OUT OF SIGHT, OUT OF MIND.

METHODS OF SEWAGE DISPOSAL.

IT has hitherto been — and, in fact, it still is — the practice of the world to consider its wastes satisfactorily disposed of when they are hidden from sight. In spite of an almost universal outcry about sewer-gas, filth diseases and infective germs, the great mass, even of those who join in the cry, pay little heed to defects in the conditions under which they are living so long as they are not reminded by their eyes or their noses that their offscourings are still lurking near them.

The life of man involves both the production of food, directly or indirectly, by the growth of plants, and the consumption and destruction of the organized products of such growth. The production and the destruction are constant. Between consumption and renewed growth there intervenes a process which prepares what we reject for the renewed use of plants.

It is this intervening process that we have to consider in applying the comparatively new science of sewage disposal. The process itself has gone on from the beginning of the world, but it has mainly been left to unguided natural action, which takes no account of the needs and conditions of the life of man in modern communities, where "Out of sight, out of mind" no longer suffices.

The sewerage of towns and the drainage of important buildings are now controlled by expert engineers, who rarely fail to do their work reasonably well. The adoption of good methods and appliances for removing liquid wastes from houses and towns is becoming general. It will in time become universal.

This, however, is only the first step in sanitary improvement. It is only the step of removal. It gets our wastes out of our immediate neighborhood; it does not destroy them. It is now recognized that quick and complete removal is only the beginning of the necessary service, and that proper ultimate disposal is no less important to health, to decency, and to public comfort. The organic wastes of human life must be finally and completely consumed. It is not enough to get them out of the house and out of the town; until they are resolved into their elements their capacity for harm and for offense is not ended. It does not suffice to discharge them into a cesspool, nor does it always suffice to discharge them into a harbor or into a watercourse.

Especially in connection with large foreign towns, efforts of the most costly character have been made to obviate accumulations due to the discharge of sewers. The floods made foul with the wastes of the huge population of London have been poured into the Thames until, in spite of years of effort to relieve that river, its condition has become, in the language of Lord Bramwell, "a disgrace to the metropolis and to civilization." The millions expended since 1850 on the still unsolved problem have not thus far effected more than a mitigation of the evil. London is to-day, apparently, as far as ever from its ultimate solution, though of course the former direct discharge of sewage all along the river, and the resulting local stench, have been forever suppressed. The case grows in gravity with the growth of the population, and measures which promise success when adopted are not able to cope with the greater volumes that are produced later. While substantial relief has been secured in the case of other towns in England, and on the continent of Europe, there is rarely as yet such an early and complete reduction of organic wastes, without offensive putrefaction, as the best sanitary condition demands.

In our own country, New York city, and the towns on the Mississippi and on other very large rivers, have such tidal and flood conditions as to secure satisfactory disposal by dilution and removal. At Boston, Philadelphia, and Chicago, the needed relief can, under the methods adopted, be secured only by works of the greatest magnitude and cost, while, as a rule, the smaller towns have yet to devise methods by which, unless they are exceptionally well placed, they can destroy their wastes at a practicable outlay.

Systematic works, chiefly involving removal through intercepting sewers, have, until recently, been confined to cities. Smaller towns are now perfecting their methods of removal, and there is a growing desire to find means for purifying the effluent of sewers which will not cost more than can be afforded. Interest is also growing among householders, who are becoming convinced of the dangers of cesspools, with their retention of putrefying wastes within contaminating reach of houses and of their sources of water-supply.

In its progress thus far, the art of disposal has worked itself out mainly by progressive practice. It began in the instinctive desire to get offensive matters out of sight. As new difficulties presented themselves, and as the requirements of a better civilization arose, new methods were devised for better concealment in the ground, or for better removal by sewers. In fact, such concealment by the use of vaults, cesspools, and large sewers still remains, with the majority of people, the accepted method of dealing with the more obvious difficulty of the situation. The difficulties which are not so obvious — the real sanitary difficulties — these methods fail to relieve. Indeed, they have greatly retarded their relief, and have made it more troublesome. For the lack of knowledge, which nowhere existed, the world went on for centuries subject to most serious evils, of which it had no adequate conception. It is hardly half a century since the evils attending incomplete sewage removal were appreciated, and radical measures of relief were adopted. In London large brick sewers, not only in the streets, but under and about houses, which had long existed as the seats of foul deposits, now had their condition pointed out, and a "Blue Book" of the British Parliament, published in 1852, set it forth in a manner to secure effective attention. It was shown that these sewers and drains were so large that they could not be kept clean by their natural flow. It was then that the movement for the use of pipes for sewerage and house-drainage received its first great impetus.

The art of sewerage had for many years confined itself to an improvement of the means for distant removal, and the world accepted, and still accepts, as a part of the policy of its great cities, the inevitable construction of majestic and costly engineering works for this service, carrying not only the foul sewage, but floods of storm-water as well. It is now demonstrated that even in London, and in all but a few exceptional conditions, like those of New York, where the whole harbor is flushed twice a day by the great tides that flow along each side of the city, the effect of such works is, largely, to remove the point of deposit, not to prevent deposit; and that the great volume of their discharge has often added to the difficulty of final disposal.

The lower Thames has reverted to a condition which is said to be hardly better than that of forty years ago. As a general rule, wherever a copious discharge of unpurified sewage is made into a river or harbor, the condition grows worse as the population grows larger, and as a heavier duty is imposed on a limited capacity for dilution. Sooner or later the provision of some means of purification, or at least of the removal of the grosser impurities of the sewage, becomes imperative, and the question of sewage disposal assumes greater importance year by year.

The tendency of legislation, here as well as abroad, is toward the prohibition of the fouling of rivers, thus far mainly for the protection of sources of water-supply. This is doing much, and promises to do more, in the way of restricting the free discharge of sewage into streams. There is also a growing sentiment in favor of cleanliness, and causes of offense which have hitherto been disregarded are now attracting attention. Those who occupy lands past which streams flow are beginning to assert and to enforce their undoubted right to have them flow in their naturally unfouled condition.

The adoption of measures for the purification of sewage by some English towns has been compelled by the firm and lawful demand of individual landowners below them; and here, as well as there, the necessity for the purification of sewage assumes increasing importance. This is especially true in the case of towns situated on minor streams. While these are natural and sufficient drainage-outlets so far as storm-water is concerned, they are often insufficient properly to dilute the sewage sent into them. These small towns, many of them having mere brooks for outlets, are growing rapidly, and modern methods of drainage are fast leading to the more and more complete discharge of water-borne filth by sewers.

So, too, on the larger streams, villages are growing to towns, towns are growing to important cities, and conditions which were formerly tolerable are now becoming intolerable. The Schuylkill River, for example, which is the most important source of water-supply for Philadelphia, is lined with populous and growing manufacturing towns, which have only this river for an outlet. The same conditions exist along many of the rivers of the older parts of the country generally, and they are extending westward. It is therefore clear that, in the case of towns not lying on the larger rivers, public sentiment and the rights of riparian owners will demand the increasing adoption of means for withholding crude sewage from them.

It is not the volume of sewage that threatens us; this is due only to water, which, if pure, might flow into our streams with advantage; it is the impurities carried in solution and in suspension in the water, and made difficult of control by it. Could anything like complete separation be effected at the outset, the problem of disposal would be simple enough. Easy means might be devised for the destruction of any amount of solid waste matters, but when these are intimately mixed with from one hundred to one thousand times their volume of water, the difficulty of treatment is correspondingly increased.

The impurities of sewage are organic matters, which, having served the uses of the community, are relegated to the domain of waste. They are the product of life and growth in the vegetable world. They have served their uses, as food or otherwise, and they are now to be prepared for a new cycle of life, use, and rejection. This preparation is effected by resolving them into their elements; only thus can they be made available for new plant-growth. Their organic condition must be completely destroyed before organic reconstruction can follow. Such destruction is inevitable, and is usually rapid. It has long been known that destruction is effected by oxidation, and the oxidizing agent is now known. Save in the case of actual consumption by fire, which is a rapid and intensified oxidation, or by the action of chemicals, the destruction of the organic condition is effected by the growth of infinitesimal living organisms known by the generic name of "bacteria." These organisms live and grow by the consumption of food, which, with the aid of oxygen, they convert into their own substance. This seems to be the last step before the final letting-go of the control of life-processes, which is followed by complete resolution.

When we have reduced the filth of our sewage to a condition in which it may be washed out of the soil, or absorbed by roots, then, and not until then, have we destroyed it as filth; but then it is completely destroyed. In the place of a particle of meat-fiber we have carbonic acid and water and nitrates, all available for the nourishment of growing plants, and all reduced to what is probably the only form in which vegetation can take them up. The same action converts into plant-food the other elements of the sewage. The result is no longer sewage, or urine, or fecal matter, or animal or vegetable refuse; it is the renewed elementary condition of the substances of which these various forms of filth were composed. If a crop is growing on the land, some or all of these resultant products of localized and disseminated decomposition will enter on their new cycle as plant-food. In the absence of such demand they will be more or less completely washed out of the soil by water descending through it. In either case, their career as filth is ended.

Under rude and careless methods, and, indeed, in the absence of method in mere deposits of filth, this ultimate reduction to elements will follow in time; but the process will be offensive and in every way objectionable. With proper methods the desired end is reached more rapidly, and with an entire absence of offense or objection.

Those of the bacteria which are best known multiply by division into two or more parts, each part growing to its allotted size and then dividing again. It has been stated that the *Bacterium termo* divides thus every hour: so that at the end of the first hour each one becomes two; at the end of the second hour these become four; of the third, eight; and so on, until, at the end of a single day, they number more than sixteen million. Sternberg illustrates this wonderful growth by the following statement:

> Let us represent to ourselves a cubic measure of a millimeter. This measure would contain, according to what we have just said, 633,000,000 of rod bacteria, without leaving any empty space. Now, at the end of twenty-four hours, the bacteria coming from a single rod would occupy the fortieth part of a cubic millimeter; at the end of the following day, they would fill a space equal to 442,570 of these cubes, or about half a liter. Let us admit that the space occupied by the sea is equal to two thirds of the terrestrial surface, and that its mean depth is a mile; the capacity of the ocean will be 928,000,000 cubic miles. The multiplication being continued with the same conditions, the bacteria issuing from a single germ would fill the ocean in five days.

The development of these organisms is limited only by the amount of material available as food, and by the supply of oxygen. It is resisted by the protective influence of life, by the presence of conditions unfavorable to bacterial growth, and by the actual absence of an organism to begin the growth. The organism is always abundantly present in sewage, and its development, under natural conditions, begins at once, and continues until the last vestige of available organized matter has been reduced to an oxidized condition, and so made ready to serve again as plant-food. This is the ultimate destiny of the organic impurities of sewage. The suspended matters may first serve as food for fish or insects or animalculæ, but sooner or later they must all pass through the final process of dissolution by oxidation. We may retard this process, as by the use of chemicals and disinfectants, but we can only retard it. Its agents are always at hand, and, when the proper conditions arise, they begin their work.

It is their work, and practically only their work, that completes purification, and the art of sewage disposal consists in suitably subjecting to their action the matters with which we have to deal, in such a way as to favor their activity, and to obviate offensive and dangerous conditions. The methods at the moment most in vogue do not fully accomplish this. They are necessarily empirical. They have been developed under the slow growth of experimental knowledge, and they had proceeded far, and had become well established in practice, before it was known that oxidation depended on bacterial life. The following, which was as much as could then be said, was written as recently as 1888:

> It is not likely that towns situated on great rivers or on the sea-coast will, for a long time to come, give thought to any other disposal of their sewage than its discharge directly into the river or into the sea. As the country fills up, and as towns situated on small streams, or on no stream, increase in size and in wisdom, they must perforce seek for some means to get rid of the copious flow of water made foul by its passage through the houses and shops of the people. The indications are clear that legislative control of this matter cannot long be delayed; and there is no more intricate or more interesting problem now presented to the sanitarian than the correct solution of this great question of the future. Its final solution implies a better acquaintance with the ultimate methods of organic decomposition and of filtration than any one now possesses. It seems, however, as though the scientific world had at last reached the threshold of real knowledge concerning the processes by which organic matter is converted into those mineral compounds, which, inoffensive and innoxious in themselves, become, in the economy of life, the direct food of growing plants. It is these processes that we must employ in the successful destruction of all organic waste other than such as is consumed by fire. They go on in spite of us; we may delay them, or conceal them, or change the seat of their activity; we may hasten them, or modify them, but we cannot prevent them. Sooner or later, by combustion, by direct putrefaction, or by indirect fermentation, they will work their destructive end, bringing all matter that has once lived again back to the domain of life. The cycle is unceasing, and according to our action concerning it, or according to our neglect, will its influence be good or bad. Thus far we are not quite sure how our action should be guided.[1]

It was only in 1877 that Schlössing and Müntz demonstrated that oxidation in soils is due to an organized ferment. They found that sewage, slowly filtered through a column of sand of sufficient depth, was completely purified. If chloroform was introduced, benumbing as it were the organisms in the sand, no purification took place until the effect of the chloroform had passed away. They accepted this as a proof—and later knowledge confirms it—that purification is due to living organisms.

The best and most conclusive experiments and investigations that have yet been made as to the processes of purification were carried on year after year under the direction of Mr. Hiram F. Mills, C. E., at the experiment station of the Massachusetts Board of Health at Lawrence. These experiments, made with large filters of earth, sand, and gravel, are set forth in detail in the published reports of the board (1890–1891). They fully confirm and illustrate the theory of bacterial action.

They demonstrated that purification is effected by oxidation taking place in the film of sewage coating the particles of the filter, with a sufficient admission of air to supply oxygen. The essential process is not straining, but bacterial growth. For example, while the paper filter of the laboratory removes practically all of the suspended impurities of sewage, it removes only eleven per cent. of the ammonias, and only eighty per cent. of the bacteria, the slowly moving films passing over the surface of stones as large as the ball of one's thumb lose ninety-seven per cent. of their ammonias and ninety-nine per cent. of their bacteria.

Practically, it was only after this clear definition and demonstration of the processes involved, and of the methods of their application, that we were in a position to work with real knowledge. Only then could empiricism be made to give place to well-established theory. Could we now set aside the influence of long years of practical work, the atmosphere would be greatly cleared; but practical work has a very persistent influence, and the art of purifying sewage will long feel the effect of experience with methods which would not have been devised in the light of what is now known. When the first attempts were made to get rid of the impurities of sewage by artificial means, great importance was attached to their manurial value, and great profit was expected to result from their development in a useful form. The obstacle of extreme dilution was not appreciated, and it was long before the discovery was made that, as with the gold said to exist in sea-water, the attempt to separate these matters by artificial methods would cost more than they were worth.

The belief also prevailed that the chief source of offensiveness of sewage lay in the solid fecal matter that it contained, and this belief still finds much popular acceptance. One of the most prominent sanitary exhibits at the World's Fair, a Russian invention, had the separation of this matter for its chief end, and the description accompanying it urged such separation as the *sine quâ non* and the chief need of hygienic improvement. Even in Paris, where the purification of sewage is being carried out on a very large scale, and where its requirements are well understood, the use of the *tinette-filtre*, which holds back the solid portions of house-drainage until they putrefy, and then allows them to flow to the sewer in this worst possible form, has, within recent years, been allowed to come into extensive use. At Newport the

[1] "Sewerage and Land Drainage," Waring, p. 233.

old rule still prevails largely that house-drainage shall be retained in cesspools until it can, after decomposition, overflow as a foul liquid into the public sewers. The fact is that fecal matter is of far less consequence than urine and the waste of the kitchen-sink.

Then, too, it was long thought that if sewage could be purged of its suspended matter,—that which clouds it and colors it,— purification would be effected. An imperfect clarification by mechanical or chemical processes is still resorted to in some cases where a high degree of purification is really needed, although it is now well known that such clarification does not remove from sewage its most putrescible matters, nor its minute living organisms. Imperfect results which have satisfied legal requirements in Europe are, apparently for that reason, accepted as sufficient, in spite of their incompleteness.

The purification of sewage is evidently on the eve of great extension in this country, and its success requires that the importance of making it as thorough as possible should be generally appreciated. If the work is to be done at all, it is worth while to do it well. Half-way measures, like chemical precipitation, may satisfy present legal demands, and they may in exceptional cases be advisable; but they will not meet the requirements of the better-informed public opinion that is now growing up. The means for entire purification are within reach, and imperfect results will not long be accepted as sufficient.

In practical work two cardinal principles should be kept in view, and should control our action:

First. Organic wastes must be discharged at the sewer outlet in their fresh condition, before putrefaction has set in.

Second. They must be reduced to a state of complete oxidation without the intervention of dangerous or offensive decomposition.

As the difficulties attending disposal are due chiefly to the water in which the wastes are borne, sewage should be, in the interest of economy no less than of efficiency, protected against an excess and fluctuation in volume, due to the admixture of storm-water. C. H. Latrobe, C. E., describes a proper system of sewerage as being "an efficient and well-regulated machine for the speedy and unobjectionable removal of water-borne filth, and its delivery as a substantially uniform product at such a point as is desired, and in a condition capable of treatment in a uniform manner by a uniform plant, whether chemical, mechanical, or otherwise."

Only by such uniformity of flow, day by day and week by week, can our problem be simplified and our work shorn of unnecessary embarrassment. This implies the adoption of the separate system of sewerage, by which only the water necessarily fouled in houses and needed for the proper removal of wastes shall be admitted to the flow that is to be dealt with; other means being used for the removal of storm-water, and the filth of streets being taken care of otherwise than by discharge into sewers with the gutter-flow. Street dirt should be swept up, not washed away. This exclusion of storm-water will, perhaps, never be reached in all cases, but wherever it is, or is likely to become, necessary that processes of artificial purification should be adopted, there at least the withholding of storm-water and street-wash should be secured. In the great majority of towns now contemplating sewerage, purification is sure to be demanded sooner or later, and sewerage systems should there be regulated from the outset with that end in view.

In considering the requirements of disposal, we should not be too much influenced by the experience and practice of England, where a natural tendency to conservatism has led to the continued use of methods which would not have been adopted had engineers known twenty years ago what is well known now. It is not unusual to see it stated in discussions of this subject that English experience points to the provision of one acre of sewage irrigation land for each hundred of the population, and projects for irrigation are sometimes rejected here because of the great cost that would thus be entailed. The fact is that no such great amount of land is required for the proper treatment of the foul elements of the sewage. If needed at all, it is needed only to meet the demand of great floods of storm-water containing more or less street-wash, sand, and clay, sent to the fields at a time when they are already saturated with rain. Where all storm-water is excluded from the sewers, this difficulty does not exist, and the irrigation area may be limited to an amount that will, when wet with rain, still admit the volume necessarily resulting from the copious use of water in our houses. Just what this limit is to be cannot now be determined. It will vary according to the character of the soil. Clay will absorb much less water than loam, sand, and gravel will, and ground underlaid with a porous subsoil, or thoroughly underdrained, will absorb more than ground underlaid with compact clay. At the same time, if only heavy land is available, this may be much improved by artificial drainage; and the freedom of its drainage will increase as time goes on, so that it will ultimately be able to cope with an increased flow.

Experience at Gennevilliers has demonstrated that, on permeable lands, even when the sewage is entirely at the discretion of the landholders, so that they may use what they want and as they want it, one acre may receive the sewage of over four hundred and fifty persons. At Breslau, where the storm-water is admitted to the sewers, the proportion is about one acre to four hundred persons. With a suitable soil,— the sewage being entirely free from storm-water, and provision being made for occasional disposal by filtration beds when the condition of the crops indicates the desirability of withholding the sewage from the fields,— one acre for three hundred persons or more would be quite safe. With intermittent downward filtration alone, in its intensified form, one acre may be made to suffice for one thousand persons or more. This capacity was reached, and was much exceeded, in England, in the Intermittent Downward Filtration Works of J. Bailey Denton.

Occupying a middle ground between the combined system of sewerage which takes in the whole rainfall, and the strictly separate system which excludes it all, there is what is known in England as the "separate system," from which street-flow is excluded, but to which roof and yard water is admitted. This is a compromise that secures only mitigation. Like all compromises, it falls far short of the best result. It leads to such wide fluctuations in the volume of flow as to call for greatly increased areas of land to absorb, during storms, surplus water which is of no use to any proper office of the sewers, and which might usually better be disposed of in some other way. The adequacy of the strictly separate system is now, after extensive and various use, so well established in this country that it may be said to be accepted as the best system for the smaller towns, assuring them a regular volume for treatment when the time for artificial purification comes. This will call for much less land than is needed where only the street-flow is excluded, leaving still great volumes of roof-water to reach the fields.

The methods of disposal to which recourse is now had are mainly:

1. Broad irrigation. 2. Intermittent filtration. 3. Chemical precipitation. Sedimentation and straining, while resorted to in rare cases, have little to commend them to favor.

1. Broad irrigation consists in the flowing of sewage in thin sheets over the surface of the ground, in such a way as to bring it into contact with the soil and with vegetation growing upon it, and to allow a soaking of the liquid into the ground, to a greater or less depth, according to its porosity or absorbent character. In its best application, the flow is all absorbed before the limit of the area is reached. The water of the sewage is removed by downward filtration, by evaporation from the surface, and by being taken up by growing vegetation. The impurities are oxidized in the absorbed or flowing liquid, or are strained out by particles of the soil, etc., and are thus so exposed to the access of oxygen that purifying bacterial growth effects their rapid resolution. The *rationale* of the processes of purification with irrigation is practically the same as with filtration. The application of the sewage is intermittent, only so much being applied at once as can be taken up by the land. The intermission of the flow is sufficient to allow the water to disappear, leaving the ground moist, but not wet. It is now ready for a new application, but the longer the time between doses, within reasonable limits, the more complete is the destruction of the retained wastes. As first applied, the flow has the general appearance of dilute soapsuds; rags, vegetable parings, and other grosser solids having usually been withheld by screening. As the flow passes on, its coloring matter having been retained, it becomes clearer and clearer, and, after a sufficient distance has been traversed, it is not only clear but clean. This description relates to the use on smooth land, usually covered with grass, grain, etc. For use in the growth of vegetables, nursery stock, etc., the area is better formed into ridges and furrows, the plants growing on the ridges and the sewage flowing in and absorbed by the furrows.

2. In intermittent filtration large volumes of sewage are applied to small areas of land, submerging it to a considerable depth, and soaking into the earth in the interval between doses. A larger proportion of the impurities of the sewage attaches itself to the particles of soil below the surface than in broad irrigation, and a smaller proportion of the water is removed by evaporation. The success of this method calls for a much more porous soil than is required for irrigation, and ample drainage is more important. The bacterial action extends to a greater depth.

No sharp line can be drawn separating irrigation from filtration. The differences are differences of degree rather than of kind. If an absorptive soil, with good drainage, is used for irrigation, so much of the flow will sink into the ground as to make it largely a filtration system; while with filtration through beds of considerable extent, the surface exposure of the area, after the subsidence of the sewage, differs little from that which follows an irrigation flow.

With both methods the result is good — more or less good, of course, according to the skill of arrangement, and to the carefulness of management. Under the best conditions it is practically perfect, the effluent being freer from organic impurities and from bacteria than the purest river water used for the supply of towns. I was one of a large party of visiting engineers who drank freely of the pure and sparkling outflow of the underdrains of the Gennevilliers sewage-fields.

The Massachusetts experiments showed that the filtration of sewage through very fine, nearly white sand, at the rate of 25,000 gallons per acre per day, and during cold weather, produced an effluent containing less nitrogenous organic matter than the waters of Lake Winnipiseogee.[1]

The adoption of one or the other of these methods will be indicated by quality of soil, area available, cost of purchase, and other local conditions. The ideal disposal-field would be one of such an absorbent character that sewage would not flow to its farthest limit before disappearing in the ground, and with such a slope as to give it a lively flow, and to prevent ponding. It would be, in short, coarse gravelly or sandy land, with a smooth surface and a marked slope. On such land full crops could be grown, even with heavy flooding, at short intervals.

3. Chemical precipitation is a much more artificial system. The sewage is treated with certain quantities of lime, salts of iron, or other chemicals, and the velocity of its flow is arrested by large vats or tanks placed in its course. Something of the nature of a coagulum is formed, having a greater specific gravity than water, and this settles to the bottom, carrying with it enough of the suspended matters to leave the liquid more or less clear and transparent. This clearer portion is drawn off and discharged into a stream or otherwise, and the sediment, known as "sludge," is from time to time removed and subjected to special treatment, the best method being to squeeze out its surplus water in filter-presses, forming solid cakes, which may be conveniently handled. The purification effected is more apparent than real, and precipitation is applicable only to conditions where apparent purification is the chief end in view. It is sometimes supplemented with irrigation or filtration, when it becomes merely a method for withholding coarse, fibrous, or adhesive matters, which might clog the ground and so lessen its absorptive capacity. This is little more than a theoretical advantage, for there is a simpler and much less costly way to obviate such clogging, which, in fact, is rarely serious when the land is reasonably porous.

As has already been said, chemical precipitation is at best a half-way measure. It does not even remove the most putrescible impurities of the sewage, and the effluent sometimes contains more bacteria than the incoming sewage did, owing probably to their development in the tanks during retention.

There is sometimes a controlling reason for adopting this process, as in the impracticability of procuring land suitable for filtration or irrigation; but this applies with much more force and frequency to Europe than to this country. Even where apparent economy suggests the use of this system, it is always a question of paying less money for a less complete result, with a probability that future requirements for better purification may compel an ultimate outlay greater than the cost of an original resort to the better process.

In the application of irrigation and filtration processes, the coarser elements of the crude sewage must be withheld. Solid fecal matter need hardly be considered in this connection. It is so broken up and macerated in its flow through the sewers as almost entirely to disappear. The amount reaching the field is inconsiderable and of no effect, and may be disregarded. There is, however, a certain amount of coarse paper, rags, vegetable parings (which would be objectionable on the score of appearance), and a good deal of paper-pulp sediment and adhesive matters, which, if allowed to flow over the land, might so coat it as to interfere with absorption. This latter is the only element of what in chemical processes goes to make up the large quantity of sludge that calls for special treatment in irrigation. The coarser objects are easily retained by a screen placed near the mouth of the sewer,—preferably a horizontal screen,—over which the water flows, and which has an outlet to the field underneath it.

The withholding of paper pulp and other fibrous matters may be affected by a method applied at Wayne, Pennsylvania, where the flow of sewage during irrigation is at the rate of about 10,000 gallons per hour. The field is divided into five sections of about two acres each, for alternate use. The sewage reaches them over and through straining areas formed of broken stone (macadam), averaging about eight inches deep, seventy-five feet wide, and ninety feet long. These retain most of the fibrous and gummy materials and they gradually disappear.

Just as the coarser parts of the sludge-forming material attach themselves to the surfaces of the broken stone, so the finer parts attach themselves to the surfaces of the earthy particles, grass, etc., over which the flow continues, and the sewage is thus clarified very early in its course.

If the flow were uninterrupted, absorption and purification would soon cease. Fibrous and gummy materials would so accumulate as to

[1] "Report of the State Board of Health of Massachusetts," 1890, p. 254.

make an impervious mat over the ground, preventing absorption and aëration. With intermittent application this does not occur; what has been deposited on the field by one dose of sewage is so changed during the dry interval as to lose its felting quality. There is no accumulation from dose to dose, gradually to close the surface of the filter.

In all forms of irrigation and filtration disposal, intermittent application is the key to success. Completeness of purification may be favored by long intervals, but capacity for purifying large volumes calls rather for intervals as short as will suffice to get rid of surface accumulations and to maintain a pure effluent.

The oxidizing organisms are short lived. When their food has been consumed, they disappear, and their disappearance implies a reduction of oxidizing capacity. This can be maintained at its maximum only by keeping up the full working force that the soil we use can accommodate. The condition in this respect cannot, of course, be regulated with anything like exactness, but experience and increasing knowledge will enable us so to adjust the supply to the demands of full activity as to approach more and more nearly to a maximum efficiency. The indications are that the conditions affecting absorption, aëration, and the maintenance of a full supply of organisms will improve with use, and especially with frequent use; so that the capacity of any suitable soil to purify sewage may be increased, not indefinitely, but to a point that has nowhere yet been reached, at least in irrigation.

We are still far from knowing enough of the detailed working of disposal processes to determine what would secure the best results in any given case, but we are at least so sure of our ground that we can work in the right direction; and we can now safely cut loose from the restrictions imposed by early English practice, where — in view of the occasional great increase of flow over rain-saturated land, due to the admission of storm-water to sewers, and of the supposed need for maintaining a good agricultural condition — it was deemed necessary to provide very large areas of land, and where it was thought that, even then, considerable periods of rest were requisite.

Under conditions which are generally available, we may feel safe with an acre for each three hundred of the population, and under conditions which are not very exceptional, one acre per thousand of population may suffice.

The practical results of broad irrigation in works of long standing show that the process, when well carried on, is devoid of all offense, and may be made to yield agricultural returns which will go far toward paying the cost of maintenance. At Gennevilliers, where irrigation and filtration are combined, and where the soil is gravelly, the sewage of Paris is made purer than the best drinking water of that city. Prosperity has been brought into the district, which was originally a poor one. Land that was formerly of trifling value now sells for $2000 or more per acre, and its rental value has quadrupled. The population has increased by one half, and general prosperity has taken the place of comparative penury. The health of the people is excellent, and even in 1882, when there was a cruel epidemic of typhoid fever in Paris, there was none here. The general mortality of Gennevilliers in 1865 was thirty-two per thousand. In 1876 it was twenty-five, and in 1881 only twenty-two. Measures have now been taken to extend the same system over other lands, sufficient for the purification of the entire outflow of the sewers of Paris, save during floods of the Seine, when there is no objection to its direct discharge therein.

Correspondingly good results have been reached at Berlin, Breslau, and elsewhere. In fact, the entire adequacy of disposal by application to agricultural lands has been fully and finally demonstrated. Wherever suitable land can be had, this method of disposal meets with no obstacles which experience has not shown us how to surmount, and it encounters no prejudices which acquaintance with its details does not remove. Sewerage engineers are sometimes asked where it is best to "dump the sewage," and other expressions are used suggestive of the disposal of putrid filth by night-soil carts. Sometimes the owners of adjoining lands object to the establishment of a sewage-field, in the belief that it will become a nuisance.

The fact is that the "dumped" matter is fresh and inoffensive, is mainly invisible save as it clouds the flow, and is a thousand times diluted. If its treatment is properly regulated, it is withdrawn from the diluting water and completely destroyed in a manner that is imperceptible to our senses; and in the case of broad irrigation, with the effect of producing a luxuriant vegetation during the growing season. At Wayne, Pennsylvania, a protesting neighbor, who had apprehended an insufferable nuisance, soon expressed a regret that his land was not so situated that the sewage could be made to flow over it.

If there is still room for doubt on any point, it is as to the character of the few bacteria which escape the action of the process employed, and are found in the effluent. It is not known that disease germs ever exist among these, and it is altogether probable that they do not. So far as these organisms are understood, it is thought that they cannot withstand the destructive activity of the oxidizing and nitrifying organisms which are always present, and it is believed that only these hardier ones exist in the effluent of land-purification works. Certain it is that no instance has been reported where contagion has been carried by such effluents, and experience at Gennevilliers has shown that typhoid fever and cholera, when rife in Paris, were completely arrested at the irrigation-fields. At Berlin, also, it is stated that no disease has been suspected of having been communicated by the sewage to any one of the large populations of the irrigation-farms.

The same methods that are used for the purifying of sewage of towns are applicable, with suitable modifications, to the sewage of single houses. There are hundreds of cases in this country where the whole liquid outflow of the household is perfectly disposed of by subsurface irrigation on a small part of an ordinary village lot. The use of the noisome and dangerous cesspool and vault has given place to a system in which putrefaction is unknown, and in which no menace to health exists—as it always exists in a cesspool system.

Chemical precipitation was adopted at the World's Fair to render the sewage fit for discharge into Lake Michigan at an unfrequented point. This it accomplished. The process was under the control of Mr. Allen Hazen, chemist of the Lawrence (Mass.) experimental station. The results and conditions of the work, where four independent tanks were used, were carefully watched, and constant analyses were also made. Mr. Hazen gives the determinations of a single day (August 16), some of which are as follows:

> The sediment in the sewage being "much," it was also "much" in two of the effluents, and "decided" in the other two. It is indicated that the sediment of the sewage being 26, that of the effluents averaged 12¼.
>
> The chlorine of the sewage being 4.4, the average of that of the effluents was 5.0. The albumenoid ammonia of the sewage being .95, that of the effluents averaged .45. The free ammonia of the sewage being 3.30, that of the effluents averaged 3.45.
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> There were 4,000,000 bacteria in a cubic centimeter of the sewage. In an equal volume of each of the four effluents the average was 8,200,000.

About two weeks earlier, when the writer visited the works, there was much odor in and about the building, and the effluent was much colored and had a foul smell. Mr. Hazen's final report will be awaited with interest.

The Massachusetts Board of Health made elaborate experiments in chemical precipitation, reaching the conclusion that

> It is quite impossible to obtain effluents by chemical precipitation which will compare in organic purity with those obtained by filtration through sand. It is possible to remove from one half to two thirds of the organic matters of sewage by precipitation with a proper amount of an iron or alumina salts, and it seems probable that, in some cases at least, if the process is carried out with the same care as is required in the purification of sewage by intermittent filtration, a result may be obtained which will effectively prevent a public nuisance.

Where the purpose is to secure such a removal of obvious impurities as to allow the effluent to pass into a watercourse during the few months of its low stages without opposition from those past whom the stream flows, and under other exceptional conditions, precipitation may be used with advantage. It will, in some cases, be a question as to the permanent adequacy of the relief. Will conditions which satisfy riparian owners now continue to satisfy them when they know more about the subject; and will streams into which an impure effluent may now be admitted, because they are not sources of water-supply, continue so long exempt from the effect of legislation looking to the preservation of the purity of streams, as to make it worth while to use a method of only relative efficiency? The conditions of each case must be considered by themselves, and there are doubtless instances where incomplete purification will satisfy the needs of many years to come.

If this incomplete result will suffice, it is even then to be questioned whether it is best to be secured by chemical precipitation. What is needed in such cases is to remove from the sewage its coarse, fibrous, and sedimentary contents, and enough of its suspended matters to reduce its turbidity to about that of the stream which is to receive it. The experience at Wayne indicates that a simpler and more economical way to do this is to be found in irrigation. Thus far it is only indicated, but the extension of irrigation processes will give further opportunity to study the effect of a brief flow under proper conditions, and will doubtless enable us to formulate an effective plan that will suffice for cases where only a clarified affluent is demanded.

Each of the three fan-shaped sections of the Wayne field begins with a screen of broken stone, having an area of about 6750 square feet. The sewage, previously screened of its rags, etc., in flowing over and through these stones, deposits all of its coarser impurities. It then passes over an area about seventy feet wide, having a fall of one foot in three feet, and containing nearly 10,000 square feet. At the lower edge of this a porous barrier collects the flow for even distribution over the next section, which has a fall of one in four, is sixty feet wide, and has an area of nearly 11,000 square feet. At the foot of this the sewage has little color, and is freely drunk by dogs. Here it passes through another barrier, and flows over a section, with a fall of about one in six, 120 feet wide, with an area of about 28,000 square feet. The condition of the sewage is now vastly improved. By the time it has reached the lower edge of this section it is perfectly clear and apparently pure. It is often tasted by visitors. It is obviously a better effluent than that of any precipitation works of which the conditions have been published. If the hillside were less steep, the result would be still better. The three sections occupying the hillside vary little in size and arrangement. The combined area of the three is about four acres. These are capable of cleansing, to the extent indicated, over 200,000 gallons of sewage per day, each section having two days' rest to one day's use. That portion of the field that is described above requires attention equal to less than the daily services of one intelligent laborer.

As is usual when the separate system of sewerage is used, the flow has no odor, and all of the retained matters are inoffensively destroyed under free exposure to the air. The effluent at the barrier last referred to is not only apparently pure, but it is nearly pure enough for admission to such a stream as is under consideration; that is, it is fit to be discharged wherever the effluent of precipitation works may be discharged. No sludge is accumulated, there is no outlay for chemicals, and over the lower two thirds of the tract there is a strong growth of grass which thrives with three heavy floodings in one day, followed by a dry condition for two days.

The method of disposal by irrigation or filtration is an extremely flexible one. It is susceptible of modifications that will make it suitable for a great variety of circumstances, and for a wide range of soil and of surface conformation.

It is equally available for a single house, for a village, or for a town, and its processes are so nearly automatic that its use on a small scale entails no material cost or care in maintenance. With a small area for surface distribution near the house, it is only necessary to provide a simple intermittent flush-tank, with an outlet that can be changed to either of the two or three alternate sections into which the area is divided, each large enough to absorb a few hundred gallons of water. Little attention will be needed beyond the periodic directing of the flow to one section or to the other. It is desirable that this ground should be withdrawn from full sight, but only for esthetic reasons; there will be no odor.

In like manner the sewage from a large hotel, or from a dozen houses, or from a village or a town, may be controlled with only such increase of cost and attention as the larger service entails. The important recent improvements in methods of application have been in the direction of simplicity, and the following facts are now fully established:

1. House drainage is practically odorless when first produced. It does not become offensive unless retained until it putrefies — only after a day or more.

2. If applied when fresh to the surface of suitable ground, its water is removed in a condition fit even for safe drinking, and its impurities are completely destroyed, both in winter and summer, without offense or danger of any kind.

In short, the bugbear of sewage disposal has been done away with, and we are now in a position to adopt simple and unobjectionable methods, which will produce a perfectly satisfactory result in all but very exceptional cases.

It will be of interest to the people of New York to know that the treatment herein set forth is especially applicable to the care of the Croton watershed. It is perfectly suited, and it is the only method that is suited, to the complicated conditions there presented. By its means every town, village, residence, factory, or farm that may cause a pollution of the Croton supply can be brought under such control as to be made harmless, at a minimum of cost and at a minimum of inconvenience to the owners. The processes used would be so easily brought under the control of the inspection that would be necessary in any case, that the purity of the water-supply would be permanently assured — as it can be assured by no other means thus far devised.

George E. Waring, Jr.