# SEWAGE UTILIZATION

BY

U.R. BURKE

# A HANDBOOK

OF

# SEWAGE UTILIZATION.

BY

ULICK RALPH BURKE, Esq.,
BARRISTER-AT-LAW.

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# INTRODUCTORY.

The question of Sewage Utilization, together with that of the drainage of towns and the purification of our rivers and water-courses, has been for some years past forcing itself upon public attention. Numerous Reports have been presented to Parliament, all setting forth the magnitude of the evils of the present system, and representing the urgency of immediate reform. As far back as the year 1858, a Commission [*S. U. C.*, 1857], of which Lord Essex was Chairman, reported to this effect, and as yet little or nothing has been done. There is no doubt that what has chiefly deterred Local Boards, or other governing bodies in towns from taking any action in the matter, has been the difficulty of finding out the most satisfactory mode of practically dealing with what everyone admits to be a gigantic difficulty. Most of the systems of Sewage Utilization hitherto adopted in many of our towns have proved unremunerative as speculations; the success of others has been supposed to depend upon certain special conditions, unattainable in other places; and some are known to have failed to accomplish the most important part of their programme, namely, that of dealing with the sewage matter in such a way as to render it perfectly innocuous, both during and after treatment.

On the whole, however, the most extraordinary ignorance prevails on the subject. Many towns would gladly establish works which would purify and utilize their sewage, even were the operations carried on at a slight loss; but they are unwilling to undertake works of whose nature they know nothing, which may involve them in considerable and unknown expenses, raise their rates, and possibly in the end fail to bring about the result they desire. Even many well-educated engineers know but little of the comparative merits of the various systems that have been already tried, and consequently of the peculiar fitness or unfitness of any particular system for the town or district in which they may be interested; they consequently hesitate to give any decided opinion or advice upon the subject. Local Boards are naturally unwilling to act without seeing exactly "where they are going," and in the end nothing is done.

We hope that between Mr. Stansfeld and Sir Charles Adderley something may be done during this session of Parliament which may render it easier for local authorities to take action in this matter, while at the same time their responsibilities as well as their privileges are enlarged. As it is, according to the Report of the British Association published in 1870, there is "only one town in England (Carlisle) "which experienced no difficulty, present or prospective," in the treatment of its sewage!

An impartial review and comparison, therefore, of the various systems that have been tried in England and on the Continent for some years past may, it is hoped, be of use, not only in directing attention to the subject, but in enabling those who are interested in it, by considering the causes of the success or failure of the various systems under different circumstances, to determine what system or what modification of any previous system may be best fitted for the requirements and capabilities of their district. In recording the good or evil fortune of the various experiments that have been tried, this little book lays claim to no greater merits than that of a compilation, and as such it is hoped it may be found a useful one. A great portion of the information contained in it has been collected from the Reports presented to Parliament by various Commissions since the year 1858, and the sources of information will be found in all cases indicated for purposes of reference, and especially for the assistance of those who desire to study any particular branch of the subject more fully than in a general abstract like the present. To a certain extent, therefore, this handbook will be found to be an epitome of most of what has already been written upon the subject, and as such will, it is hoped, be appreciated by those whose time is of value, and who desire to have an opportunity of judging of the relative merits of the different systems in a small compass. I took up the subject without any prejudices or preconceived notions. I have no theory to support, no set system to advocate, and whatever may be the shortcomings of the work, and I know how many they are, I can at least lay claim to having been animated throughout with a spirit of perfect impartiality, which will, I trust, be evident in the composition of the following pages, and may recommend them to the mercy of the professional critics.

1, King's Bench Walk, Temple,
*February*, 1872.

# LIST OF ABBREVIATIONS USED IN THE COURSE OF THIS WORK.

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|---|---|
| 1st Report of the Commission appointed to inquire into the best mode of distributing the Sewage of Towns, and applying it to beneficial and profitable uses, 1858, *referred to as* .. .. .. .. .. .. .. .. .. .. .. .. | 1 *S. U. C.* |
| 2nd ditto, ditto, 1861, *referred to as* .. .. .. .. .. | 2 *S. U. C.* |
| 3rd ditto, ditto, 1865, *referred to as* .. .. .. .. .. | 3 *S. U. C.* |
| 1st Report of the Commissioners appointed in 1868 to inquire into the best means of preventing the Pollution of Rivers, 1870, *referred to as* .. .. .. .. .. .. | 1 *R. P. C.* |
| 2nd ditto, ditto, 1870, *referred to as* .. .. .. .. .. | 2 *R. P. C.* |
| Report presented to the Tottenham Local Board of Health, by P. P. Marshall, Esq., C.E., and others, 1871, *referred to as* .. .. .. .. .. .. .. .. .. .. .. .. | *Tott. Rep.* |

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# A HANDBOOK

OF

# SEWAGE UTILIZATION.

## I.—TREATMENT OF SEWAGE.

Although the scope of this book is strictly confined to the *treatment* of sewage with a view to its deodorization and utilization, it may be as well, before reviewing the various modes of treatment which have been hitherto suggested as remedies for the existing evil, to devote a few pages to a consideration of the evil itself. According to the old Spanish proverb, "To understand the disease is half the cure." The evil of which we have to speak is of two kinds: positive and negative. The one is the imperfect and dangerous manner in which the drainage of our towns is removed, entailing the pollution of our rivers, the destruction of fish, the defilement of water for domestic, and in many cases even for manufacturing, purposes, and the contamination of both air and water with a deadly poison, to which numbers of our population annually fall victims. The other is the systematic waste on a gigantic scale of a valuable manure.

These two evils are necessarily and intimately connected, for the sewage which is so deadly in a watercourse or a cesspool, when properly distributed upon land, becomes as valuable as a manure as it was previously noxious as a poison. According to the late Lord Palmerston, "Dirt is a useful thing, at present put in the wrong place." The most perfect system of sewage treatment therefore is that which leaves the smallest amount of filth where it should not be, and conveys the largest amount to where it should.

The most noxious as it is the most common effect of our present system of dealing with the drainage of towns is undoubtedly the pollution of rivers, wells, and watercourses.

What account, say the Royal Commissioners of 1868, do the various municipal bodies give of the state of the stream as it comes to them? They all complain that the water is polluted by sewage . . . . that it is most offensive to the sight and smell; that it is unfit for use; that even when used for steam-engines it clogs up the boilers, and is injurious to the machinery . . . . [1 *R. P. C.*, p. 12]. Again . . . . when taking samples at Throstlenest Weir, below Manchester, say the Royal Commissioners of 1868, we saw the whole water of the River Irwell, then 46 yards wide, caked over with a thick scum of dirty froth, looking like a solid sooty-crusted substance. Through this scum, here and there, at intervals of six and eight yards, heavy bursts of bubbles were continually breaking, evidently rising from the muddy bottom; and wherever a yard or two of the scum was cleared away, the whole surface was seen simmering and sparkling with a continual effervescence of smaller bubbles rising from the various depths in the midst of the water, showing that the whole river was fermenting and generating gas. The air was filled with the stench of this gaseous emanation many yards away. The temperature of the water was 76° Fahr., and that of the air 54°. [1 *R. P. C.*, p. 16 in note. See also on this subject 2 *S. U. C.*, pp. 11–13, and note.] It is not pleasant to know that the water of the Thames is contaminated with the putrefying sewage of no less than 880,000 persons before it reaches the spot whence our water companies draw the water for the use of the metropolis; nor to find on examination that this water contains a *larger amount* of impurity derived from fæcal matter than filtered sewage. [*Tott. Rep.*, p. 57; 1 *R. P. C.*, p. 66.]

Memorials and petitions to Her Majesty on the subject of river pollution from Birmingham, Huddersfield, Nottingham, Rotherham, Sheffield and York, will be found among the Parliamentary papers for 1865 (ordered to be printed 6th March—Lord Robert Montagu). [See also on river pollution by sewage generally, 2 *S. U. C.*, pp. 11–13, and notes.]

The amount of this pollution is almost incredible, and will startle those who have not yet studied the statistics. An analysis of the river *Cornbrook* just before its junction with the *Irwell*, in June, 1868, gave the following results. In 100,000 parts of the water in the river, there were:—Total solid matters in solution, 142·90; organic carbon, 4·209; organic nitrogen, ·243; ammonia, ·852; total combined nitrogen, ·994; nitrogenous nitrates and nitrites, ·049; chlorine, 38·97; salts of lime and magnesia, considered as "hardness," 67·70; matter in suspension, 64·40. The most injurious constituents of this water are, of course, the organic carbon and the organic nitrogen, inasmuch as they serve as a measure of the animal or vegetable matter with which the water is polluted. A comparison of this with the composition of the Mersey water near its source may be instructive. Total solid matter in solution, 7·62; $O^{ic}$ carbon, ·222; $O^{ic}$ nitrogen, 0; ammonia, ·002; total combined nitrogen, ·023; chlorine, ·94; hardness, 5·02; suspended matter, 0. The "hardness," which in this latter case represents more than one-third of the entire polluting matter [1 *R. P. C.*, 15], is in no way injurious to life. [See 1 *R. P. C.*, 16, note.]

Although there can be no possible doubt as to the deleterious effects of water that has been contaminated with sewage, it is exceedingly difficult to obtain any exact chemical details upon the subject. Thus Dr. R. P. Thorne, . . . . examining into the causes of an outbreak of typhoid fever in 1867, in the village of Terling, reports [*Tenth Report of Medical Officer of Privy Council*, 1867], that the outbreak was caused by the drinking of water from certain wells; *chemical analysis did not discover any noxious substance in the water*, but the analytical results gave for three of the wells a *previous* sewage or animal contamination as follows:—

| | |
|---|---|
| Well 1.—Previous sewage or animal contamination in 100,000 parts of water .. .. .. .. .. .. | 24,850 |
| Well 2.—Ditto .. .. .. .. .. .. .. .. .. .. | 9,160 |
| Pump.—Ditto .. .. .. .. .. .. .. .. .. .. | 10,980 |

This is an amount of pollution hardly conceivable, being in the case of well No. 1 nearly one quarter of the entire volume of water. Again, at Guildford, in 1867, in consequence of an outbreak of typhoid fever, Dr. Buchanan went down to make investigation as to the causes, and turned his attention to a new well which had for a short time supplied over three hundred houses, many of which were visited by the epidemic. It was found that a sewer ran within 10 feet of the well, and that the sewage leaked through the joints of the brickwork and saturated the soil just above the spring which supplied the well. The water was afterwards analyzed, and although no ingredient was found that could be pronounced noxious, the results showed that each 100,000 lbs. of it had been *previously* polluted with a quantity of animal matter equivalent to that found in 7330 lbs. of average London sewage. [1 *R. P. C.*, 114. See also on this subject, *Royal Commission on Water Supply*, 1869; *Evidence of Mr. Simon*, *Minutes of Evidence*, p. 167; and that of *Drs. E. Parkes*, *Farr*, *Letheby*, *Brodie*, *Frankland*, and other celebrated analysts. *Report*, pp. 73–94.]

As the evidence of these gentlemen may be somewhat difficult to be understood by those who are not practical chemists, especially as to how water, in which no present impurity is to be found, may yet be pronounced to have been *previously* contaminated with so much sewage, we will say a few words in explanation of this branch of the subject, and refer such of our readers as desire to find a fuller exposé, at once popular and practical, to Professor Roscoe's 'Progress of Sanitary Science (1871),' from which we quote the following:—

"You will understand," we read [at page 127] "that the danger lies in the water being impregnated with animal decomposing matter, and with sewage matter generally. . . Although no chemist can tell whether any particular water contains the typhoid poison, yet he is able to tell the difference between pure water and a water which contains animal impurity, for when the decomposition of an animal body occurs, the nitrogenous portions which are thrown off, that is the liquid and the solid products, get into the sewers; and if we can find in water a large quantity of this nitrogenous animal matter, we may be certain that that water is not fit to drink. . . . . .

"By a chemical analysis of water we can at once detect, by the organic or albuminous nitrogen, whether it still contains animal impurity, and by the ammonia and nitric acid whether the water *has been* polluted by animal matter which has since been destroyed, or by the absence of excessive quantities of these nitrogenous bodies, whether the water has never been in contact with animal matter. It is thus possible to calculate by a very simple process how much sewage has come into such a water."

As to the mode of detecting impurities by the permanganate of potash, see *Roscoe*, p. 131; but this test is a rough one at best, and in many cases fallacious.

"There is still another means which chemists have of telling whether water is pure, and that is by the presence of common salt. Pure spring-water ought to contain very little common salt; but water which contains the infiltrations of sewage brings in with it a large quantity of common salt derived from the urine. Any water which contains more than one part of common salt in 100,000 is almost sure to have that salt brought in by sewage, and will therefore be impure. This does not apply of course to water flowing through salt districts."

As regards this branch of the subject, which, in the words of the Royal Commission on Water Supply, "is beset with difficulties," we cannot do better than quote the *conclusions* to be found on pp. 116, 117 of the 1 R. P. C. :—

"1. There is at certain times, in human excreta, some material capable of producing disease of a very fatal character in the human subject. 2. That this morbific matter can be detected only by its specific action upon the human subject, and cannot be distinguished either by chemical or microscopic analysis, even in the concentrated excreta, much less in water mixed with the excreta. 3. That inasmuch as the organic matters of sewage are oxidized and destroyed with extreme slowness in running water, there is great probability that the morbific matter will escape destruction, and be conveyed to great distances in rivers and streams. 4. That owing to the rapid oxidation and destruction of the organic matters of sewage during filtration through porous soils, the passage of this morbific matter into deep wells carefully preserved from the admission of surface water is but little to be feared."

But however difficult it may be to trace the existence of morbific matter in water, there can be no possible doubt of the deadly influence of water that has been contaminated by sewage, on health. There is no need of argument upon this point, and instances might be endlessly multiplied; the inquirer is, however, referred to some very interesting statistics furnished by Dr. Farr in a letter to the Registrar-General (printed in the quarterly return of the births, marriages, and deaths for the quarter ending 31st December, 1854), as to the cholera epidemic in 1849, giving details as to the respective number of deaths in houses supplied by the various water companies both in 1849 and in 1854.

With regard to the influence of the contamination of water by sewage on health generally, see 2 *S. U. C.*, Appendices 2. 3. 4. 5., and Professor Roscoe's *Progress of Sanitary Science*, pp. 123–8. Finally we give the suggestions of the R. P. C. as to what is to be deemed pollution [1 *R. P. C.*, 130].

(*a*) Any liquid containing *in suspension* more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter, in 100,000 parts by weight of the liquid.

(*b*) Any liquid containing *in solution* more than 2 parts by weight of organic carbon, or 3 parts by weight of organic nitrogen, in 100,000 parts by weight.

(*c*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed on a white porcelain or earthenware vessel.

(*d*) Any liquid which contains *in solution* in 100,000 parts by weight more than 2 parts by weight of any metal, except calcium, magnesium, potassium, and sodium.

(*e*) Any liquid which in 100,000 parts by weight contains, *whether in solution or in suspension*, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

(*f*) Any liquid which after acidification in the sulphuric acid contains in 100,000 parts by weight, more than 1 part by weight of free chlorine.

(*g*) Any liquid which contains in 100,000 parts by weight more than 1 part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h*) Any liquid possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic acid to 1000 parts by weight of distilled water.

(*i*) Any liquid possessing an alkalinity greater than that produced by adding 1 part by weight of dry caustic soda to 1000 parts by weight of distilled water [1 *R. P. C.*, p. 130].

It has frequently been alleged that the natural flow of a river, however largely impregnated with sewage matter, would rapidly purify the volume of water by oxidation. It was asserted [*Report of Royal Commission on Water Supply*, p. lxxix.] that if sewage were mixed with twenty times its volume of river water, the organic matter which it contains will be oxidized and completely disappear while the river is flowing a dozen miles or so. Experiment has, however, demonstrated the fallacy of this vague assertion, and we find that of sewage matter mixed with twenty times its volume of water, less than two-thirds would be destroyed by oxidation in a flow of 168 miles at a rate of one mile an hour [1 *R. P. C.*, 21]. It is evident therefore that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation.

The destruction of the fish forms a very important consideration in this sewage pollution of rivers, and especially in Scotland and Ireland: when the fisheries represent a property of large annual value to all classes of the community, it is of the highest importance as population increases that proper preventive measures be adopted. It is most encouraging to learn that even where the fish have been entirely banished by the pollution of the water, yet when the stream has been purified by the adoption of an improved system of sewage removal, the fish return to their old haunts. This happy result has occurred, among other places, at Leicester [1 *S. U. C.*, p. 11]. It may be remarked in this place that it appears to be the decomposed matter which proves so fatal to the fish; the fresh sewage, except in very hot weather, being beneficial rather than injurious [2 *S. U. C.*, p 11, note].

With regard to the second branch of the evil, the waste of a great quantity of valuable manure, let us consider for a moment how much the fertility of land depends upon the amount of live stock that is kept upon it. Their excrement forms, indeed, one of the most valuable sources of the farmer's profit; and yet although one-third of the live stock of England is *mankind*, human excrement is turned to no valuable account. This will seem the more incredible when we consider that as a consequence of the superior richness of the food of man to that of cattle, his excrement is in every way more valuable as a manure than that of any other animal. Yet, notwithstanding this, we learn [1 *R. P. C.*, 72] that the excrement of a sheep is worth at least five shillings a year to the farmer, while the annual value of the excrement of a man is worth (in South Lancashire) something less than fourpence halfpenny! The annual loss to the country from our wanton waste of human manure amounts to many millions sterling; and while we are compelled to import guano and other manures from distant countries at great expense, we allow our own valuable human manure not only to go to waste, but to pollute our streams and spread deadly diseases over the country. We should copy the Chinese in such matters. A good account of their mode of treating the excrement would be a most interesting contribution to our Sanitary literature: a few words may be found on the subject in *Oliphant's* 'China,' p. 118.

## II.—REMEDIES.

The few facts that we have gathered together with regard to the evils attendant upon the present system of treating our town sewage must have been sufficient to convince anyone of the urgent need for reform in the matter. Although we have taken a most cursory glance at the subject, we have endeavoured to give such statistics and references as may direct the mind of the inquirer to the nature and differences of the various forms of evil which have to be guarded against, so that he may be able to consider with advantage the various remedial schemes which it is now our purpose to lay before him.

Of these schemes there are two great classes, of which the first proposes to go to the very root of the evil, and prevent the sewage from getting into the drains at all; and the second, to direct, deodorize, and utilize it when it has got there. Of the first class, the common privy and ash-pit system is the commonest example. There are not wanting advocates even at the present day for this well-known nuisance, especially in Manchester, where it has been preferred, most unfortunately as we think, to the water-closet [see also *Birmingham Report*, 1871]. The fallacy of the privy as a preventive system is sufficiently evident from a comparison of the analysis of the sewage flowing through the drains of a town like Manchester and Salford, where the proportion of privies to water-closets is about six to one, with that of London, where the water-closet is universally adopted. These statistics may be found in full on pp. 26–29 of the 1st Rep. of the R. P. C., 1870. We will at present content ourselves with remarking that as the "middens" are usually in some way connected with the sewers, a considerable proportion even of solid excrement, partly in solution and partly in suspension, finds its way into the sewerage system. Indeed the figures show a very slight diminution of the *strength* of the sewage of a "midden" town, although the *volume* is somewhat less in about the proportion of 1066 to 1154; the cause of this difference in volume being obviously to be sought for in the increased quantity of water needed under the water-closet system.

The very slight difference in the volume and strength of the liquid sewage in "privy" towns and "water-closet" towns is somewhat surprising, and is certainly an additional argument in favour of the water-closet system. [See also 1 *R. P. C.*, p. 30, where it is stated that the case is not substantially different when the earth-closet is substituted for the midden.] But the failure in a financial point of view of the privy, and the numerous ingenious modifications of it that have been hitherto tried, is to be attributed to the fact that they are only able to deal with the solid matter—the least injurious and the least valuable part of the excreta [1 *R. P. C.*, 48], while the greater part of the urine—so rich in ammonia—and the whole of the fluid refuse from the kitchen and house generally, is passed direct into the sewer. It is evident therefore that by all these systems a great quantity of dangerous polluting matter is suffered to flow into the sewers, not much decreased either in volume or polluting power from ordinary raw sewage; while that portion which is intercepted is deprived of a great portion of its most valuable constituents, considered as a manure. Under the old-fashioned privy and cesspool system, an intolerable and dangerous nuisance is created by the accumulation of sewage filth within a few yards of the dwellings of the people; and the noxious emanations consequent upon every removal of the accumulations are often the cause of various forms of disease. And this is the less to be wondered at when we learn that in many instances the privy refuse can only be removed by being carried into the street from the back door to the front, through the very room in which a large family is crowded at the time. This deadly nuisance at least is guarded against in Moule's, Goux's, and the Eureka system, which are all improvements upon the privy. There is no doubt that some of these systems, or modifications of them, may be introduced with advantage into large country-houses, public institutions, or small villages, and we will say a few words upon them before leaving this branch of the subject. Those who wish to enter more fully into the question we have just been discussing will find an elaborate comparison between the privy and water-closet systems on pp. 23–30 of the Report of the R. P. C. (1870).

In the *Eureka* system, which was tried at Hyde, near Manchester, boxes containing a small amount of deodorizing mixture were fitted in at the back of every privy, and as they became full, were exchanged for empty ones, after a certain number of days, according to the number of persons making use of the closet. The boxes when removed were covered with closely-fitting lids, and carried away in covered vans to the manufactory. Here the rags were first removed and sold to the paper-makers. More disinfectant was then added, and the matter concentrated by distillation, the distilled water being sold to the dyers and bleachers. The residue thus thickened was then mixed with coal ashes, which had previously been collected in the houses of the district and finely ground, and was ready for distribution as a manure. Messrs. Lawes and Gilbert, however, found by an analysis that it contained scarcely two per cent. of ammonia, and would obviously therefore not be worth more than its carriage beyond a few miles. [See *Notes on the Composition, Value, and Utilization of Town Sewage, reprinted from the Journal of the Chemical Society*, 1869. *Harrison.*]

The great objection, however, to the Eureka system as conducted at Hyde, was the proximity of the manufactory to the town. The mode of collection of the sewage was unobjectionable, but the works themselves were considered by many to be a nuisance, and for this reason, as well as the weakness of the manure manufactured, the system was abandoned at Hyde. [See 1 *R. P. C.*, 50, 51.]

The system in operation at *Milan* (a city of some 200,000 inhabitants), advocated by Mr. Gilbert Child [see '*Times*' *newspaper*, *August* 29, 1867, *January* 2, 1868, *and November* 20, 1871], consists in the collection of all the house sewage in cesspools, which are frequently emptied by means of an iron barrel from which the air has been exhausted, and which sucks up all the sewage through a hose without the carrying, and necessary odour resulting from the ordinary mode of emptying cesspools. The sewage is afterwards deodorized and sold to the neighbouring farmers. [See further as to the Milan system and generally as to those pursued in North Italy, including the Lombard Irrigation, 1 *S. U. C.*, 38–53.]

*Goux's System* is similar in principle to the Eureka, but the final treatment is somewhat different; the manure manufactured by this process is also feeble, but inoffensive, and has been adopted to a certain extent at Rochdale. [See *Report of the Sanitary Committee of the Town Council of Rochdale.*]

Of all the modifications of the privy, the best that has as yet been invented is no doubt *Moule's*. In this system a quantity of common dry earth is placed above the closet, and after use a certain amount, about 1½ lb., of this earth is, by a simple and ingenious mechanical contrivance, made to fall upon the excretion, which is thereby perfectly deodorized. The receptacle containing this dry excrement is emptied from time to time without any smell or danger, and after storage for as long as may be necessary in a sheltered place, the mixture forms a valuable and inodorous manure, worth from 2*l.* to 3*l.* per ton. [See *Moule's Pamphlet*, p. 12.] If it should be desirable, this manure, when dry and pulverized, may be again used three or four times over, instead of common dry earth, the value of the manure being necessarily increased after each using. The amount of this increase has not, as far as we know, been calculated, so it yet remains to be seen whether using the dry fæcal matter over again, or introducing new earth into the closet-cistern, is more profitable in the value of the total amount of manure produced. Mr. Moule's earth-closets have been introduced with success at Wimbledon Camp [see *Appendix to Twelfth Annual Report of the Medical Officer to P. Council by Dr. Buchanan*]; and has met with such success in India as to obtain for its inventor a donation of 500*l.* from the Secretary of State for India, together with the most flattering eulogiums. [*Pamphlet*, pp. 1 and 23.]

The advantages of the system have been so ably summarized by Dr. Buchanan, that we give his words *in extenso*:—

"1. The earth-closet, intelligently managed, furnishes a means of disposing of excrement without nuisance, and apparently without detriment to health.

"2. In communities, the earth-closet system requires to be managed by the authority of the place, and will pay, at least, the expenses of its management.

"3. In the poorer class of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers especial advantages.

"4. The earth system of excrement removal does not supersede the necessity for an independent means of removing slops, rain-water, and soil-water.

"5. The limits of application of the earth system in the future cannot be stated. In existing towns, favourably arranged for access to the closets, the system might at once be applied to populations of 10,000 persons.

"6. As compared with the water-closet the earth-closet has these advantages:—It is cheaper in original cost; it requires less repair; it is not injured by frost; it is not damaged by improper substances being thrown down it; and it very greatly reduces the quantity of water required by each household.

"7. As regards the application of excrement to the land, the advantages of the earth system are these: the whole agricultural value of the excrement is retained; the resulting manure is in a state in which it can be kept, carried about and applied to crops with facility; there is no need for restricting its use to any particular area, nor for using it at times when, agriculturally, it is worthless; and it can be applied with advantage to a very great variety, if not to all, crops and soils. After the disposal of excrement by earth, irrigation will continue to have its value as a means of extracting from the refuse water of a place whatever agricultural value it may possess, for the benefit of such crops and such places as can advantageously be subjected to the process."

There can be little doubt, however, that 10,000 is too large a limit, for in order to ensure the proper and advantageous working of the system, it appears to be necessary that all the closets should be under the supervision of one authority, which would be difficult to bring about in practice in a town of 10,000 inhabitants. It will be observed also that the valuable liquid filth is not in any way treated by Moule's system, so that in order to prevent river pollution in any district where the earth-closets have been set up, a system of irrigation, filtration, or some other approved mode of dealing with the liquid sewage would have to be adopted in addition. Taking for granted that irrigation is the most successful of them, it will be a question whether the liquid sewage, *minus* all the valuable constituents abstracted by Moule's process, could be utilized in such a manner as to pay its expenses.

We fear, however, that the difficulty of dealing with the liquid sewage (apart from the solid excrement) would be too great to permit of the adoption of earth-closets, in large or even moderate-sized towns.

At the same time, while considering Mr. Moule's system, it may be remarked that in the highly successful mode of treatment of the sewage by irrigation pursued at Beddington (Croydon), the solid matter is separated from the liquid before distribution over the land.

How far the liquid sewage may be enriched by the presence, even for a very short time, of the solid fæcal matter, I know not how to estimate, but I should imagine that the solid refuse was more likely to gain in fertilizing power than the liquid; which is borne out by the fact that although Mr. Moule, in his own pamphlet, only claims a value of from 2*l.* to 3*l.* per ton for the solid manure refuse from his closet, we learn through Mr. Latham that the manure manufactured from the solid matter retained in the filters at Beddington is worth about 3*l.* 10*s.* per ton. Theoretically, then, there would seem to be no reason why the "dry earth" and the "irrigation" system should not be adopted together in any moderate-sized town or district; but how far, in practice, such a combination would be superior to the water-closet and irrigation system, as has been adopted at Beddington and elsewhere with so much success, has yet to be determined. We confess that we are not very sanguine as to the result, although we have no doubt that in villages and large public buildings, especially in the country, where the liquid sewage, house slops, &c., can be easily and profitably disposed of and utilized on the neighbouring gardens and fields, we think the earth-closet may be adopted with very great advantage.

An attempt has been lately made [1 *R. P. C.*, p. 50] by Mr. W. J. Garnett, of Quernmore Park, near Lancaster, to get the house scavenging of the town done upon a modification of the dry-earth system, and to deal with the whole excrement of the household instead of only the solid refuse. By daily collection in tubs and pans the whole excrement is collected from a large number of houses, and the payment of a penny per week per house is said to secure the collection of the chamber slops as well as of the privy contents. Nearly one-tenth of the town is thus dealt with. Earth is sent round daily and thrown into the privy holes, and when the pit is full the whole is taken to a depôt, where it is mixed with material derived partly from street sweepings and ash-pit refuse; and being thereafter piled beneath a shed built upon a farm near the town, the whole is soaked with the collected urine. A sample analyzed proved to contain—

| | |
|---|---|
| Organic matter and ammonia containing ·207 of tot. comb. nit. | 6·671 |
| Mineral matter containing ·326 of phosphoric acid .. .. | 66·782 |
| Water .. .. .. .. .. .. .. .. .. .. .. .. | 26·547 |

These figures indicate a practical value much smaller than would have been supposed, and it is evident from the small amount of total combined nitrogen, that much of the urine escapes preservation. The results are certainly curious. [1 *R. P. C.*, p. 50.]

## III.

THE second class of remedies of which we have to speak, are those which deal with the sewage after it has been passed into the drains and mingled with the entire liquid refuse of the houses and streets of the district, and most generally, under our present system of town drainage, with the surface water and unintercepted rain water of the place. There are three principal ways, under this head, in which it has been attempted to deal with town sewage:—1. Precipitation by chemical means; 2. Filtration; 3. Irrigation. Of these the second is, in practice, only an artificial and imperfect modification of the last; but we are not prepared to say that under peculiar circumstances and in certain localities an artificial system of filtration may not be adopted with advantage, and we will say a few words upon the subject in connection with what has been called plant-filtration, or irrigation.

Precipitation by chemical means is certainly the most attractive form of sewage utilization, and although nothing has as yet been achieved at once practical and remunerative, it seems impossible, considering the rapid advance of scientific knowledge, that we can long remain without some chemical composition, which will fulfil all requirements. The preservation of the ammonia can alone render any process of precipitation remunerative, but that subtle chemical enigma has so far eluded the vigilance of the chemists; and never fails to fly off during treatment, either entirely or in such large proportions as to leave nothing but a worthless manure behind it.

We will now notice the principal experiments in this direction, with their success or results.

1. The sewage has been treated with *lime* at Tottenham, at Blackburn, and at Leicester. The *modus operandi* is simple, but the treatment entirely fails to get rid of the organic nitrogenous matter in the sewage, and consequently to render the liquid sewage admissible into a river. We subjoin a table of the analyzed results of the lime process, which may be interesting in many ways.

PRECIPITATE OF SEWAGE BY LIME.

| | Before Treatment. | After Treatment. | Precipitate. |
|---|---|---|---|
| Organic matter :— | | | |
| (*a*) Insoluble suspended .. | 39·10 | .. | .. |
| (*b*) Soluble .. .. .. .. | 19·40 | 19·35 | 35·41 |
| Lime .. .. .. .. | 10·13 | 9·28 | 14·80 |
| Magnesia .. .. .. | 1·42 | 0·94 | 0·22 |
| Soda .. .. .. .. | 4·01 | 2·26 | |
| Potash .. .. .. | 3·66 | 3·80 | 1·02 |
| Common salt .. .. | 26·40 | 24·49 | |
| Sulphuric acid .. .. | 5·34 | 5·99 | 1·11 |
| Phosphoric acid .. | 2·63 | 0·45 | 2·06 |
| Carbonic acid .. .. | 9·01 | 5·19 | 8·92 |
| Silica, sand, oxide of iron, &c. | 6·20 | 0·23 | 5·96 |
| | 127·30 | 71·98 | 69·50 |
| Ammonia .. .. .. .. | 7·48 in solution only. | 7·50 in solution only. | 2·80 |

1st. It may be remarked that no organic matter is precipitated except that which would have been equally separated by mechanical filtration.

2nd. The ammonia in the precipitate is entirely due to the same insoluble organic matter, and none of the ammonia of the liquid is saved by this process.

3rd. Five-sixths of the phosphoric acid are precipitated. But as this is the only element of agricultural value preserved by the lime process, it may be safely affirmed that it can never be profitable in an agricultural sense. [See 2 *S. U. C.*, p. 69, and *Tott. Rep.*, p. 10.]

2. *Lime and chloride of iron* have been tried without satisfactory results at Northampton. The chloride of iron delayed, without preventing, the putrescence of the effluent fæcal matter; and the Court of Chancery at length stepped in and restrained the Improvement Commissioners from discharging any more sewage into the river after June 1, 1870. [1 *R. P. C.*, 58.]

3. At Stroud, in Gloucestershire, *sulphate of ammonia* has been tried with partial success, but under circumstances which would not warrant its adoption elsewhere; the sewage being very weak and the effluent liquid containing more solid matter in suspension than the sewage before treatment. [1 *R. P. C.*, 59.]

4. A somewhat more complicated mode of treatment, known as *Holden's* process, seems to combine all the disadvantages of the foregoing system. The sewage is treated with a mixture of sulphate of iron, lime, and coal-dust, and has been tried, among other places, at Bradford. According to the analysis on page 60 of the R. P. C., we find that not only is the amount of the putrescible organic matter in solution in the sewage absolutely increased by treatment, but that the amount of solid matter in solution is also increased, and the effluent water rendered in addition so permanently hard as

to be very objectionable for manufacturing purposes. In addition to this the solid refuse obtained may be considered practically worthless as a manure. [1 *R. P. C.*, 60.]

5. Experiments have been also tried with *sulphate of alumina*, with results not greatly different from those of the lime process [see *ante*, *table*, p. 18]; the precipitate on the whole, however, being of less value as a manure [2 *S. U. C.*, 70–71]; but see *post* as to the PHOSPHATE of Alumina, pp. 22–25.

6. In *Blyth's process*, the polluting matter in the sewage is precipitated by soluble phosphate of magnesia, but the results of experiments are not satisfactory. [2 *S. U. C.*, 71-72.]

7. In *Lenk's process*, the sewage was treated with a preparation of alum, the deposit being valued as a manure by Professor Voelcker at about 2*l.* 2*s.* per ton dry, and 25*s.* to 30*s.* in a semi-dry state. The deodorizing fluid was tried at Tottenham with very fair results [*Totten. Rep.*, pp. 30–35], and Dr. Voelcker reports favourably upon the disinfecting power of Lenk's composition [*id.*, p. 34].

The reader is also referred to an interesting American pamphlet upon this process, in which a fully detailed account will be found of the mode of treatment and results.

8. The best practical precipitants of sewage, according to Messrs. Hofmann and Frankland [*Rep. add. to Met. Bd. of Works*, 12th August, 1859, whose opinion is endorsed by the Royal Commissioners in this Second Report of 1861], are the *persalts of iron*. Of these, the perchloride of iron may be considered as the most valuable, and its high price alone appears to interfere with its adoption. But it has been suggested that in case of a large demand it might be produced "at a price sufficiently moderate to allow of its general employment in the purification of sewage" [2 *S. U. C.*, 1861, page 18, and *id.*, *Appendix* 6.] We cannot do better than quote the words of this Report as to the advantage of sewage

treatment with perchloride of iron. When perchloride of iron is added to sewage, a precipitate is formed which rapidly settles down, leaving above it a clear liquid. This precipitate is chiefly composed of peroxide of iron, precipitated not by the acids of the sewage as in the case of the alkaline precipitants, but by the alkalinites of the carbonate of ammonia and other compounds of the same nature which exist in, or are rapidly formed from, the urine and fæces of the liquid. The deposit so formed contains, of course, all the suspended matter of the sewage, whether organic or otherwise; it also contains, and to a greater extent than in the case of the lime process, the phosphoric acid previously existing in the sewage in a soluble form; moreover, and this constitutes about all the advantage of this method of precipitation, in the precipitate is removed the sulphuretted hydrogen, which in the case of the lime process remains as a sulphuret in the liquid. The value of a precipitating process depends upon the extent to which it fulfils the very different, but equally necessary, requirements of a *mechanical clearing* of the liquid and of its *chemical purification.* Salts of peroxide of iron (or more properly persalts of iron) when neutralized by an alkali give a large flocculent precipitate of peroxide of iron, which is extremely well adapted for the mechanical separation of the suspended particles. The resulting precipitate rapidly settles down, and the clear liquid is easily separated from it. In this respect, the iron compounds hold a high rank as a means for the purification of sewage. But moreover, in this precipitate is removed, as we have before seen, the sulphuretted hydrogen in the form of sulphuret of iron, a compound quite innocuous and not readily decomposed by subsequent agencies. Oxide of iron has also the property, like alumina, of carrying down with it organic matter in solution, and we have reason to believe that it does practically remove animal matter, which would otherwise be left in the discharged liquid. The result of these conjoined actions is, that with the iron process we are able to separate town sewage with great facility into solid and liquid, both of which are comparatively free from noxious or offensive smell, and neither of which is liable to a recurrence of this evil quality. [2 *S. U. C.*, pp. 16-17]. As regards the best mode of obtaining perchloride of iron, see Appendix, p. 73.

9. We have now to notice a chemical process which seems likely to take the place of all those that have hitherto been invented, and to play a very prominent part in sewage utilization, namely, the *Phosphate process.* The most interesting experiments upon this system have been made at Tottenham, when the Lime process adopted some time ago may be said to have almost completely failed; and we refer our readers for an admirable *exposé* of the new system to a Report published on the subject by Mr. P. P. Marshall, C.E., the engineer to the Tottenham Local Board of Health.

The sewage is treated in this process with phosphate of alumina, a natural product existing in large quantities on the island of Altovola, near St. Domingo, in the West Indies, and procurable at about 3*l.* 10*s.* per ton. The essential difference between this and any other system of deodorizing sewage is that the agent employed contains the most valuable fertilizing properties itself, and these properties can only be made available by a process of precipitation. All other methods are simply precipitant, and the consequence has been that the manure made from the sewage has been little better than mud. [See *Analyses of Composition*, pp. 18 and 28.]

The phosphate process has a twofold character, and combines the principles of irrigation and chemical precipitation, or it can be used independently of irrigation, if that course be preferred. In one case, if the phosphate of alumina alone is used, the sewage is defecated, the solid matter in the sewage is precipitated, and the water is left; the latter, it is stated, "still maintaining all its nitrogenous and valuable properties, *plus* any excess of phosphoric acid which has been added, and therefore highly useful for the irrigation of cereals and other crops, and at the same time perfectly inoffensive." This application of the process would be suitable where it was deemed desirable to use the water as a fertilizing agent for irrigation purposes. In the case of towns where sewage irrigation presents peculiar difficulties, and where it is desired to render the sewage sufficiently clear and pure to mingle with a river or stream, this object, it is stated, "can be obtained by adding a small quantity of lime to the sewage, after the treatment by the former process, by which means the excess of phosphate and organic matter is precipitated, and the water so clarified is rendered tasteless and harmless." In either case it is claimed that the sewage is effectually defecated, and rendered free from all trace of putridity. Of course the precipitate or deposit has to be removed from the precipitating tank and dried, in order to be converted into a portable manure. This is accomplished by means of an Archimedian screw, and the precipitate is dried and pulverized in a large open shed.

*Process.*—The phosphate of alumina is rendered soluble in water by the application of sulphuric acid in proportions of about 2 to 1, and is then mixed with water until the whole is reduced to the consistency of thick chocolate for drinking. [*Marshall, Rep.*, p. 7.] This composition is then applied to the sewage, and afterwards run into a series of tanks. After precipitation "the water is finally passed through a filter composed of coke, charcoal, or some other carbonized substance, so as to remove any organic matter that may remain in solution. This filter is re-oxidized by exposure to the atmosphere, the water being run out and the air admitted every twelve hours alternately." The deposit is afterwards removed into shallow pans to dry, and when of sufficient consistency is made into bricks and air dried. The whole process is remarkably free from smell, in consequence of the phosphate in the precipitating composition.

The practical results of the process are most satisfactory, and for a detailed account of them we must refer our reader to Mr. Marshall's exceedingly impartial Report [pp. 9–18], and to Dr. Voelcker's letter or Report on the whole process (6th April, 1871), and printed in the Appendix to Mr. Marshall's work. [See also *Evening Standard*, December 26, 1871.]

Professor Voelcker's analyses show that the raw sewage at the time of his visit contained 16½ grains of suspended matter per gallon, while the effluent water yielded "no perceptible and weighable suspended matters." The gallon of raw sewage held 57 grains of solid matter in solution, while the effluent had 63 grains, there being a large increase of sulphate of lime. Of organic matter the gallon of raw sewage held in solution 6·35 grains, and the effluent 5·74. In suspension the raw sewage held 11·41 grains, and the effluent none. Of mineral matter the gallon of raw sewage held in solution 50·80 grains, and the effluent 57·71. In suspension the raw sewage held 5·11 grains, and the effluent none. Thus the total solid matter, organic and mineral, was 73·67 grains per gallon in the raw sewage, and 63·45 grains in the effluent. The total organic nitrogen in the gallon of raw sewage was 1·60 grain, of which 0·96 were in solution. The effluent had simply 0·47 in solution. This would be equal to 1·94 grain of ammonia in the raw sewage, and 0·57 in the effluent. The saline ammonia in the raw sewage was 2·66 grains, and in the effluent 3·32. Finally, the total nitrogen, calculated as ammonia, was 4·60 grains per gallon in the raw sewage, and 3·89 in the effluent. "It follows from these results," says Professor Voelcker, "that sewage by treatment with the phosphate of alumina process is deprived of by far its largest proportion of nitrogenous organic matter."

Theoretically, and indeed as far as the experiments have so far shown, the process is highly remunerative, the value of the manure having been estimated by Professor Voelcker at from 2*l.* 10*s.* to 7*l.* 7*s.* per ton. Mr. Marshall estimates the cost of producing three tons of manure at Tottenham at about 9*l.* [*Report*, p. 16.] The manure which has been produced at Tottenham by some experiments conducted under decidedly unfavourable circumstances sells for 4*l.* per ton, thus giving a profit of 1*l.* per ton on the estimated working expenses. The extreme simplicity of the phosphate process is one of its greatest recommendations; we cannot believe in the practical success of any system that cannot be worked in a rough way. As far as deodorization is concerned, the phosphate leaves nothing to be desired, and speaking from personal observation we can say that not only the effluent water, but the deposited mud, is perfectly free from any offensive odour.

10. We have now to notice somewhat more fully a process which has attracted a large and we cannot but think an undue share of public attention, and which is known by the name of the *A B C system*, or Siller's patent. The following is the specification filed at the Great Seal Patent Office :—

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

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

| | | |
|---|---|---|
| Alum .. .. .. .. .. .. | 600 | parts. |
| Blood .. .. .. .. .. .. | 1 | ,, |
| Clay .. .. .. .. .. .. | 1900 | ,, |
| Magnesia .. .. .. .. .. | 5 | ,, |
| Manganate of potash .. .. .. | 10 | ,, |
| Burnt clay .. .. .. .. .. | 25 | ,, |
| Chloride of sodium .. .. .. | 10 | ,, |
| Animal charcoal .. .. .. .. | 15 | ,, |
| Vegetable charcoal .. .. .. | 20 | ,, |
| Magnesian limestone .. .. .. | 2 | ,, |

"These substances are mixed together and added to the sewage to be purified until a further addition produces no further precipitate. The quantity required will be about 4 lbs. of the mixture to 1000 gallons of sewage. In many cases it is preferable to mix the above compound with a small quantity of water, and add it in a liquid state to the sewage. The sewage must then be thoroughly mixed with the compound and allowed to flow into settling tanks. The greater part of the organic and other impurities will be immediately separated in the form of large flakes, which rapidly fall to the bottom, leaving the supernatant water clear and inodorous, or nearly so. The water may then be allowed to flow away into a river, or be disposed of in any other way, and the sediment or mud allowed to accumulate at the bottom of the tank. In some cases it is preferable to add the compound of manganese to the water after the sediment produced by the other ingredients has been allowed to subside. The sediment will be found to possess the power of precipitating a further quantity of sewage; it must therefore be pumped or otherwise taken from the tank and mixed with fresh sewage, the sediment being allowed to subside in the same way as before. The sediment may be used five or six times over in this way. When the sediment no longer possesses the power of precipitating the impurities in the sewage, it must be removed from the tank and allowed to dry; when partially dry a small quantity of acid, by preference sulphuric acid, may be mixed with it, which will retain all the ammonia in a soluble form. When dried the sediment will be a valuable manure."

A series of experiments were conducted, chiefly at Leicester and at Leamington, upon the A B C system, and the results published in the early part of the year 1870 as the 2nd Report of the R. P. C. They were, on the whole, unsatisfactory; and the patent mixture appears to be in no way superior to lime in its effect upon the sewage. The amount of organic nitrogen indeed, including the most putrescent particles of the sewage, the most injurious to health and the most valuable as a manure, seems to be nearly as great in the effluent water as in the raw sewage. Again, in consequence of the ammonia contained in the alum used in the A B C process, the effluent water invariably contains more ammonia than the raw sewage, a result equally fatal to the purity of the water and the value of the residuum as a manure.

The smell arising from the process is pronounced offensive to an extent which would make it a "nuisance" whenever conducted in or near a town. [2 *R. P. C.*, p. 8.]

The results of some experiments upon the London sewage by the A B C process, which are considered to have been very accurately conducted, are summed up in p. 13 of this Report in the following words [2 *R. P. C.*, p. 13] :—

"We learn then from the above results :—

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

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

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

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

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

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

"7th. That the proportion of chlorine remained unaltered.

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

With regard to the manure value of the solid refuse, after treatment by the "A B C" process, it seems clear that unless the mud is greatly strengthened by the addition of other substances valuable as manures, its practical value is exceedingly small. For, although in theory, a certain number of tons of valuable constituents are separated daily from the raw sewage, yet they are mixed with so large an amount of clay and other substances of no value, as to render the refuse on the whole hardly worth the carriage. Such being the state of the case, we can enter into no further details upon this branch of the subject, but merely refer such as may desire further information as to the manure resulting from the "A B C" system of treatment to 2 R. P. C. (1868), 1870, pp. 15–18.

As to the "A B C" system generally, we find the following Conclusions at p. 19 of the 2 R. P. C. :—

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

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

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

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

Finally, as regards the purification of sewage by charcoal, see further, generally, 2 S. U. C. (1861), pp. 14–21.

11. Among the systems of treating sewage by chemical means, we must not omit that recently invented by Major-General Scott, R.E., and which has been tried under his superintendence at Ealing.

In this process the sewage is treated with lime and clay, made into a thick paste and mingled with the sewage, as it flows into a tank about 60 feet in length. The precipitation is so rapid that the effluent water is almost tasteless, and the process is said to be entirely unattended with any offensive odour. But the peculiar feature of the system is the subsequent treatment of the refuse, which is dried and burnt with the help of its own organic matter, and when pulverized has all the properties of the best Portland cement.

This ingenious process has been in operation but a short time, but has so far been perfectly successful. See Appendix V., p. 55, as to Hille's process.

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

The water pumped from the shallow wells in London is nothing but filtered sewage, a large volume of which, be it remarked in passing, exists in the ornamental water in St. James's Park, which is supplied from the well on Duck Island.

Irrigation is of course the most natural way of getting sewage filtered, and while its adoption has generally met with success, all the more artificial systems of filtration which have been hitherto tried have proved complete failures.

At Ealing, for instance, the liquid sewage is received in tanks, and forced upward through filters of burnt clay, ballast, gravel, and charcoal. The process, which will be found fully entered into in 1 R. P. C., pp. 60–70, entirely failed to transform the soluble putrescent organic matter into innocuous mineral compounds. This failure, we quote the Report, is due partly to the filters being too small for the volume of sewage dealt with, and partly to the circumstance that the filtration is performed upwards instead of downwards. For efficient purification by filtration, it is essential that the atmospheric oxygen should have frequent access to the interior of the filter, a condition which is entirely excluded in upward filtration. A very interesting course of experiments upon filtration will be found recorded in 1 R. P. C., pp. 60–70, and Tottenham Rep., pp. 49–69. Average London sewage was filtered through sand, sand and chalk, Beddington soil, Hambrook soil, Barking soil, Dursley soil, and Leyland peat, with various results. There is no doubt that the sewage may be effectually purified by filtration through almost any porous soil, when applied in quantities not greater than 5½ gallons per cubic yard of soil per diem, in almost all soils up to nearly 10 gallons per cubic yard in the case of Dursley soil, the most efficacious in this respect of any which were submitted to experiment. In the case of peat, an application of about 4 gallons per cubic yard was successful.

It is computed that the sewage of a water-closet town of 10,000 inhabitants could be cleansed upon five acres of land drained to the depth of six feet [1 *R. P. C.*, 65]. Upon this purifying power of the soil is based Mr. Bailey Denton's ingenious scheme of intermittent downward filtration, a scheme for whose details we must refer our readers to his recent publication, 'The Sewage Question,' 8vo, 1871. We do not, however, believe in the advantage of this artificial system for many reasons, amongst others—

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

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

3. 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 action of the filter must not be considered as merely chemical. The process carried on in it is also mechanical. Filtration, properly carried out, results in the oxidation and transformation of offensive organic substances in solution, as well as in the mere mechanical separation of the suspended solid matters, which, when in motion, sewage conveys with it. [*Tott. Rep.*, pp. 67–68.]

With reference to this scheme of Mr. Bailey Denton, Professor Voelcker says:—" The greater portion of the soluble alkaline medicinal salts, together with the products of oxidization of the nitrogenous constituents of fæces and urine, cannot be removed by filtration through any amount of soil. The effluent water is not fit for use until mixed with other pure water."

## IV.—IRRIGATION.

The last method of dealing with sewage which will engage our attention is Irrigation, or continuous application of the sewage to cultivated land, which is laid down by the S. U. Commission in their third Report, 1865, p. 3, to be "the right way to dispose of town sewage, and the only one by which the pollution of rivers can be avoided." Although this is, perhaps, going rather too far, there can be little doubt that, regarded from every point of view, *Irrigation* is on the whole the most practicable mode of disposing of town sewage that has yet been tried. To obtain a maximum amount and gross value of produce from a given amount of sewage, it should be applied in small quantities per acre and in dry weather; but the great dilution of town sewage, its large daily supply at all seasons, and its greater amount in wet weather, when the land can least bear or least requires more water, render it quite inappropriate for application on a comprehensive scale to arable land for corn and other ordinary rotation crops. As to the mistakes that have been committed in adopting systems of sewage irrigation, especially as to the area of the land under irrigation, the use of hose and jet, and the kind of crops to be manured, see 1 *S. U. C.*, pp. 17–20.

Having regard to the cost of distribution, it is probable that the most profitable mode of utilization would be to limit the area by specially adapting the arrangements for the application of the greater part, if not the whole, to permanent or other grasses laid down to take it the year round; trusting to its occasional use to other crops within easy reach of the line or area so commanded, but relying mainly on the periodically broken-up rye-grass land, and on the application to arable land of the solid manure resulting from the consumption of the sewaged grass, for obtaining other produce than milk and meat, by means of sewage.

Judging both from the results of the experiments and from the experience of common practice, it is considered that the most profitable utilization of town sewage will in most cases be attained by the application of about 5000 tons per acre to meadow or Italian rye-grass, but that the farmer would not pay $\frac{3}{4}$*d.*, and probably not $\frac{1}{2}$*d.* per ton the year round for sewage of the average strength of that of the metropolis (excluding storm-water) delivered on his land. [3 *S. U. C.*, pp. 78–80.]

It is also necessary, in order to bring about the most profitable results, that the liquid sewage should only be applied to such crops as are known to be specially benefited by it. There seems to be no doubt that meadow land is the most fitted for the reception of sewage; and of all grasses, perhaps the Italian rye-grass is the crop that derives most benefit from its application. There is no doubt that many other crops, such as turnips or mangold-wurzel, would be immensely improved by occasional sewage dressing; but it must always be borne in mind that in order to make sewage irrigation successful, it must be constantly applied to the same area of ground. We have already shown that it is most undesirable to extend the operation over too large an extent of land, and it is evident that if the sewage is to be applied to a small area, it must be continually flowing on to the land. Now in no crop can this be permitted but on grass land. A system of intermittent application to various fields on a farm by means of hose and jet has been tried, but the expense as well as the difficulty of applying the sewage only when it was required by the crop led to its failure. Upon this branch of the subject, see 1 *S. U. C.*, 17; and as regards the distribution of sewage in the neighbourhood of large towns, *Tottenham Rep.*, p. 91, where it is stated that the visit to Barking satisfied "the

Committee that sewage farming near London ought to be market gardening."

It will be well to bear in mind, while considering the various modes of sewage irrigation, that the chief valuable ingredients in ordinary sewage are: 1st, the various forms of nitrogen; 2nd, phosphoric acid. The money value of these constituents in solution in 100 tons of average sewage is about 15*s.*; while the matter in suspension in the same quantity is worth only about 2*s.* [*Tottenham Rep.*, p. 9]. The latter only is retained by precipitation, the former can only be separated by chemical agency on the action of plants growing in the soil through which the sewage is filtered. The advantage of plant-filtration, which retains the matter in solution, over merely mechanical filtration, which only retains that in suspension, becomes immediately clear.

Before proceeding any farther to consider the merits of sewage irrigation, we will say a few words as to the disadvantages of the system, which are chiefly: 1st, that the cost of partial distribution prevents the profitable application of the sewage to any but grass land; 2nd, that a vast amount of sewage is applied to land when it does not need it; 3rd, that owing to the dilution of the sewage with the surface water, its application in wet weather may be positively injurious. But it will be remarked: first, that these disadvantages only touch the farmer and not the sanitary reformer; and secondly, the success in an economic point of view of the system in some places proves that, however much these disadvantages may detract from the benefits to be derived from the application of sewage to land, irrigation can be successfully carried on in spite of them. In fact, the first difficulty may be got over by laying down the farm to be sewaged almost entirely with grass crops, which, as long as hay and beef and milk continue to be in large demand, must always be a profitable crop. The second disadvantage can only be moderated by the treatment of a proper area of land and a judicious distribution of the liquid sewage, and even this may be greatly diminished, if not entirely done away with, by not permitting the surface-water to flow into the drain with the sewage; a system which is already recommended [see *Bateman, Report on Sewage of Oxford*, 1857, and *Times*, Jan. 2, 1868, *Letter on Sewage, by Gilbert Child*] in many quarters and for many reasons; at Tottenham, for instance; and at the Broadmoor Asylum, under the auspices of Mr. Menzies. There is indeed another disadvantage in the application of raw sewage to land, namely, that in course of time the solid particles are left on the surface, interfering with the proper growth of the plant and giving off an offensive odour. The remedy for this is the separation of the suspended matter and deodorization of the sewage, as is now done to a certain extent at Croydon, but which appears to be effected in the most satisfactory manner by the phosphate of alumina, which, completely deodorizing the sewage, renders the effluent water as rich in manurial materials as the raw sewage.

It would be beside our plan to give a detailed account of the various experiments and analyses connected with sewage irrigation, but an exceedingly interesting analytical *exposé* of the whole system, based upon experiments conducted at Rugby in the year 1861, is to be found in 2 S. U. C., 1861, pp. 23–37, and Appendix VIII., pp. 88–133. It will be sufficient for the purposes of the present work to quote the CONCLUSIONS based upon these experiments and analyses.

1. By the application of large quantities of dilute town sewage to permanent meadow land during the spring and summer months, there was obtained an average increase of about 4 tons of green grass (which, owing to the lower proportion of dry substance in the sewaged grass, was equal to only about three-fourths of a ton of hay) for each 1000 tons of sewage supplied, until the amount of the latter approached

the rate of about 9000 tons per acre per annum. The largest produce obtained was about 33 tons of green grass per acre. The period of the year over which an abundance of green food was available was, with the largest amounts of sewage, between five and six months.

2. Oxen tied up under cover and fed on cut green grass alone, whether sewaged or unsewaged, gave a far lower rate of increase than the average obtained by animals fed on ordinary good fattening food; but when, for a few weeks, oil-cake was given in addition to the grass, they yielded a good average rate of increase.

3. Cows tied up under cover, and fed on cut green grass alone, after previously receiving oil-cake, fall off considerably in their yield of milk, and about equally whether the grass was sewaged or unsewaged. The cows on unsewaged grass consumed more food and gave more milk in relation to their weight than on sewaged grass; but the amount of milk yielded for a given amount of fresh food consumed was almost the same in the two cases, though in proportion to the dry or solid matter which the food contained, the sewaged grass yielded considerably more milk than the unsewaged. Milk to the gross value of 32*l.* per acre was obtained where the largest quantity of sewage was applied. The gross value of the milk from the increased produce of each 1000 tons of sewage was between 5*l.* and 6*l.*

4. The composition of the Rugby sewage water varied very much during the course of the season, being much more concentrated during the drier months. On the average over about seven months, 1000 tons of sewage contained about 21½ cwt., or little more than 1 ton of solid matter, about 212 lbs. of ammonia, or about as much as is contained in 11 cwt. of Peruvian guano, and probably represented the excrements of twenty-one or twenty-two individuals of a mixed population of both sexes and all ages for a year. This

average composition agrees very closely with that which published analyses indicate for the sewage of London.

5. On the average the sewaged grass contained, as cut, a considerably lower proportion of dry or solid substance than the unsewaged, but the dry substance of the sewaged grass generally contained a higher proportion of nitrogenous compounds.

6. Analysis shows very little difference in the quality of the milk yielded respectively from sewaged and unsewaged grass. The difference in composition, such as it is, is slightly in favour of the milk from unsewaged grass when grass was given alone, and slightly in favour of the sewaged grass when oil-cake was given in addition. [2 *S. U. C.*, pp. 36–37.]

Some experiments were made in applying sewage to oats, which appear to have been very successful [3 *S. U. C.*, p. 78]; but various circumstances seem to have unduly favoured the crops, and the results are not to be taken as indicating what might be expected in average seasons. It seems probable, however, that an application at the proper time of about 500 tons of sewage per acre to arable land might be attended with the most satisfactory results, the real difficulty being the expense and impracticability of an intermittent system of distribution. Indeed Mr. Rawlinson considers that the expense of distributing 500 tons of sewage by the hose-and-jet system would be greater than that of distributing 5000 tons by the open-channel plan. [*Duthie*, *Utilization of Towns' Sewage*, p. 19.] In the third Report, S. U. C., 1865, pp. 5–28 and 51–65, and Appendix I., may be found the details of further experiments at Rugby during the years 1861–2–3, which are most interesting, and should be carefully read by all who are studying the subject of sewage irrigation; but as no new *principle* appears to have been evolved in the course of these experiments, we content ourselves with referring the reader to the Report for the details, merely quoting the summary to be found in pp. 73–74 of the Report.

1. As there is a daily supply of sewage the year round

which, on sanitary and engineering grounds, it is essential to dispose of as soon as it is produced; and as passing it over the land is the best mode, both of purifying and utilizing it, it should be employed for purposes of irrigation, and be applied in winter when of comparatively little value, as well as in summer when of more.

2. *Italian Rye-grass.*—By the application of sewage to grass land during the winter months a very early cut or bite of green food may be obtained; but the amount of increased produce due to the winter application is comparatively small for the amount of sewage employed.

3. By means of sewage irrigation the period during which an abundance of green food was available was extended considerably at the end as well as at the beginning of the seasons, and the more so the larger the quantity of sewage applied, almost up to the highest amount employed—9000 tons per acre.

4. One of the experimental fields gave much less produce per acre without sewage than the other, and analysis showed its soil to be much less naturally fertile, but it gave fully as much produce per acre under the influence of liberal dressings of sewage as the naturally more fertile soil.

5. Taking the average over three years, and in the two fields, the amount of produce obtained without sewage was about 9½ tons of green grass per acre per annum, equal to about 3 tons of hay; and with 3000, 6000, and 9000 tons of sewage per acre per annum, the amounts were respectively 22¼, 30¼, and 32¼ tons of green grass, equal respectively (reckoned according to the percentage of dry substance in each) to about 5, 5¾, and 6½ tons of hay.

6. The largest quantities of produce per acre were obtained in the third year of the experiments and with 9000 tons of sewage per acre per annum, namely, in one field 35 tons, and the other 37 tons of green grass, equal respectively about 6 tons 12¾ cwt. and 7 tons 1 cwt. of hay.

7. The average increase obtained for every 1000 tons of sewage was, when 3000 tons per acre per annum were applied, 4 tons $2\frac{1}{4}$ cwt.; and when 9000 tons were applied, 3 tons $3\frac{1}{4}$ cwt. of green grass.

8. The amount of increase per acre was the greater, the greater the quantity of sewage applied, up to 9000 tons per acre; but the amount of increase of produce obtained for a given amount of sewage was the less where the greater amounts were applied.

9. Experiments with rye-grass were made in one season only; sewage was not applied until the end of April, and comparatively small quantities were put on. The results so obtained indicated much about the same amount of increase of produce for a given amount of sewage as for meadow grass.

10. When cut and given to fattening oxen tied up under cover, more sewaged than unsewaged grass, reckoned in the fresh or green state, was both consumed by a given weight of animal within a given time, and required to produce a given weight of increase; but of real dry or solid substance, less of that of the sewaged than of the unsewaged grass was required to produce a given effect.

11. When cut grass was given alone, the result was very unsatisfactory; but when oil-cake was given in addition, the amount of increase upon a given weight of animal in a given time, and for a given amount of dry substance of food consumed, was not far short of the average result obtained when oxen are fed under cover on a good mixed diet.

12. The money return, whether reckoned per acre, or for a given amount of sewage, was much less with fattening-oxen than with milking-cows.

13. When cows were fed on sewaged or unsewaged grass, as much as they chose to eat, a given weight of the animal was more productive both of milk and increase, but especially of milk, on the unsewaged than on the sewaged grass.

14. From a given weight of unsewaged grass reckoned in

the fresh or green state, more milk was produced than from an equal weight of fresh sewaged grass; but a given weight of the dry or solid substance supplied in sewage grass was on the average more productive than an equal weight supplied in unsewaged grass.

15. The milk-producing quality of the grass was very different in different seasons, and at different periods of the same season; it was very inferior in the wet and cold season of 1862, and towards the close of the seasons as compared with the earlier periods. It appears probable that Italian rye-grass deteriorates less towards the end of a season than meadow grass. On the average, about six parts by weight of fresh grass yielded one part by weight of milk.

16. By the aid of sewage, the time that an acre would keep a cow and the amount of milk yielded from the produce of an acre were increased between three and four fold.

17. So far as the results of the experiments afford the means of judging, it is estimated that with an application of 5000 tons of sewage per acre per annum to meadow land, an average gross produce of not less than 1000 gallons of milk per acre per annum may be expected.

18. In experiments conducted with Italian rye-grass (but in one season only), more milk was obtained by the use of a given amount of sewage applied to it than to meadow land.

19. With an application of about 5000 tons of sewage per acre per annum, an average grass return of from 30*l.* to 35*l.* per acre in milk, at 8*d.* a gallon, may be anticipated.

It must be well known to everyone who is interested in the utilization of sewage, that the ammonia contained in it constitutes its most valuable manurial quality, and we have already seen how the various systems of chemical precipitation have failed to secure the volatile substance; and it becomes a question, in considering the advantage of the irrigation system, to see how far this ammonia is liable to be wasted by the conveyance of the liquid sewage in *open* conduits; a mode of distribution which must of course greatly diminish the expense and increase the practicability of all irrigation operations. The experiments have been most satisfactory, and show that while in twenty-four hours the loss of ammonia is scarcely appreciable, after three days the proportional loss amounts to little over thirteen per cent. Another extremely satisfactory fact connected with this loss of ammonia is that when sewage becomes putrid the ammonia which it contains is diminished in quantity, so it becomes the interest of the farmer as well as the public to apply the sewage before it becomes offensive. For detailed account of the experiments, see 1 R. P. C., 93–94.

The disposal of sewage by means of irrigation is as old as it is simple and natural. As early as the year 1561 there was a sewage farm near Edinburgh, and the irrigation of the celebrated Craigentinny meadows was begun before the year 1760. The sewage of Edinburgh is still applied to these meadows with great success and profit, and those who desire a full and detailed account of the works and operations generally, will find a very interesting account by Mr. McPherson, engineer to the city of Edinburgh, quoted in the *Tottenham Report*, pp. 72–80; 3 *S. U. C.*, p. 198, and 1 *R. P. C.*, p. 74. There appears to be a great waste of sewage, owing to the insufficient area of the land under treatment, and many improvements might be made in the formation of the channels, yet the success of the works in a sanitary point of view is most encouraging, and the profits derived from the crops almost incredible; the crops of rye-grass fetching from 25*l*. to 36*l*. per acre. The lower end of the Craigentinny estate was simply sea-shore, until the sewage was applied to it; it is now as fertile as the rest of the farm, getting richer and richer every year, notwithstanding the enormous crop annually taken off it.

The two most successful sewage farms in the South of England are Norwood and Croydon, the clay land at the former place appearing to be equally successful in purifying the sewage as the light porous soil of Croydon. As to the value of differently constituted soils, see 1 *R. P. C.*, pp. 65–70. It must always be borne in mind that the plant or vegetation has infinitely more to do with the purification of the sewage than the nature of the soil itself. As to the relative success of the works at Croydon and Norwood, see *Tott. Report*, pp. 80–90, and 1 *R. P. C.*, pp. 85–87.

As to Barking, where a farm of about 220 acres has been laid out by the Metropolitan Sewage Reclamation Company, under Mr. Martin, see *Tott. Rep.*, 90, and 1 *R. P. C.*, 76. The land was cropped with early carrots, onions, parsnips, potatoes, and mangold, as well as rye-grass, and the agricultural result appears to have been most satisfactory, the value of the crops in some instances reaching 38*l.* per acre. At Aldershot, again, the best cabbages that come into the London market are said to be grown on the sewage farm. [*Tott. Rep.*, 93, and 1 *R. P. C.*, 77.]

But perhaps the irrigation system has been carried out with the greatest success at Croydon. The soil and "lie of the land" are most favourable for the adoption of the system, and while citing Beddington meadows as an example of the advantages of the irrigation process, it is not to be supposed that the results could be quite so favourable in every locality, though an examination of the comparative table, 1 *R. P. C.*, 94–95, will show that in many other places the results have been nearly as satisfactory. The soil at Beddington is open, on a gravelly subsoil, with just sufficient slope to render easy the distribution of the liquid sewage over and through it, and there is just sufficient fall between the top and bottom of the farm to allow the tail water of the upper fields to be spread a second time over the fields below before it drains finally away. The works now in the hands of the local authorities were planned by Mr. Baldwin Latham, whose admirable letter to the 'Echo,' Sept. 29, 1871, will give as good an account of the past and present state of Croydon as it is possible to have in a few words. He says:—

"Before the year 1849 Croydon was governed by various authorities, each having a separate jurisdiction. Soon after the passing of the Public Health Act of 1848 it was adopted in Croydon, and a Local Board was established in August, 1849. Previously to this period Croydon had long been known for its unhealthiness. An Act of Parliament was passed in 1809, to enable the Archbishop of Canterbury to alienate the site of the Palace at Croydon, the preamble of the Bill stating that the site was 'damp and unwholesome.' Before the formation of the Local Board little or nothing had been done in the way of alleviating the sufferings which had arisen from sanitary neglect. No wonder, therefore, that the rate of mortality in 1848, when the population slightly exceeded 19,000, was upwards of 28 per thousand, and that the average rate of mortality for seven years before the completion of the first operations of the Local Board, was over 23 per thousand.

"In the matter of the disposing of the sewage the authorities were, at one time, very unfortunate. The first operations for purifying the sewage consisted in the construction of filter works for filtering it through charcoal and other materials. These works were erected near the town, but even before the whole works of sewerage were complete their insufficiency became apparent, as numerous complaints were lodged with the Board by those living on the stream as to the state of pollution into which the river Wandle was being brought by reason of the filtered sewage being discharged into it. Then followed a series of experiments, with all kinds of material, to attempt to precipitate and deodorize the sewage. Some of the first chemists of the day were consulted, but it is rather a significant fact that the more the money spent in deodorizing, the greater the number of the complaints of the people living lower down the stream. In fact, when the sewage was discharged into the stream in its normal state it created a great nuisance near the outfall, but a species of self-purification took place, consequently the water lower down the stream was not in a very bad state; but when deodorizing agents were used the sewage was preserved, or pickled, but its noxious elements were not removed or destroyed.

"In the midst of their troubles they appealed from authority to authority, but could meet with no remedy or repose; at last, driven to extremities by the Court of Chancery, the Local Board took a farm at Beddington on the recommendation of the chairman, Mr. C. W. Johnson, F.R.S., upon which to apply the sewage. The farm was subsequently let to, and laid out by, Mr. John Marriage, and shortly afterwards a second farm was taken at Norwood. Since the first acquisition of land for irrigation purposes, the area has been considerably increased, and the mode of treating and distributing the sewage has undergone considerable improvement. The sewage of Croydon and a portion of Upper Norwood is conveyed to the Sewage Irrigation Farm at Beddington, comprising an area of 450 acres, of which about 400 acres are now under sewage irrigation. The works at Norwood are in the hands of the local authorities, and during last year they received for the produce of 33 acres the sum of 888*l*., or 27*l*. per acre. These works, inclusive of outfall works, cost the authorities about 2500*l*. After paying rent at the rate of 10*l*. per acre, taxes, tithes, labour, purchase of implements, seeds, &c., and the cultivation for ensuing year, there was left a profit of 173*l*., or a sum nearly equal to 7 per cent. on the gross outlay for works. The rent paid for land is excessive, for before the local authorities acquired the land for sewage purposes it was let at 18*s*. per acre, and was considered dear at that price.

"The works at Beddington have been worked from the 25th March, 1870, by the Croydon Farming and Irrigation Company, Limited. The area they had under cultivation last year was about 270 acres. The company paid the local authorities of Croydon, during the year, 974*l.* 10*s.* for rent of land, and 900*l.* for the sewage. The gross receipts from the land were 4818*l.* 2*s.* 2*d.*, or about 18*l.* per acre. The gross outlay for rent, sewage, seed, labour, &c., was 4209*l.* 7*s.* 2*d.* The profit made in the year, after writing off about 12 per cent. for depreciation, and one-sixth the preliminary expenses, was 608*l.* 6*s.* 6*d.* The capital called up by the company was 2028*l.*, the amount earned in the year being at the rate of 30 per cent. per anuum. The total cost of these irrigation and outfall works to the local authorities, exclusive of the purchase of land, has not exceeded 8000*l.* The 900*l.* received for the sewage would pay a dividend of 11 per cent. on this outlay.

"The mode of dealing with the sewage consists, first, in separating the solid fæces, sand, paper, &c., from the liquid sewage. The liquid sewage alone, in the state conveyed by the sewers, is applied in its fresh state to the land. When sewers are perfectly constructed they discharge their contents with rapidity, the sewage conveyed by such sewers having the appearance of slightly dirty water, in which are suspended fæcal and other matters; in this state sewage is by no means very offensive, but if the sewers are not properly constructed and become sewers of deposit, the decomposition of the fæcal and other matters takes place before the sewage arrives at its outfall, and it is then discharged as a blackish, loathsome, stinking liquid. At Croydon the solid sewage is removed from the liquid before the decomposition takes place; consequently the sewage is comparatively sweet, and needs no deodorizing. The apparatus used for the purpose of separating the solid and liquid sewage consists of an upright vertical revolving screen, impelled by the liquid sewage, so that the liquid sewage in motion is made the motive power to remove the solid sewage, just as fast and continuously as it is conveyed to the outfall. The amount of solid sewage daily removed at the Croydon outfall is about one-tenth of a pound per head of the population contributing to the sewers, being a greater amount than was found to be removed by the phosphate of alumina process recently tried at Tottenham. The Farming Company are now about to manufacture this solid sewage into a portable manure, worth 3*l.* 10*s.* per ton. After leaving the separating works, the sewage is distributed by means of carriers over the surface of the land; the area daily under sewage treatment is about one-tenth of the whole farm. All kinds of produce are grown with the liquid sewage, and at the present time may be seen on the land crops of mangolds, rye-grass, onions, cabbages, broccoli, celery, potatoes, and parsnips, which are not to be equalled in the neighbourhood; and so great is the repute in which the produce is held in the open market, that buyers are known to wait to ascertain if the Farm Company's carts are coming before they will purchase from other persons. The health of the stock on the farm is remarkably good; when disease has been imported it has taken the mildest type, and although the Farm Company have had a large number of cattle on their farm, they have not lost a single head from disease. The milk produced by the dairy stock is very rich, often containing 16 per cent. of cream, and is sold, unadulterated, to large customers at 10*d.*, and to small customers at 1*s.* per gallon.

"As regards the effect of irrigation on the purification of sewage, the reports of the Rivers Commissioners, who have made repeated analyses of the effluent water, show that the system, properly managed, is a perfect purifier of sewage. The Royal Rivers Commissioners also investigated the matter, and took samples of purified Croydon sewage and river water for analysis, and gave the results, showing that the river Wandle at Mitcham, after receiving Croydon purified sewage, was purer than the Thames above Reading. With regard to the influence of sewerage and sewage irrigation works on public health, the evidence on this point is conclusive. At the present time the population of Croydon is close upon 60,000; the average rate of mortality, for ten years past, has been under 19 in the thousand; and—what is still more remarkable—the districts in closest contiguity with the irrigation works have had the lowest death rate."

With regard to the last paragraph in the letter, see Rep. Social Science Meeting at Bristol, Oct. 2, 1869, a paper by Dr. A. Carpenter, whence we take the following statistics. Death rate for Norwood population, about 5000, for six years:—

| | | |
|---|---|---|
| 1863 .. .. .. | 18·76 | |
| 1864 .. .. .. | 18·89 | |
| 1865 .. .. .. | 18·17 | (Sewage Farm established). |
| 1866 .. .. .. | 15·34 | |
| 1867 .. .. .. | 14·21 | |
| 1868 .. .. .. | 12·07 | |

See also 1 R. P. C., 91, as to the entire absence of smell or nuisance at the farm at Beddington; and at Barking, Tott. Rep., p. 93.

Having now concluded what is, I hope, an impartial review of the principal systems of sewage utilization that have been tried in this country, I bring this little work to a close, for it is no part of my plan to offer any further comment upon the various schemes than is necessary for properly explaining their mode of working. Some systems have necessarily occupied more of our time than others, but in every instance a reference will be found to some fuller and more detailed account than was possible in a handbook like the present. As such, I trust it may be of use in directing and assisting the labours of those sanitary reformers whose efforts are now attracting so large a share of public interest, and whose success is so ardently to be desired by all.

# APPENDIX I.

A LIST OF PLACES IN ENGLAND WHERE SEWAGE OPERATIONS HAVE BEEN CARRIED ON WHICH HAVE NOT BEEN REFERRED TO IN THE COURSE OF THE FOREGOING WORK, WITH REFERENCES TO REPORTS AND OTHER SOURCES, WHERE A FULL DESCRIPTION OF THE WORK IS TO BE FOUND.

| | |
|---|---|
| ALDERSHOT .. .. .. .. .. | 1 R. P. C., 77. |
| ASHBY-DE-LA-ZOUCH .. .. | 2 S. U. C., Appendix VII., pp. 75–87. |
| BANBURY .. .. .. .. | 1 R. P. C., 80. |
| BARKING .. .. .. .. | 1 R. P. C., 75. |
| BEDFORD .. .. .. .. | 1 R. P. C., 83. |
| BILSTON .. .. .. .. | 2 S. U. C., pp. 75–87. |
| BIRMINGHAM .. .. .. .. | Ditto, and Birmingham Report, 1871. |
| BURY .. .. .. .. .. .. | Report of British Association, 1870, pp. 49–72. |
| CAMBRIDGE .. .. .. .. | Ditto. |
| CARLISLE .. .. .. .. | 1 R. P. C., 78. |
| CHELMSFORD .. .. .. .. | 2 S. U. C., pp. 75–87. |
| CHELTENHAM .. .. .. | Ditto. |
| CLIFTON .. .. .. .. | Ditto. |
| COVENTRY .. .. .. .. | Ditto. |
| ELY .. .. .. .. .. .. | Ditto. |
| LEICESTER .. .. .. .. | Ditto. |
| LEITH .. .. .. .. .. .. | 3 S. U. C., Appendix V. |
| LUTON .. .. .. .. .. .. | 2 S. U. C., pp. 75–87. |
| NORWOOD .. .. .. .. | 1 R. P. C., 85. |
| PENRITH .. .. .. .. | 1 R. P. C., 79. |
| PLYMOUTH .. .. .. .. | 2 S. U. C., pp. 75–87. |
| PRESTON .. .. .. .. | Duthie, Utilization of Sewage, pp. 31–39. |
| ROMFORD (Breton's farm) .. | Report of British Association, 1870, pp. 49–72. |
| RUGBY .. .. .. .. .. .. | 1 R. P. C., 79, and 2 S. U. C., pp. 75–87 |
| STROUD .. .. .. .. .. .. | 2 S. U. C., pp. 75–87. |
| UXBRIDGE .. .. .. .. | Ditto. |
| WARWICK .. .. .. .. | 1 R. P. C., 82. |
| WOKING .. .. .. .. .. | 1 R. P. C., 89. |
| WORKSOP .. .. .. .. | 2 S. U. C., pp. 75–87. |
| WORTHING .. .. .. .. | 1 R. P. C., 82. |

# APPENDIX II.

## SMOKE DRAINAGE.

A VERY interesting little pamphlet was published at Manchester in the year 1857, by Mr. Peter Spence, entitled 'Coal, Smoke, and Sewage.' The system advocated by Mr. Spence was brought into public notice by some letters which appeared in 'The Times,' 'Pall Mall Gazette,' and 'Daily News' during the month of December, 1871, upon the advisability of carrying the smoke from our house fires through the drains, with a view of both deodorizing the sewage and purifying the atmosphere of our great towns. It appears that the amount of ammonia produced and wasted by being thrown into the atmosphere in the burning of coal is something enormous. Mr. Spence (p. 30) considers 22 lbs. of ammonia for every ton of coal consumed a very low estimate; and, taking 2,000,000 tons of coal as the quantity annually consumed at Manchester, we have nearly 20,000 tons of sulphate of ammonia, which would be deposited in the smoke drains. As the value of this sulphate of ammonia for manure is at present about 20*l.* per ton, some idea may be formed of the value of this deposit, and Mr. Spence's figures show the most golden results. There would be no doubt a very great difficulty in adopting any system of smoke drainage in some of our large towns; in fact, a complete revolution would have to be worked in our house and street architecture, but if only half the practical advantages dilated upon by Mr. Spence could be guaranteed to any town willing to undergo the process of transformation, I am sure all would willingly submit to a vast amount of preliminary annoyance for the sake of the new life and health to be obtained

# APPENDIX III.

### MR. BAZALGETTE'S PROPOSED SYSTEM.

As to Mr. Bazalgette's great scheme for purifying the Thames between London and Windsor from sewage, a very imperfect notion is all that can be given at present. A few years ago, various Acts were passed to prevent the pollution of the water by allowing sewage to flow direct into the river, and the Royal Commissioners of Water Supply, in their Report of 1869, recommended the Thames as one of the permanent sources of the water supply of the metropolis. It seems that since the passing of the various Thames Navigation Acts, the inhabitants of the town and villages of the valley of the Thames have experienced great difficulty in disposing of their sewage, or rather that no system of sewage utilization has met with sufficient favour in their various localities as to lead to its permanent adoption: and in order to carry away the united bulk of the sewage to a place where it may be conveniently and safely dealt with, Mr. Bazalgette, the chief engineer of the Metropolitan Board of Works, has devised a scheme which is to be submitted to the consideration of Parliament this session. It would be idle to criticize a scheme of which we know so little; but it certainly appears to be bold and comprehensive, and we hope it may be satisfactorily worked out. The area to be dealt with consists of about 100 square miles, containing a population of over 300,000 persons. Mr. Bazalgette proposes, in the first place, to purchase and adapt about 3000 acres of almost uncultivated land, between Woking and Bagshot, which it appears may be obtained for a comparatively small sum of money. To this tract of land it is proposed to apply the sewage much upon the same principle as that at present in successful operation at Croydon [see *ante*, p. 46], and of which no further mention need be made in this place. The sewage would be conveyed by natural gravity from Acton, Chiswick, Ealing, Hanwell, Brentford, Isleworth, Barnes, Mortlake, Kew, Richmond, Twickenham, Mitcham, Merton, Malden, Morden, Wimbledon, Teddington, Kingston, Hampton, Esher, Thames Ditton, Moulsey, Walton, and Weybridge, TO HAMPTON, where it would be conveyed by powerful pumping engines, and again flow by gravity till it arrived at Chertsey, receiving on its route the drainage from Southall, Norwood, Heston, Hounslow, Sunbury, Hunworth, Laleham, and Shepperton. Other main sewers, commencing at Eton and Windsor, would bring the drainage from Windsor, Datchet, Horton, Old Windsor, Colebrook, Egham, and Staines, also by gravity alone, TO CHERTSEY, where a regulating reservoir would be formed, and where a second pumping station would raise the united volume to a reservoir at the head of the proposed sewage farm, on, to, and over which the entire sewage would ultimately flow. The total cost of this gigantic combination is estimated by Mr. Bazalgette at less than 700,000*l*. Owing to the prohibition against the mixing of storm water in the sewage, the rainfall, except in particular instances, would be excluded from the local sewers. To carry out this plan, says 'The Times' (February 1, 1872), a Board of Commissioners elected by the parishes interested, and invested with all necessary powers, is proposed. The promoters allege that the scheme would answer two ends—relief from the penalties of the Thames Navigation Acts, and a cheap and effectual mode of disposing of sewage at a distance. The cost is such as to compare favourably with that of other plans, and would be rapidly reduced, and ultimately extinguished, leaving a large profit to the credit of the ratepayer.

# APPENDIX IV.

## ON THE LAW CONNECTED WITH THE UTILIZATION OF SEWAGE.

Up to the year 1865, sewage operations could only be carried on in towns or parishes in which the Public Health and Local Government Acts had been adopted; and previous to 1867, all sewage operations in towns or districts where those Acts had been adopted could only be carried on under the provisions and in the manner prescribed by them. The Sewage Utilization Act of 1867 [30 and 31 Vic., c. 113] at present enables all parishes or districts to carry on the necessary operations for the removal and utilization of their sewage without adopting the Public Health Acts of 1848 and 1858, which in some places may for various reasons be considered undesirable.

Sewage operations may now therefore be carried on both in places where the Public Health and Local Government Acts have been adopted, under the provisions and in the manner prescribed by those Acts, modified and enlarged by the Sewage Utilization Acts of 1865 and 1867; and in places where the Public Health and Local Government Acts have not been adopted, by virtue of the Acts of 1865 and 1867 alone. In each case, of course, the powers and provisions are modified and controlled by subsequent legislation.

It would be out of place at present to do more than indicate the Acts of Parliament to which reference must be made by all who seek to learn how far and in what direction they may go in their sewage utilization operations; and the present law upon the subject will be found touched upon in

Glen's 'Laws relating to Public Health and Local Government, 1869;' 'The New Sanitary Laws, 1871,' by W. G. and E. Lumley; 'The Sanitary Acts,' by W. H. Michael, and other books.

It may be added that a thorough reform in the law connected with this subject is anticipated this session of Parliament, to say nothing of Mr. Stansfeld's Bill for establishing a local authority for sanitary matters in every parish or district. Pending further legislation, therefore, we have restricted our remarks on the present law to these few words.

Some of the most recent cases of interest connected with sewage operations are: Brown, App., Russell, Resp., and Francomb, App., Freeman, Resp., L. R., 3 Q. B. 251 (as to nuisance); Lord Derby *v.* Bury Improvement Commissioners, L. R., 3 Ex., 121 (ditto); Goldsmid *v.* Tunbridge Wells Improvement Commissioners, L. R., 1 Eq., 161 (injunction): on appeal, L. R., 1 Ch., App. 349; Crossley *v.* Lightowler, L. R., 3 Eq., 279 (pollution of river); on appeal, 2 Ch. Ap. 478.

# APPENDIX V.

## HILLE'S PROCESS.

In Hille's process, which has been tried with great success at Wimbledon, the sewage is treated with lime, tar, salts of magnesium, and the products arising from the calcination of the lime, and by other chemicals, according to locality. The effluent water is afterwards filtered on the downward intermittent principle (*ante*, p. 31); the results thus obtained have been found to reach the standard of purity required by the Thames Conservancy, and also that mentioned in the Reports of the Rivers Pollution Commission (*ante*, p. 7).

The disinfecting compound is applied to ordinary town sewage in the proportion of about 1 in 1000 of sewage, as it flows into the works.

The thorough amalgamation of the chemical compound and the sewage here takes place, after which the whole is allowed to accumulate in the deposit tanks, where nearly the whole of the suspended matters are deposited, together with a considerable quantity of the various matters held in solution.

After the sewage water has risen to a height of two-thirds of the total depth of the deposit tank, the liquid is drawn off by means of a floating outlet through a regulating valve. This outlet is formed of strong galvanized wire, the interior of cage being filled with vegetable charcoal.

The maximum speed of filtration is at the rate of one gallon to each superficial yard of filter, which is so designed that the filtering materials have time for thorough and complete aëration.

Into the filtered effluent water carbonic acid gas is forced, and complete purification takes place. This gas is a waste product of the lime which is burned on the premises.

The outlet chamber is provided with a second floating outlet with a governor regulating valve. The water is then in such condition as to be admissible into rivers.

The works, and everything connected therewith, are in duplicate, and may be used alternatively.

The deposited sewage residue is removed daily from the tanks, through valves, into a tunnel constructed in the divisional wall, and raised by the steam-engine into the hydro-extractors ; from thence the semi-dried sewage is placed on a drying-kiln, the gases evolved being drawn off and consumed in the boiler's furnace.

It is contended that the whole process can be worked without the least nuisance, and that the works may be constructed in populated parts of towns without injury to the health of the inhabitants.

The value of the sewage precipitate will vary in different districts, but it is calculated to realize on an average 26*s.* per ton in its raw state.

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