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Philosophical Society of Glasgow.

1891-92.

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ON THE

SEWAGE PROBLEM IN VILLAGES AND SMALL TOWNS.

[FROM THE *PROCEEDINGS* OF THE PHILOSOPHICAL SOCIETY OF GLASGOW.]

The Sewage Problem in Villages and Small Towns. By GILBERT THOMSON, M.A., C.E., Lecturer on Civil Engineering and Sanitation, Glasgow and West of Scotland Technical College.

[Read before the Society, 30th March, 1892.]

ALTHOUGH, in its broad features, the sewage problem is the same whatever the size of the community, and although its solution depends upon the same natural principles, there are still so many differences in the application of these principles that it is, I think, worth while to look specially into the question as it affects smaller communities. The large towns have either settled their sewage problems long ago, or they have, at least, been struggling with them for a long time, but many smaller places are only now waking up to the consciousness that such a difficulty is before them; and the progress of sanitary science makes it certain that before long they will have to face it, and decide how far the methods of larger places are suitable for them, and to what extent modifications must be adopted. I did not take up this question with the expectation of introducing anything novel, but because on various occasions I have seen instances of division of opinion, of uncertainty of opinion, and of doubt as to results. All that I hope to do is to take up some of those points, to consider what has been done, and, without presuming to pass final judgment, to trace them to the principles on which that judgment should depend.

In a large town the sewage difficulty consists in the immense volume with which we have to deal, and the apparent impossibility of finding, at any cost, a thoroughly satisfactory method of treatment. In a small place the difficulty is of a different nature. The volume of sewage produced is not large, the works required for its removal and disposal are not elaborate, and the whole treatment, so as to secure satisfactory results, would be easy, if a small fraction of the amount spent in a large town were available in the small one. But although the absolute cost may be small, it would be large in proportion to the available funds, and a place where a penny of assessment only yields £30, £40, or £50, has to

look to an expenditure of hundreds more closely than a large town does to thousands. And as to disposal, unless the simple plan of running the sewage direct into the sea is adopted, there is, on the one hand, the chance of interdict if a river is used as the receiver, or if, by a too primitive system of irrigation, a nuisance is created; while, on the other hand, to adopt more modern methods of disposal requires more or less attention, and this, in a small place, may be a matter still more serious than the capital expenditure. The employment of an additional man may make, from the ratepayers' point of view, all the difference between economy and extravagance. The difference practically comes to be that while in a large town ample resources may not be sufficient to cope with the difficulty, the question in a small place turns very largely on expense.

Although the water-carriage system is the one that concerns us now, it must not be forgotten that in many places this system is only very partially in use, and although it is rapidly extending, there are still many districts where removal by hand is necessary. I would only say, with respect to the latter, that, in order to be a sanitary success, it is absolutely essential that removal should be frequent, that the receptacles should be small, and that precautions should be taken to prevent the wholesale pollution of earth and water. Practically, the removal must be under official control. With proper arrangements, there is little fault to find with removal by hand; but the old system, which unfortunately still exists in many places, of accumulating for months a putrefying mass of rubbish and filth in the immediate vicinity of almost every house, is one that cannot be too strongly condemned. It is, however, chiefly with water-carried sewage that we have to do, as sewers cannot be dispensed with in any populous place, even if much is removed by hand.

Of the two parts into which the problem is divided—sewerage and sewage disposal—the former has so far attracted most attention. The latter, however, is every day coming more to the front, and is sure to become in many places a very pressing question. Although the two are distinct, they have an important bearing on each other, for the feasibility or otherwise of a system of disposal may depend altogether on the method of collection, and it is therefore necessary in any inland scheme, at all events, to keep in view during the carrying out of the sewerage the possibility that works for disposal may sooner or later have to be added.

Leaving that question, however, for the moment, we may take up that of sewerage, which, although a very old acquaintance, is constantly assuming new phases. I do not propose, of course, to refer to matters which are elementary parts of an engineer's knowledge, such as the general considerations of shape, material, gradient, and size of sewers. The matters which I do propose to mention are some which are less conspicuous, and regarding which there are differences both of opinion and practice. Some of these have come directly or indirectly under my own observation, and while attending the meetings last autumn of the International Congress of Hygiene I had the opportunity of hearing some of these points discussed by those well qualified to form opinions.

The first of these points is the connection between sewage proper and surface water, and the admission or non-admission of the latter to the sewers. Much may be said in favour of admitting it altogether. It avoids the inconvenience of a double system of conduits, and the rainfall forms a very effective flushing agent. But there are, on the other hand, serious disadvantages. Apart from those connected with sewage disposal, which will be afterwards referred to, there is the serious fact that the sewers require to be made large enough to carry not only the sewage proper, but the rain-water as well. The former is by no means a constant quantity, but it has a maximum tolerably well defined; while the latter is not only extremely variable, but frequently exceeds by many times the volume of actual sewage. As the sewer has to be large enough for the maximum flow, it follows that it is for most of the time acting as a reservoir for gases more or less foul —a state of affairs made more serious by the fact that while a heavy fall of rain no doubt flushes the sewer, it also coats its whole surface with putrescible matters.

For two reasons this objection to the combined system applies with more force to small than to large places. The first is, that in a small place the sewers are generally too small to require the use of anything but pipes, and as these are almost necessarily circular, they are ill adapted for a very variable flow. The other is that in a small place the density of population is less, and, therefore, other things being equal, the proportion of rainfall to sewage is greater; and this difference is intensified by the fact that much of the rainfall in a rural district reaches the sewers or water-courses in a tolerably clean condition, while in a large town the rainfall is practically no better as regards purity

than sewage. It is generally recognised, therefore, that for rural districts the separate system, modified to suit local requirements, is usually desirable.

There are several considerations, however, which prevent its being carried out in its entirety. In poorer districts it may be assumed that the street gullies will be utilised to a great extent as sinks, as may be observed by walking through the back streets of any town or village. These gullies are, therefore, receptacles for sewage, and, as such, must be connected with the sewage system. And again, in houses which have any system of drainage, the water from roofs, courts, &c., is naturally led into the house drains, and so into the sewers. Any attempt to carry the system of separation to this extent would involve large expense, and would, besides, do more harm than good. The plan which is usually most economical and efficacious is as follows:—There is generally in any district in which a sewage scheme is proposed a set of drains of some sort, discharging more or less directly into the natural water-courses of the country. These drains, when used for sewage, become what are called "sewers of deposit," and, in fact, very often include some old water-course, arched over so as to hide its filthiness from sight and smell. In such a case it is often desirable to allow these old drains to remain, but to restore them to the condition of rain-water channels. By this means the rain-water is allowed to find its way without much hindrance to the river or stream, while, by a system of intercepting sewers, the actual sewage is collected for what treatment may be necessary. It must be remembered that, although the bulk of the rain water is kept out of the sewers, and, therefore, that these may be made much smaller, a considerable proportion will find its way into them, and a volume of several times the actual sewage must be allowed for.

There are other matters to be considered. A small place has more trouble than a large one as regards gradients. It is well enough known that with a large volume of sewage a flatter gradient will give the required velocity than when the volume is small, and although we occasionally come across instances of sewers being made large in order to counteract insufficient gradient, quite indifferent as to whether there is sufficient sewage for them to carry, such gross mistakes will not be made by any but an amateur engineer. The velocities as given in tables and by formulæ, refer to pipes running either full or half full, and

not to a trickle along the bottom. Assuming, however, that the size is properly proportioned to the volume of sewage, and that the pipe is laid with an inclination not less than would be sufficient for a pipe with a steady flow, a pipe in a sparsely populated district is in an exceptionally bad position. The conditions, in fact, approach very closely those of a house drain, and no man in his senses would lay a house drain, without very special precaution, at a gradient even distantly approaching those often used for small sewers. A house drain has an occasional rush through it, varied by periods in which there is no flow at all, and, to secure satisfactory working, it is necessary to provide a gradient much greater than what would be calculated for a constantly running pipe. But in a country district, where, perhaps, a sewer of considerable length serves only for a few houses, the same conditions of use are present; but the gradient is calculated very often as for a half-full flow. The case, indeed, is worse than in a house drain, for while in the drain, especially with the modern styles of closets, water is occasionally sent through in considerable bulk, and with momentum due to the vertical descent, the flow before it reaches the sewer becomes less concentrated, and the momentum is spent. In fact, with whatever body and force the water reaches the main intercepting trap, the sudden turns there are sufficient to destroy the last appearance of rush. The result is that the suspended sewage matters are apt to become deposited, and while the liquid may pass along with fair velocity, the solids, if not hopelessly stranded, are leisurely lurched along towards their destination by each successive flow of water that passes. In such a case, even if there is no actual stoppage, the sewage matter may take a much longer time on the journey than would be given by the theoretical velocity—long enough, in fact, to putrefy and to cause great unpleasantness. The odours so produced are, no doubt, much more unpleasant than dangerous, but a proper system of sewerage should not only be free from danger, but should inspire confidence, and for this, if for no other reason, the existence of any odour which will direct public attention to the sewers is a serious evil. If the sewers are ventilated in the most common fashion, by gratings at the road surface, the primary result is an agitation to have the gratings closed, to do which of course, would merely intensify the evil. The smells are really the outward signs of a disordered system of drains, and it is the removal of the cause, and not of the symptoms, that should occupy the

attention of those in charge. Closing of ventilators leads to the concentration of the contained gases, and probably to their escape in more dangerous places. In any case, I believe that in a small town the sewers can be, and should be, so laid and managed that the ordinary ventilators, placed with some discrimination, will not be objectionable.

To effect this, however, in the case of slightly used sewers, the gradients should be similar to those used in house drainage. If that cannot be done, special flushing may be very desirable. There are, of course, objections to this remedy, sufficiently weighty to make it only a last resort, but, as a last resort, it may have to be used; and it is certainly better in such a case to include the flushing in the original plan, rather than have it forced on after the whole system, perhaps, has been discredited by complaints of smell. There are three special objections to flushing. It uses water which, when most required, may be none too plentiful; it adds to the volume of sewage, and increases the difficulty of disposal; and it requires attention either to work non-automatic appliances or to see that automatic ones are kept in order. It must, however, be remembered that the effect of a flush does not depend merely on the quantity of water used, that momentum depends on velocity as well as on mass, and that a compact body of water, suddenly set free, has more flushing power than ten times the quantity if allowed to dribble off. It would mostly be in dry weather that flushing would be required, and, therefore, the addition to the volume of sewage would be less serious, and although at the same time there would then be the greatest scarcity of water, it might, in many cases, be possible to use for sewer flushing, not the ordinary domestic supply, but some other of less purity and scarcity. Flushing may, at all events, be regarded as a plan which, in special cases, may be of considerable value.

Assuming, however, that we have done everything in our power to keep the sewers clean, the certainty remains that gases will be generated which we have to dispose of. The question of sewer ventilation is one that we must face. We may argue that, in these circumstances, the gases are not sewer gases in the extreme sense of the word, but they are still gases which have been in contact with sewage, and which the public generally, with good cause, look on with great suspicion. The attempt to bottle up these gases will not do. They are certain to escape, and the only

question is whether they will escape by ways of our choosing or of their own. It is, therefore, recognised by every one that we must provide means for the ventilation of the sewers; but, although many different systems have been tried, no plan has yet been devised which will do this with thorough efficiency and without objection. Ventilation by means of private rain-pipes and soil-pipes is recommended by some, but condemned by most on the ground that it allows sewer gas to come much too near our dwellings; ventilation by means of occasional shafts of considerable height is expensive and doubtful; the same objection applies to furnace ventilators; charcoal trays are troublesome, and may readily become ineffective; ventilation by untrapped gullies, or by gratings in the middle of the road, is objected to on the ground of escaping smells; and while the last mentioned plan, gratings in the middle of the road, is the one usually adopted, it cannot be denied that sometimes the objections are well founded. It is impossible to lay down any hard and fast rule as to ventilation, further than to say that, having, in the first place, done our best to make the ventilators unobjectionable, we must also place them in such positions as will cause least annoyance, if, by any chance, smells do escape from them. The difficulty of ventilation will serve, at least, one useful end, if it impresses on us the necessity of so constructing and managing our sewers that smells in them, and, therefore, that smells escaping from them, will be reduced to a minimum.

But, assuming that we have satisfactorily disposed of these and other difficulties regarding the conveyance of sewage, we have still to attack the companion problem of its disposal, and this, in all probability, will be found more full of perplexity and difficulty than the other. The operations of nature run in cycles, and, under natural conditions, the substances which go to form sewage would be returned directly to the earth, there to form a valuable fertilising agent. But when a number of people are collected on a small space of ground, the production of these substances is too great for the ground to utilise, and so, in place of being dealt with in detail, sewage has to be dealt with in bulk. The result is, that in every populous place a large volume of sewage is produced—this sewage consisting of water containing a quantity of suspended matter and a quantity of dissolved matter. These substances, when not actually putrefying, are, at all events, in a state approaching putrefaction, and are more or less offensive.

Besides the impurities which a chemist can detect, we may have, and must always assume that we have in any given specimen of sewage, the germs of specific disease. The definition of dirt, "matter in the wrong place," is, of all things, true of sewage. Its constituents could be applied to the ground, not only without harm, but with great advantage; and the mixture of this valuable manure with the water produces a most dangerous and worthless substance. If the two could be separated both would be valuable, but it is in the separation that the difficulty lies. When the question of sewage disposal first became urgent, the manurial value of sewage matters was fully realised, and great fortunes were looked for by individuals, and great profits by communities, in utilising this waste product. After many costly experiments, most of them more or less failures, the dream of boundless wealth to be derived from sewage was slowly abandoned, and those towns which could solve the difficulty by the simple means of running the sewage into the sea came to be envied, as being able, at least, to dispose of their sewage without loss. In other cases, given the sewage, we may do one of two things with it. We may purify it thoroughly, or we may purify it partially. In the former case it will be costly; in the latter, with favourable conditions, it may be profitable. It is an easy matter to take some of the pollution out of the water, but the difficulty increases as the proportion to be removed increases. It is not the first, but the last, step that costs. If the purification must be pushed to a degree at which the effluent water may be considered harmless, the financial result will most probably be on the wrong side. Certain places, no doubt, with exceptionally favourable circumstances and careful management, may be able to show a balance of profit, but the margin is an extremely narrow one, and has a strong tendency to convert itself into a loss.

Where purification is a secondary matter, and profit the first, there is no doubt that profit can be realised, as in the well-known example of the Craigentinny meadows, where very inferior land, drenched with sewage, produces immense crops; but few towns are in that happy position, and it is with the cases where purification comes first that we are chiefly concerned.

The first stumbling-block in the way of sewage purification is the difficulty of convincing the popular mind that apparent and real purification are two different things. I know that by referring to the difference between precipitation and purification, I am

laying myself open to the charge of repeating elementary information; but so many cases are constantly occurring where this distinction, if not unknown, is at least ignored, that it is not altogether unnecessary to repeat that sewage from which the suspended matters have been removed by precipitation still contains much of the most valuable manurial matter, or, from the other point of view, much of the most offensive sewage matter. It is, however, such an obvious improvement, as regards appearance, to have the suspended matters removed, that it is extremely difficult to convince people that the purification is incomplete, especially when financial considerations come in to support the incomplete system. When the effluent is to be discharged into a tidal river, or is of small volume compared with the stream into which it runs, this rough purification may sometimes be tolerated; but in most cases the risk of interdict is not inconsiderable, and, therefore, more efficient means must be adopted. At present the system most suited for any small inland town seems to be filtration in some form or other, either through land or special filters. Precipitation is valuable, not as a substitute, but as a preliminary, sewage being thus roughly purified before it passes on to the filters; and by a combination of the two an effluent may be secured which, for all practical purposes, may be regarded as pure, and which may be safely run into any stream. The prospect of making a profit had better be ignored. I had hoped to give some figures, resulting from experience, as to the financial results of different methods of purification, but the difficulty in doing so in such a way as to be of any value lies in the fact that the results depend on data which are extremely variable. The expense side of the account consists of items readily compared, such as cost of land, works, and management; but the credit side, with such items as rental received for sewage, sale of sewage crops and of sewage manure, is extremely unreliable as a guide, for these values vary not only from place to place, but from time to time. Sewage sludge, for instance, has at some times commanded a considerable price, while the same sludge at the same place has at other times been declined as a gift—the tendency of prices being usually downward. In these circumstances, then, it would be of little value to detail figures which might be rather misleading than otherwise.

The plan which, according to usual experience, comes nearest to squaring accounts, if it does not even yield a profit, is that of

irrigation over a considerable area. By this means the manurial value of the sewage is transferred to the land, and then absorbed by the crops. The chief difficulty with this, as with any other system of applying sewage to crops, is that at the time when the crops least require irrigation—that is, in wet weather—there is the greatest volume of sewage, and this must all be passed through the land in order to be purified. The admirable economic results obtained at Craigentinny are due to the possibility of ignoring this requirement, and allowing the sewage to flow past when it is not wanted. The larger the area, on the other hand, the greater the risk of nuisance.

As regards purification, the essential point is that the sewage must pass through the soil, and that the soil should not be continuously saturated with it. We occasionally come across cases where sewage is allowed to run on to the surface of water-logged land, in the expectation that its manurial elements will be extracted by the surface growths. It has, however, been again and again proved that sewage which merely runs over land is not purified entirely by the growing plants. Our reliance for thorough purification is not the absorptive power of the plants, but the oxidysing action of the soil. The plants are added as a means of utilising as far as possible the valuable portions of the sewage, but the ground itself is the final reliance. The difference between irrigation and land filtration is very much one of degree. The area, in the case of irrigation, is decided by considerations of how best to grow profitable crops; the area, in the case of filtration, is decided on the basis of how little will effectually purify the sewage. Good crops are aimed at in the one case, economy of land in the other. In the latter case, the land is really laid out as a large filter; and although crops are usually grown on its surface, the purpose is merely to make what use can be made of the matters which the filter would otherwise burn. The ground is prepared and underdrained to a depth of six or seven feet, and each part is used only intermittently. Both of these plans—irrigation and filtration—can be carried out so as to produce an effluent not only apparently but actually harmless, and from their comparative simplicity will probably be the solution of the difficulty adopted in many cases. In those cases where land is too limited even for the adoption of land filtration—"intermittent downward filtration," as it is technically called—some system of chemical treatment may have to be adopted. The number of

these systems is enormous, and it would be tedious even to enumerate them. The most prominent just now is probably that known as the International system, in which, by a combination of precipitation and filtration, a very good effluent is produced. I had occasion recently to visit more than one place where this system was in operation, and, to all appearance, with great success.

The smaller the area occupied by the works, the less chance there is of nuisance being produced; but any of the systems to which I have referred can be carried out with reasonable freedom from offence. A sewage farm, of course, is not exactly the place to lay off as a pleasure ground, any more than a field to which guano is being applied would be. With reference to all these systems, it may be remarked that their proper working almost certainly depends on the exclusion of rain water; and it may now be taken as an axiom that, in a rural district, where sewage has to be treated in any way before discharge, rain water should not to any extent enter the sewer. The smaller the area of land available for purification, the more important it becomes to keep down the quantity of sewage.

In the case of a community on a hillside, with a considerable amount of suitable ground at a lower level, the sewage will be readily disposed of by irrigation; but where irrigation would imply any handling of the sewage, such as pumping, then it is undoubtedly best to adopt a more compact method of purification, if by that means pumping can be saved. The increased results from broad irrigation will not repay the cost of pumping. Those communities are in the worst position where pumping is necessary as a preliminary to any method of purification.

Reviewing the situation generally, it may be said that difficulties as regards sewerage must apparently be met in the future by the means already at our command, which are in most cases quite sufficient. As regards sewage disposal, on the other hand, while the means we already have can be made to serve the purpose, for such places as we are considering, with considerable efficiency, it is not impossible, perhaps not even improbable, that scientific researches may yet provide us with some means whereby sewage may become a valuable, in place of a very troublesome, possession. In the meantime, however, public opinion is becoming more and more decided against the pollution of streams, and many places cannot afford to wait for new discoveries, but must make the best they can of those which are already available.