SEWAGE UTILIZATION

BY

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Presented by the Publishers
to the Parkes Museum of Hygiene

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at-Law. "A Handbook
of Sewage Utilization."
Presented by E. & F. N. Spon

A

HANDBOOK

OF

SEWAGE UTILIZATION.

BY

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Second Edition.

REVISED AND ENLARGED.

LONDON:

E. & F. N. SPON, 48, CHARING CROSS.

NEW YORK:

446, BROOME STREET.

1873.

LONDON: PRINTED BY W. CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.

PREFACE TO SECOND EDITION.

In thanking the Public and the critics for the favour which has necessitated the preparation of a new edition of this little Handbook, I would say a few words with regard to a fault, and as far as I know the only one, that has been found with my work,—that it is not long enough. My original idea in compiling a 'Handbook of Sewage Utilization,' was to bring out a book which, laying claim to no literary merits, should as far as possible be all information. Nothing was further from my intention than to produce an exhaustive treatise on the subject, although the amount of reading which I had devoted to the preparation of the work might possibly have enabled me to do so; but my little book only laid claim to being a Handbook, and in some sort an *Index* to much that had already been written upon the subject. In the present edition I have been able to add a considerable amount of new matter, and to modify in some instances remarks that I had made with reference to certain systems; but I have endeavoured to preserve strictly the original character of the work, both as regards brevity and impartiality.

1, King's Bench Walk, Temple,
June, 1873.

PREFACE TO FIRST EDITION.

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An impartial review and comparison 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, 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.

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.*
3rd ditto, ditto, 1871, *ditto*	3 *R. P. C.*
4th ditto, ditto, 1872, *ditto*	4 *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.*
Report of the Sewage Inquiry Committee, presented to the Council of the Borough of Birmingham, October, 1871, *referred to as*	*Birm. Rep.*

INTRODUCTION.

While few questions are of greater interest and greater importance at the present day than that of the proper distribution of the sewage of our towns, few are more beset with difficulties of every kind. That any question, which has for so many years defied alike the researches of science and the experiments of practical men, must be intrinsically and essentially difficult of solution, is almost self-evident; but the study of the subject under our consideration is further complicated and retarded by two artificial difficulties: the prevalence of party spirit and the fallacy of statistics. As regards the first of these two stumbling-blocks, a well-known sanitary reformer once said to us that he only knew one topic besides polemics upon which men's party spirit got the better of their good sense, and even of their regard for truth and justice, and that was the treatment of sewage. An out-and-out irrigationist would go to the stake in support of his views, and would hardly even use an A B C dispatch box, while the advocates of the various "systems" are equally bigoted in their own way, and consider all those who differ from them as quite outside the pale of sanitary or scientific consideration. This excessive orthodoxy has the same effect in sewage matters as it has in religious, and naturally tends to make men narrow-minded and illiberal, and incapable of taking a broad and impartial view of distasteful and especially of novel themes.

As to the fallacy of statistics, using the expression generally, a good deal of the evil may be laid to the score of the moral aberration consequent upon this sewage "bigotry" to which we have just alluded; and as almost all books or pamphlets upon the subject of sewage utilization are written by partisans with the avowed object of ventilating and lauding their own pet system, we find the most hopelessly confusing discrepancies in all values and quantities which should be but the data and not the deduction of the various authors. A manure will be spoken of by one writer as worth 3*l.* 17*s.* 9½*d.* per ton, while another values it at 8*s.* 11¼*d.*; and when we have seen it carefully proved by the most accurate statistics that a certain deposit is not even worth its carriage for more than two or three miles from the place of its production, we find in the next *brochure* we take up that the farmers all over England cannot get enough of it at 5*l.* per ton! This is bad enough, but it is absolutely impossible for anyone who has not the most accurate knowledge of the prices of the commonest substance which can in any way be brought to bear upon Sewage Utilization, to carry away any but the most confused notions after a course of sanitary study. Clay, charcoal, alum, coal, wood, ammonia, lime, and every conceivable substance, animal, vegetable, and mineral, are gravely valued at prices so ridiculously different that it can only be assumed that everyone must estimate them at either four times or one-fourth of their actual value, according to his views or predilections. Again, one high authority, whose reputation entitles his opinion to the greatest respect, tells us that irrigation pollutes not only the land but the surrounding atmosphere, and that the neighbourhood of a sewage farm must necessarily be extremely unhealthy. This seems simple enough to understand until we come to read the statistics, which prove that not only has the death-rate *decreased* in a prodigious ratio since the year when the sewage farm was established, but that the immediate neighbourhood of the land under irrigation is the favourite resort of those who desire pure air! But these discrepancies are as nothing compared with those to be found in the purely chemical statistics. One would think that when we had reached the region of pure science a calm voice would speak from the laboratory in the unprejudiced tones of perfect accuracy; yet it is precisely here that the earnest student becomes utterly and hopelessly bewildered. Professor A analyzes a gallon of water, finds it contains three grains of nitrogen, and pronounces it unfit for drinking. Professor B analyzes a gallon of the same water, finds but one grain of nitrogen, and asserts that even if there were three grains of nitrogen in the gallon, which there are not, the water would be perfectly innocuous, and even possibly superior to water not so fortified. The presence of *nitrates*, again, is by some considered to indicate a deadly amount of previous sewage contamination; others consider this opinion to be of a highly "sensational" character, and in no way warranted by science. Perfectly pure water, we are told, on the highest authority, is unfit for human consumption, while, on the other hand, we learn that the smallest trace of impurity may involve a whole district in cholera or typhoid fever.

There can be no doubt that too much caution can hardly be used in dealing with any water that has at any time been contaminated with sewage matter; nor too high a standard of purity demanded from those who profess to purify the contents of our sewers, and discharge the effluent water into our streams and rivers. But it is absurd to place too blind a reliance upon statistics, or to act without the exercise of common sense and practical observation. There is one thing especially in which we think the dogmas of science have led astray the most honest and impartial investigation, and that is the undue importance that has been attached to the presence of certain constituents in sewage manure. For example, in No. XV. of the '*Royal Agricultural Society's*

Journal,' published in the spring of the year 1872, Dr. Voelcker has a paper on the "Earth-Closet System of Mr. Moule," in which he gives it as his opinion, based upon analysis, that the earth-closet manure is of such trifling value as to render the adoption of the system, of which he highly approves in almost all other respects, undesirable. This paper induced Mr. Moule to publish a pamphlet in reply—(*Town Refuse the Remedy for Local Taxation*)—in which he lays claim to a much more extended sphere of operations with the dry-earth system than the mere closet, and proposes to absorb all the refuse liquid and solid of our larger towns (utilizing for that purpose all that now finds its way into the ashpits) in the preparation of the manure. With regard to the value, he sets *experience* against *analysis*, and proves his case conclusively, by references to numerous most carefully conducted experiments, and to the independent testimony of over a hundred agriculturists who, after some years' actual experience, report deliberately and most favourably upon the utilizing power of earth-closet manure. There can be no doubt, indeed, that the earth-closet manure possesses a very high agricultural value. It appears to us that analytical chemists have rather overshot the mark in professing to determine the precise manure value of any preparation merely by the amount of ammonia and phosphates which they may be able to find in it. Admitting the immense importance of the presence of these two agents in any manure, can analysis be certain of discovering them, in whatever form they may be? And again, is the general character of the whole a matter to be taken into no account? The hardness or the softness, the fineness or the coarseness, of the manure under analysis, the very form in which the valuable ingredients are found, appear to be lost sight of by these closet agriculturists, who put blind confidence in their *fetisch* of ammonia and phosphates, and condemn manures whose practical value has been proved by a thousand experiments. On this point Mr. Moule has the following :—"From a very little consideration of the infinitesimal minuteness to which, before they can be absorbed into the sap vessel, the nutritious particles of any manure must of necessity be reduced, it will readily be perceived that the aggregate amount of such nutritious particles requisite for the healthy growth of a given plant or of a given crop must, in its actual and immediate application, be very small indeed. It may fairly, I think, be asked here, in immediate relation to the value of manures, has the analytical chemist ever calculated how small the needful supply for a healthy plant or a healthy crop may be? and when ammonia or silex or phosphate has by digestion and assimilation been reduced to that infinitesimal minuteness requisite for absorption into the *radix* does his science enable him to detect it?"

It appears to us that the solution of the whole question lies in the consideration of the profound differences which may result from the different *conditions* in which any substance may occur. "The water," says Professor Lewes, "which will allay our burning thirst, augments it when congealed into snow. . . . . We know that a change in the condition will cause a change in the manifestation of a force, so that often what ordinarily takes place in the laboratory will not take place in the organism. . . . . The physiological question is not 'What are the chemical constituents of nutritive substances?' *it is*, 'What are the substances which will nourish the organism?'"—(*Physiology of Common Life*, i., 115.)

A chemist might manufacture a substance which should be similar under analysis to roast beef, yet this chemical roast beef would not support life; and the nourishment of plants is not of so entirely different a character from the nourishment of the body as to render the "digestibility," so to speak, or the condition under which nutritive substances are presented to the plant, matters of no moment; and it is evident that these favourable or unfavourable conditions can only be learnt from experience.

In fact, the nitrogen hobby has been already ridden to death in the matter of human food: at one time *beans* were put down as two and a half times as nourishing as *wheat* because they contain two and a half times as much nitrogen; but the experience of mankind taught them to prefer bread to beans, and to laugh at Liebig. It is surely but reasonable to allow the plants as well as the men the benefit of experience in the choice of their food, and to consider any particular plant-food or manure as valuable as far as it is *found to nourish the plant*, and not only as far as it satisfies some abstract scientific standard. If chemistry can find no nutritive element in a manure which experience has proved to be nutritious, chemistry is at fault; and the sooner it is admitted, the sooner are we likely to arrive at a proper understanding of the whole question.

Admitting that it is extremely difficult to obtain any exact information with regard to the utilization of sewage, there is at least one point which we must insist upon as one which we think should never under any circumstances be lost sight of, and that is the value of the sewage as a manure. This has been ignored by so many reformers and disregarded to a greater or less degree in so many "systems," that we think it necessary to call attention to the enormous value of the human manure that is annually wasted in this country, and of that which is annually imported or manufactured to attempt in some measure to supply its place, and prevent the soil, which has been robbed of so many of its most valuable constituents without any return, from refusing any longer to feed its thriftless population. Everyone knows what an important part is played by the live stock on any farm in manuring and fertilizing the land, and the farmer would justly be reckoned either fraudulent or insane who allowed the dung of his stock to go to waste instead of applying it to the land; and yet this is precisely what we are doing in England on a gigantic scale with the manure supplied by the most highly-fed class of live stock in the country—mankind.

In order to counteract the fatal results of this waste, an enormous amount of manure is both imported and manufactured artificially at great expense, and in the case of the artificial manures the result is usually rather advantageous to the pockets of the manufacturer than those of the cultivator. Indeed, the number of artificial manure companies paying large dividends, as well as the immense fortunes realized by so many private manufacturers, has almost passed into a proverb, and is perhaps the best index to the enormous demand for artificial manure in this country, even although a great proportion is known to be adulterated almost to the point of worthlessness.

The most valuable of the imported manures, when it is imported at all, and not "home-made," is, no doubt, the guano; and in spite of the amount of adulteration and the large sale of worthless imitations, a prodigious amount of genuine guano is annually imported into England from Peru and other islands. So great, indeed, has been the consumption of late years that the government of Peru has been alarmed, and from the results of an official survey made of the guano beds we learn that the supply of the best and richest deposit will be exhausted in a very few years. Some new beds have been discovered, but the guano is inferior in quality to that of the Chincha Islands, whence the best manure has always hitherto been brought; and the supply even from these newly-discovered deposits cannot last at the utmost for more than ten years to come.

In fact, we read in the 'Evening Standard,' June 27, 1872.

The reports about new discoveries of immense deposits of guano on the coasts of Peru are exaggerated. Should no new deposits be discovered the present stocks will not last more than four years.—[Dispatch *per* 'Tasmanian.']

As to the value of human excrement as a manure, Thorwirth, in his "Canalisirung grosser Städte," says, speaking of China, "We cannot but be surprised, on comparing the mournful experience of European states and the exhaustion of their soil with this over-populated empire, which, cut off as it was during thousands of years from all intercourse with other nations, and consequently from all importations of foreign breadstuff, always produced its own food, and yet preserved the fertility of its soil. The only explanation to be given is that the Chinese, like the Japanese, by observation and experience ever knew the high value of human excrement and human offal, and by carefully restoring both to their fields, followed the only true course to afford complete compensation to the soil and maintain its fertility unimpaired for all time."

It is computed that the application to land of the entire excrement of one person, in the form of manure, would yield an increase of over three bushels of wheat per acre, worth, say, about twenty shillings. From this computation we may easily see how gigantic is the annual loss of food to the country in consequence of the systematic waste throughout England of the sewage manure.

The statistics on this head, as they must necessarily be common to all systems, as indeed being, so to speak, their starting point, are much more satisfactory than those connected with any other branch of the subject; and yet there is a considerable difference in the various estimates of the annual average value as a manure of the excrement of every man, woman, and child of the population of this country, for while some analysts compute it at but 6*s*. 8*d*., others (Liebig for instance) put it as high as 12*s.* 6*d.* About 8*s.* 6*d.*, however, as a fair mean between these two extremes, and also as coinciding with the value arrived at by one of the most justly celebrated of our analysts, may be accepted as about the real value. Now, considering that the population of Great Britain amounts to nearly thirty-five millions of human beings, we find that the value of the human manure annually produced in this country amounts to no less than 15,000,000*l.* And yet, until a very few years ago, all this was unblushingly and systematically thrown into the sea, after having duly polluted our rivers and watercourses, and carried sickness and death along the banks of every stream.

And this brings us to what everyone must consider the most important aspect of the subject—the influence of the present mode of disposing of our sewage upon the public health. And upon this point there can be no doubt that nothing can possibly be worse than our present arrangements. A great authority gave it as his deliberate opinion last year that upwards of forty thousand deaths occurred annually in England from what he called "preventible diseases"—or diseases mostly of a low fever or typhoid character, whose origin can be clearly traced to preventible causes—the poisoning of the air and water by the improper and defective means adopted for the disposal of our town refuse. This fearful loss of life casts a great responsibility upon our governors, whether local or imperial; and should awake the attention and interest of every thinking man. That educated men should be found to sneer at the efforts of sanitary reformers, and to speak of a "policy of sewage" in any other terms than those of respect, if not of admiration, passes our comprehension. That the diseases can be clearly traced to the causes assigned is capable of the most conclusive and satisfactory proof, and it is only doubtful whether drinking impure water or breathing impure air is the more actively deleterious. Volumes might be filled with extracts from reports and opinions of medical men as to the direct influence of sewage pollution on the health of the people, but we think that every well-informed member of society is by this time aware of this great fact of modern civilization, even though everyone may not be alive to the extent and complications of the evil. The commissioners appointed to inquire into the best mode of dealing with town sewage, in their second Report, tell us that the South London districts (comprising nearly a fifth of the entire population of the metropolis) have been notorious for the great severity with which cholera has visited them on each occasion of its epidemic prevalence in England. During the last invasion these districts were accidentally the seat of a gigantic sanitary experiment; and a difference in one sanitary condition was seen to influence most remarkably the distribution of the cholera-mortality. For throughout those districts during the epidemic of 1853–4 there were distributed two different qualities of water; so that one large population was drinking a tolerably good water, another large population an exceedingly foul water; while in all other respects these two populations (being intermixed in the same districts, and even in the same streets of these districts) were living under precisely similar social and sanitary circumstances. And when, at the end of the epidemic period, the death rates of these populations were compared, it was found that the cholera-mortality in the houses supplied by the bad water had been three and a half times greater than in the houses supplied by the better water. This proof of the fatal influence of foul water was rendered still stronger by reference to what had occurred in the epidemic of 1848–9; for on that occasion the circumstances of the two populations were to some extent reversed. That company which, during the latter epidemic, gave the better water, had given, during the earlier epidemic, even a worse water than its rival's; and the population supplied by it had at that time suffered a proportionate cholera-mortality. So that the consequence of an improvement made by this water company in the interval between the two epidemics was, that whereas, in the epidemic of 1848–9, there had died 1825 of their tenants, there died in the epidemic 1853–4 only 611; while among the tenants of the rival company (whose supply between the two epidemics had become worse instead of better) the deaths, which in 1848–9 were 2880, had in 1853–4 increased to 3476. And when these numbers are made proportionate to the populations or tenantries concerned in the two periods respectively, it is found that the cholera death rates per 10,000 tenants of the companies were about as follows:—For those who, in 1848–9, drank the worse water, 125; for their neighbours, who, in the same epidemic, drank a water somewhat less impure, 118; for those who, in 1853–4, drank the worst water which had been supplied, 130; for those who, in this epidemic, drank a comparatively clean water, 37.

The quality of water which (as illustrated in the first three of these numbers) has produced such fatal results in the metropolis—causing two-thirds of the cholera deaths in those parts of London which have most severely suffered from the disease—has been river water, polluted with town drainage; water pumped from the Thames, within range of the sewage of London; water which, according to the concurrent testimony of chemical and microscopical observers, was abundantly charged with matters in course of putrifactive change.

But, as in too many other cases, it is the "indirect damage" that is the greatest and the most to be deplored. A large death-rate is as nothing compared with the enervation and deterioration of the survivors; and is the less to be dreaded, as by calling attention of itself to the evil it paves the way to a reform. The evidence of those medical men who have devoted their attention to this part of the subject is perfectly appalling.

Speaking of the inhabitants of Manchester, who are exposed to the sewage *malaria*, Dr. Southwold Smith says ('Second Report of Sewage of Towns Commission,' p. 46):—

"They do not appear to be labouring under any particular form of active disease, but their general aspect indicates a depression and want of energy. When questioned as to their state of health, they very commonly answer, 'Cannot complain much,' 'Not in very good health, but not to say ill.' 'Feel very poorly, but have had no serious illness.' Many look prematurely old, and of those who have chanced to come under personal examination, a very large number were found to be labouring under an enfeebled or positively disordered state of the nutritive organs—a dangerous condition of health, in which the power to resist the ordinary causes of disease, such, for example, as the severer atmospheric changes, is diminished; in which the susceptibility to the extraordinary causes of disease, as epidemics in all their forms, is increased, in which the production of healthy offspring, the long retention of the ability to labour, and the attainment of long life are impossible."

This is bad enough, but there is another, and perhaps the greatest evil, of English social life—drunkenness, which springs in but too many instances from our defective sanitary arrangements. Nothing predisposes a man so much to indulgence in ardent spirits as the low state of bodily health, and the deficiency of animal spirits engendered by drinking impure water and breathing foul air; and this is no vision of a sanitary enthusiast, no exaggeration of the riders of sanitary hobbies; it is the calm and deliberate opinion of some of our most respected and experienced medical men. Let us turn from these distressing considerations to see what can be done to alleviate so much suffering.

We have complained in the first page of this article of the partisan spirit by which the advocates of the various systems are actuated, and we are prepared in this place to give expression to a somewhat novel opinion, namely, that there is a great deal of good in most of the systems that have engaged public attention. They may have failed more or less, it is true, and their failure is sure to have been exaggerated by the advocates of all other systems; but in many instances the experiments have been conducted under unfavourable circumstances, and the process, even if unable alone to secure complete success, may possibly only require to be supplemented in order to render the result eminently satisfactory.

This combination of systems appears to us to be the great secret of Sewage Utilization. Hitherto, no doubt, it has been exceedingly difficult to bring about, on account of the jealousy of the proprietors of the patents, and the advocates of the various systems, but we hope that in future a more liberal view may be taken by those interested in social economy and the preservation of public health.

It has been the fashion of late with those who are too clever to look into the details of such matters, to laugh at all "systems" of sewage utilization.. "Everyone knows," say they, "that human manure is of very small value, and can never pay the cost of collection, and as to the sanitary part of the question, *education* will, no doubt, do wonders among the working classes." While such or similar reasoning goes a long way to retard practical sanitary reforms, the fact is admitted by all who have impartially studied the various statistics, that all systems of precipitation succeed in arresting a considerable portion of the valuable matter contained in the sewage; and it must be admitted, on all hands, that the collection of a large part of the solid matter in the sewage, in the form of a portable manure, is one of the greatest desiderata.

This is undoubtedly accomplished by many widely-different systems, such as the phosphate process (whose manure sells for about 4*l.* per ton), the A B C (3*l.* 10*s.*), Moule (3*l.*), Goux, and Weares'. It is true there are certain disadvantages in these systems which have led to their not being universally adopted; a great amount of effluent water has in every case to be got rid of, and this is rarely sufficiently pure to be allowed to flow into any stream from which drinking water is to be drawn.

But on the other hand, there are systems of filtration and irrigation whose success is endangered or prevented by the amount of solid matter in the sewage to be filtered, which chokes up the pores of the land, requiring continual re-oxidation, and in the case of irrigation, polluting the surface of the ground, and fouling the surrounding atmosphere with deadly gases.

Why should not the water which is unfit to be poured into the river, and although deprived of all its solid or suspended impurities, containing a very large portion of fertilizing ingredients, be passed through a charcoal filter, or used for irrigating the neighbouring meadows? Or, again, the solid matter might be intercepted at a still earlier stage by the use of earth or charcoal closets, leaving only the "house slops," and possibly the surface-water to flow into the drain?

Above all, the system, or combination of systems, to be adopted must depend upon the place in which they are to be used, and nothing can be more absurd than to expect to discover a sort of sanitary philosopher's stone in the shape of some one system of transcendant merit which is at once to solve the question, to become a panacea for every sanitary ill, and to be adopted with equal advantage in every town throughout the land. If we were to set to work quietly to utilize our present experience instead of seeking for what we are never likely to find, we might do more towards bettering our condition than we have at present accomplished. That the same system should succeed on the top of a hill or in a valley, in a large city or a small village, or a sandy plain or in a rocky or mountainous country, is too much to expect of anything on this side of the grave. Suffice it, then, to sum up in conclusion.

The object of any system of sewage disposition must be threefold: (1) the extraction of as much of the valuable constituents of the sewage as possible; (2) the perfect defæcation of the sewage during treatment; and (3) the securing of a pure effluent water in the end. We have never yet seen any single system which accomplished all these ends to a satisfactory extent; but we have no doubt that a judicious combination can bring about the object desired.

In country houses, public institutions, prisons, and in very small towns, we would recommend the interception of the solid fæcal matter *ab initio*, by means of Moule's earth closets; or in case that charcoal can be procured at a very moderate cost, of Weares' charcoal closets. In either of these cases the house slops must be disposed of by distribution over the cottage gardens, or neighbouring fields and paddocks, being collected in the first instance in barrels or cisterns, as far as convenient from the dwelling-house, and emptied every day.

But, as a general rule, we would recommend the adoption of a system of precipitation, or General Scott's process, in COMBINATION with a system of irrigation in places where the natural circumstances (a proper fall, suitable land, &c.) are favourable, or in other cases with charcoal filtration. The more the subject is impartially studied, the more apparent will it be that the true secret of success is to be found in COMBINATION.

A HANDBOOK

OF

SEWAGE UTILIZATION.

I.—NATURE OF THE EVIL.

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 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, *Report of the Royal Commission on Water Supply*, 1869, pp. 73–94. *Evidence of Mr. Simon, Minutes of Evidence*, p. 167; and that of *Drs. E. Parkes, Farr, Letheby, Brodie, Frankland*, and other celebrated analysts].

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*, 'Progress of Sanitary Science,' 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, Professor *Roscoe's* 'Progress of Sanitary Science,' pp. 123–8, and *Birm. Rep.*, pp. 131–150. 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 may be interesting to compare this with the standard of purity required by the Thames Conservancy Board, so frequently referred to in all questions as to the admissibility of any water into running streams.

1. That the effluent water will be perfectly free from offensive odour.

2. It shall not contain more than 3 grains to the gallon of suspended matter, and shall not exhibit by daylight a distinct opacity when a stratum of it 1 inch deep is placed in a white porcelain vessel.

3. It shall not be more acid than 1 of muriatic acid in 1000 of water, nor more alkaline than 1 of dry caustic soda in a like quantity of water.

4. It shall not contain more than 70 grains of solid matter to the gallon when dried at 260° Fahrenheit.

5. It shall not contain more than 2 grains of organic carbon to the gallon.

6. Nor more than $\frac{3}{4}$ths of a grain of organic nitrogen.

7. When exposed for 6 hours mixed with a quantity of river water which, in relation to the effluent water, shall be in the same proportion as the quantity flowing into the river is to the quantity of effluent water from the sewers, 1 grain of organic carbon and 1 half grain of organic nitrogen per gallon shall be considered as innocuous matter.

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 that 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 might take a lesson from 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. See also *Corfield*, 'Utilization of Sewage,' p. 290.

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 ordinary privy and ash-pit system is the commonest example. There are not wanting advocates even at the present day for this well-known nuisance, and although the filthy and pestilential "middens" are universally condemned, the "privy," with various modifications, has been preferred—most unfortunately as we think—to the water-closet, at Manchester, Rochdale, Halifax, Leeds, Nottingham, Stamford, Hull, Birmingham, and other towns. [V. *Birmingham Report*, 1871, pp. 11–13.] At Manchester the privy is so contrived that ashes can be emptied only through the seat, which is capable of being raised for this purpose. At Rochdale receptacles containing disinfecting fluid are placed under the privy seat and removed weekly in covered carts. For a full description of the Manchester and Rochdale privies, see *Birm. Rep.*, pp. 25–28 and App. xii. At Birmingham the desire to reduce the volume of sewage has led to the adoption of a privy system and a tax on water-closets. [V. *Birm. Rep.*, pp. 37–42.]

According to Professor Corfield, the best form of midden-closet is that in use at Hull. ['Sewage Utilization,' p. 32.]

For an account of *Fosses mobiles*, the various modifications of the "midden" and "cesspool" systems adopted in various continental towns (especially Paris and Brussels) see *Corfield op. cit.*, pp. 35–45 and 54–62; *Krepps*, 'The Sewage Question,' pp. 81–111; but as we have never heard it suggested that any of these continental systems (except possibly Liernur's, on which see *post*, p. 24) could be advantageously adopted in this country, it would be superfluous to give any detailed account of them in a work like the present.

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.

The argument of the R. P. Commissioners [1 *R. P. C.*, 30], that the abolition of water-closets diminishes but to a very slight extent the sewage pollution, appears to be founded on the supposition that the privies must allow not only all the liquid excrement [30], but even some of the solid [27], to find its way into the sewers. This was no doubt the case in the old-fashioned privies; but nothing can be so fallacious as to make use of this argument, and the elaborate Tables [28, 29] of the relative amount of polluting matter in the sewage of "midden" and "water-closet" towns, whereas in only one instance (Broadmoor Asylum) earth-closets were even "partially used." In all other instances, of course, the old-fashioned privies, which no doubt polluted the drains, were established. It is perfectly evident that in the case of earth or charcoal closets nothing of this kind can take place; and we very much regret that no statistics are to be had of the relative strength and volume of sewage in places where water-closets are in use, and that in which *dry* closets have been adopted. In the latter case only the "house slops," containing, no doubt, a large amount of urine, would find their way into the drains. And, although we readily admit that such polluting matter, however much diluted in the surface water, should not be allowed to flow into any stream or river, it is evident that the difficulty of treating the sewage at the outlet would be greatly diminished, as not only the strength, but the volume, would be considerably lessened; for not only would the amount of water otherwise required for water-closet purposes be saved by the consumers, and kept out of the sewers, but the sewers themselves would rarely, if ever, require flushing. Even supposing, in spite of obligatory sink-traps, a certain amount of solid foreign substances found their way into the drains with the house slops—and no system is worth anything which depends in any degree upon the carefulness of servants—yet the house water (and surface water, if allowed to run into the sewer) would be quite sufficient to carry everything down to the outlet. It is the greasy and highly tenacious nature of the fæces which renders it so difficult to cleanse any drain or sewer in communication with a water-closet; and in any system which only allowed the liquid refuse to pass into the sewers, this great difficulty would of course be entirely obviated.

The statement made by the R. P. Commissioners that the volume of sewage is only less in the proportion of 10 to 11 in midden than in water-closet towns is, of course, based upon the same assumption as that to which we have just referred (p. 13), with regard to the *extent* of the pollution. [On the subject of water-closets in general, especially as to the supply of water, the "trough" closet, "tumbler" closet, &c., a great deal of valuable information will be found collected in *Corfield's* 'Sewage Utilization,' pp. 105–125.]

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), and are further referred to the Transactions of the Institution of Engineers in Scotland, vol. x., in which is printed a paper by a Mr. Hoey, of Glasgow, on the best means of economizing the water in water-closets.

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 2 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, and First Rep. Health of Towns Commissioners (1844), pp. 405–6, &c.]

Goux's system is similar in principle to the *Eureka*, differing chiefly in that the box or tub is lined with absorbents in order to preserve the fæces in a dry state. The final treatment is also somewhat different: but the manure manufactured is equally feeble and perfectly inoffensive. The system has been adopted at Halifax, Bradford, and Wakefield.

We add a description of the working of a "Patent Sanitary Closet," proposed by Mr. Goux as an improvement upon his ordinary "absorbing" privy :—

"By the use of these patent closets, the objections raised against dry closets in general are entirely obviated and done away with. They not only screen from the sight the contents of the tub placed under the seat, but they actually absorb and completely deodorize all the gases, which, under the best conditions, still escape from other dry closets—a thick dust of disinfecting powder being spread evenly over every motion, from a box which is so placed under the seat that it constantly covers the contents of the container, and thereby intercepts all emanations which might arise from under. The mechanism is self-acting, totally independent of the action of the occupier, and so simple that there is hardly a possibility of its getting out of order.

"This closet may be used for one or even two weeks without removal; the only care required is to refill the box with any kind of disinfecting powder. About two ounces of powder being used at each motion, one hundredweight would suffice for nearly one year for three persons."

In the *Goux* system the absorbents that line the container taking up all the liquid, a very small quantity of powder suffices to cover the solid portion that remains. No other dry system admits of this advantage.

When the seat is occupied, the box is removed to one side automatically, and, as soon as the weight of the person is removed from the seat, the box returns with a jerk, and the powder contained in it falls in a shower of dust, covering the droppings, and preventing effectually all emanation of gases.

The box, when full, may serve for about thirty motions. When it requires refilling, the powder is introduced through the hinged opening on the top. When the container itself is sufficiently filled, it is removed and replaced by another container prepared beforehand.

The full container should be emptied under a shed, and the contents treated in exactly the same manner as stable manure. After two or three months the produce is ready for use as manure.

The Corporation of Rochdale has adopted a system not very different in principle from *Goux's*, and of which we may advantageously give a brief description.

In 1872 the population of Rochdale was 45,000; the number of houses about 9900. The number of water-closets 300; the number of privies on the old system 2700; and the number of privies on the new system 1770.

The mode of collection is as follows: — The town is divided into six districts, and each privy numbered consecutively in a district register, so that in case of any contagious or infectious disease arising in the town, the numbers of the privies attached to the houses in which the disease exists can be communicated to the local authority, when arrangements can be made for the daily disinfection of the privies and for the isolation of the excreta.

All privies are emptied once a week, to insure which the driver of the collecting van on his return to the works gives in a list showing the number of each privy he has collected, the public thus not having to give notice for emptying, or being annoyed by privies unfit for use, the entire onus of removal resting upon the Corporation.

No emptying or filling takes place in this weekly collection, the privies being supplied at each collection with a fresh receptacle which has been well washed, and in which is placed a liquor deodorizer and disinfectant, which retards decomposition till the next removal.

The collections are made during the day, and to prevent any nuisance arising from the collecting vans when passing through the streets on their return to the works, air-tight lids are placed upon each receptacle collected. The ash and refuse tubs are also systematically emptied, being collected in open carts.

The process of manufacturing the manure is as follows:— The house refuse is tipped from the carts on to drying floors, and when thoroughly dry is passed through a riddling machine worked by steam power, which takes out the paper, shells, and vegetable refuse, and separates the cinders in two sizes from the ash, the ash being carried forward by machinery into another shed, where it is deposited ready for use, and the cinders removed and used on the works for generating steam, heating the drying floors, for the engines at the public baths, and for sale. All the saleable refuse, such as iron, &c., obtained by this riddling is disposed of, and the vegetable refuse is burnt and used in the manure.

The nightsoil or excreta, upon its arrival at the works, is emptied into a trench formed by a banking of ash which has previously been brought into the shed from the riddling machine; and ash is thrown upon the excreta as the trench is being filled. Whilst in the trench the contents are treated with sulphuric acid, to cause the evaporation of the water, and to retard the formation of ammonia. The whole mass is occasionally turned during about three weeks, when it is pulverized and bagged for sale. According to the Report published by the Corporation of Rochdale in June 1872, the objects attained by the new system are—an improved health of the people, by the town no longer being soaked with nightsoil, and by the consequent relief from the abominable exhalations arising from the decomposition of animal and vegetable matter, and the offensive system of emptying (both of which seem to have been specially arranged for spreading the maximum of disease); a power to limit the spread of infection arising from the fæces of fever and choleraic patients; a cleanly mode of removal; a reduction in the cost of erecting privies; and an ultimate saving of 1600*l.* per annum, or, in other words, the whole of the cost.

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. [As to Dr. Voelcker's estimate of the composition and agricultural value of earth-closet manure, see 'Journal of the Royal Agricultural Society,' No. XV. (1872), Article 6.]

In *Morrell's* system fine ashes have been substituted for dry earth. The advantage of having the deodorizing material necessarily on the premises is very great, not only as saving the carriage of the earth into the town, but inasmuch as dry earth is not always easily procurable in the immediate neighbourhood of a large town. Unfortunately, however, ashes are by no means as suitable for the purpose required as dry earth, requiring about three times as much material to deodorize the excrement, and retaining a smaller proportion of the ammonia. It will thus be seen that while the amount to be carried out of the town is trebled, the value of the manure is lessened.

Mr. E. C. Stanford, F.C.S., has lately patented a modification of the dry-earth closet system, which he claims to be applicable to large towns with greater advantage than *Moule's* or any other similar system. The deodorizer employed instead of earth is either seaweed, charcoal, or charcoal derived from the carbonization of the excreta themselves. The inventor considers that one-fourth the weight of earth required to deodorize the excrement will be sufficient in the case of charcoal, and he estimates the quantity required for the treatment of the entire excrement, fluid and solid, of one person at less than 9 cwt. of charcoal per annum. For a further account of this system see 4 *R. P. C.*, 53–54.

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.]

A comprehensive but somewhat complicated system of disposing of the sewage of towns, invented by a Captain Liernur, may be appropriately noticed in this place, although it can hardly be said to fall under any specific classification. It has been adopted to a certain extent at the Hague and at Haarlem, but has met with but little favour in this country. The most important features of the scheme are as follow:—Small iron reservoirs are placed under the pavement of all principal street-crossings, each reservoir being connected by means of small iron pipes with the privies of the houses next to it, in such a manner that no offensive gas can escape. The communication between each privy and its street reservoir can be established or cut off at will by means of a valve, which can be worked from the street by a handle. These valves always remain hermetically closed, except at the moment when the privy contents are being discharged into the reservoir, which is done once in the course of every twenty-four hours, at night, by means of a locomotive engine working an air-pump, and sucking all the contents of the privy into the street reservoir, and thence into the portable reservoir attached to the engine. The urine, which exceeds the fæces in volume about eight or nine times, affords sufficient moisture to render this process perfectly easy, especially as the suction-power of the air-current is, as may be supposed, enormous. (On this point, however, *vide ante*, INTRODUCTION.) The pure sewage, undiluted by water and unincumbered by earth, is then emptied into closely-fitted barrels, and conveyed at once to the fields, when it is ploughed into the soil. This system, of which we give but the briefest outline, has been elaborated by Captain Liernur with very great ingenuity. The construction of the privies, the pipes, the reservoirs, engines, barrels, and even ploughs and machines for applying the sewage to pasture lands, have all been considered, and an account of them may be found in *Krepp's* 'Sewage Question,' pp. 112–177.

This system appears to us to merit the very greatest attention. It is dismissed by Mr. Corfield in a few words. "We have no evidence of the practical working of such a plan, but we know what air-tight carts filled by pneumatic pressure are in continental towns, and we have no desire to see their disgusting nocturnal processions in London or anywhere else" (p. 40). A fairer and more practical objection taken by the *Lancet* (March 30, 1867), is that the water used for domestic purposes, and all that fluid matter known in English households under the general name of "slop," would infallibly find its way into the drain-pipes. Captain Liernur would apparently dispose of these by passing them into the sewer; but we fear we cannot agree with him that "the fluid can advantageously be discharged into rivers and watercourses." On the whole, and in spite of the contention of Mr. Krepp that this system has solved the great problem of sewage utilization, we think that it is far more ingenious than practical;

and we are sure that the cost, as estimated by the promoters, is very greatly under-estimated.

Those, however, who desire a more intimate acquaintance with the details of the system, are referred to Mr. Krepp's work on the subject, mentioned above; a book written by a somewhat violent partisan, but containing a good deal of useful information, especially as to the various methods of disposing of towns' sewage on the Continent.

III.—CHEMICAL TREATMENT.

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 also been tried at Stroud, Cheltenham, and other places, with crude sulphate of alumina (*Bird's process*). The results were not very different from those obtained by the lime process [see Table, *ante*, p. 27]; the precipitate being, however, on the whole, of somewhat less value as a manure. [2 *S. U. C.*, pp. 70, 71.]

Dr. *Corfield* ('Sewage Utilization,' ed. 1871, pp. 211, 308) states that this process has been abandoned at Cheltenham in favour of irrigation; but, according to Dr. Letheby (April, 1872), this system has of late given much satisfaction at Stroud. There is no doubt of the value of alumina, in almost every form, as a precipitant for sewage, although it yet remains to be decided in what form it may be used with the greatest advantage.

6. Since the first edition of this book was published, a scheme has been laid before the public in which it is proposed to use sulphate of alumina and lime as the deodorizing and precipitating agents. The plan at present proposed is a modification of the processes of Stothert and Bird, the former of which was shown by the Sewage of Towns Commission (2nd Report) to give results not greatly different from those of the lime process, the manure from which (*ante*, p. 27) has already been shown to have very small value as a fertilizer. It has been tried at Coventry on the recommendation of Dr. Anderson. "The tank contained" (see Dr. Letheby on the Sewage Question) "100,000 gallons of sewage on each occasion, and these were treated with 9½ cwt. of the sulphated material, which, after thorough agitation, was precipitated with 1¾ cwt. of lime previously slaked." Dr. Letheby states that the sulphate is produced by adding 1 part of common sulphuric acid to 2 parts of ordinary clay, and then mixing it with its own bulk of water. Dr. Anderson says that the total cost of producing one ton of manure by this method is 11*s.*; 7*s.* 6*d.* being for the chemicals and

3*s*. 6*d*. for labour, &c., and the value of the manure is estimated at 30*s*. per ton.

7. An interesting system was pursued for some time at Ely; but we do not know whether it has been permanently adopted. The process was as follows:—At the end of the main sewer, on the top of it, a tank was placed in which clay and lime were mixed with water, and allowed to run down through a pipe into the sewage. This mixture fell into a movable strainer, which, when full, was hoisted up, being immediately replaced by another empty one. The full strainer was now emptied on a floor higher up, where the deposits were mixed with charcoal and gypsum, at the rate of four parts deposits, two of charcoal, and one of gypsum, and then left to dry. The floor was ventilated by a chimney, which served also as a channel for the strainer to move in. The liquid portion, falling below, was filtered upwards through a perforated floor, overlaid with twelve inches of charcoal and six of ground gypsum.

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

9. 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].

10. Sulphites of lime and magnesia (McDougall's compound) in conjunction with some products derived from tar, have been employed to some extent in the purification of sewage. The sulphuretted hydrogen is destroyed by the sulphurous acid of the sulphites, and animal decomposition and fermentation are to a certain extent prevented. But unless the sul-

phurous acid is used in great quantities, it soon ceases to exist in the sewage. Tar merely masks the smell; and the precipitation depends upon the amount of lime in a free or caustic state. [2 *S. U. C.*, p. 16.]

11. *Stothert's* process consists in the addition of a mixture of sulphate of alumina, sulphate of zinc, and fine charcoal to each gallon of sewage, with slaked lime; but, although the clarification of the sewage was greater than in the *Lime* process, the manure was of even less value. [*Corfield*, 'Sewage Utilization,' p. 211, and 2 *S. U. C.*, 70.]

12. 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 their Second Report (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, p. 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, *id.* p. 73.

13. We have now to notice a chemical process which takes a high place among all those that have hitherto been invented, and seems likely 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, where the Lime process adopted some time ago may be said to have almost completely failed; and we refer our readers, for an admirablo *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 Altavela, 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 Archimedean 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 reoxidized 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 $16\frac{1}{2}$ 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 was 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.

14. We have now to notice somewhat more fully a process which has attracted a large share of public attention, and which is known by the name of the *A B C system*, or Sillar'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 [whence the title 'A B C'], 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 added to the mud, for the purpose of decomposing insoluble phosphates, and of fixing, as a sulphate, any free ammonia to prevent loss of the latter in the drying process. "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 Second Report of the R. P. C. They were, on the whole, unsatisfactory; and the patent mixture appears to have been in no way superior to lime in its effect upon the sewage.

The advocates of the "A B C" process, however, assert that these experiments were carried on under unfavourable circumstances, and in an unsatisfactory manner; that the Commissioners were inclined to investigate the working of the process in a somewhat hostile spirit; and that, finally, improvements have been effected both in the substitution of crude sulphate of alumina for ammonia alum, and in the subsequent drying of the residuum for manure, or *native guano*. We will, therefore, add some statistics which have been furnished by the promoters of the "A B C" process, together with the personal observations made at the model works of the Native Guano Company, at Crossness, to the conclusions arrived at by the Commissioners, and published on page 13 of their Report, which are as follow:—

"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.

Now, with regard to the value of the manure, in the first place, the advocates of the "A B C" process assert that the "native guano" contains about 4 per cent. of ammonia, and 9 per cent. of phosphate of lime. The accuracy of this representation is denied by Dr. Voelcker [*Journal of the Royal Agricultural Society*, pp. 421–2]; but, notwithstanding the expression of his opinion, the company find a ready sale for their native guano at 3*l.* 10*s.* a ton, and have, indeed, frequently been offered more. As far as we can learn, also, the farmers who have used this manure are almost invariably well satisfied with the results, and desire to continue its use. For once, the teachings of the laboratory do not seem to be borne out by the experience of the field; and, without presuming to offer a decided opinion upon so vexed a question, it is evident that, in getting the farmers to take away their manure at all, the "A B C" process has accomplished what few, if any other, systems of precipitation have succeeded in doing; that, in doing so, they have overcome at least one of the difficulties of sewage utilization. But they have done more; for a pamphlet lies before me in which are collected together over a hundred favourable testimonials as to the value of the "A B C" manure, judged by experience, and the results obtained by the writers—farmers both in this country and in Belgium.

With regard to the effluent water obtained by the "A B C" process, Mr. Crookes, the company's chemist, "doubts whether it will ever be possible to get it up to the standard of the Rivers Pollution Commission" [see *ante*, p. 7], but says [*Rep. upon the "A B C" process*, by W. Crookes, F.R.S. (1871), p. 4]: "If it is required *only* to remove all nuisance from sewage, and not to render the effluent water pure enough to drink, I think the "A B C" process effects the object very well. A water which is as bright and colourless as ordinary spring-water; which is sufficiently free from colour, taste, and odour to be taken into the mouth and swallowed without repugnance; which does not putrefy or develop unpleasant smell on standing for several days in a warm room; and which does not deposit any sediment, cannot certainly be considered an unfit water to throw into a river.

At the same time, having in view the large amount of volatile matter, ammonia, decomposing organic matter, and chlorine present when it is compared with even a somewhat inferior kind of potable water, I should not recommend that this effluent "A B C" water be cast into a river near a spot whence the water supply of a town is taken."

An analysis of the "A B C" effluent water as compared with other water may be interesting in this place. The "irrigation effluent" is from the Lodge Farm at Barking; the "Lambeth water" is that supplied to the inhabitants of Lambeth for drinking.

PARTS IN 1,000,000.

	"A B C" Effluent.	Irrigation Effluent.	Sewage Filtered.	Lambeth Water.
Solid residue, fixed	501·2	450·3	..	254·4
Ditto volatile	47·2	134·4	..	47·0
Ditto total	548·4	584·7	..	291·4
Chlorine	58·4	99·0	104·0	16·8
Organic matter decomposing ..	1·9	1·3	..	..
Ditto albuminoid ..	·5	1·1	1·3	0·14
Ditto, fully decomposed Nitrates and Nitrites ..	0·4	2·5	..	..
Ammonia	24·0	0·3	24·4	0·01

Finally, it has been proposed, in cases when the effluent water after "A B C" treatment is not considered sufficiently pure to be allowed to flow direct into a river, that it should be further and finally purified either by means of filtration through charcoal or by intermittent irrigation of a small amount of land. But as this plan might be adopted with the effluent water from almost every system of interception, destruction, or precipitation of the solid matter in the sewage, we merely allude to it casually here.

In conclusion, we refer those who desire fuller information upon the "A B C" process to the 'Standard' newspaper for the year 1871, under the dates of September 2nd and 30th; October 7th, 12th, 16th, 23rd, and 31st, and November 6th.

15. 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; and while the effluent water flows out of the depositing tanks in a comparatively pure state, the remaining sludge or semi-solid matter is burnt and converted into a valuable cement. The strongest cement known, the Portland cement, is made by thoroughly incorporating, by mixture with a large body of water, chalk, or lime and clay, in the proportion of two parts of *quick-lime* to one part of clay, allowing the compound to settle in large tanks, drying the mixture on hot plates, and then calcining it at a high temperature, and grinding the burnt material to a fine powder.

Lime and clay are both well-known precipitants for sewage water, and the latter certainly exercises a strong decolourizing, deodorizing, and preservative action. The first is an inexpensive substance, very widely met with, and the other is in most localities of a nominal value only. When added to sewage water they form a precipitate which rapidly subsides, carrying with it all the suspended mineral and organic matters, together with a considerable portion of such matters as exist in the sewage in a state of solution. The organic matter carried down generally amounts to one-third or one-fourth of the whole, and supplies almost a sufficiency of fuel for the calcination of the lime and clay even to the point at which Portland cement is produced. It is only necessary to set the dried mixture fairly alight, and it will burn freely.

As to the cost and profits of this most original system, the following estimate has been made by the inventor.

To deal with 1,000,000 gallons of ordinary sewage, the process requires—

	£	s.	d.	£	s.	d.
For materials:						
$1\frac{1}{3}$ ton of lime at 12*s.*	0	16	0			
$\frac{2}{3}$ „ clay at 2*s.* 6*d.*	0	1	8			
				0	17	8
For labour and fuel:						
Mixing ingredients	0	2	6			
Collecting and drying precipitates ..	0	12	8			
Burning and grinding, &c.	0	6	6			
				1	1	8
Cost of materials and labour for 2 tons of cement ..				1	19	4
Value of 2 tons of cement (wholesale)				3	0	0
Balance of selling price over cost of production, not including first outlay, wear and tear of plant, &c.				£1	0	8

Note.—This estimate makes no allowance for the increase in the mineral matters of the deposit (lime and clay) derived from the sewage itself, which we may estimate at more than 20 per cent. It often exceeds 30 per cent.

General Scott himself says [Paper read before the Society of Arts, May 15th, 1872], a "year's supply of chemicals at a place like Leeds would, in the 'A B C' process, which is now being tried there on a portion of the sewage, cost upwards of 30,000*l.* The supply of materials for the same period for the cement process would not exceed 6000*l.* or 7000*l.* I say nothing about the value of the manure resulting from the 'A B C' process, or the cement produced by mine, the point to which I desire to draw your attention here being simply the amount of capital required for the purchase of the materials in the two cases. For the phosphate of alumina process the cost of the chemicals would exceed 45,000*l.* per annum in such a case as Leeds, and for the sulphate of alumina system would considerably exceed 20,000*l.* per annum."

Although this process makes no attempt to extract any of the valuable *manurial* ingredients from the sewage water, its peculiar advantages are undeniable and most practical. It extracts from the sewage water additional lime and other mineral matter valuable in cement-making, and leaves an effluent far better suited for irrigation than the original sewage water, for it increases the quantity of ammonia in it. It also promotes the oxidation of the dissolved organic matter by the slightly alkaline condition imparted to the liquid. It removes from the liquid the whole of the fæcal matter which would choke the pores of the soil and injure vegetation. And when the land will bear no more irrigation, it enables the effluent to be dealt with and rendered completely pure by a comparatively small filtering area.

Finally, it has been proposed by the inventor of the cement process, with the view of introducing a more perfect system for the deodorization and precipitation of sewage matter (see patent obtained by him, and dated 2nd December, 1870), that the chemicals employed shall be introduced into the sewers at a distance from the depositing tanks, and by taking advantage of the running water in the drains, the necessity of mixing machinery be obviated. The joint precipitating action and clarifying effect of the lime and clay, or other chemicals employed, is thus promoted to the fullest extent by the natural agitating process to which the mixture is subjected. Moreover, the sewage matter undergoes purification while flowing through the drains, and thereby the generation of noxious gases, which now find their way into our streets and houses, is prevented.

16. In Hille's process, which has been tried with some 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 (*post*, p. 51); 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*, pp. 7, 8).

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.

IV.—FILTRATION.

The process of filtration through charcoal, sand, gravel, chalk, or certain kinds of soil, if properly carried out, is the most effective means for the purification of sewage which has yet been discovered; 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 was received in tanks, and forced upwards through filters of burnt clay, ballast, gravel, and charcoal. The process, which will be found fully entered into in 1 *R. C. P.*, 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. The superiority of downward over upward filtration in consequence of the difficulty of refreshing the filter with air in the latter system, and the consequent impossibility of nitrification, or conversion of the ammonia and animal organic matter into nitrates, is most strongly insisted upon by the R. P. Commrs. (1st. Rep. p. 63). We think that filtration has not had a fair chance; in fact, because it has not performed everything, and that exactly in the particular way that may be desired, it is condemned as worthless. The Rivers' Pollution Commissioners do not appear to have tried any experiments with pure *charcoal* as a filtering medium, and it is in our opinion the best, if not almost the only one, that could be adopted with advantage.

A charcoal filter has been tried with great success, among other places, at Stoke-on-Trent, and there seems no reasonable doubt that it is only the high price of charcoal at the present day which forms any bar to its general adoption. A company, however, has recently been formed for manufacturing charcoal from peat, and the directors contend that they will be able to supply pure vegetable charcoal in unlimited quantities, and at such a price as to render the filtration of sewage and the sale of the result for manure highly remunerative. (*Vide* 'Concerning Sewage,' by F. Hahn Danchell, C.E., pp. 26, 27.)

Stoke Workhouse has about seven hundred inmates, and is fitted with water-closets, the daily outflow of sewage being in dry weather about 10,000 gallons, and in wet about 20,000. The system in operation is thus described by Mr. Danchell:—" The sewage is first discharged into a depositing tank, where the heavier matter is allowed to subside, and is then passed through a rough filter of coarse cinders and charcoal into a second tank, two-thirds filled with the same filtering material. After leaving the second tank, the sewage passes into a chamber in which is placed a cage filled with charcoal, which can be raised, renewed, and replaced, when required. At this point the suspended matter is for the most part removed, and the sewage is then conducted to a second series of smaller filters, three in number, filled with finer charcoal and cinders, and the clear effluent water is allowed to escape into a drain. The various tanks are periodically emptied, and their contents thrown into the first tank, which is cleared out once in eight months, its contents mixed with ashes to ensure dryness, and carted to a manure factory at Newcastle-under-Lyme. At the factory it is watered with a mixture of sulphuric acid and ammonia to bring it up to a standard strength, sifted to a finish powder, packed in bags, and sold for 4*l.* a ton. The Birmingham Committee of Inquiry, who visited the sewage works and the manure factory, report that in neither place could they detect any offensive odour."

This system of charcoal filtration is being experimented upon, on a large scale, at Bradford.

While we are upon the subject of artificial filtration, it may be interesting to many to learn the views of the late Prince Consort, contained in a letter written to the Royal Agricultural Society by his secretary, General Grey. If the experience of the last twenty years has shown the superiority of downward over upward filtration, the remainder of the system so modestly advocated by His Royal Highness is worthy of the most respectful attention.

"BUCKINGHAM PALACE, *April* 12, 1850.

"SIR,—The subject of turning the sewage of towns, which is now the cause of disease and pestilence, into a source of national wealth by its application to purposes of agriculture, has, along with the general interest which it has lately excited in the public, become also a matter of interest and study to His Royal Highness Prince Albert; and I am commanded by His Royal Highness to bring, through your medium, before the Council of the Royal Agricultural Society, for their consideration and inquiry—should they think the subject worthy of it—what has struck His Royal Highness as being a simple plan for effecting this object.

"Leaving it to more competent judges to decide whether the sewage should be used as a liquid manure or solidified, upon which point His Royal Highness wishes to give no opinion himself, he has confined his consideration to the latter mode of application for two causes:—

"First, that in that shape it could be more easily transported; and,

"Second, could be obtained at the least possible expense.

"The plan which His Royal Highness proposes is simply this: to form a tank with a perforated false bottom, upon which a filtering medium should be laid, and to admit the sewage into the tank below the false bottom, when, according to the principle of water finding its own level, the sewage will rise through the filters, and will run off into the drain, if the filtering medium has been of sufficient thickness and of the proper nature, as clear as spring-water.

"This medium will then have absorbed all extraneous matter, and consequently become the richest manure, which, when the further supply of sewage matter is stopped, can be taken out by a common labourer with a shovel, and carted or shipped wherever desirable.

"His Royal Highness has tried the operation on a small scale with apparent success.

"The medium which His Royal Highness has used is charcoal, gypsum, and burnt clay, substances in themselves highly useful as manures.

"Charcoal is admitted to be the most perfect filter for obnoxious water, and is known to retain effectually extraneous matters.

"Chemists describe, as one of the chief uses of gypsum as a manure, its property of fixing ammonia and other volatile substances.

"Burnt clay, from its aluminous ingredients, has a similar property, and, in addition, the power of extracting ammonia in the alkaline salts present in manure; and is cheaply produced.

"It will remain to be decided what is chemically the best and what the cheapest substance for the filter—what the cheapest and best construction of the tanks—how long the sewage will pass before the filter becomes choked—and how soon the filter would be sufficiently saturated to make it profitable as a manure.

(Signed) "C. Grey."

We have already expressed our regret that the Rivers' Pollution Commissioners did not make any experiments in filtering sewage through pure charcoal, but 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 (discovered, as we are reminded by the 'Gardener's Chronicle,' June, 1872, by Dr. Frankland) is based Mr. Bailey Denton's ingenious scheme of *intermittent downward filtration*, a scheme which is every day exciting a larger share of public attention, notwithstanding the unfavourable report of the Rivers' Pollution Commissioners (3rd Rep., p. 70), which may be summarized as follows :—

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.]

It is only proper, however, to state, that this system of intermittent downward filtration has been adopted after careful and serious consideration at Birmingham, as the best adapted to the requirements of that town. The population of Birmingham is nearly 400,000, with a few water-closets (see *ante.*, p. 11); and the scheme, as set forth in their Report, involved the purchase of about 900 acres of land, to be used as a filter. The total cost of the proposed works and purchase of land is estimated at 324,000*l.*, the annual expenditure for payment of interest and part repayment of capital, at 14,160*l.*, and the annual income at 9200*l.*, leaving an estimated annual loss of about 5000*l.* (*Birm. Rep.*, xxiii. p. 70.) As to the intermittent downward filtration at Merthyr Tydvil, see *id.*, pp. 74–79, and 4 *R. P. C.* (1872), p. 56.

As regards the chemical aspects of this scheme, 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."

Practically, the following are the conditions necessary for the successful conduct of downward intermittent filtration of sewage :—1. The soil of the land to be used must be porous. 2. A main effluent drain, which must not be less than six feet from the surface, must be provided. 3. The surface of the soil to be so inclined as to permit the sewage stream to flow over the whole land. 4. The filtering area should be divided into four equal parts, each part to be irrigated with the sewage for 6 hours, and then an interval of 18 hours to elapse before a second irrigation takes place; each of the four parts would thus be used for 6 hours out of the 24. It is said that an acre of land so prepared would purify 100,000 gallons of sewage per day.

We take the following description of the filtering beds at Merthyr Tydvil from a pamphlet on the subject of intermittent downward filtration, by Mr. T. J. Dyke, of Merthyr Tydvil. Premising that the sewage of about 25,000 persons is treated by Mr. Bailey Denton at Merthyr, that the sewage is very weak, and that the extent of the filtering area is about 20 acres.

"About 20 acres of the land, immediately adjoining the road on which the tanks are placed, have been arranged into filtering areas or beds on a plan devised by Mr. J. Bailey Denton. The land is a loamy soil, 18 inches thick, overlying a bed of gravel. The whole of these 20 acres has been under-drained to a depth of from 5 to 7 feet. The lateral drains are placed at regular distances from each other, and run towards the main or effluent drain. This is everywhere 6 feet deep. The surface of the land is formed into beds; these have been made to slope towards the main drain by a fall of 1 in 150. The surface is ploughed in ridges; on these vegetables are planted or seeds sown; the line of the ridged furrow is in the direction of the under-drain. Along the raised margin of each bed in each area delivering carriers are placed, one edge being slightly depressed. The strained sewage passes from the conduits into the delivering carriers, and, as it overflows the depressed edges, runs gently into and along the furrows down to the lowest and most distant part of the plot. The sewage continues to be so delivered for 6 hours; then an interval of rest of 18 hours takes place, and again the land is thoroughly charged with the fertilizing stream. The water percolates through the 6 feet of earth, and reaches the lateral drains, which convey it to the main effluent drain. As to the purity of the effluent water after this process, nothing can be more satisfactory (see 4 *R. P. C.*, p. 56). As to the profits, Mr. Dyke says, "Italian rye-grass will yield five crops this season, averaging 60 tons per acre, and yielding a net profit of 24*l.* per acre. A plot of cabbages planted in October has yielded a gross sum averaging 43*l.* per acre. A plot of onions has lately been sold at the rate of 63*l.* an acre!"

Finally the Rivers' Pollution Commissioners, in their last Report (4 *R. P. C.* (1872), pp. 56, 57), considerably modify the unfavourable opinion they had formed of the Merthyr process in their former report, but suggest that the area of the filtering beds should be enlarged. Mr. Bailey Denton himself, however, proposes to increase the number of filtering beds, upon which point, and others of equal interest, we refer our readers to his last publication, '*Intermittent Filtration through Natural Soil.*'

V.—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. Commissioners 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 many points 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; and *Corfield's* 'Sewage Utilization' (1871), pp. 261–267.

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 *pumping* of the sewage to enable it to flow over the land, see *Corfield's* 'Sewage Utilization' (1871), pp. 259, 260. As to the distribution of sewage in the neighbourhood of large towns, see *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 or by 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 further 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; and 4th, that during frost the sewage cannot be filtered at all, but must be run off the land into the nearest stream without any attempt at purification. It will be remarked, however, of the first three of these disadvantages that they only touch the farmer and not the sanitary reformer; and 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 *Birm. Rep.*, *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; and it is contended that the sewage farm itself may become in time a "stinking morass," a nuisance to the neighbouring population, and polluting the very crops that it produces. On this point we give the evidence of Dr. Letheby, taken before a Board of Inquiry at Slough, April 20, 1872. He said he had visited most of the sewage farms in operation throughout the country, and whenever he had gone to them without his visit being made known, they had all been in an offensive condition, and at almost all of them the sewage was allowed to flow into the neighbouring watercourses. He visited Aldershot on one occasion, and saw the sewage by well-worn channels running into the Blackwater stream, and not a drop going on the land. At Edinburgh, Banbury, and Rugby he had witnessed the same thing. He had investigated the condition of things at Croydon, and found that the wells were nearly always polluted. Sewage farms on the irrigation principle were apt to become like a stinking morass. He investigated the cause of disease at Haileybury College, and attributed it to a neighbouring sewage farm. He visited Shaftesbury in 1862 at the request of the local authorities. One-eighth of the population had been attacked with fever of a typhoid type, which was owing to the distribution of sewage on the land. They were now about to try a system of precipitation with crude sulphate of alumina. If it was found that that did not precipitate sufficiently they would use lime as well. His opinion of nearly all the sewage farms in the country was that they were offensive and dangerous to the public health. At the Westmoreland and Cumberland Lunatic Asylum there was an outbreak of dysentery, which ceased when the neighbouring sewage farm was discontinued ('Times,' April 22, 1872).

In answer to these and similar charges the advocates of irrigation say that when a sewage farm becomes a nuisance it is entirely the result of mismanagement, and not to be attributed to any inherent defect in the system itself. Professor Christison of Edinburgh says [1 *R. P. C.*, 1, 90]:—"I am satisfied that neither typhus nor enteric fever, nor dysentery, nor cholera is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood." For Dr. Littlejohn's opinion that the Edinburgh (Craigentinny) sewaged meadows are in no wise injurious to health, see 4 *R. P. C.*, pp. 49–50. Dr. Corfield goes a step farther, and denies the fact of nuisance in the present sewage farms. "Persons who have accompanied us to see sewage farms have invariably been surprised at the absence of nuisance." [*Corfield*, 'Sewage Utilization,' 273]. The opinions of Mr. Baldwin Latham and Dr. Alfred Carpenter on this point will be found farther on in this work.

But another charge has been laid against sewage irrigation, and one which may, we trust, have the fullest investigation, before many more steps are taken towards irrigation on a large scale. Dr. Cobbold, a man who even according to his opponents "has the best right to give an opinion upon any question relating to *entozoa*," is of opinion that profuse distribution of sewage tends both directly and indirectly to propagate no inconsiderable variety of parasitic diseases; and suggests that the *Bilharzia*, a parasite which infests the blood-vessels of the natives of many parts of Africa, may be introduced into this country by sewage irrigation. Dr. Letheby tells us, again, that large *entozoa* parasites have been found in the Craigentinny meadows, and although Mr. Corfield says that there is no evidence of any *disease having been produced*, we think the presence of *entozoa* is decidedly unsatisfactory, and, coupled with the opinion of Dr. Cobbold, even alarming. As to whether a dry-earth system is less likely, as maintained by Dr. Cobbold, to produce parasitic entozoa than sewage irrigation, see *Corfield*, 'Sewage Irrigation,' pp. 319–322; and generally on the whole question of entozoa being produced by sewage, Report on Sanitary Improvements in India, 1869 to 1870, p. 72; Report of the British Association, 1870, p. 52; Dr. A. Carpenter's 'Physiological and Medical Aspect of Sewage Irrigation,' *passim;* and Corfield, *op. cit.* 274–281, and Appendix, 'Entozoa Question,' pp. 318–322.

We cannot forbear quoting in this place a remark of Mr. W. Hope, V.C., at the Society of Arts (May 15th, 1872), in a discussion on this point. "In nine cases out of ten the bad results were produced, not by the food, but by the water which the animals were supplied with. Last year he had an ox killed on his farm, after having been shut up in the house and fed on sewage-grown grass for twenty-two months. That ox was dissected by Dr. Cobbold, assisted by Professor Marshall, of University College, and Professor Corfield, professor of hygiene; and although they examined the animal with the utmost attention, and even with the utmost jealousy on the part of Dr. Cobbold, they were entirely unable to find the smallest trace of any disease whatever. In addition to that, several veterinary surgeons and butchers said that they had never seen a more healthy animal. He attributed this result to the fact that the ox had had water from the house-well instead of from the horse-pond."

It is impossible to overrate the importance, whether for man or beast, of pure and wholesome drinking water.

However ill-founded the entozoa theory may be, and we sincerely trust it is, Dr. Letheby's evidence (p. 58) is incontrovertible, and the more the subject is studied, the more essential to the success of any system of sewage irrigation does the separation of the suspended matter and the deodorization of the liquid appear. This has already been effected to a great extent at Croydon, by an ingenious contrivance of Mr. Baldwin Latham; but on the whole, it would appear to be effected in the most satisfactory manner by the phosphate of alumina, which, while completely deodorizing the liquid, renders the effluent water as rich in manurial materials as the raw sewage (see *ante*, p. 32).

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 substances 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 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 $9\frac{1}{2}$ 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 $22\frac{1}{4}$, $30\frac{1}{4}$, and $32\frac{1}{4}$ tons of green grass, equal respectively (reckoned according to the percentage of dry substance in each) to about 5, $5\frac{3}{4}$, and $6\frac{1}{2}$ 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 to about 6 tons $12\frac{3}{4}$ 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 result 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 yeilded 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 annum. 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; at Barking, *Tott. Rep.*, p. 93; and at Saltley, *Birm. Rep.*, pp. 168–171; and *generally* upon the merits and demerits of sewage irrigation from a sanitary point of view, *ante*, pp. 57–61.

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 work to a close, with the hope that my little book may be of some use in directing and assisting the labours of those sanitary reformers whose efforts are 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 described in the course of the foregoing Work; with Reference 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, and Birm. Rep., 187.
Barking	1 R. P. C., 75.
Bedford	1 R. P. C., 83, and Birm. Rep., 187.
Bilston	2 S. U. C., pp. 75–87.
Birmingham	Ditto, and Birmingham Report, 1871.
Bolton	Birm. Rep., pp. 22–24.
Bury	Report of British Association, 1870, pp. 49–72.
Cambridge	Ditto.
Carlisle	1 R. P. C., 78, and Birm. Rep., 190.
Chelmsford	2 S. U. C., pp. 75–87.
Cheltenham	Ditto, and Birm. Rep., 191.
Clifton	2 S. U. C., pp. 75–87.
Coventry	Ditto.
Ely	Ditto.
Glasgow	4 R. P. C., pp. 13–16 and 53.
Hull	Birm. Rep., 37.
Leeds	Birm. Rep., pp. 31–36.
Leicester	2 S. U. C., pp. 75–87.
Leith	3 S. U. C., Appendix V.
Liverpool	Birm. Rep., pp. 19–22.
Luton	2 S. U. C., pp. 75–87.
Norwood	1 R. P. C., 85.
Nottingham	Birm. Rep., 36.
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, and Birm. Rep., 63.
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, and Birm. Rep., 193.
Woking	1 R. P. C., 89.
Wolverhampton	Birm. Rep., 194.
Worksop	2 S. U. C., pp. 75–87.
Worthing	1 R. P. C., 82.

A brief account of the sewage operations that have been carried on at Alnwick, Blackburn, Bradford, Dover, Hastings, Hexham, Lancaster, Portsmouth, Sunderland, Swansea, Tynemouth, Wigan, will be found in the Report on Indian Sanitary Improvements, &c., 1868.

APPENDIX II.

India.

It has been suggested that a few words upon sanitary matters in our Eastern possessions might be interesting to many readers of this little book; and I cannot do better, by way of giving a notion of the nature of the evil in that part of the world, than quote a few lines from a pamphlet recently published by an educated and thoughtful native of India who has lived for some time in this country, Mr. Syed Abdoollah.

"The houses of an Indian town are generally situated in enclosures which present towards the street or alley a dead wall of sun-dried bricks, stone, or mud, a small doorway being the only opening seen. On entering this doorway, the visitor finds a yard from ten to twelve feet square, on the sides of which are a number of dark rooms or cells with an open verandah before them, in which the people live. The rooms are for the most part very badly ventilated, and are lighted by an aperture about a foot square. The yard often communicates with others of the same kind, forming a labyrinthine succession of such courts. Some houses are visited by *mehtars* (sweepers) at stated intervals; but the poorer classes perform the office for themselves. Of drainage, there is absolutely none at all.

"There are vile and offensive receptacles in nearly every enclosure; and these diffuse the most abominable and poisonous effluvia around. In some dwellings, the occupants do not even take the trouble to provide a vessel to receive the filth, but throw it carelessly behind a thin partition wall upon the bare ground, which thus becomes completely saturated with putrescent organic matter.

"The foul waste water of houses abutting on a street is discharged into a side gutter, and is there allowed to evaporate. Where no such gutter exists, an unglazed earthen jar is sunk at the side of the lane or street, and a pipe formed of baked clay, passing through the wall, discharges the noisome liquid into it. When full, the jar is supposed to be carried away and emptied on the nearest *ghura* (or dunghill), one of which is placed opposite nearly every native gentleman's house, and forms a convenient receptacle for the offal and refuse of the neighbourhood; and as the manure thus collected is looked upon as valuable property, the owner continually places a veto upon its removal.

"Instead of the porous jar, cesspools of masonry are constructed inside some of the wealthier houses. When these become full, the contents are baled or thrown out indiscriminately over the thoroughfares, there to be absorbed or to evaporate.

"Many families merely dig a hole at the side of the street for the reception of the liquid refuse. This is the most pernicious of all cesspools; for the absorbent nature of the soil causes a longer time to elapse before it is actually filled. From the fact, also, that it gives so little trouble, it is unfortunately the form most frequently adopted in poor neighbourhoods. When its removal at last becomes imperatively necessary, the fetid abomination accumulated in it is scattered broadcast over the vicinity.

"Were it not for carrion crows, hungry pariah dogs, swine, and other creatures which perform the office of scavengers, and for the extreme dryness of the air, human life could scarcely be maintained under these pestilent conditions. Again, the fields and *maidans* are covered with all sorts of offensive objects. . . ."

But, in addition to all this, there is a very great reluctance on the part of the natives of India to fall in with any schemes for bettering the sanitary condition of the country. It is with great difficulty that the lower classes at least can be induced to make use of privies; and the pollution of the *maidans* or fields in the neighbourhood of the towns is still a deadly nuisance. The prejudices of Caste, again, interfere with the sanitary reformer, as none but those of the very lowest class will assist in the removal or other treatment of the excrement in any way. And finally, it is very difficult to make proper sanitary provisions in camps, even in those of regular soldiers, and in the case of pilgrims moving about in large numbers almost impossible.

But, in spite of all these difficulties, a good deal has been done, and a good deal more is being done every day. We have but lately set the good example in England, and now public attention has been called in India to the bad and unwholesome water supply, especially that from *shallow wells*, which is always largely polluted with the sewage and other offensive matter. These shallow wells are the chief sources from which the water supply is derived, both for troops and native inhabitants; and the number of instances in which outbreaks of fever, cholera, and other diseases have been traced to the use of contaminated water are too numerous to mention, but will be found in the various Reports on sanitary improvements and on the outbreaks of disease in India which have been published by the Government during the last ten or twelve years. Reports on the sanitary improvements in the various provinces of India are now regularly published, and abound with interesting information for those who desire to pursue this branch of the subject further. To quote from one of them:—

The Indian Army Sanitary Commissioners say: "This as yet partial examination of Indian waters has opened an entirely new chapter of the diseases caused in India. . . . London was formerly scourged with fever and dysentery, just as India is now. . . . . The practical solution of the water question is the same for India as it was in London."

But in many cases water itself, apart from the sewage, is a source of disease in India, and it need hardly be said that marshes are perhaps the most deadly parents of ague and fever malaria. The greatest care is needed to preserve the water in tanks so as not to be injurious to health, and even the well requires the closest supervision. In a letter from Miss Florence Nightingale, printed in the Report on Indian Sanitary Improvement, 1870, p. 46, we read that "all the drownings reported—1608 in number—took place in wells and tanks. No fewer than 1100 bodies were taken out of wells during the year in this Presidency alone!"

With regard to the more immediate question of the treatment of sewage in India, there can be no doubt that a dry system of dealing with the sewage is the best adapted to a country where the temperature of the air, and especially of the water, is always high; for whenever the temperature of the water rises above 60° Fahrenheit it ceases to absorb gases to any extent, and therefore becomes a bad vehicle for the removal of organic matter in a state of decomposition or putrescence.

Under these circumstances the value of a system like Mr. Moule's (q. v., *ante*, pp. 19–23) in India becomes at once apparent. In 'Some Unsolved Problems in relation to the Public Health, by *W. R. Cornish* (1864),' the author, now Sanitary Commissioner at Madras, regards the Moule system as "an almost complete solution of the practical difficulty of establishing an efficient dry conservancy for Indian towns and military stations." Mr. Cornish suggests that all vessels for receiving the excretion should be painted or soaked in coal tar—a valuable and practical suggestion. He also admits the value of charcoal, on which point see *ante*, p. 48.

The dry-earth system, indeed, has been viewed with considerable favor by the Indian Government, as we have before had occasion to mention (*ante*, p. 20). "Nowhere," writes Dr. de Renzy, "is the dry-earth system carried out to greater perfection than in the Punjab jails."

At the same time it is only right to give both sides of the question, and in the Report on Indian Sanitary Improvements, 1869, pp. 208–212, is printed a memorandum by the Army Sanitary Commission, which is decidedly unfavourable to any "dry conservancy" system. The main objections put forward are, first, the expense, said to amount to £420 per annum for every 1000 men; secondly, the waste, as far as the sewage is concerned, of the great amount of water which must under any circumstances be dealt with, amounting to about 12 gallons per head per day, and in the case of sick persons to as much as 35 gallons; and lastly, the amount of dust resulting from the use of earth which a tropical sun has torrified almost to powder.

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