewage, instead of being poured on to the surface was conducted by large pipes laid just below the surface, and when not wanted on the land, it ran straight into the brook in the same condition in which it entered. In this way the public were being deceived, and large sums were spent on sewage farms without really benefiting the public health.'[1] Leaving the agricultural view of the matter out of consideration, it is evident that any statistics as to the cost of treating the sewage of Aldershot while it is dealt with in so partial a manner would be quite worthless, and, also, that the system as there in operation in no degree meets the sanitary necessities of the case.

BARKING, *Essex*, affords valuable results of an agricultural experiment with sewage. Valuable, inasmuch as they have extended over 6¼ years, and have been conducted, under very able supervision, by those who believed in, and had an interest in exhibiting the value of town sewage. It must not be overlooked that this was no attempt to treat continuously an entire flow of sewage from a town. A small portion of the London sewage only was dealt with, and the proprietors of the farm were able to take the sewage in such quantities as they liked, and only

[1] The Sew. Quest., 1872, p. 4; and Jour. Soc. Arts, Dec. 3, 1875, p. 43.

when they liked. Thus they were freed from one of the greatest practical difficulties which stands in the way of this mode of disposing of sewage. Some important and reliable facts in reference to sewage irrigation from the agricultural point of view have, however, been elicited and recorded through this undertaking.

It was in 1866 that the Metropolis Sewage Company acquired about 200 acres of land of a light gravelly soil, and established the Lodge Farm at Barking, for the purpose of ascertaining whether the application of sewage to land would be attended with the results which were predicted. A portion of the Metropolitan sewage, amounting to about 562,454 tons a year, was pumped from the outfall into the Thames near Barking on to the farm. The table on the following page gives the results of the undertaking :—

Extract from accounts of the Lodge Farm, Barking, Essex.

Total area about 212 acres.

Years	1869 and 1870, ending August 31	1870 and 1871, ending August 31	1871 and 1872, ending December 31 (16 months)	1873, ending December 31	1874, ending December 31	1875, ending December 31	Notes
	a. r. p.	a. r. p.	a. r. p.	a. r. p.	a. r. p.	a. r. p.	The years ending Aug. 31, 1870 and 1871, were favourable to sewage, being without rain. The land was new to sewage, and we were also selling milk, which is, perhaps, the most profitable mode of turning sewage to account.
Acres under sewage . .	112 3 23	162 3 6	189 2 23	117 2 30	112 2 30	71 2 8	
Acres not under sewage . . .	71 1 0	26 3 17	—	71 3 32	76 3 3	117 3 15	
Pasture . .	13 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	
Total No. of tons of sewage . . .	508,871	622,324	624,876	622,648	526,743	609,880	
Average tons per acre .	4,400	3,800	3,300	5,200	4,600	8,500	
Average No. of tons to Italian rye grass per acre . . .	5,000	5,600	6,500	4,800	7,000	9,000	

Tons of grass cut (average per acre) .	20¼		23		22		18¼		25½		24		The increase in the area of land was obtained when the high-level iron troughing, strongly recommended by Mr. Hope, V.C., was in use. The decrease is marked by the rotting away of this superstructure.
Average per acre from special plots	36		31		42		44		49		43		
	£	s. d.	£	s. d.	£	s. d.	£	s. d.	£	s. d.	£	s. d.	
Gross receipts and valuation . . .	10,147	15 7	10,190	5 9	11,013	10 11	9,254	1 7	9,325	5 6	9,421	11 3	
Less previous valuation .	4,529	12 3	4,068	9 4	4,908	12 5	4,724	13 7	4,715	13 1	4,945	8 4	
Total payments . .	5,618	3 4	6,121	16 5	6,104	18 6	4,529	8 0	4,609	12 5	4,476	2 11	—
	4,998	19 3	4,797	4 11	6,195	9 11	4,972	10 3	4,845	13 5	4,768	9 11	
Profit . . .	619	4 1	1,324	11 6	—		—		—		—		This leaves an average profit of 145*l.* per annum for the 6¼ years.
Loss . . .	—		—		90	11 5	443	2 3	236	1 0	292	7 0	

The average cost of pumping the sewage to a height varying from about 35 to 40 feet, through a main rather over 1½ miles in length, is about 450*l.* per annum, without allowing anything for depreciation in machinery, &c. This is not included in the list of payments, which are merely those of the farm.[1]

[1] Soc. Arts, p. 108.

From the figures given in the foregoing accounts it appears that the application of town sewage to land for agricultural purposes has not been a profitable mode of farming, but, on the other hand, has, excepting in dry seasons, resulted in an annual loss. It appears also that each succeeding year the quantity of land in a given area to which sewage can be applied becomes less and less. The sewage (notwithstanding that the quantity taken was optional) appears to have been used with considerable regularity, and affords a valuable guide as to the quantity of land of a suitable character that is requisite for sewage irrigation conducted in a manner to ensure good sanitary results. The sewage was used at the average rate of about 345,000 gallons a day, and the area of land used averaged 197 acres, thus showing, that for a daily flow of 1,000,000 gallons of sewage, an area of 571 acres of land of suitable soil would be requisite. How far this proportion of land to a flow of sewage could be curtailed by the employment of filtration areas such as those in operation at Merthyr Tydfil, as supplementary to irrigation, was tried at Barking with the following unsatisfactory result: It is stated that 'this method was largely carried out at the Lodge Farm where the soil formed a natural filter bed. They also applied it in much less quantities than in a filter bed, and at greater intervals, and they also had vegetation in operation. At the same time, the effluent water which went away contained more than two-thirds of the value of the ammonia, or nitrates, which the sewage originally contained.'[1]

A small experiment, carried on for twelve years at CARLISLE, with a portion of the sewage previously treated with carbolate of lime, does not afford much data to be of service. The population is 31,049, and the sewage is derived from 2,750 water-closets, but no manufacturing

[1] Soc. Arts, p. 73.

refuse, and drains direct into the river Eden. Irrigation with a portion of the sewage only has been tried privately on a farm of 110 acres of alluvial soil, but as no statistics as to the quantity of sewage applied are available, no conclusions can be drawn from this locality. It is stated that the rental of the land soon rose from 4*l.* to 7*l.*,[1] but the undertaking was abandoned about two years ago on account, as stated by the lessee, of a rise in coal, a small pumping engine being necessary.

CHELMSFORD, *Essex*, shows a very partial attempt to purify the sewage by irrigation. The population is 9,500. The sewage is derived from 1,600 water-closets, and refuse from three or four breweries. The local board pumps the sewage to a height of about 20 feet on to about 70 acres of private land, called 'Barnes Farm,' situated at Springfield, in Essex. The tenant of this land pays the local board 35*l.* a year for the sewage. The character of the land is a tender loam with a gravel substratum. This arrangement has been in existence for ten years, and the outlay by the local board has been 2,300*l.*[2] irrespective of 300*l.*[3] a year, the cost of pumping the sewage, &c. As the whole of the sewage is not dealt with (a portion from an outlying district flowing into a ditch and thence into the river, and that which accumulates between pumping hours being conveyed away by an overflow sewer),[4] it is impossible to obtain any useful statistics from this undertaking. It would appear, however, that, even under circumstances some of which are favourable, the annual charge on the town for this incomplete work, inclusive of interest at 5 per cent. on capital expended, but exclusive of supervision, is 415*l.*, or 10½*d.* per head of the population.

Much has been reported and recorded in reference to

[1] Soc. Arts, p. 5.
[2] Roseb. Ret., p. 11.
[3] Soc. Arts, p. 5; Roch. Ret., p. 6.
[4] Roseb. Ret., p. 11.

the irrigation of the Craigentinny Meadows with the sewage of Edinburgh. The city has a population of about 196,979. The volume of sewage is about 5,900,000 gallons per day. However interesting to local agriculturists the results obtained here during the last 125 years may be, from the application of water-carried sewage to 250 acres of sandy and gravelly soil, they, unfortunately, fail to assist sanitary authorities, and are apt to be misleading because, having been conducted as a private speculation, the commercial results only have been kept in view, and the sanitary interests disregarded, the land having been loaded and choked with sewage, to the extent of nearly 2,000,000 gallons per acre per annum. The result has been a yield of heavy grass crops, but the meadows are described as being in a most insanitary condition.[1] Some of the sewage escapes into the sea during flood time.[2] Analyses of the sewage and the effluent are given in the Appendix. The Rivers' Pollution Commissioners, after a careful investigation as to the rapid and abundant growth of the grass crops (stated to be of a coarse and washy character), report[3] that irrigation is carried on in a most careless manner, and that 'these meadows cannot, however, be named as a good example of the agricultural remedy for the nuisance created by town sewage; for it is poured over them in such enormous quantities that the soil has not fair play given it as a cleanser, and water, therefore, leaves the grass land still filthy and offensive.' The Commissioners further say:[4] 'The area is not sufficient to take up the whole of the filth brought down by the water. A much larger extent of crop could be obtained from the use of it if there were

[1] The Sew. Quest., 1872, pp. 25, 200.

[2] Select Com. on Sewage of Towns, 1st Report, 1862, p. 34. Evidence of Professor Way.

[3] Riv. Pol. Com. 1st Report, 1868, pp. 74, 95.

[4] *Ibid.*, p. 75.

any land convenient on which it could be applied, or if there were a sufficient demand for the produce of it. The Edinburgh experience, therefore, must be quoted not as a successful example of sewage cleansed by irrigation, but rather as an instance of the largest produce raised by means of it from a limited area of land.' The insanitary condition of these sewage meadows does not appear to have caused up to the present time any unhealthy results in their neighbourhood;[1] but notwithstanding this, the Commissioners' reports are sufficient to prevent their being regarded as affording much guide in the disposal of water-carried sewage by means of irrigation.

WORTHING, *Sussex*, has a population varying from 5,000 to 16,000, according to the season of the year. The sewage is taken by the Worthing Land Improvement Society, who pay 10*l.* a year for it, and is utilised on 97 acres of loam land. The Local Board, however, pump the sewage at an annual cost of 450*l.*[2] The arrangement is that for the first 7 years the Board deliver the sewage of the district on to the land without payment; for a second term of 7 years, which commenced in December, 1871, the Company pay the Board 10*l.* per annum for the sewage, at the expiration of this term, if the sewage is still supplied, the amount to be paid for the same is to be determined by arbitration.[3] This, however, is an arrangement scarcely likely to continue, as it appears the Company have agreed to take no more of the sewage than they like, and only when they like.[4] The flow of sewage is about 55,000 gallons per hour during the daytime from a resident population of 7,500. About four-fifths of this is lifted to a height of nine feet on to the

[1] Address on Public Health delivered at the Social Science Congress in 1863, by Professor Christison, M.D.

[2] Roseb. Ret., p. 39.

[3] Roch. Ret., p. 17.

[4] The Sew. Quest., 1872, pp. 14, 15.

farm by means of the surplus power from the engine of the waterworks.

Sewage farms that are incomplete and in course of preparation.

ABINGDON, *Berkshire*, has a population of 5,809, and it is in contemplation to spend upwards of 20,000*l.*[1] in constructing an outfall sewer, in erecting a sewage pumping station, and in purchasing 48 acres of land for irrigation and filtration.

The circumstances here are most unsuitable for irrigation; the site is on the Kimmeridge clay, and is situated at the junction of the river Ock with the Thames, upon the former of which there are several locks, and the locality is already more or less water-logged.

OXFORD has a population of 32,477, and water-closets are in universal use. The sewage is purely domestic. Works are now in operation for its utilisation upon 330 acres of land, and a sum of 42,500*l.*[2] has already been spent in this respect, but they are not yet completed.

READING, *Berkshire*, has a population of 32,314. An extensive irrigation scheme is now in course of preparation. The authorities obtained an Act in 1870 to acquire 900 acres of land for the purpose of dealing with the sewage. The character of the soil is suitable, being loam and light clay, overlying gravel. The character of the sewage is chiefly domestic, and contains but little refuse from manufactories. Carrying out this work will involve the purchase of land and its preparation, deepening a portion of the river Kennet, and the erection of a pumping station. The sewage will have to be pumped a height of 42 feet and a distance of 2,733 yards. It is

[1] Includes also sewering of the town, about 8,000*l.*

[2] Roseb. Ret., p. 32.

intended at first only to purchase 765 acres, and to prepare 80 acres of it for irrigation, including 10 acres as a filtering ground. The sum of 252,557*l.*[1] has been authorised, and 234,917*l.*[2] has already been borrowed.

WOLVERHAMPTON, *Staffordshire*, has a population of 70,000; there are about 750 water-closets in use. The sewage contains manufacturing refuse from galvanising and brass foundry works, and amounts to an average daily flow of about 2,500,000 gallons, passing on to the farm by gravitation. In the year 1868, the Corporation adopted a scheme for acquiring 900 acres of land for utilising the sewage. A commencement was made by purchasing a farm of 283 acres of a loamy sand, mixed with peat and light soil, at the following cost:—

	£
Sewage farm	32,000
Works on sewage farm	9,391
Compensation and survey charts . . .	5,150
Total	46,541 [3]

This farm was let on lease for 7 years from 1868, at an annual rental of 750*l.* It soon became apparent, however, that the tenant was more of a farmer than a sanitarian, and that he did not hesitate to use only such quantities of sewage as he needed. The Corporation, therefore, paid him 1,000*l.* compensation to give up the farm, and have since kept it in their own hands.

The difficulty experienced here in obtaining more land upon anything like reasonable terms is so great, that it is endeavoured to treat the sewage upon this limited area; but satisfactory results are not obtained, and are not likely to be until additional land is acquired, or some other plan adopted.

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[1] This amount appears to include also the cost of sewering the town, and improvements to the water-works.

[2] Roseb. Ret., p. 4.

[3] Soc. Arts, p. 17.

Places where irrigation has been entertained and the idea abandoned.

Near ALNWICK, the Duke of Northumberland put down machinery and pipes over some 270 acres of mixed land, and applied sewage in various quantities to all kinds of crops; but although the tenants got the sewage free of cost, the whole arrangement has been abandoned, the bailiff of the district reporting unfavourably on the use of liquid sewage for corn or any rotation crops.[1]

COVENTRY.—The reasons for abandoning the idea of irrigation are stated at page 38.

EDMONTON.—The local authorities purchased 113½ acres of gravelly land for 13,613*l.* for irrigation purposes, and now only partially irrigate on 30 acres, having supplemented it by a precipitation process, 8 acres of the land being used for filtration of the effluent water, a reference to which is made elsewhere.

LIVERPOOL.—A company was formed, in 1866, with a view of irrigating a portion of the sea-shore known as the Crossby Sands. The contract to take the sewage was for a term of 25 years, and although considerable expense was incurred by the company in the erection of a pumping station and mains, the work has been abandoned.

RICHMOND.—In 1850, a proposal was made to irrigate the Deer Park with sewage, but it was disallowed by the Government.

WEST HAM.—The authorities sought to dispose of the sewage by irrigation, but Government refused to sanction it. A pumping station and precipitating tanks have been erected at a cost of 7,700*l.*,[2] but the sewage is pumped

[1] Krepp on Sewage, p. 32. [2] Roseb. Ret., p. 12.

direct into the river Lee, at Bow Creek, without any treatment, at a cost, in the year 1875, of 1,740*l.*[1]

WIMBLEDON. — The authorities here acquired 48½ acres of clay land at 306*l.* per acre, and have supplemented it by precipitation works, which are referred to elsewhere.

LEEDS. — The idea of irrigation was at one time entertained, but abandoned as impracticable. It would have involved either pumping the sewage to a considerable height, or conveying it a distance of some 25 miles towards the Humber before sufficient suitable land could be obtained. The great outlay involved by either of these plans led to their unanimous rejection by the Committee.[2] Precipitation works have been adopted, and a reference to them is made elsewhere.

KINGSTON-ON-THAMES.—The sewage goes direct into the river, and the Thames Conservancy recently obtained a summons against the Corporation for penalties to the extent of 100,000*l.* for not abating the nuisance. Several years ago the authorities purchased 106 acres of a sandy soil, at a cost of 9,000*l.*[3] with a view of irrigation, and the necessary works were estimated to cost 28,875*l.*; but the scheme has been abandoned, and it is now proposed to treat the sewage by precipitation.

Places specially illustrating the requisite quantity of land for irrigation.

An account of the successful utilisation of the sewage of STAFFORD JAIL on land has been recorded.[4] The number of inmates of the gaol was 1,300. The flow of domestic sewage was 36,720 gallons a day. The land

[1] Roseb. Ret., p. 12. [2] Soc. Arts, p. 36. [3] Roch. Ret., p. 8.
[4] First Rep. Riv. Pol. Com., 1866, Appendix, p. 42.

irrigated comprised 34 acres of meadow with a peaty soil, being at the rate of about 1,000 acres to a flow of 1,000,000 gallons per day.

Another instance of successful disposal of sewage on a small scale on land has also been recorded,[1] at BROADMOOR LUNATIC ASYLUM, the number of inmates being 600, and the flow of domestic sewage 21,000 gallons a day. The land irrigated was 19 acres in extent, and its character gravel and sand, the proportion being 950 acres of land to a flow of 1,000,000 gallons per day.

It should be observed that in each of these cases the circumstances were favourable, and that the land, which was of the most suitable character, was used in the proportion of about 1,000 acres to a daily flow of 1,000,000 gallons of sewage.

A more practical or reliable illustration of the quantity of land requisite for *proper* disposal of town sewage probably does not exist than that shown by the experiment of the Earl of Essex with the sewage of WATFORD, *Hertfordshire*. He, in the year 1855, was induced, by the theoretical value assigned to sewage for agricultural purposes, to incur the expense of applying the sewage of that town to his land. The population of Watford was then 4,000, and the flow of sewage amounted to 60,000 gallons a day. The land to which it was applied was loam on gravel, which is the very best description for such a purpose. It was anticipated that 210 acres of land would be required for this amount of sewage, and accordingly that quantity was underpiped or drained; but it was found after a time that 60 or 70 acres represented the area to which the sewage could be applied with advantage,[2] thus showing a proportion of 1,090 acres of land to a daily flow of 1,000,000 gallons. His

[1] First Rep. Riv. Pol. Com., 1866, Appendix, p. 42.

[2] Select Committee on Sewage of Towns, First Report, 1862, p. 1.

lordship was successful in growing good crops, but he says: 'I think that my operations just pay, and that is all'; and this work, upon which so much labour and expense had been bestowed, was subsequently discontinued. An injunction having been granted against the local board of Watford (the population having increased to 7,461), they now employ a very elaborate system for the treatment of the sewage. It is a combination of precipitation by lime, filtration, and irrigation, and is thus described: 'First, irrigation on eighteen acres of land; second, (auxiliary) precipitation by lime, with small quantity of chloride of lime added. Horizontal filtration through coke; upward filtration through coke; downward filtration through cocoa matting, shingle, and gravel; horizontal filtration through screens of charcoal.'[1] There are 1,400 water-closets in use; the land used is a gravelly loam in character, and the sewage is partly pumped and partly delivered by gravitation. This plan has been in operation four years, but little information is afforded as to its results. The intercepting sewers and works are said to have cost about 1,400*l.*, and the land rental to be 44*l.* per annum. The cost of dealing with the sewage, for the year 1875, is said to be 725*l.* 14*s.* 2*d.*, but it is not stated if the cost of pumping, rent of land, and interest on capital are included. The income from sale of crops, during the same period, is given at 523*l.* 9*s.* 6*d.*[2]

Contemplated Sewage Farm.

NOTTINGHAM has a population of 90,000,[3] and there are about 3,000 water-closets in use; there is also manu-

[1] Roseb. Ret., p. 14. [2] Soc. Arts, p. 17.

[3] It is proposed to include six adjacent places in the sewerage scheme which would make the population to be dealt with 150,000 and the average daily flow of sewage 5,000,000 gallons.

facturing sewage from lace, hosiery, dye, and bleach works. A scheme has been suggested for the disposal of the sewage on 530 acres of land, at a considerable outlay. Although the land selected is of suitable quality, its area, in comparison to the sewage to be dealt with, appears to be quite disproportionate according to existing experience in irrigation. Mr. Baily Denton, C.E., seeks to meet this objection, and says: 'With favourable soil it may be taken as certain that 1 acre of suitable land drained 2 yards deep, and used intermittently, will permanently cleanse the sewage of 1,000 persons, and, consequently, that 150 acres so drained would suffice for the cleansing of the sewage at present discharged from your district; with the same conditions 500 acres would be ample provision for the next 50 years if these respective quantities of land were carefully prepared for intermittent downward filtration, and devoted to that purpose. Thus the 530 acres of land, all of which is capable of being drained at least 2 yards deep, would satisfy the future as well as present requirements, and leave a surplus.' It seems doubtful how far the authorities of Nottingham will feel justified in trying this experiment.

PART IV.—FILTRATION.

Excepting in laboratory experiments, and a few instances upon a very small scale, filtration of crude or untreated sewage apart from irrigation has never yet succeeded. Experiments were tried by the Rivers' Pollution Commissioners, in 1868, with filtration of sewage through various soils, and they came to the very natural conclusion, 'that the process of filtration through sand, gravel, chalk, or certain kinds of soil, if properly carried out, is the most effective means for the purification of sewage.'[1] It should, however, no longer be lost sight of that the Commissioners' experiments were all upon a very limited scale, and were not carried on uninterruptedly for any length of time. In dealing continuously with sewage of a town by filtration, two great difficulties are in practice found to arise, which are not perceivable in merely experimental measures. Whatever the filtering medium may be, land, gravel, charcoal, or other substances, the result in the end is the same, viz.: I. The pores of the filter become choked after a time with the solid matter contained in sewage; and sooner or later when they are choked, the filter acts only in a partial manner, ceasing to purify what sewage may find its way through it, and eventually is unable to filter at all. II. The collection of solid fæcal and other matter deposited from sewage upon the surface of the soil, or filter, does give rise to a formidable nuisance. Attempts have been made

[1] First Rep. Riv. Pol. Com., 1868, p. 60.

to meet the first of these difficulties by removing and replacing the filtering medium, and, when charcoal has been employed, either to utilise it, thus fortified by the solid matters from sewage, as a manure, or to revivify it by burning out the organic matter it has arrested from the sewage, and using it over again for the same purpose. However seemingly successful either of these may be on a very small scale, they have completely failed when put into practice; no ready sale for the charcoal as a manure occurs. It is, moreover, too expensive an article to keep in large quantities on hand, and, in addition, the cost of labour to constantly remove the large amount of filtering medium necessary for either purpose is so great as to make such an undertaking, even if it were satisfactory in other respects, quite impracticable; attempts have also been made to meet the second difficulty by the cultivation of the surface of the filtering beds, the supposition being, that the vegetation grown thereon will take up and utilise the organic matter deposited from the sewage. In practice, however, it is found that such an expedient will only answer as an auxiliary to irrigation or sewage farming, where the overdosing of the vegetation growing upon the filters may be avoided. Earth being a filtering medium easily obtained, and chemical as well as mechanical in its action, is of much value for this purpose, if carefully used. It may be safely employed, when the sewage is weak or very dilute, in combination with irrigation, and for the filtration of effluent waters from precipitation processes, but with risk if used apart from either of these.

Though many trials have been made, no instance can be adduced of a successful attempt to purify crude sewage by filtration alone. From the following places (38 in number) where various modes of filtration have been adopted or tried, there appear scarcely

any but unsatisfactory results in a sanitary point of view.

ABERGAVENNY, *Monmouthshire.*—'Two sets of wicker-work filled with gravel,' have been employed. The filters are cleaned out every 6 weeks, and the residue, dried, sells for manure at 3*s.* 6*d.* per ton;[1] but a nuisance arises from it in hot weather.[2]

ALTON, *Hampshire*, tried subsidence, and filtration through coarse shingle, but it proved unsuccessful.[3]

ASHBY-DE-LA-ZOUCH, *Leicestershire.*—The sewage was received in tanks divided into compartments, between which strainers were placed, composed of perforated boards 3 feet apart. The upper strainers were filled with coarse, the lower ones with finer, pebbles, and the last with fine gravel; but the plan was abandoned.

ATHERTON, *Lancashire*, 'employed three settling tanks and two filter beds, composed of broken stones, gravel, and sand';[4] but these are about to be replaced by some other method.[5]

BACUP, *Lancashire.*—'Five vertical compartments, four charged with coke and one with charcoal, were used.[6] Although it is said that no nuisance arises, there is yet scarcely any sewage to deal with.

BANBURY, tried filtration of the sewage, but abandoned it, and resorted to irrigation.[7]

BILSTON, *Staffordshire*, filtered the sewage, 'first, through ten 12-inch pipes filled with straw, then subsiding tanks, and finally through two ash filter beds.'[8] As it has been recently stated that the sewage goes direct into the river,[9] this plan has evidently been found ineffectual.

BUXTON, *Derbyshire.*—'A settling tank, the effluent

[1] Soc. Arts, p. 1.
[2] Roch. Ret., p. 19.
[3] Roch. Ret., p. 25; also the Sew. Quest., p. 35.
[4] Roch. Ret., p. 19.
[5] Roseb. Ret., p. 17.
[6] Roch. Ret., p. 19.
[7] Soc. Arts, p. 2.
[8] Roch. Ret., p. 19.
[9] Soc. Arts, p. 3.

water passing through a straw filter,' was tried, but it gave rise to a nuisance in dry weather.[1]

BISHOP AUCKLAND, *Durham*.—'Subsiding tanks and filtration through beds of coke and ashes'[2] have been tried but abandoned.[3]

BRADFORD, *Yorkshire*, entered into a contract in 1873 with the Peat Engineering and Sewage Filtration Company Limited, for the use of Weare's filtration process, which had been found to answer on a small scale at the Stoke-upon-Trent workhouse; but after some time it was found not to succeed upon so large a scale, and has been abandoned.[4] This process had for its object the conversion of the filtering material into a manure.

BURY ST. EDMUNDS.—Previous to irrigation, filtration through charcoal and gypsum was tried, but failed.[5]

CANTERBURY.—From the year 1868 to 1872 the sewage was filtered through charcoal, 'but was abandoned, being too expensive and producing no good results.'[6] The present system is as follows:—The sewage is treated in five settling tanks, and flows on until it comes to the filtering beds, which are in duplicate. In the first place, it passes through two yards of gravel and straw combined, then it comes up through a layer 4 feet wide and 8 inches thick, passes down through another layer of straw and coke, then up through another, and away to the river.[7] No account of the cost of this work is afforded, but it must be heavy, because the gravel has to be removed every fortnight, and laid out in the open air to be renovated. It also fails to be satisfactory in a sanitary point of view,[8] as it is stated to be only fairly

[1] Roch. Ret., p. 19.
[2] Roch. Ret., p. 19.
[3] Roseb. Ret., p. 10.
[4] Birm. Sew. Enq., p. 47.
[5] Roch. Ret., p. 4.
[6] Roseb. Ret., p. 15.
[7] Soc. Arts, p. 74.
[8] Roch. Ret., p. 18.

successful, and that in the end there was no doubt but that the authorities would adopt some other system.[1] It is stated that 500 cubic yards of sludge is taken out of the sewage per annum, which sells for 150*l.*[2]

CHELMSFORD.—Previous to irrigation, subsidence and filtration through charcoal were tried, but failed.[3]

CHELTENHAM.—Previous to irrigation, filtration through gravel, with lime treatment, was tried, and abandoned.[4]

CHESTERFIELD, *Derbyshire.*—'At the outlet of each sewer is fixed a filter, consisting of three screens composed of perforated metal plates, forming boxes filled with gravel and animal charcoal';[5] but a nuisance arises from the process.[6]

COVENTRY.—Previous to the process now in use, subsidence tanks with lateral filters formed of perforated planks inclosing walls of gravel 3 feet thick, were constructed at considerable expense and used, but completely failed.

CROYDON, previous to irrigation, tried filtration through charcoal, but it failed.[7]

ELY, *Cambridgeshire.*—'Upward filtration through sand, &c.' has been tried and abandoned, and 'catch-pits, with upward chequered woodwork sieves,' are being tried with no better success.[8]

EALING, *Middlesex.*—The sewage was received in depositing tanks, and then passed through a rough filter of gravel or burnt ballast, and baskets filled with charcoal; the Rivers' Pollution Commissioners report as follows of this process: 'The suspended matters were of course to

[1] Soc. Arts, p. 4. [2] *Ibid.*
[3] Roch. Ret., p. 7; and Birm. Sew. Enq., p. 58.
[4] Soc. Arts, p. 105. [5] Roseb. Ret., p. 8.
[6] Roch. Ret., p. 19. [7] *Ibid.*, p. 7. [8] *Ibid.*, p. 18.

a great extent arrested, but the effluent liquid retained nearly all the original amount of soluble putrescible organic matter, and was totally unfit to be admitted into running water.'[1] It has since been abandoned.

ENFIELD, *Middlesex*.—Lateral filtration tried, and failed.[2]

EAST BARNET, *Hertfordshire*. The British Land Company tried filtration through burnt gravel, but it failed.[3]

FAREHAM, *Southampton*.—'The sewers discharge into settling tanks, at the top of which is suspended charcoal in baskets; from these tanks the liquid sewage passes through filters and rough gravel. After passing through the filtering bed, the effluent water passes over clay which is changed, or to which is added a little, every day.'[4] Although the effluent water passes into the sea-water creek, this system was not satisfactory,[5] and no recent reports of it have been furnished.

GRANTHAM, *Lincolnshire*, tried 'a system of settling tanks with iron grates,' but it did not succeed and was abandoned.[6]

HARBORNE, *Staffordshire*, deals with the sewage partly by lime and partly by upward filtration through gravel, coke, and charcoal, placed upon perforated elm boards.[7] The process is still in operation, but no recent report of it has been made.

HURSTPIERPOINT has made an attempt to filter the sewage through 'straw, dry earth, ashes, sand, heath, and burnt clay,' but it resulted in a nuisance.[8]

LITCHURCH, *Derbyshire*.—The sewage passes into tanks, and, after subsidence, runs through a wicker screen, and

[1] First Report Riv. Pol. Com., 1868, p. 60. [2] Roch. Ret., p. 9.
[3] Second Report Riv. Pol. Com., 1867, p. xiii.
[4] Roch. Ret., p. 20. [5] *Ibid.* p. 21. [6] *Ibid.* p. 21.
[7] Roch. Ret., p. 21; Soc. Arts, p. 8; and Roseb. Ret., p. 35.
[8] Roch. Ret., p. 21.

then through a bed of coke or slag and two beds of charcoal. It is not satisfactory.[1]

LUDLOW, *Shropshire*, filters the sewage simply through broken stone and fine gravel, but no sanitary accounts of this work are published.

MORLEY, *Yorkshire*, has made an attempt to filter the sewage, but it gives rise to a nuisance.[2]

NEWCASTLE-UNDER-LYME, *Staffordshire*, passes the sewage through 'wickerwork and perforated planks, filled in with charcoal, coke, and sandstone, broken in pieces.' The process, however, gave rise to a nuisance, and completely failed.[3]

OSWESTRY, *Shropshire*, filters the sewage at the outlet of depositing tanks, through 6 inches of gravel laid upon perforated iron plates, and covered with similar plates, but the result is not satisfactory.[4]

ST. THOMAS-THE-APOSTLE, *Devonshire*.—An attempt to deal with the sewage, amounting to about 200,000 gallons a day, was made. First, a small dose of carbolic acid and lime was added, it was then passed through subsiding tanks, and next through a coarse strainer of perforated iron, and finally filtered through a lateral filter of coarse gravel about 2 feet thick. It then flowed away in an open gutter for 2 miles, but the result, though better than some instances of filtration, does not appear upon the whole to have been satisfactory.[5]

SAFFRON WALDEN, *Essex*, passes the sewage into subsiding tanks, and then through gravel filters, but no reports of results have been published.

SOUTHAM, *Warwickshire*, filtered the sewage through perforated elm boards, filled in between with gravel, burnt soil, or coke, but it completely failed.[6]

[1] Roch. Ret., p. 21. [2] Roch. Ret., p. 22. [3] *Ibid.* [4] *Ibid.*
[5] The Sew. Quest., p. 34; and Roch. Ret., p. 22.
[6] Roch. Ret., p. 22.

TEWKESBURY, *Gloucestershire*, filters the sewage through three filtering beds of different sized gravel. It is said to answer the purpose.[1]

ULVERSTON, *Lancashire.*—The sewage was first passed through a gorse screen, then upwards through broken stones. This process, however, failed to purify it; and, as a nuisance arose, arrangements were made to pass it to Morecambe Bay into the sea.

UXBRIDGE, *Middlesex.*—The sewage flows first into subsiding tanks, and is then filtered through twelve boxes of coarse vegetable charcoal. The process is very unsatisfactory, and an injunction has been granted to restrain the Local Board from polluting the river Colne.[2]

WALTON-ON-THE-HILL, *Lancashire.*—The sewage was passed through two tanks containing three vertical filters filled with gravel, broken stones, &c. The result has been a complete failure. Legal proceedings were threatened, which, however, were stayed by the Local Board endeavouring to purchase a sewage farm.[3]

WELLINGBOROUGH, *Northamptonshire.*—At one outfall nine tenths of the sewage are treated by mechanical filtration, viz., with vertical gravel filters and cocoa matting strainers; and at another outfall one tenth of the sewage is treated by intermittent filtration through one acre of land. The process, after sixteen years' use of the former and three of the latter, is unsatisfactory, and it is stated that 'no method tried has been found successful in preventing pollution of rivers.'[4]

Other places might be mentioned where filtration experiments have been tried, but it is considered that suffi-

[1] Soc. Arts, p. 16.

[2] Roch. Ret., p. 22; Soc. Arts, p. 16; the Sew. Quest., p. 35; Roseb. Ret., p. 29; and Birm. Sew. Enq., p. 58.

[3] Roch. Ret., p. 22; and Soc. Arts, p. 16.

[4] Roch. Ret., p. 23; Soc. Arts, p. 17.

cient evidence has been obtained to prove conclusively that whatever be the filtering medium employed, and whether in conjunction with subsidence tanks or not, for crude or untreated sewage the system has been unsuccessful.

Mr. C. E. Austin, C.E., has proposed a 'Prompt separation process of sewerage' for removing solids from the fluid, which is thus described. 'A shaft or chamber is constructed at each central point of drainage.' 'In the centre of the chamber a manure box is fitted in such form as to receive all the solid matter passing from the sewer; and it is enclosed in a strainer so arranged as to allow the fluid portion of the sulliage to flow through into the chamber, but to deliver the solid parts and cause them to be deposited in the box or caught in the deodorising materials which form the filter.'

PART V.—DISCHARGED INTO THE SEA.

WITH so much doubt and uncertainty hitherto existing on the subject, it is not surprising that sanitary authorities and engineers have sought to dispose of town sewage by a plan which at first sight seemed certain to relieve them from further trouble. Being content to view sewage in the light of a useless thing to be got rid of, and thinking that by casting the whole of it into the sea it was out of the way, they have in some instances adopted this plan; but the sea has not been found to afford the anticipated solution of the difficulty, inasmuch as where there are no currents setting off the point of delivery of the sewage it is returned to the shore. Opinions favourable to this mode of dealing with sewage exist in some quarters which can hardly be reconciled with a knowledge of what actually takes place when sewage is cast into the sea. There are, however, some places where circumstances are favourable to this course being pursued in dealing with sewage, but in general it will be found to be

Uncertain in its sanitary results.
Attended with heavy cost.
Entirely wasteful.

In reference to the first of these, it being a fact that sewage has a higher temperature and a lower specific gravity than sea water, the two will not mix together, consequently the sewage floats upon the surface of the sea,

and is frequently carried in shore by currents in a decomposing state. It is, therefore, of little use to run it into deep water, for it will rise to the surface like a cork, nor is distance from the shore of much avail, for it will be brought back again by the tide. These results have frequently been observed and recorded. It is stated by Mr. Hanvey that at Dover 'a bay is formed by the Shakespeare Cliff and the Admiralty Pier, with Archley Fort almost in the centre, where the outlet pipe discharges; the result was that for a considerable period there was slack water, a quantity of sludge was deposited and flocculent matter was seen floating about. This passed on towards the pier, and remained there until a north-easter, or some other powerful agent, carried it away. Efforts had been made for many years to get rid of the nuisance. Some persons thought the best mode would be to lay a pipe to the end of the Admiralty Pier, while others considered the pipes should be extended into a depth of seven fathoms. He had himself made experiments with corks at different times of the tide, which in about a quarter of an hour returned to the bathing machines on the Marine Parade. He also put in some corks in front of Archley Fort, and in about the same time they were on shore. There was a south-west breeze for about nine months in the year, which carried any floating matter in towards the shore. In quiet seasons the matter suspended in the water was precipitated, with what result might be easily imagined.'[1] In the neighbourhood of Carnarvon it has been said by Mr. Humphreys (Mayor of Carnarvon) that the sewage is cast into the estuary of the harbour, and a great deal of the sludge is left at corners on the beach where it is thrown by the current. The nuisance is so great that the authorities are desirous of adopting some means of obviating it.[2]

[1] Proc. Inst. C.E., vol. xliii. p. 221. [2] Soc. Arts, p. 87.

It is said that when decayed organic matter is discharged into the sea, salt water acts as a preservative, and that it floats about, giving off into the atmosphere most unhealthy gases.[1] To this cause has been assigned the insanitary state of some of the Mediterranean harbours, for instance 'the Bay of Naples, so justly celebrated for all that is lovely and picturesque in natural scenery, but behind the road from Chiaja towards the Grotto of Cicero, a spot which otherwise might be emphatically called an earthly paradise, lies in the direction of Posilipo, a veritable infernal pit, the outlet of the Cloaca of Naples into the sea. The effluvium arising from it, horrible beyond description, brings sure death to all within its vicinity, in consequence of which many noble castles and villas scattered along the coast have long since been abandoned; amongst others the beautiful but gloomy palace of Queen Giovanna I., which, once the favourite abode of wealth and luxury, now lies in utter desolation, mouldering in ruins and dust.' 'At the Port of Marseilles also the death-like fatality which hangs over it is well known. Founded 400 years B.C., it was already in the time of Cæsar celebrated for its trade and shipping. The harbour is quite a marvel of nature and art, but at the same time wofully notorious for its immense accumulations of filth, which are still daily increasing by the recently constructed sewage works.'

'It is currently reported amongst mariners that the Marseilles pilots can take a ship into that port in the thickest of fogs and on the darkest of nights guided by the smell alone.'[2] Other instances of unhealthiness arising from this cause are mentioned. The Bay of Cadiz, Rio de Janeiro, in South America, and Havana, are ports said to be now reaping the results of pouring sewage into the sea continued through ages.[3] It has

[1] Krepp on Sewage, 1867, p. 60. [2] *Ibid.*, p. 61. [3] *Ibid.*, p. 62.

been stated by Mr. James White that 'some thirty-seven years ago Government directed an investigation into the causes of bad health on the west coast of Africa, and the injury to the copper sheathing of vessels, with the remedies which might be suggested. The report showed that when any animal or vegetable matter came into contact, not with sea-water itself, but with the sulphates contained in it, sulphuretted hydrogen was produced in an enormous quantity, and it was calculated that an area of 12,000 square miles on the west coast of Africa was thus rendered unfit for Europeans to live in. With regard to throwing sewage into the sea, it should be remembered that for two-thirds of the year a south-west wind was pretty general on the whole of the south coast of England, and as long as that blew there was no offence; but with an east wind, at Hastings for instance, the stench from the outfall sewer, nearly half a mile or a mile distant, was something fearful. This was also the case at Margate; and all who had resided there knew that when an east or north-east wind blew, the stench from sewer gas was very bad, consisting of sulphuretted hydrogen to a large extent. It was the same at Ipswich, and even as far as Edinburgh, where the nuisance was very bad with an east wind. Some sixteen years ago at Campbelltown, where there was not a single water-closet, the whole of the ordure was thrown into the street and swept into the large beautiful bay, and there it remained, a portion passing away at each tide. Two years afterwards that fine town was nearly decimated by disease. This showed that unless you had a swift and free discharge the throwing of sewage into sea water was dangerous.'[1] Mr. Abernethy, C.E., says, 'At Margate, after a long discussion upon competing schemes, it has been resolved to discharge the sewage about one and a

[1] Soc. Arts, p. 87.

half miles eastward of the town into the sea, beyond a reef which projected at right angles to the shore, forming a low-water groyne. Eastward of that natural groyne there was another of the same character, and between them a sandy bay, so that the sewage discharged between those two natural groynes at low-water would be cooped up between them, and would remain permanently deposited at that point. Near high-water mark, when the current was exceedingly strong, a portion would no doubt be carried back to Margate, and gentlemen enjoying the pleasures of natation might find articles parted with long ago in close proximity to their persons.'[1] The same authority states, that 'having been recently consulted with regard to the sewage of Ramsgate, he found that the whole of the sewage of the town was discharged at low-water mark quite close to the western pier, the result being that when the foreshore was uncovered the nuisance was exceedingly great. He had ascertained that at certain periods of the tide and of the discharge, the sewage found its way directly into the harbour, and even beyond the western pier on to the foreshore, which was extensively used as bathing ground.'[2]

Previous to the construction of the new sewerage works at Brighton, and when there were eight outfalls into the sea into deep water, and far from the beach, the sewage used to rise and float on the surface in front of the town, and has been thus referred to by Mr. Hayter: 'The specific gravity of sewage being less than that of sea water, the sewage rose to the surface; and even at the old central outfall at the Steyne, which was 1,760 feet from the shore, and further seaward than any of the others, the stream of sewage was plainly visible from the shore, and to those who went in boats and came near

[1] Proc. Inst. C.E., vol. xlv. p. 190. [2] *Ibid.*, vol. xliii. p. 207.

the point of discharge the effluvium was unpleasantly evident.'[1]

Mr. Lockwood, borough surveyor at Brighton, also says: 'There was to be seen when it rained a yellow patch of water, which gave alarm to visitors when they were told what it was;'[2] and the late Dr. Alfred Smee, F.R.S., stated that at Brighton he 'had seen for half a mile or one mile in length the sewage floating at the top of the water—a nasty and a noxious thing.'[3]

Six years ago the authorities at Brighton sought to escape from these evils by conveying the sewage into the sea at some point other than that immediately adjoining the town, and they united, for this purpose, the eight existing outfall sewers by an intercepting sewer. The population of BRIGHTON is stated to be 92,473, but the drainage area is said to embrace a population of 109,319. The sewage is of a purely domestic character, and the average daily flow amounts to about 2,500,000 gallons. The intercepting outfall sewer commences at Cliftonville, the west end of Brighton, and discharges to the eastward, into the sea at Portobello. The entire length is 7¼ miles. The average internal diameter is from 5 ft. to 7 ft. It is constructed of brickwork, terminating at the outfall in iron pipes. The invert of the sewer at Cliftonville is 21 ft. 6 in. above low-water of spring tides, and the invert of the iron pipes is level with low water at spring tides; beyond the mouth of the pipes the sewage runs in a trench, only visible at low-water during spring tides. The range of tide is about 15 ft., the greatest rise being 22 ft., and the least 9 ft. Ventilators are placed at every 200 yards along the line, and the cost of the whole work was 100,000*l.*[4]

How far success will permanently attend placing

[1] Proc. Inst. C.E., vol. xliii. p. 224.
[2] *Ibid.*, vol. xliii. p. 217.
[3] *Ibid.*, vol. xlv. p. 184.
[4] *Ibid.*, vol. xliii.

the outfall at Portobello remains to be seen, but no sooner was the work completed, than a new difficulty arose, viz., that of sewer gas. This trunk sewer, 7¼ miles long, and averaging 6 ft. in diameter, has its outlet closed by the sea to such an extent as to be rarely able, if ever, to completely empty itself. It is clear, then, that the sewer became practically an enormous elongated cesspool. Large quantities of sewer gas generated, more than could escape through the ordinary ventilators, and as the tide rose, the sewage rising in the sewer would diminish the space available for holding gases, and they would be forced up the branch drains into the houses. Mr. Abernethy states that 'a similar intercepting culvert to that at Brighton had been made at Aberdeen, and it was found that during the period when the tidal valve was closed and the sewer had no outlet, the noxious gases generated in the main culvert found their way up the various drains and subsidiary sewers into the higher part of the town.'[1] During this stagnation of sewage another evil also occurs, the solid matter deposits, and a large accumulation of sludge takes place in the sewer.

Although the works were only completed lately, complaints have already been made on the subject, and the Brighton authorities have been obliged to endeavour to meet these difficulties by introducing a ventilating arrangement, consisting of a furnace and chimney, to produce a draught through a portion of the sewer about one mile eastward of Kemp Town.

The sludge deposited in the sewer is removed at night from the catch pits at the rate of six to twenty-one loads or cubic yards per week.[2]

So far as the cost is concerned the authorities of

[1] Proc. Inst. C.E., vol. xliii. p. 208. [2] *Ibid.*, p. 223.

Brighton would not have had much to complain of, as the works involve a charge of 5*l.* 10*s.* per million gallons of sewage, or about 1*s.* per head per annum of the population; but at present it is impossible to foresee what further expense may become requisite, inasmuch as the sanitary results must be regarded as uncertain.

The sewage of GLASGOW is discharged direct into the Clyde; it has for years produced a most intolerable nuisance, and has been the subject of more than one enquiry. Up to the present time the prevailing idea has been to convey it miles away from the city to the sea.

The population of Glasgow, together with that of the small burghs and suburbs which are now included in it for drainage calculations, has been recently estimated at 680,000. The sewage from these places is of a manufacturing character, and has lately been stated to amount to an average daily flow of 48,000,000 gallons.[1] In the year 1868 it was proposed by Messrs. Bateman and Bazalgette to construct intercepting sewers to connect the various outfalls from the city of Glasgow itself, which discharge into the Clyde, and to convey the whole of the sewage to the sea by means of a large trunk sewer 9 ft. in diameter, and 27 miles in length, having a fall of 20 inches per mile. This outfall sewer was for the greater portion to be in tunnel, and was to have its outfall in Irvine Bay, midway between Irvine and Ardrossan, on the west coast, opposite to the Isle of Arran, which is distant about fourteen miles, the invert of the sewer being on a level with low-water ordinary spring tides. The cost of this entire work, including the necessary pumping stations, was estimated at 1,089,756*l.*, and the probable outlay at 1,253,256*l.*[2] At that time the population to be dealt with was estimated at 500,000,

[1] Sir John Hawkshaw's Report on the Purification of the Clyde, p. ix.

[2] Sewage of Glasgow: Bateman and Bazalgette, p. 30.

and the volume of sewage at thirty-five million gallons per day, so that 5 per cent. interest upon the above expenditure, exclusive of the cost of pumping the sewage and maintaining the works,[1] would have entailed a charge of about 5*l.* per million gallons of sewage, or at the rate of 2*s.* 6*d.* per head per annum of the population. This plan embraced the proposal of irrigating 11,000 acres of land with a portion of the sewage on its way to the sea.

Further steps were not taken in reference to this subject until the year 1874, when Sir John Hawkshaw was appointed by Royal commission to examine and report upon the best means for the purification of the Clyde. Accordingly he held an enquiry at Glasgow in the early part of 1875, and his report was issued in the early part of the following year. This investigation embraced more than the sewage of Glasgow, and extended to other places, situated in the valley of the Clyde, the sewage from which also pollutes that river. Sir John Hawkshaw states in his report that, 'considering the Filtration and Irrigation systems[2] inapplicable in this case, it remains to be considered whether it would be advisable to discharge the sewage into the Clyde at Whiteinch after subjecting it to some process of deodorisation, or to convey it still farther and to discharge it into the river, or Firth of Clyde, or the sea, at some place to be decided upon. By the addition first of suitable deodorising and precipitating substances, such as alum, clay, lime, and charcoal, to the sewage, thus allowing the solid matter to subside, and afterwards filtering the liquid through prepared filters to be used intermittently, I believe that the whole of the sewage of the district under consideration

[1] Estimated at 4,870*l.* per annum.

[2] According to practical data the quantity of land for this purpose would amount to 18,864 acres.

might be discharged into the Clyde at Whiteinch without causing a nuisance to the neighbourhood.'[1] Sir John Hawkshaw having thus pointed out the practicability of dealing with the sewage by precipitation, was deterred from advising its adoption for two reasons—1st. The seemingly heavy cost of a chemical process; and 2nd. The difficulty of disposing of the large amount of manure that would be produced. The former he estimated, inclusive of pumping and labour, at 80,000*l.* a year, and the latter at from 400,000 to 500,000 tons annually. These deductions appear to have been drawn from the results of lime treatment and of working the A B C process at Crossness. It should, however, be noticed that treatment of sewage by precipitation has made considerable progress since those data were published, and that a suitable chemical process could deal with sewage like that of Glasgow, at an annual cost for chemicals not exceeding 25,000*l.* for treatment of 48,000,000 gallons per day, and that the amount of dry manure produced could be brought down to 40,000 tons per annum, or 150,000 tons containing 75 per cent. of moisture suitable for carting.

Sir John Hawkshaw, influenced, however, by the considerations above mentioned, hesitated to advise precipitation and fell back upon almost a similar recommendation for the city of Glasgow and its immediate neighbourhood as that made by Messrs. Bateman and Bazalgette eight years before. He, however, abandons the idea of applying any of the sewage to land on its route to the sea. He also changes a portion of the line for the main sewer so as to pass through about two miles and a half less of mineral country, and to discharge into the Firth of Clyde, at Farland Head, nine miles farther

[1] Sir John Hawkshaw's Report, p. xi.

north than the spot selected for an outfall by Messrs. Bateman and Bazalgette, five miles and a half from Ardrossan, six miles and three quarters from Saltcoats, and one mile and a half from Little Cumbrae Island.

The length of the outfall sewer is the same, viz. twenty-seven miles. It would be in tunnel the entire way from Whiteinch to Farland Head, at depths below the surface ranging from 20 to 470 feet. The proposed internal diameter is thirteen feet and the gradient $10\frac{1}{2}$ inches in a mile. The estimated cost of this outfall sewer is 1,500,000*l.*, which at 5 per cent. interest (exclusive of pumping the sewage and maintenance) would involve a charge equivalent to 4*l.* 5*s.* 7*d.* per million gallons, or 2*s.* $2\frac{1}{2}$*d.* per head per annum of the population dealt with. This work would only provide for the requirements of Glasgow, Paisley, Johnstone, Renfrew, Coatbridge, and Ardrie, so that upwards of two and twenty other towns and villages, including Greenock, Gourock, Port Glasgow, Helensburg, Dumbarton, Barrhead, Thornliebank, Neilston, Busby, New Cathcart, Wishaw, Motherwell, Hamilton, &c., with a united population of upwards of 150,000, would continue to pollute the Clyde and remain still to be dealt with. Objections can easily be made to any plan for dealing with the sewage of Glasgow and its neighbourhood, but experience with long outfall tunnelled sewers having very little inclination and discharging at low water does not point to this plan being unobjectionable, and it would be well to carefully consider the following points before a work of such magnitude is carried out.

I. The discharge of 48,000,000 gallons of raw sewage daily into the sea in the neighbourhood of Ardrossan, Saltcoats, Great Cumbrae, Little Cumbrae, and Bute Islands, may be attended with serious nuisance in those localities.

II. The line of sewer will apparently pass through at least two miles, and immediately along the border for nine miles, of land liable to be undermined by coal or mineral workings. There is, therefore, a risk, although it may be but a small one, of the sewer being deflected or fractured by subsidence of the strata so as to render it inoperative.

III. The great length, the small amount of fall, and the fact that the mouth of the sewer would be closed for a considerable portion of time, might cause a repetition of the difficulties which have occurred in the Brighton outfall sewer as regards ventilation, sewer gases, and the deposit of sludge.

At WESTON-SUPER-MARE, ST. LEONARDS, TORQUAY, EASTBOURNE, LLANDUDNO, and other sea-coast places the sewage has been discharged into the sea. At the latter place, in Carnarvonshire, with a resident population of 3,500, works have been recently carried out to convey the sewage 1,200 yards into the sea to a point below low-water mark, where it is said the currents both at high and low water are all seawards. The cost of this work with sewering the place was estimated at 23,000*l.*, which would impose an extra rate of 1*s.* in the pound.

The following may be noticed as efforts to unite together for sewage purposes perhaps more than as proposals to cast sewage into the sea.

During the session of 1875, the West Kent Main Sewerage Board obtained parliamentary powers for uniting the parishes of Bromley, Beckenham, Hayes, Orpington, Chislehurst, Mottingham, the Crays, Bexley, Crayford, East Wickham, Erith and Dartford, in one drainage scheme, and to convey the sewage from those places in one trunk outfall sewer thirteen miles and a half in length to Long Reach in the River Thames, eight

miles below the outfall of the Metropolitan sewage. This scheme appears to possess the advantages likely to arise from a combination of several districts similarly circumstanced.

Upon the same principle of combination it has been proposed by the Surbiton Improvement Commissioners to unite sixty-seven places with a population of 347,000 situated in the Thames Valley, in one common drainage system.

For this purpose Sir Joseph Bazalgette proposes the construction of a sewer to 'start from Eton, follow the left bank of the Thames to Datchet, there cross the river to its right bank, which it follows to Old Windsor, thence proceed in a nearly straight line through Egham, to a point opposite Staines, where it would receive a branch bringing the sewage from Colnbrook, Horton, Stanwell, &c., thence in a southerly direction to Chertsey, thence, taking an easterly direction, to cross the left bank of the river at Shepperton, where it would be joined by a branch sewer bringing the sewage from Littleton and Laleham, thence proceeding in the same (easterly) direction to Kingston, crossing the Thames beneath its bed, receiving between Shepperton and Kingston the sewage of Halliford, Sunbury, and Hampton.

At a point on the right bank of the river, about one and a half miles east of Kingston, the main sewer would receive (1), an arterial sewer with branches which convey the sewage from Weybridge, Walton, Hersham, West and East Molesey, Esher, Thames Ditton, Long Ditton, and Surbiton, on the right bank of the river; (2), a second arterial sewer with branches from Heston, Hounslow, Twickenham, Teddington, Hampton Wick, Brentford, Isleworth, &c.; and (3), a third artery with branches from Ealing, Acton, Chiswick, on the left, and Kew, Barnes, Mortlake, Richmond, Petersham, Kingston, &c., on the right

bank of the river. As far as this point, near Kingston, the sewage of all the places in the united district lying to the north and west of that place is brought by gravitation. The population of the northern and western portion of the district is about 240,000. From this point the whole volume of sewage is to be raised by pumping fifty feet into a higher sewer, along which it flows by gravitation to a point near Mitcham, receiving in its course, by branches, the sewage of Epsom, Ewell, Sutton, Malden, Merton, Morden, Carshalton, Cheam, Wimbledon, &c.'

'From Mitcham, the sewage is again pumped through a rising main (96 feet vertical height) to Thornton Heath, where it flows by gravitation to Beckenham. At Beckenham, it is proposed that the sewage shall be received into the sewers of the West Kent Drainage Board, and flow by gravitation to their outfall in the Thames in Long Reach, about three miles and a quarter east of Erith.'

The work is estimated approximately to cost 476,000*l.*

This proposal gave rise to an enquiry by Lieut.-Col. Ponsonby Cox, R.E., an Inspector of the Local Government Board, and a report of his, published in April 1876, is not favourable to the carrying out of this scheme. He says: 'I am prepared to admit that there are difficulties existing in greater or lesser degree through the whole united district, difficulties which are, perhaps, felt to their greatest extent in the district of the applicants and of their immediate neighbours; yet, regarding the proposed united district as a whole, these difficulties appear to me to be much exaggerated, and I do not consider that they are so great as to require for their solution quite so heroic a treatment as that proposed by the Surbiton Commissioners.'

In reference to those places which are comparatively

remote from the river, Colonel Cox says their sole difficulty appears to be that land is valuable because they are suburban to London, and consequently the sites for purification works are costly, but he does not think this a sufficient reason for the authorities of those places embarking in so large a scheme as the combination proposed by Surbiton. As regards the towns and villages above the Water Companies' intake, he considers that by grouping several of them together for common pumping works their sewage might be disposed of in a perfectly satisfactory manner at not unreasonable cost; and with regard to the places between Hampton and the Western boundary of the Metropolitan district (situated below the Water Companies' intake) he remarks: 'That filtration through land before admission into the Thames above the intake of the Water Companies is necessary may be admitted; but lower down the stream, where the necessity for purity is much less, sewage may be sufficiently purified or clarified by precipitation for admission into the river.'

PART VI.—APPENDIX.

Analysis of Sludge, produced by the Coventry process, by Dr. Voelcker, F.R.S.[1]

NOTE.—This analysis is taken from the Report of the Local Government Board Committee, and the value of the same containing 15 per cent. of moisture is also here given, to correspond with other analyses in that report.

Moisture	47·36
Organic matter (containing nitrogen 0·69 equal to ammonia 0·84; or, approximately, if reduced for 15 per cent. of moisture, ammonia 1·50)	15·95
Oxide of iron and alumina . . .	5·17
Tribasic phosphate of lime	1·81
Carbonate of lime	7·32
Sulphate of lime	1·19
Alkaline salts and magnesia (containing potash 0·20, and chloride of sodium 0·02) . .	2·38
Insoluble siliceous matter	18·82
	100·00

	£	s.	d.	£	s.	d.
Estimated money value of sludge (containing 47·36 per cent. of moisture) per ton . .	0	16	9½[2]			
Corrected for manure containing 15 per cent. of moisture .	1	7	1½			
Market value of sludge (containing 47·36 per cent. of moisture) . . .	0	5	6 to	0	8	4[2]
Corrected for manure containing 15 per cent. of moisture . .	0	8	10½ „	0	13	5½

[1] Loc. Gov. Bd. Rep., p. 49.

[2] *Ibid.* p. lxiii.

Analysis of Effluent Water, from Coventry Sewage Works, by Dr. Voelcker.

'The sample of water, on evaporation to dryness, left 45·22 grains of residue per gallon, dried at 130° C.'

'In this residue I found by direct determination'—

Organic and volatile matter (including ·672 oxydisable organic matter)	1·27
Oxide of iron and alumina	·28
Phosphoric acid	·13
Lime	12·61
Magnesia	·50
Chloride of sodium	7·44
Soda	·63
Potash	3·56
Sulphuric acid	9·99
Nitric acid	2·24
Soluble silica	·42
Carbonic acid (not determined)	

The water further contained per gallon—

Free (saline) ammonia	·630
Organic (albuminoid) ammonia	·042

'According to these analytical data, the composition of this sample of effluent may be expressed as follows:'—

'An imperial gallon contains'—

Organic and volatile matter (including ·672 of oxydisable organic matter)	1·27
Oxide of iron and alumina	·28
Phosphoric acid	·13
Sulphate of lime	16·98
Carbonate of lime	9·20
Nitrate of lime	1·35
Nitrate of magnesia	1·85
Chloride of sodium	7·44
Carbonate of soda	1·07
Carbonate of potash	5·23
Soluble silica	0·42
Total solid constituents (dried at 130° C.)	45·22 grs.

Free (saline) ammonia	·630 of a grain
Organic (albuminoid) ammonia	·042 „

'The water contained a few flakes of suspended matter, which rapidly settled to the bottom of the bottle in which it was received. It had no perceptible smell, and was free from colour; the residue which was left on evaporating the water was only slightly coloured yellow.'

'The sample of effluent water contains but little organic (albuminoid) ammonia, and not much more than half a grain of saline ammonia per gallon. From this sample the nitrogenous organic constituents of raw sewage appear to have become oxydised and changed into nitrates, to a very large extent.'

Analysis of Dry Powdered Sewage Manure, from the Works at Coventry, by Dr. Voelcker, February 27, 1875.

Moisture	7·43
Organic matter and water of combination (containing nitrogen 1·38, equal to ammonia 1·67)	26·45
Phosphate of lime	3·75
Sulphate of lime	1·93
Carbonate of lime	11·46
Oxide of iron	3·75
Alumina	7·98
Alkaline salts and magnesia	2·75
Insoluble siliceous matter	34·50
	100·00

Analyses of Sewage Manure, produced by the Coventry process during experiments made in 1871 *(previous to the erection of the Sewage Works), for the Corporation, by Dr. Voelcker and Dr. Odling on three occasions.*

Constituents	Dr. Voelcker		Dr. Odling
Moisture	12·01	15·70	20·16
Organic matter	26·89	31·86	22·98
Bone phosphate	2·60	2·55	2·20
Other mineral salts	6·61	10·33	16·47
Siliceous matter and clay	51·89	39·56	38·19
Total	100·00	100·00	100·00
Ammonia from organic matter	1·39	1·22	1·44

'According to Dr. Voelcker, the two samples have practically the same commercial value, and will probably find a steady sale at about 30*s.* a ton.[1]'

Analysis of Coventry Sewage, taken April 8, 1874, *during dry weather.*

	Hours at which sewage was taken					
	6 a.m.	9 a.m.	noon.	3 p.m.	6 p.m.	9 p.m.
Superficial area of flow in square inches . .	285	405	480	360	360	210
Estimated flow per hour in gallons	37,500	67,500	80,000	60,000	60,000	35,000
Containing ammonia by boiling	1·60	3·20	3·35	not determined	not determined	not determined
Containing ammonia by potash and permang: solution	·80	2·00	2:50	"	"	"
Containing chlorine . .	4·00	6·00	12·00	8·00	6·00	7·00
Containing residue, combustible	32·00	62·00	60·00	45·00	not determined	not determined
Containing residue, incombustible	28·00	38·00	50·00	30·00	"	"
Total parts in 100,000[2].	60·00	100·00	111·00	75·00	"	"

Analysis of Manure, produced from Leeds Sewage by the A.B.C. process, by Dr. Voelcker, 1875.

Moisture	15·00
Organic matter (containing nitrogen 0·61, equal to ammonia 0·74)	18·77
Oxide of iron and alumina	16·09
Tribasic phosphate of lime	1·51
Carbonate of lime	11·12
Sulphate of lime	0·89
Alkaline salts and magnesia (containing potash 0·77 and chloride of sodium 0·04) . . .	2·78
Insoluble siliceous matter	33·84
	100·00

	£	*s.*	*d.*		£	*s.*	*d.*
Estimated money value per ton .	0	16	8½				
Market value of one ton . .	0	5	6	to	0	8	4[3]

[1] The Sewage Question, p. 83.

[2] To convert parts per 100,000 into grains per gallon, multiply by 7 and then move the decimal point one place to the left.

[3] Loc. Gov. Bd. Rep., pp. 52 and lxiii.

Analysis of Effluent Water produced at Leeds Permanent Sewage Works in 1875–76, *by the Native Guano Company.*[1]

'Constituents per imperial gallon:'—

	Grains.
Actual or saline ammonia	1·207
Ammonia derivable from organic matter	0·147
Nitrogen or nitrates	0·000
	1·354
In Solution.	
Carbonate of lime and magnesia	13·70
Sulphate of lime	14·28
Sulphate of magnesia	10·78
Alkaline sulphates	3·99
Chloride of sodium	11·79
Phosphoric acid	a trace
Organic matter	4·59
Total dissolved	59·13
In Suspension.	
Organic matter	0·32
Mineral	0·22
Total suspended	0·54

'The amount of oxygen required for the oxydation of the organic and other oxydisable matter in solution, was 1·28 grain per gallon.

'Under the microscope the suspended (or insoluble) matters were found to consist of amorphous mineral matter, with filiments of sewage fungus and particles of vegetable tissue.

'These results show that the effluent water is a good sample of defecated sewage, and that if exposed to the air, instead of being corked up in a bottle for several days before I received it, it would have been inoffensive and admissible into a running stream which is not used for drinking purposes. It fulfils, in fact, the conditions required by the Conservators of the River Thames for the effluent water which is admissible into the river Thames below Teddington Lock.'

October 12, 1875. H. Letheby.

[1] Description of the Leeds Sewage Works, &c.

Analysis of dried residuum, produced at Leeds Permanent Sewage Works in 1875–76, *by the Native Guano Company, by Dr. Voelcker, June* 2, 1876.[1]

Moisture	24·53
Organic matter and water of combination	20·39
Oxide of iron and alumina	14·23
Phosphate of lime	1·66
Carbonate of lime	11·98
Sulphate of lime	1·88
Alkaline salts and magnesia	1·95
Containing ·45 of potash and insoluble siliceous matter	23·38
	100·00
Containing nitrogen	·43
Equal to ammonia	·53

The following analyses are taken from the Reports of the Rivers' Pollution Commissioners.

Treatment of London Sewage by A.B.C. process. Results of Analyses expressed in parts per 100,000.

Sample	Dissolved matters							Suspended matters		
	Total solid matters left on evaporation	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Chlorine	Mineral	Organic	Total
London sewage	67·3	3·614	1·886	5·418	0	6·348	10·23	10·30	18·00	28·30
Effluent	80·5	2·257	1·878	6·086	0	6·890	10·20	traces	traces	traces

Treatment of Leicester Sewage by A.B.C. process. Results of Analyses expressed in parts per 100,000.

Sample	Dissolved matters						Suspended matters		
	Solid matters left on evaporation	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Mineral	Organic	Total
Sewage.	111·0	3·745	·722	1·650	·021	2·102	28·78	28·78	57·56
Effluent	117·0	2·778	·297	2·000	·000	1·944	2·30	3·82	6·12

[1] Description of the Leeds Sewage Works, &c.

'A large volume of river water mixed with the effluent, hence the favourable results shown in the analysis.'

Effect of the A.B.C. process on Leamington Sewage. Results expressed in parts per 100,000.

Sample	Dissolved matters							Suspended matters		
	Total solid matters left on evaporation.	Organic carbon	Organic nitrogen	Ammonia.	Nitrogen as nitrates and nitrites	Total combined nitrogen	Chlorine	Mineral	Organic	Total
Raw sewage	83·5	4·355	2·890	5·971	0	7·807	11·00	96·24	56·28	152·52
Effluent without filtration	94·3	2·803	1·334	4·460	0	5·172	9·50	6·68	4·12	10·80

The Leamington manure is as follows:—

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

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

Although said to be saleable at 3*l.* 10*s.* per ton, the value assigned to it at that time was 32*s.* per ton.

Treatment of Stroud Sewage with crude Sulphate of Alumina. Results of Analyses expressed in parts per 100,000.

Description	Total solid matters in solution	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Suspended matters		
							Mineral	Organic	Total
Sewage before treatment	48·5	2·289	1·330	3·152	·044	3·970	15·15	27·85	43·00
After	53·5	2·203	·692	2·275	·033	2·598	1·88	2·20	4·08

Analysis of Effluent Water produced from Bolton Sewage by treatment with Marsden and Collins' process, made by Dr. H. E. Roscoe, F.R.S., Owens College, Manchester, December 27, 1873.[1]

	Grains per gallon.		Parts per 100,000.
Total residue	62·65	...	89·5
Loss on ignition	5·25	...	7·5
Nitrogen as nitrites and nitrates	0·23	...	0·3292
Free ammonia	1·75	...	2·5
Albumenoid ammonia	0·448	...	0·64
Chlorine	4·20	...	6·00
Temporary hardness	16·2°		
Permanent hardness	20·0°		
Total	36·2°		

'As regards the result of this analysis, it appears that the water as compared with London sewage contains about half as much animal refuse, or products of animal decomposition. As regards the inorganic portion, this water contains considerably more than the London sewage does. These animal impurities are not completely got rid of by oxydation; and, on keeping, the water has a putrescent smell. It cannot, therefore, be said that the process, whatever it may be that the sewage has undergone, has done much to render the effluent water innocuous.'

Analysis of Manure, produced from Bolton Sewage by Marsden and Collins' process, by Dr. Voelcker.[1]

Moisture	15·00
Organic matter (containing nitrogen 0·89, equal to ammonia 1·08)	31·82
Oxide of iron and alumina	8·52
Tribasic phosphate of lime	1·49
Carbonate of lime	17·75
Sulphate of lime	1·27
Alkaline salts and magnesia (containing potash 0·64, and chloride of sodium 0·08)	3·68
Insoluble siliceous matter	20·47
	100·00

Estimated money value of 1 ton	£1 1 1
Market value of one ton	7*s.* to 0 10 6

[1] Loc. Gov. Bd. Rep., pp. 41 and lxiii.

Sample of Birmingham Sewage. The average of one week's flow. Specific Gravity = 1·0018. *Results of Analysis in parts per* 100,000. *Oct.* 4, 1876.

Total solid residue	168·00
Suspended matters	85·20
Consisting of mineral matters	53·66
And organic volatile ditto	20·21
Silica	26·10
Copper	trace
Zinc	trace
Peroxide of iron	18·60
Alumina	1·60
Lime	19·44
Chloride of sodium	61·77
Chloride of potassium	1·23
Phosphoric acid	·851
Sulphuric acid	32·07
Chlorine	27·02
Ammonia (free)	3·30
Ditto (albuminoid)	1·75

Neutral to test papers
Hardness=26·5 grains carbonate lime per gallon.

Sample of Birmingham Effluent Sewage, after having been limed. August, 1876. *Results of Analysis in parts per* 100,000.

Total solid residue	82·00
Lime	23·80
Sulphuric acid	25·88
Chlorine	16·60
Free ammonia	3·20
Albuminoid ammonia	·06
Organic carbon	1·973
Organic nitrogen	1·804
Nitrogen as nitrates and nitrites	none
Total combined nitrogen	4·484

Appearance, quite clear
Action on test paper, alkaline
Smell, none

Analyses of the Sewage of Wimbledon, the effluent water and the residue produced by treatment with Hille's process, by Dr. Letheby, Nov. 9th, 1871.[1]

The constituents per imperial gallon were as follows :—

	Raw Sewage. Oct. 18th, 1871	Effluent Water. Oct. 18th, 1871
	Grains.	Grains.
Ammonia per gallon . . .	5·440	2·560
„ obtainable from organic matter .	0·472	0·085
Oxygen required by oxydisable matter .	1·733	0·265
Nitrogen, as nitrates and nitrites . .	0·000	0·054
Soluble matter per gallon . . .	47·73	67·00
of which chlorine . .	6·13	13·83
„ organic matter . .	12·42	2·69
„ mineral „ . .	24·31	63·31
Suspended matter, per gallon . .	136·18	0·00
of which organic matter . .	61·28	0·00
„ mineral ditto . .	75·60	0·00

The solid residue from these operations had the following percentage composition, when dried completely at a temperature of 240° Fah. :—

	Sample No. 1. Oct. 18th, 1871	Sample No. 2. Oct. 25th, 1871
Organic matter, &c. (Loss by Incineration) .	32·67	15·49
Phosphate of lime (insoluble) . .	5·82	8·64
Carbonate of lime and magnesia . .	32·33	10·17
Silica and alumina and oxide of iron .	29·18	65·70
Total	100·00	100·00
Nitrogen in the organic matter . .	1·181	0·799
Equal to ammonia	1·434	0·970

[1] Sewage disinfecting and filtration process, by F. Hille, 1876.

Analysis of Effluent Water, obtained from Leeds Sewage by Hanson's process, by Mr. Thomas Fairley, Borough Analyst, April 1, 1876.[1]

	Grains per gallon.
Mineral matter, consisting of chlorides, salts of lime, magnesia, alkalies, &c.	42·24
Volatile organic matter	3·68
Total dissolved solid matter	45·92
Containing chlorine	4·62
Equivalent to common salt	7·79
Containing ammonia	0·40
„ albuminoid or organic ammonia	0·14
Corresponding to nitrogenous organic matter about	1·40

Analysis of residuum, obtained from treatment of Leeds Sewage by Hanson's process, by Dr. Voelcker, June 2, 1876.[1]

Moisture	23·17
Organic matter and water of combination	20·38
Oxide of iron and alumina	12·28
Phosphate of lime	·98
Carbonate of lime	26·86
Sulphate of lime	4·21
Alkaline salts and magnesia (containing ·26 of potash)	2·63
Insoluble siliceous matter	9·49
	100·00
Containing nitrogen	·45
Equal to ammonia	·55

Analysis of Effluent Water, obtained from experiment with Leeds Sewage by Goodall's process, by Mr. Fairley, February, 1874.[1]

	Per cent.
Mineral matters, consisting of chlorides, salts of lime, magnesia, alkalies, &c.	40·75
Volatile and organic matter	9·72
Total dissolved solid matter	50·47

[1] Description of Leeds Sewage Works, &c.

Containing chlorine	7·93
Equivalent to common salt	13·11
Containing ammonia	0·574
„ albumenoid ammonia	0·30
Equivalent to nitrogenous organic matter about	3·00

Analysis of undried residuum, obtained from experiment with Leeds Sewage by Goodall's process, by Mr. Fairley, February, 1874.[1]

Moisture	68·95
Organic matter	5·65
Phosphate of lime	6·40
Sulphate of lime	2·38
Carbonate of lime	2·90
„ of magnesia	3·04
Oxide of iron	2·07
Alumina, alkalies, &c.	0·12
Siliceous matter	8·40
	100·00
Containing nitrogen	0·13
Equivalent to ammonia	0·156

Analysis of Manure produced at the Tottenham Sewage Works, by Campbell's process.[2]

Moisture	19·04
Organic matter (containing nitrogen 1·2, equal to ammonia 1·45)	15·26
Precipitated phosphate of lime	23·14
Insoluble phosphates	3·80
Sulphate and carbonate of lime and lime uncombined	19·25
Alkaline salts and magnesia	3·14
Insoluble matter	16·37
	100·00

[1] Description of Leeds Sewage Works, &c.

[2] From Paper by Mr. Shelford, Proc. Inst. C.E., vol. xlv.

Analyses of Effluent Waters Produced by Treating Sewage with Campbell's Process.[1]

Experiment	Nov. 22, 1873 per cent.	Jan. 13, 1874 per cent.	April 10, 1874, per cent.	March 12, 1875, per cent.
Mineral matter in solution . .	41·76	35·52	38·72	46·40
Organic „	5·92	15·04	13·44	10·56
Total solid constituents per gallon in grains	47·68	50·56	52·16	56·96
Free ammonia	2·952	4·02	5·03	4·34
Organic nitrogen	0·217	0·3488	0·2405	0·27
Mineral matter in suspension .	none	none	none	none
Organic „	—	—	—	—

Treatment of Sewage at Leicester and Blackburn with Lime. Results of Analyses Expressed in Parts per 100,000.[2]

Description	Total solid matters in solution	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Suspended matters		
							Mineral	Organic	Total
Leicester sewage	107.5	2·017	·809	2·083	0	2·524	10·50	11·62	22·12
After treatment .	85·9	1·514	·452	2·552	0	2·553	12·10	4·70	16·80
Blackburn sewage	59·7	4·103	·460	1·426	0	1·634	13·38	28·30	41·68
After treatment .	66·0	2·619	·412	1·956	0	2·022	6·34	6·98	13·32

Analysis of Manure, produced from Sewage of Bradford, by Lime Treatment, by Dr. Voelcker.[3]

Water	15·00
Organic matter (containing nitrogen 0·67, equal to ammonia 0·81)	36·44
Oxide of iron and alumina	3·77

[1] Paper by Mr. Shelford, Proc. Inst. C.E., vol. xlv.
[2] First Rep. Riv. Pol. Com., 1868, p. 52.
[3] Loc. Gov. Bd. Rep., pp. 44 and lxiii.

Tribasic phosphate of lime	3·34
Carbonate of lime	27·36
Sulphate of lime	2·36
Alkaline salts and magnesia (containing potash 0·77 and chloride of sodium 0·52)	3·52
Insoluble siliceous matter	8·21
	100·00

Estimated money value of one ton £1 0 1
Market value of one ton . £0 6 8 to £0 10 0

Analyses of Hertford Sewage and Effluent Water Produced by Lime and Chloride of Lime Treatment, November, 1867.[1]

Constituents per gallon	Raw sewage	Effluent water
	Grains	Grains
Matters in solution	25·00	28·33
Organic matter	2·50	1·25
Ammonia	0·343	0·457
,, organic	0·480	0·560
Nitrogen as nitrate	0·026	0·091
Oxygen required to oxydise	0·296	0·281
Matters in suspension	1·42	0·43
Organic matter	0·72	0·17
Mineral ,,	0·70	0·26

Analyses of Effluent Water from Hertford Sewage treated with Lime.[2]

	Parts per million		Grains per million	
	Free ammonia	Albumenoid ammonia	Total alkalinity as caustic soda	Solid residue
1875				
April 19	2·244	1·175	16·2	28·7
May 23	2·05	1·225	15·4	29·2
July 2	2·335	1·175	15·4	27·3
August 20	3·35	1·225	14·0	26·8
September 23	3·35	1·15	13·3	27·9
October 18	3·75	1·1	15·4	28·3
1876				
May 10	4·05	1·75	15·4	29·4

'In no case did the effluent water contain suspended matter. In all cases the effluent had a very slight taste of lime, but had no perceptible odour.'

[1] The Sewage Question, p. 56. [2] Soc. Arts, p. 108.

The following are taken from The Rivers' Pollution Commissioners' First Report, 1868 :—

Treatment of Northampton Sewage with chloride of iron and lime. Results expressed in parts per 100,000.

Description	Total solid matters in solution	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Suspended matters		
							Mineral	Organic	Total
Sewage before treatment . . .	88·0	3·700	2·859	6·000	·000	7·800	66·72	16·40	83·12
After. . . .	88·5	1·845	1·779	5·000	·000	5·897	·92	0·04	·96

Raw and Effluent Sewage, Lodge Farm, Barking. Results expressed in parts per 100,000.

Sample	Total solid matters	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Suspended matters		
							Mineral	Organic	Total
Sewage . . .	112·50	12·182	3·664	4·000	0	6·958	—	—	—
Effluent. . .	79·25	1·366	·329	·800	2·955	3·943	—	—	—

Raw and Effluent Sewage, Banbury. Results of analyses expressed in parts per 100,000.

Sample	Total solid matters in solution	Organic carbon	Organic nitrogen	Nitrogen as nitrates and nitrites	Ammonia	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage .	111·5	6·246	2·764	·000	13·590	13·956	—	3·90	8·62	
Effluent .	70·9	2·241	·549	·000	2·282	2·428	13·25	·52	·84	

Raw and Effluent Sewage, Rugby. Results of analyses expressed in parts per 100,000.

Sample	Solid matters in solution	Organic carbon	Organic nitrogen	Nitrogen as nitrates and nitrites	Ammonia.	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage . .	52·60	5·505	2·322	·000	7·276	8·314	8·25	3·48	8·96	12·44
Effluent . .	68·20	1·526	·164	·000	·420	·510	10·50	·88	·36	1·24

Raw and Effluent Sewage, Bedford. Results of Analyses expressed in parts per 100,000.

Sample	Total solid matters in solution.	Organic carbon	Organic nitrogen	Nitrogen as nitrates and nitrites	Ammonia	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage at 4.45 P.M. . .	74·8	2·732	·668	·000	2·700	2·891	—	13·26	13·14	26·40
Effluent . .	76·8	·575	·163	·398	·023	·580	7·15	0	0	0

Raw and Effluent Sewage, Norwood. Results expressed in parts per 100,000.

Sample	Total solid matters in solution	Organic carbon	Organic nitrogen	Nitrogen as nitrates and nitrites	Ammonia	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage . .	117·80	5·407	2·294	·000	8·970	9·681	8·87	4·08	14·96	19·04
Effluent . .	83·10	1·294	·184	·381	·965	1·360	8·87	trace	trace	trace

Raw and Effluent Sewage, Croydon. Results of Analyses expressed in parts per 100,000.

Sample	Total solid matters in solution	Organic carbon	Organic nitrogen	Ammonia	Nitrogen as nitrates and nitrites	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage . .	48·0	2·882	1·269	2·700	0	3·493	4·30	3·80	10·80	14·60
Effluent . .	45·0	·772	·076	·530	·678	1·190	2·95	trace	trace	trace

Analyses of effluent waters during frosty weather call forth the following remark from the Commissioners: 'The frost was by no means severe, yet the organic nitrogen rose from ·098 to ·419 per 100,000 parts of effluent water, showing that the removal of offensive nitrogenous organic matter was partially arrested, and indicating that during a severe winter the purification of sewage upon a non-absorptive clay soil may be seriously interfered with.' The Commissioners also state that: 'It is difficult to account for the emission of exceptionally impure water from the Norwood farm at other periods of the year, but it probably arose, in some cases at least, from unpurified sewage gaining access to the drains through cracks in the soil.'

Raw and Effluent Sewage, Warwick, 1869. *Results expressed in parts per* 100,000.

Sample	Total solid matters in solution	Organic carbon	Organic nitrogen	Nitrogen as nitrates and nitrites	Ammonia	Total combined nitrogen	Chlorine	Suspended matters		
								Mineral	Organic	Total
Sewage . .	66·90	5·133	1·680	·000	2·439	3·689	6·30	2·64	3·36	6·00
Effluent . .	66·10	1·454	·175	·137	·839	1·003	8·18	trace	trace	trace

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4·24	5·52
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