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“Sewage-Sludge and its Disposal.”

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INTRODUCTORY.

THE subject of this Paper is one of such vast importance, and the literature, published from time to time, so thorough and complete, that it is with no little diffidence that the Author, with the view of more fully discussing certain new points, has undertaken the task of condensing facts into a small compass, in order that the case may be presented in a tangible and concrete form.

Before entering upon the subject, the first impulse is to re-study the innumerable reports, papers, and other documents which have accumulated during the last thirty years, and to commence the discussion by a summary of their contents. The admirable digests, however, already before the public render such a proceeding unnecessary.

As the subject of this Paper is “Sewage-Sludge,” it will naturally be inferred that it is not proposed to consider other than water-carried sewage in this connection. As that is indeed the vexed question of the hour, probably little exception will be taken to this course.

GENERAL CHARACTER OF WATER-CARRIED SEWAGE.

One of the first questions to be considered is “What is Sewage?” The answer recently given by an eminent authority, “Sewage is variable, very variable; complex, very complex,” is no doubt correct. To answer the question completely is not within the capacity of our present knowledge, and it is not intended to enter upon an attempt at its definition. It is evident that sewage must vary according to the water-supply per head of population;

quantity of subsoil water; distance it has to be carried before arriving at the works; number of times it passes through pumps, &c.

This latter consideration is one of the utmost importance, as the greater the agitation, the greater the division of the solid matters, and the consequent more solvent action of the water. The question of decomposition is one which materially affects the ultimate treatment; but in few cases, if any, is the delay in transit sufficient to allow time for decomposition to advance to any considerable extent. In any case, however, it would be most desirable if measures could be generally adopted for the immediate deodorization of faecal matters before their discharge into the sewers. It will be readily admitted that if this could be brought about, a complete revolution would be effected in the character of all effluent waters after chemical precipitation, and many of those who look for an advance in the now imperfect methods of chemical treatment, consider that this is by no means an unpromising field to explore. Already many houses and large establishments have adopted simple means of effecting this object. When these are more widely known, as in time they must be, an enormous stride will have been made.

The main characteristic of water-carried sewage is its division into two portions, viz., the liquid and the solid. As above stated, the quantity of the latter must depend upon the treatment the sewage receives in the sewers. Great agitation means fewer solids, and those in a finely divided state. It is no doubt due to this fact, that so many persons are apt to be misled in their ideas of what sewage must necessarily be. The great diversity of evidence given before the recent Royal Commission on Metropolitan Sewage Discharge must have given rise to no little surprise in the minds of observant onlookers. By means of the systematic examination of series of samples extending day and night over months, it has been conclusively demonstrated that the average quantity of suspended matter in a dry state, in the London sewage, is about 27 grains per gallon. Reliable data, obtained from the sewage of other places, show this to be an exceptionally low figure, as in many smaller towns the average suspended matter is more than double or treble that quantity. Of the 27 grains about 54 per cent., or 15 grains, are of an organic nature. This organic portion of the suspended sewage matter consists, to a certain extent, of the undigested food of the population, and contains practically all the substances of a manurial value obtainable by means of chemical precipitation.

The liquid portion of the sewage contains in solution, on an average, about 60 grains of solid matters, 33 per cent. of which, or 20 grains, are of an organic character.

While these figures fairly represent the condition of the dilute metropolitan sewage, they by no means afford an indication of the character of water-carried sewage in other places, as stated above.

SOLUBILITY OF THE SUSPENDED MATTERS.

The solubility of a portion of the suspended matters in solutions of lime seems to have been entirely overlooked by the numerous writers on the subject. The results of numerous experiments, made by the Author on both large and small quantities of sewage liquid, have fully demonstrated this fact. The use of an excessive quantity of lime, while affording a rapid settlement of the sludge, and a more or less clear effluent, dissolves a by no means inconsiderable quantity of the offensive matters previously in suspension, and this is apt to render the last state of the liquid worse than its first.

In proof of this statement, the Author submits the following results of a special experiment made for the purpose of demonstrating the fact clearly. Carefully washed sewage-sludge was diffused in clean water, the mixture was agitated for five minutes and a sample withdrawn; an excess of lime was then added, and the mixture again agitated for another five minutes. If the action of the lime were purely one of precipitation, no increase should have been observed in the soluble matters previously in the water. The limed liquid, however, instead of containing less dissolved oxidizable organic matter, was found to absorb about three times the quantity of oxygen required by the unlimed liquid. The actual result being:—

EXPERIMENT to ASCERTAIN the EFFECT of LIME upon SLUDGE.

	Oxygen absorbed from Permanganate in 4 hours.
Aqueous extract of thrice washed sludge (filtered through paper)	0·23 grain per gallon.
The same, after the addition of lime, agitation for five minutes, and filtration through paper . . .	0·71 " "

The well known objectionable character of the liquid pressed from sludge, which has been treated in the usual way with lime, is a striking instance of its action on the solid matters.

The obvious lesson to be learnt from these results is, that before

any system of precipitation is adopted for a particular sewage, care should be first taken to ascertain, that the intended process in no way exerts a solvent action on the matters which it is desired to remove. Having determined this primary point, the next question is, "To what extent are the matters in solution affected?"

DISSOLVED IMPURITIES AND THEIR PARTIAL REMOVAL.

This point has given rise to no little controversy. Authorities on either side have differed widely, and it is only in view of the unmistakable results, obtained in the course of many experiments, that the Author ventures to set aside all statements hitherto made on the subject, and to place on record the outcome of work, specially conducted for the elucidation of this important branch of the subject.

It must be obvious to the most superficial observer, that in dealing with so variable a substance as water-carried sewage, results of an equally varying nature are likely to be obtained. If a large quantity of a soluble organic substance is diffused in half-a-pint of water, it might be thought that little trouble would be experienced in precipitating a considerable portion of it, and that with only a moderate quantity of the chemical agents suitable for the purpose. On the other hand, if the same quantity of matter is diffused in several gallons of water, it would not be surprising if the desired precipitation were not so readily effected.

This consideration is not a suggestion merely, but the outcome of actual demonstration, and it explains the cause of the various contradictory statements on the subject. To exhibit the facts in a clear light, the Author has tabulated the results of the examination of varying samples of sewage and other solutions, both before and after treatment by the usual precipitation agents employed on sewage-works (Appendix I). For the purpose of ascertaining the degree of impurity present in the samples, the quantity of oxygen absorbed by the organic matters from permanganate of potash, acting in an acid solution at a temperature of 80° Fahrenheit, during four hours in a closed vessel, has been adopted as a standard. In some cases these results have been checked by the albuminoid-ammonia process, but the former method is one peculiarly adapted for indicating the work required to be done, in the ultimate purification of the objectionable matters. The various chemicals used were first dissolved in portions of the sewage treated, to avoid errors due to the apparent removal of the dis-

solved matters which would have been indicated if the solutions had been made with clean water.

The conclusions indicated by the results given in Appendix I are tolerably clear. The first portion of the Table shows the results of the examination of 23 series, each consisting of twenty-five different effluents, obtained by as many processes, resulting from the treatment of a given sample of sewage collected from the Metropolitan system. This exhaustive examination fully confirms the statement, made elsewhere, that no practical process of chemical precipitation is capable of removing more than a limited quantity of the oxidizable organic matters in solution in London sewage.

The results further demonstrate the striking superiority of iron over alumina for sewage purification. By the use of iron sulphate in conjunction with lime, as much work is effected (on the basis of the London sewage) for £31,000 per annum as would be obtained by an expenditure of £82,000 for alumina and lime. Even when lime and alumina, with the help of only one-twentieth of their weight of iron sulphate, were added to an extent of £178,000 per annum, not so much work was accomplished as by an expenditure of only £54,000 for lime alone when used in solution. Alumina is valuable chiefly for its effect in removing some of the colour from the effluent, and thus appealing to the eyesight; while the matters actually dissolved are there nevertheless. The experiments with animal charcoal (column 17) show that when this substance was used to an extent of £182,500 per annum the benefit would be practically *nil*. The Table also indicates most clearly the danger of drawing conclusions from the examination of one or two samples only.

The second portion of the Table gives some results, which will explain the remarkable differences of opinion expressed, by various authorities, as to the percentage reduction of dissolved solids by various processes, when acting on sewage of a different character to that of London. The sewage used for this purpose was obtained from other sources, and was evidently of such a character, that the oxidizable dissolved solids were readily precipitated by even a small quantity of lime in solution, viz., 5.0 grains per gallon, no less than 52 per cent. being removed. The addition of an iron salt to the limed sewage effected a further reduction of from 9 to 17 per cent., or, in the latter case, a total reduction of the dissolved oxidizable matters of 69 per cent.

In order to test this point further, and to show that no benefit is derived from the use of an excessive quantity of chemicals,

the results of a series of precipitation experiments on solutions of clear mutton extract are given in Appendix II. The results show, that the same quantity of chemicals is capable of removing from 46 to 90 per cent. of the total oxidizable matter, according to the strength of the solution, and that a very large increase in the quantity of the chemicals used affords no advantage whatever, the results being practically the same, the differences, such as they are, being in favour of the smaller quantity of re-agents employed.

It is thus seen, that statements which have hitherto met with a great deal of scepticism on either side may be perfectly correct, the difference being solely due to the variable nature of the sewage operated upon.

These various considerations unquestionably point to the general conclusion, that where it is intended to treat the sewage by chemical means, the following rules should, as far as practicable, be observed, viz. :—

1. That the sewage should be diluted as little as possible.
2. That the flow of sewage should be adjusted, so that the agitation of the particles in suspension should be of a minimum character.
3. That unless absolutely necessary, no pumping should take place before precipitation.

The peculiar conditions affecting the metropolis are of such a nature as to recall the saying that “the exception proves the rule.” The want of fall, combined with the necessity for removing the excreta from densely populous districts with the greatest rapidity, combine to insist upon a modification of these rules which are otherwise admirable.

PRECIPITATION OF SUSPENDED MATTERS.

The various methods proposed from time to time for separating the sludge from the liquid sewage next invite attention. To enumerate these would require more time and patience than the recital would be worth when done. The sum and substance of nearly all of them is comprised in the use of lime, either alone or in conjunction with the sulphates of iron and alumina, or of one or both of those salts, alone or in combination with charcoal. The use of an excessive quantity of lime, whilst having a temporary antiseptic action, is objectionable by increasing the quantity of putrescible matters in solution in the effluent, as already shown. One object claimed for the use of an excessive quantity of lime, and also for some other substances, is that they destroy the living organized

bodies such as bacteria, &c., which give rise to the phenomena known as putrefaction. This question is one of such vital importance to the after character of the effluent, that it is necessary to discuss the subject at length.

The researches of Warington¹ have demonstrated, that the process known as nitrification of the complex nitrogenous bodies existing in sewage, during its filtration through land, is brought about by definite organisms, who in their life processes feed upon the sewage matters and evolve the nitrogen in the form of nitric acid. As with the nitrogen, so it is with the carbon, which is absorbed as food and evolved as carbonic acid. Without these life processes, whether they be of an animal or of vegetable nature, no destruction of the objectionable matters can take place. As the very essence of sewage purification is the ultimate destruction, or resolution into other combinations, of the undesirable matters, it is evident that an antiseptic process is the very reverse of the object to be aimed at. If a preservative process be required, a receptacle should be provided for the preserved matters; and in order to ensure that the antiseptic process should be a continuous one, any subsequent treatment or method of disposal must avoid the destruction of the antiseptic employed. In the case of lime, which in the form of strong solutions is a solvent of organic structures, what time will elapse before its neutralization by absorption of carbonic acid, and consequent loss of antiseptic properties, after the discharge of the effluent into running water? Obviously only a very limited period, after which the growth of organisms, so zealously destroyed, will recommence by reason of the numerous spores in the water of the river, and in the air with which it is constantly in contact, and there will thus be an end to the antiseptic properties of the system.

The lesson to be learnt from the numerous experiments published by various authorities, both in this country and on the Continent, is that bacteria and other low forms of organic life are most potent in the destruction of all objectionable refuse. Modern experience shows that, when this subject is better understood and thoroughly worked out, in all probability the true way of purifying sewage, where suitable land is unavailable, will be first to separate the sludge, and then to turn into the neutral effluent a charge of the proper organism, whatever that may be, specially cultivated for the purpose; retain it for a sufficient period, during which time it should be fully aerated, and finally discharge it into

¹ Journal of the Chemical Society, vol. xlv. 1884. Transactions, p. 637.

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the stream in a really purified condition. This is, indeed, only what is aimed at and imperfectly accomplished on a sewage farm. It is true that knowledge on the subject is not yet sufficiently advanced to put such a system into practical operation, but sufficient is known to show that the antiseptic treatment of sewage is the very reverse of Nature's method. The Author has not the slightest doubt, but that the future treatment of sewage will be a combined chemical and biological one, as suggested elsewhere by Dr. Dupré.

If, then, an excessive quantity of lime is injurious by reason of its solvent action, and its destruction of organisms, the next question requiring consideration is, "In what manner can the action of lime, when used in moderate quantities, be best supplemented?" Before attempting to answer this question, it may be as well to consider the best method of applying lime, whatever the quantity may be, which it is desired to use. The method generally adopted for applying lime to sewage is to use it in the form of "milk of lime," in which condition only a small portion is dissolved, and the remainder is in a solid form, in which state it is chemically inactive. It cannot be too strongly pointed out, that if the whole of the chemically effective strength of the lime is to be utilized, it must be in solution and not in suspension. Whether this is brought about by first adding the lime to the sewage in the form of "milk," and afterwards agitating the sewage for a period sufficient to ensure the whole of the lime entering into solution, or first dissolving it in water, and then adding the lime-water so obtained to the sewage, matters not, the result is the same. The point being that the whole of the lime used must be dissolved. If this precaution is observed, a far less quantity of lime will be required to effect precipitation, and a few grains of lime will effect as much work as three or four times the quantity when used in the usual form of "milk of lime," without sufficient subsequent agitation of the sewage.

When it is considered advisable to increase the effect of the lime, experience has shown that either sulphate of alumina, or sulphate of iron, or, as some prefer, both of these substances in various proportions, are best adapted for the purpose. One great reason shown for the alumina salt is that it affords a less coloured effluent than does the iron; and that the latter is apt to lead to deceptive appearances when used in excessive quantities. This argument is one that requires refutation. Long and disastrous experience has now taught the public that, in the case of drinking-water, nothing is more deceptive than appearances, that often

the most cooling, sparkling draught contains the elements of death. Numbers upon numbers of self-sufficient people have succumbed, after having seen their dear ones carried off before them. Who cannot now recall instance upon instance of over-confidence in some long-used source of the daily water-supply, and equal want of confidence in the advice of medical men, resulting in that stern lesson which none can unlearn? If this is so with water, how much more does the case apply to sewage? Hold up a glass of clear liquid poison, declare it to be pure, and thousands will believe the statement; but hold up a glass of pure water with but a small fraction of clean ferruginous clay diffused in it, declare it to be harmless, and how many will turn away with a smile of incredulity? These cases, extreme as they may appear to be, illustrate only too well what may, and indeed what often does, happen, in reference to sewage effluents, and demonstrate that clearness is no more a sign of purity than is turbidity a sign of foulness.

It must not be thought, that in thus indicating a fruitful source of self-deception, the Author is not fully aware that the removal of the whole of the suspended matters in sewage is preferable to the abstraction of only a part, even although that part may be 99 per cent. The point it is deemed expedient to guard against is, that in effecting the precipitation of the last few traces of the solids, it is important that the putrescible matters in solution should not be increased tenfold the fragmentary quantity it is endeavoured to remove, in order to render the effluent perfectly bright. It is better to leave a small quantity of suspended matter in an effluent, than to increase the dissolved matters by some four or five times that amount. In order to avoid this, it is necessary that only as much lime, and no more, should be added as will do the work required. If this precaution is observed, and equal care taken with the other precipitating agents employed, little trouble will be experienced in obtaining an effluent of the maximum purity possible (even though it be not perfectly clear), together with the equally desirable result of a minimum quantity of sludge, which, by reason of the small quantity of precipitants added, will have the whole of its manurial properties, such as they are, unimpaired.

In choosing between the salts of alumina and iron, it is desirable to bear in mind the different chemical changes which take place with the hydrated oxides of these metals, when they are precipitated by the lime. Oxide of alumina is thus precipitated in only one form, viz., the fully oxidized one, in which state it remains. On the contrary, oxide of iron is precipitated in two forms, viz.,

the ferrous oxide, or lower state of oxidation, and the ferric oxide, or higher state, according to the condition in which the sulphate exists. The peculiar property of the hydrated ferrous oxide, is that it rapidly changes its condition from a lower to a higher stage of oxidation in the presence of air. The salt known as protosulphate of iron, or more generally as "green vitriol," affords the ferrous hydrate. This is rapidly converted into the ferric hydrate, by combination with the oxygen dissolved in the water. In this condition it has the remarkable power of parting with the oxygen thus taken up, and of giving it to the sewage matters. Having thus been reduced to the ferrous state, it is again ready to combine with fresh atmospheric oxygen, which it again yields up to the sewage, and, acting as a carrier of the oxygen dissolved in the sewage liquid, becomes an agent for oxidizing the more readily attacked foul matters, within the limits of the quantity used. A remarkable result, noticed in some effluents obtained by the use of a sufficient quantity of iron, is that sulphuretted hydrogen is very seldom formed, whilst in others, obtained by the use of some much-favoured precipitation agents, this objectionable gas is freely generated.

FILTRATION.

The alternative, so often proposed to the precipitation process for the collection of the sludge, is filtration. This system has been advocated in so many different ways, and every conceivable material proposed for it, that it would be a useless task to enumerate them. Unfortunately the outcome of them all is the same. Rapid choking of the filters; frequent cleansing; heavy manual labour; unmanageable quantity of sludge mixed with filtering material, &c. As regards the question of sludge, it is generally admitted by practical sanitarians that filtration is out of the question. As effecting the further purification of the clarified sewage, filtration is without doubt a rational process in all respects save one, and that is, expense. If further purification is desirable, and suitable land can be obtained, filtration in the form of effluent-farming is to be commended beyond all other proposals. But the land must be suitable, and not overdosed with the liquid to be purified, otherwise ultimate failure is a foregone conclusion.

SUBSIDIARY TREATMENT OF EFFLUENT.

Should it be desired to effect the stoppage of the putrefactive decomposition of the soluble matters in the effluent, under circum-

stances where land is not available, other means must be sought to effect this object. A consideration of the object in view in the treatment of sewage, in addition to the remarks already made, may not be out of place at this point.

The Author has already endeavoured to point out, that an antiseptic treatment of sewage is the last to be desired; that it is against the whole plan and scheme of sewage-disposal. The object to be gained is the destruction of the sewage matters with the greatest rapidity possible. In searching for a material which will at the same time not only remove the odour peculiar to all effluents, but do so by absolutely destroying those products of putrefaction which are its source, sanitarians are limited to but very few compounds, and practically only two, viz., chloride of lime and permanganic acid. The former is unquestionably a most powerful disinfectant. But it is open to the grave objection that, after its first effects have ceased, a decidedly unpleasant odour is created by the combination of the chlorine with the organic matters of the sewage. It also creates a serious difficulty by reason of its poisonous character both to animal and vegetable life. On the other hand, permanganic acid, in the form of permanganate of potash or of soda, in the presence of sulphuric acid, is harmless; it has no odour of its own to set up in the place of the one destroyed; it is an instantaneous and complete deodorizer; and in doing its work is itself destroyed. Its method of action is the reverse of that of antiseptics, for it accomplishes its work by destroying the putrescent matters presented to it. In short, its use is the nearest approach to the practical application of ozone known to science.

But, it may be argued, the quantity of permanganate that can be added within financial limits is so small, as to be only a trifling quantity of that required to oxidize the whole of the objectionable matters in the effluent. This is true, but it only deals with the first stage of an oxidation scheme. The matters in an actual putrescent state in the effluent are the only ones which require immediate destruction, and these are but insignificant in quantity compared with the total organic matter present. Consequently the quantity of permanganate required is only a fraction of what would be necessary for the complete destruction of the whole of the organic matter. When it is remembered that a minute quantity of a strongly odoured essence is sufficient to scent a room, it will be readily understood that a small portion of actually putrescent substance will be sufficient to give an odour to a gallon of water. It is a valuable and remarkable characteristic of permanganic acid, that it exerts a selective action on those

matters which are in an advanced state of decomposition. For instance, a cold solution of fresh gelatine is but slightly affected by permanganate, but when putrefaction has commenced its action is instantaneous.

Having now treated the effluent so as to render it odourless, and stopped the immediate putrescent decomposition, by an acid solution of permanganate of soda, the means to be adopted for its further purification are next to be considered. What has been already said against the antiseptic method of treating sewage indicates the further treatment required, viz., Aeration.

AERATION.

Aeration has recently been put forward under the title of "oxidation." This is a misnomer. It is true that the ultimate object is oxidation; but if the idea is to be retained that a very partial aeration of a strongly alkaline effluent is equivalent to thoroughly complete aeration of a neutral effluent, free from actual putrescent matters, a powerful blow will be struck at the system, which, when properly carried out, is incontestably one of the utmost importance.

The ultimate oxidation is, as has previously been shown, brought about by the life-processes of various micro-organisms, and not by direct combination of the aerial oxygen dissolved in the water with the organic matters. This is the ultimate object of aeration, which must be thorough and sustained as long as possible.

Of the various systems of aerating large bodies of water when artificial means are necessary there can be little doubt, in the opinion of the Author, as to the superiority of the aquarium or "jet" system. By this means the air is introduced into the water in an exceedingly fine state of division, instead of being in large bubbles, as in the "blowing" system. The smaller the size of each air bubble, the longer will it remain suspended in the water, and thus the maximum rate of absorption will be obtained. If the site of the works allows of a sufficient fall, beyond question a series of cataracts presents the most economical and efficacious method, but when steam-power must be resorted to, the jets comprise the most elements of success, both as to space and efficacy.

THE DISPOSAL OF THE SLUDGE.

The variability of sewage-sludge is by no means an unimportant point, but one which need not materially delay the consideration of the subject. Obviously the sludge arising from the treatment

of strong sewage, which has undergone but little disturbance by pumping, &c., will have greater manurial value than the more agitated and finely-divided matters. This consideration should be carefully borne in mind when discussing the relative manurial value of the sludge of different towns.

The numerous patents, taken out for the utilization of this undesirable substance, show that the subject is one of peculiar fascination. The idea of realizing wealth is undoubtedly the cause of so much activity. On reading over specification after specification, it will be noticed that there is all but a total absence of regard for practicability and cost of working. The great idea pervading the minds of inventors seems to be that local authorities should undertake vast trading-operations, instead of strictly confining their functions to the prevention of nuisance. Such systems may be dismissed with the observation that, if an inventor has a process by means of which he can more than repay the cost of working-expenses, doubtless he will pursue the usual course adopted by business men, and, after obtaining the sludge for nothing and paying working-expenses, put a handsome sum in his pocket.

The first consideration in connection with the disposal of sewage-sludge is its bulk. This is largely composed of water, which varies from 90 to 97 per cent. Of this quantity a considerable portion can be separated, by allowing the sludge to settle in tanks specially constructed for the purpose, into which the slimy matter can be placed to a depth of from 12 to 15 feet. On standing for some twelve hours, the solid matters will be found to form a stratum about one-third below the top of the water. The top water can then be drawn off and returned to the sewage for re-treatment.

Now comes the problem—If the quantity of sludge be small, and suitable land available, by all means dig it in. This is simple and satisfactory when well done, and when sufficient earth is used to absorb all the liquid. But when the volume of sludge is large, and land unattainable, or, even if it is attainable, unsuitable, other means must be adopted. The recent successful introduction of sewage-sludge presses, for converting the sludge into a semi-dry portable form, at first sight appeared to be eminently suited for the purpose. Doubtless they are so under many conditions. If farmers are desirous of the sludge for manurial purposes, the presses are all but absolutely necessary. For small quantities they are manageable, and, as far as the subject will permit, cleanly. Evidence has been put forward in numerous Papers that the cost of pressing is about 2s. 6d. per ton. Strenuous efforts have been made to reduce

the cost, but apparently up to the present, without much success. If, however, that sum could be realized by the sale of the pressed "cake," it would be but a small matter. Unfortunately the hopes of sanitarians and agriculturists on this point seem to be doomed to disappointment, and in place of the farm, in many cases the furnace appears to be looming in the distance as the ultimate destination of the unwholesome matter.

Beyond doubt the wants of farmers should be most carefully considered. So long as they remove the sludge from the works, so long should sufficient be pressed to meet their demands; but the moment the stock increases, that moment should it be disposed of by the best means available.

When the quantity of sludge is small, a ready and economical method of reducing it to a portable condition is to mix it thoroughly with freshly-slaked lime, as for pressing, and then to run it out on to porous beds, constructed of ashes or other suitable material, such as burnt clay, and allow it to rest. The action of the lime will cause a curdling of the solid matters, the water will gradually drain away, and in a few days the sludge will have attained a consistency sufficient to enable it to be readily cut out with a spade and removed. By this means the water is reduced to some 70 per cent., as against 55 to 60 per cent. by the expensive pressing process.

Another good plan is that adopted at Southampton, which consists in mixing the semi-liquid sludge with dry road-sweepings, or ashes from a destructor furnace, in which form it is portable, and in a suitable condition for the purposes of the farmer. This system necessitates the control of the dust-bin refuse and road-sweepings by the sewage-authority. It has one great advantage in that the ammonia, which is driven off in large quantities in the process of pressing, is retained.

Having reduced the sludge to a portable condition by one of these means, its disposal, in those cases where its bulk exceeds the demands of the farmers, has still to be considered. The recent Royal Commission took the evidence of numerous experts on this point, with the outcome that they recommended the application of the sludge to the raising of low-lying lands, burning, digging into land, or carrying it away to the sea. These four systems may be considered in the order in which they are given.

The utilization of the sludge for the raising of low-lying lands is an admirable idea in the concrete. But no one having experience in exposing the wet sludge at all seasons over large areas would suggest that it should be so used in its unpressed state. If land is so raised with it, pressing must inevitably be resorted to. Here

again, comes the initial task and cost of the presses, which, coupled with the cost of transit, spreading on the land and covering with earth, make up a total so excessive, as to render the consideration of other methods eminently desirable.

Before the pressed sludge can be burnt, the water must be driven off by heat. This involves a quantity of heat greater than that obtained from the combustion of a weight of material equal to that to be dried. In other words, expense for fuel is incurred plus the cost of pressing. When the dust-bin refuse of a town is available, doubtless the object can be attained by the use of "destructors." The case of the Metropolitan sewage is, however, different, as no excess fuel is obtainable without considerable expense. The suggestion that the ammonia, afforded by the combustion of the nitrogenous portion of the organic matters, could be collected and sold for the reduction of a part of the expense, is a fascinating one. Assuming the average percentage quantity of nitrogen in the pressed sludge to be 0.87, which is the average result of a number of analyses of "cake" obtained by pressing London sewage-sludge, Appendix III, probably not more than one-half that quantity would be obtainable by destructive distillation in a closed vessel on a working scale. Laboratory experiments have shown that not more than 60 per cent. can be obtained with the utmost care. Calculated on 800 tons of "cake" per day, about £70,000 per annum might be expected as the gross return from the sale of the sulphate of ammonia, at the rate of £12 per ton. The cost of pressing, distillation, collection of ammonia, conversion into sulphate, business charges, interest on capital, &c., deducted from this sum would be such as to lead inevitably to a financial disaster. If feasible, enterprising capitalists will speedily undertake it.

Digging the wet sludge into the ground, as practised at Birmingham, would be a good plan in the case of the Metropolis if suitable land were available in sufficient quantity. The soil at Birmingham is mostly gravel, and eminently suited for the purpose, whereas that in the neighbourhood of the Metropolitan outfalls is heavy and sodden, being, in fact, marsh land. The old saying "that circumstances alter cases" applies here with full force. What is suitable in Birmingham would be decidedly unsuitable in London.

Carrying the sludge away to sea, is thus left as the only tangible and economical system available. The cost of transit is the only one to be considered. Careful estimates show that the whole expense will fall far short of that which would be necessary for the

preliminary process of pressing, independent of the further cost of disposing of the cake when obtained.

The great advantage of this method is that the sludge will never be seen. Precipitated in covered reservoirs, transferred from the precipitating tanks to special settling tanks, from thence pumped into the sludge vessel, and discharged under water far from land, the sludge will disappear in the most speedy, cleanly, and safe manner that can be devised.

The objections to this system are threefold :—

1st. Waste of valuable manure.

2nd. Possibility of nuisance on the coast.

3rd. Delay in transit by fogs and stress of weather.

The first objection is speedily met by the reply, that if the commercial manurial value of the sludge is a fact, commercial men may be safely relied upon to utilize it. They can have the sludge for nothing in any quantity. Let them take it, and deal with it as they will. This consideration applies to all propositions for the profitable utilization of the filthy matter, whatever they may be.

The second objection as to the possibility of nuisance on the coast is a mistaken one. Examine the point closely. Some 3,000 tons of "settled" sludge, equal to about 150 tons of organic matter, will be discharged per diem under water several miles from the coast. This will not be discharged at one spot, but be spread over some 30 miles. Assuming that the discharge from one vessel holding 1,000 tons, equal to 50 tons of organic matter, formed a track when diffused in the water 4 yards deep by 4 yards wide, and 10 miles in length, what would be the quantity of organic matter in that polluted line of water? Only 16 grains in each gallon. Given a gallon of water, containing 16 grains of organic matter, situated say 10 miles from the shore, and in a strong tidal way, how much offence will be given after diffusion, oxidation, the feeding of fish, &c., have acted their part, by the time it has reached the coast, if ever it does reach it? Considering that in a comparatively trifling quantity of water, as in the river, it has rarely been traced more than a few miles from the outfalls, even when mixed with all the multitudinous sources of pollution other than sewage, is it likely that the infinitesimal particles will ever be seen again when once they are fairly deposited in the great bulk of the Channel water? Furthermore, the strongest antagonist to the system cannot but admit that it is absolutely, and in every detail, fully in accordance with both the letter and the spirit of the recommendations of the Royal Commission.

The third objection, delay by fogs and stress of weather, is a trivial one. An increase in the capacity of the sludge-settling tanks, with reserve steam-power, which must be provided in any case to guard against breakdowns, will effectually overcome this difficulty. If the whole of the enormous maritime traffic of England can be carried on, as it is, with almost mathematical precision, surely the carriage of a few thousand tons of sewage-sludge to the Channel can be as readily accomplished.

While it is thus clear that in the case of the Metropolis the conveyance of the sludge to sea is the only available remedy, it by no means follows that under other circumstances, and where local conditions are favourable, other systems are undesirable. Each case must be dealt with on its own merits, and according to local requirements.

APPEN

APPENDIX I.—SHOWING the PERCENTAGE REDUCTION OF OXIDIZABLE ORGANIC

(All quantities are stated

Liquid used for Experiment.	Percentage reduction of dissolved Oxidizable											
	1	2	3	4	5	6	7	8	9	10	11	12
Raw Sewage from	Lime in solution 3·7	Lime in solution 5·0	Lime in solution 10·0	Lime in solution 15·0	Lime as Milk 15·0	Lime in solution Iron sulphate 3·7	Lime in solution Iron sulphate 3·7	Lime in solution Iron sulphate 3·7	Lime in solution Iron sulphate 3·7	Lime in solution Iron sulphate 5·0	Lime in solution Iron sulphate 5·0	Lime in solution Iron sulphate 5·0
Metropolitan system	20	26	29	37	30	27	27	29	33	31	33	35
" "	6	10	28	64	12	10	10	18	32	27	34	32
" "	18	21	14	19	22	12	19	25	24	26	21	27
" "	26	26	26	37	10	24	25	38	33	30	31	32
" "	10	9	10	12	11	10	12	13	27	26	24	24
" "	23	29	29	34	27	23	27	35	37	33	33	39
" "	2	8	15	29	0	0	5	17	20	12	16	22
" "	12	25	30	33	25	16	22	24	32	26	30	34
" "	7	19	21	27	10	18	9	20	22	17	14	25
" "	5	12	13	18	4	5	3	11	16	13	15	17
" "	3	12	9	18	3	10	13	15	17	14	13	17
" "	15	16	19	48	44	11	15	17	20	17	21	20
" "	12	15	21	25	17	10	16	20	22	17	20	22
" "	9	15	19	23	19	11	17	20	21	18	18	19
" "	10	14	22	19	9	8	16	14	14	16	17	21
" "	12	12	17	24	12	7	12	12	22	19	19	21
" "	15	16	16	15	9	9	11	13	17	13	14	15
" "	8	8	20	35	8	11	8	14	17	14	20	19
" "	8	7	19	34	7	10	7	13	16	13	19	18
" "	3	4	4	4	9	4	4	4	8	7	6	8
" "	4	5	5	0	7	5	5	7	5	7	7	9
" "	12	20	26	28	16	15	22	23	24	23	22	23
" "	6	9	9	14	3	5	5	7	11	9	12	12
Average	11	15	19	25	13	11	13	18	21	18	19	18
Cost per annum for chemicals	£ 13,505	18,250	36,500	54,750	54,750	15,635	20,805	31,755	50,005	32,850	47,450	54,750
Other sources	..	52	..	..	..	..	..	..	..	58	61	..
" "	..	..	10	..	..	..	..	..	..	..	..	56

Lime taken as costing	£	s.	d.	
Iron	1	0	0	per ton.
Alumina	2	0	0	"
	3	10	0	"

D I X E S.

MATTER in SOLUTION by VARIOUS METHODS of CHEMICAL PRECIPITATION.

in grains per gallon.)

Organic matter by treatment of liquid with													
13	14	15	16	17	18	19	20	21	22	23	24	25	
Lime in solution Iron sulphate . 8.0	Lime in solution Iron sulphate . 5.0	Lime in solution Iron sulphate . 10.0	Lime in solution Iron sulphate . 10.0	Lime in solution Iron sulphate . 5.0 Alumina sulphate . 5.0	Lime in solution Iron sulphate . 5.0 Animal charcoal . 5.0	Lime in solution Iron sulphate . 1.5 Alumina sulph. . 5.0	Lime in solution Iron sulphate . 2.0 Alumina sulph. . 10.0	Lime in solution Iron sulphate . 3.0 Alumina sulph. . 10.0	Lime in solution Iron sulphate . 3.0 Alumina sulph. . 15.0	Lime . . . 28.0 Iron sulphate . 6.0 Alumina sulph. . 20.0	Lime . . . 66.0 Iron sulphate . 12.0 Alumina sulph. . 40.0	Lime . . . 700.0 Iron sulphate . 100.0 Alumina sulph. . 500.0	Average.
34	36	36	33	40	32	32	34	37	39	44	49	53	34
36	38	36	32	32	33	36	67	46	45	40	43	58	33
28	30	28	15	27	19	17	25	22	23	21	28	45	23
32	36	30	26	32	30	31	30	25	36	30	30	45	30
21	25	24	16	24	14	14	16	12	29	14	26	41	19
36	36	40	37	38	38	39	33	37	39	44	55	62	36
25	28	32	16	21	19	24	22	11	26	20	24	59	19
37	41	32	24	26	28	32	29	25	31	28	43	59	30
42	25	26	21	26	19	21	16	19	22	29	31	54	22
21	22	21	16	22	21	25	25	25	26	25	25	45	18
19	21	16	14	15	13	15	16	11	14	8	18	39	15
24	25	38	24	24	25	24	26	27	38	40	46	59	27
26	25	24	16	22	25	21	21	24	22	25	40	54	22
22	32	19	23	18	19	19	18	18	20	19	18	48	20
20	20	21	21	19	16	17	22	27	19	17	21	47	19
23	23	24	15	19	17	18	22	26	25	28	39	62	21
20	11	17	10	19	15	14	15	13	17	16	17	45	16
26	27	31	20	23	18	23	28	29	31	30	41	58	23
25	26	29	19	22	17	22	26	18	29	29	40	55	20
8	10	10	0	7	7	11	12	13	12	13	29	58	10
9	7	11	0	12	11	12	13	14	11	13	16	44	10
26	22	23	20	20	20	20	22	21	25	22	33	59	23
14	13	14	10	10	11	28	18	12	12	14	19	50	17
25	25	30	18	22	20	22	24	21	26	24	31	52	..
76,650	91,250	109,500	82,125	237,250	89,425	100,375	178,850	200,750	268,275	401,500	803,000	9,672,500	..
61	69	..	33	..	..	..	..	..	..	..	..	..	..

Volume of sewage taken at 156,800,000 gallons per day.

APPENDIX II.—PERCENTAGE REDUCTION OF OXIDIZABLE ORGANIC MATTER in a SOLUTION of clear MUTTON EXTRACT by CHEMICAL PRECIPITATION, as ESTIMATED by the ABSORPTION OF OXYGEN from PERMANGANATE of POTASH in FOUR HOURS ACTING at a TEMPERATURE of 80° F. in CLOSED VESSELS.

Solution used.	Oxygen absorbed by untreated Solution.	Percentage reduction of Dissolved Matters by treatment of Liquid with			
		3.7 grains Lime 1.0 " Sulphate of Iron	7 grains Lime 5 " Sulphate Alumina 1 " "	14 grains Lime 10 " Sulphate Alumina 2 " "	
Solution containing 20 per cent. of clear mutton extract	Grains per Gallon.	Per Gallon.	Per Gallon.	Per Gallon.	
100.0	90.3	90.1	91.2		
" " 10 " "	50.0	87.2	87.0	..	
" " 5 " "	25.0	86.7	86.6	..	
" " 3 " "	15.0	83.5	82.5	..	
" " 1 " "	5.0	82.2	81.2	..	
" " 0.5 " "	2.5	78.4	76.4	..	
" " 0.2 " "	1.0	59.0	55.0	..	
" " 0.1 " "	0.5	56.0	46.0	..	

APPENDIX III.—AVERAGE COMPOSITION of PRESSED SEWAGE-SLUDGE from CROSSNESS.

	Per cent.
Moisture	58.06
Organic matter	16.69
Mineral	25.25
	100.00

The organic matter contains—

	Per cent. on pressed Sludge.	Per cent. Nitrogen.
Saline ammonia	0.035	0.87
Organic nitrogen, calculated as ammonia	1.025	

The mineral matter contains—

	Per cent.
Carbonate lime	7.94
Free lime	2.45
Silica	8.08
Oxide of iron	0.97
" alumina	3.39
Phosphoric acid (= Phosphate lime 1.44)	0.658
Magnesia	traces.