The Disposal of Sewage

—— OF ——

Isolated Country Houses.

WM. PAUL GERHARD, C. E.

1890.

With the compliments of the author.

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OF

SEWAGE OF ISOLATED COUNTRY HOUSES,

BY

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ISOLATED COUNTRY HOUSES.

A serious and all-important problem presents itself to all builders or occupiers of suburban and country residences, not located within reach of sewers. I refer to the question what method should be adopted by architects or householders to get rid of the liquid wastes from the household in a manner calculated to avoid at once all nuisance to sight or smell, all danger to health arising from the pollution of the soil, the water and the air, and all causes of contamination of water courses, whether flowing streams, or ponds, lakes, estuaries and harbors. The problem is not at all a novel one, for nearly two thousand years ago Hippocrates discussed the same subject of the relation existing between health and soil, air and water, yet, if we contemplate, for a moment, the numberless filth-reeking and disease breeding privies and barbarous leaching cesspools which we still encounter everywhere, and which apparently are accepted as necessary adjuncts to farm houses, summer residences, mechanics' dwellings, etc., we hope to be considered justified in again calling attention to the evil results of improper methods of sewage disposal, and in discussing briefly the proper remedies.

Let us begin with a consideration of the smaller farm houses, mechanics' cottages and laborers' dwellings. The crude methods usually adopted to get rid of all filth from these are the discharge of the liquids into some open ditch, or into some neighboring water-course, brook or pond, and the accummulation of the excreta in privy-vaults. In other cases, slops are retained on the premises by pouring them directly in front of the kitchen window on to the surface of the ground, which is thus kept continually wet, and quickly becomes saturated with filth, or else the liquid sewage is stored in leaching

cesspools or poured into disused wells. It seems unnecessary to explain at length the disadvantages and dangers of privies, vaults and stagnant pools of slops, from a health point of view. The objections against them are well recognized, and hence such devices are now utterly condemned by all sanitarians as relics of primitive stages of civilization. The proper disposal of the slop-water of such small houses is so easily accomplished, wherever, as is almost always the case, a small vegetable garden, or lawn, or grape vine trellis, or an apple orchard adjoin the house, as to make us wonder why better methods than those indicated above are adopted as yet in comparatively rare instances. In all such cases, the sewage may, with advantage, be used to feed plants and fruit trees, or to irrigate the soil. The ruling principle should be to keep solid and liquid waste matters, as much as possible, apart, for this will facilitate the disposal of both. The kitchen water, soapsuds from washing, chamber slops, urine, and other fouled water, are easily disposed of, by a daily distribution in the garden, either by irrigation, or by subsurface irrigation. The slop-water should be collected every day in a tight tank and carried by hand, or carted in a wheelbarrow, to the garden, and there used to water plants, shrubbery and fruit trees, or to cultivate garden vegetables. Instead of by surface irrigation, the slop-water may be discharged into one or more lines of absorption drains, laid with open joints under the surface. For the smallest cottage, fifty feet of absorption tiles are sufficient, and in proportion, as the quantity of household sewage increases, the amount of tiles should be increased. The principal points of importance are that the sewage be applied to the soil while *fresh*, and before decomposition sets in, that it should be applied in moderate quantities only, to prevent oversaturation of the soil, that the sewage be applied on or near the surface of the soil, within reach of the oxidizing influence of the air and of the bacteria in the soil, and, finally, that the application be made intermittent, so as to give the soil, after each discharge, a chance to breathe, as it were, and to allow the finer solid particles to be oxidized and destroyed. An easy method of accomplishing the disposal of slop-water, where the house contains no plumbing fixtures, is to have near the house a hopper or receiver of wood or rustless iron, or, better, of earthenware, and provided with a strainer and a proper cover. From this a pipe may be carried underground to the absorption tiles, while the house sewage may be carried to and discharged into the hopper by means of a pail, thus sending rapidly a full volume of slops at proper intervals into the absorption tiles.

The solid excrements are taken care of in the case of small cottages quite as readily and inoffensively by adopting an earth or ash closet, in place of the usual privy, still so much *en vogue*, although long ago unanimously condemned by practical sanitarians. In the application of the dry earth system sufficient dried earth, garden loam, or sometimes coal ashes are mixed with the excreta to absorb all foulness, keep down all odor, and prevent putrefaction. Such earth closets work quite satisfactorily with only a little attention, and form a simple and cleanly substitute for the privy nuisance. They are manufactured in various grades, and with more or less complicated mechanism. As a rule, the simpler the arrangement, the better. If placed out of doors, the earth closet should not be located too far away from the house. The outer structure should be strong, substantial, with a good roof to protect it against rain or dampness, well lighted, well ventilated, not too much exposed to the rays of the sun, and preferably plastered on the inside as a protection in cold weather. A carefully kept dry walk should lead to it from the house, and it is better to have the walk and the closet shed screened from view and from the prevailing winds. The excreta should be received in a movable wooden box, well tarred, or else in a galvanized iron pail, not too large, and of such shape and construction that it can easily be carried. The box or pail should fit close up under the seat, and each time the closet is used, ashes or dry earth should be used as deodorizers, being thrown down either by a handscoop or by a mechanical apparatus. There can be scarcely any doubt about the economy, efficiency, and convenience of such apparatus in the case of small houses. The property of dry earth, of not only deodorizing, but also absorbing, and rendering harmless excreta of animals has long been well known. Some difficulty has been experienced in cases where the earth was kept too damp. According to recent observations a much smaller quantity of earth is required for earth closets, if the separation of the liquids and solids is at once effected. This may be accomplished by intercepting the urine under the seat, and removing it by a waste pipe. The closet is thereby more easily kept free from smell, and if properly used and well taken care of, it can be located in an extension of a dwelling without becoming a nuisance. The dry earth manure ought to be removed at frequent intervals, and in summer time used and dug under the soil in the garden attached to the cottage. In winter time it may be dried in out-house and can then be applied over and over again. Ashes are sometimes used in place of earth, or else finely powdered charcoal, which latter is a well known deodorizer.

The latter can be applied with a mechanism similar to the one used in earth closets, and it is claimed that only about one-fourth the quantity will be needed. As charcoal is rather expensive this is an important consideration. Some also claim that removal need not be so frequent in the case of charcoal closets, but this is, at best, a doubtful advantage.

In cottages, or suburban residences of somewhat more pretension, the earth closet is sometimes located, for conveniences sake, in an extension of the cottage, and it then usually becomes desirable to have also a somewhat more convenient method of disposal of the slop-water, which would avoid exposure of the housewife or servant to the inclemencies of the weather. This may be secured by arranging a properly ventilated and trapped waste-pipe—a pipe two inches diameter is plenty large enough—to carry the waste from the kitchen sink, the laundry tub, and wherever this is provided for, from the bathtub, into a small receiving tank, located outside of the house, and placed below the depth to which frost usually penetrates. This tank may be a plain wooden box, or an earthen or iron tank, or finally a tank built of brickwork. It may be emptied in the plainest kind of an arrangement by hand, or else it may be discharged by an automatic device, such as a siphon, a tumbler tank, or other mechanical appliance. It may become useful, even in the case of small houses, to build some sort of a grease trap to prevent the grease from being discharged and finally clogging the small absorption pipes. It is, of course, assumed that the general topography of the lot is favorable to such an arrangement, in other words, that there is not a slope from the garden, or absorption field, toward the house, in which case disposal by gravity becomes impossible. If the earth closet is placed inside of a dwelling the same precautions should be observed which are taken in the case of water-closets. The ventilation of the apartment is an important matter, and should receive careful attention. As a rule, it is better to locate an earth closet in an isolated or detached part of the cottage. While an earth closet is inferior to the best water-closet, I have no hesitation in pronouncing it, if well taken care of, superior to many water-closets *as usually arranged and kept.*

The question whether a farm house or laborer's small cottage should be provided at all with plumbing work, and above all, whether it is wise to have a water-closet indoors, which in turn requires a more or less complicated system of service pipes and a service cistern, is, more than anything else, one of convenience and comfort. The annoyance and cost of frequent repairs, and the difficulty in country districts of

getting a mechanic to fix such apparatus when out of order, the danger of exposed pipes and traps freezing in mid-winter, or sometimes the lack of an abundance of water for flushing, or the necessity of raising it by hand-pumping,—all these are considerations which may deter many from putting any plumbing work into their homes. It is undoubtedly much easier and less troublesome to deal with the sewage problem of cottages, if the strict separation of solids and liquids is adhered to. A water-closet in a house not only requires a larger discharge pipe than the two inch waste pipe for slop-water, but it complicates at once the whole arrangement. That it can be made quite safe, perfectly inodorous and inoffensive it is not necessary for me here to assert. Those who have followed the recent improvements in house drainage and plumbing work will know that it is possible to select a good water-closet and fit it up in such a way as to be in all respects satisfactory. In points of cleanliness, I think it certainly stands ahead of any other device. Its advantages are many, but its disadvantages under certain conditions ought not to be overlooked. If a water-closet is used in a cottage, the solids should not enter the outside tank for slop-water, for they would soon clog the siphon or the absorption tiles, but they should be intercepted in a settling chamber and frequently removed. How this may be done will be explained later on when detailed reference is made to larger country houses.

The proper disposal of the sewage of larger country or suburban residences, fitted up with all the usual plumbing appliances, is often, indeed in most cases, a much more puzzling problem. What shall be done with the more or less large daily volume of sewage of detached and isolated country houses, without creating a nuisance either on one's own premises or on those of the neighbors? This is a question of much interest to thousands of householders who live in the better class of country or suburban houses, and who are often compelled to meet the difficulties as best they can. The problem has long engaged the attention of civil engineers, who make a specialty of sanitary drainage, and while it is possible that the best solution has not yet been discovered, there are several methods which are in more or less successful use. Whatever method of disposal of the sewage may be adopted, it is obvious that one must decide about it before arranging the house drainage system inside of a house, for the best arrangement of the main drain and its branches in the cellar or basement of a house will depend upon the direction in which the sewage tank will be erected, or upon the location of the final outlet. Generally speak-

ing, an isolated country house; not in reach of sewers, may dispose of its sewage by one or the other of the following methods :

1. It may discharge its sewage into an open surface ditch or gutter, removing everything from the house, and carrying the wastes into a more or less distant sink hole, or to some low spot where the sewage is allowed to soak away and to evaporate slowly. This method, based on the principal of "out of sight, out of mind," is a very primitive one, and one that has not a single feature of merit. As a rule, such a system becomes highly offensive to the immediate vicinity of the house.

2. The house drain may empty the sewage into a large open or leaching cesspool, allowing the liquids to ooze away through underground porous strata, or by fissures and cracks in the rock. This, although a very common method of disposal, is in reality one very dangerous to health, particularly so where the water supply is local, being derived from a well, a cistern or spring on the premises. It is a method uttterly to be condemned as both unsafe and nasty.

The most primitive form of cesspool is a hole dug in the ground, into which all the sewage is continually poured, the result expected being that at least the liquid will soak away through unknown underground recesses, and disappear. Occasionally the sides of such a cesspool are lined with loose stones, laid dry, the liquid sewage escaping at the numerous open joints into the surrounding soil, while more or less of the solid matter and grease are retained in the cesspool, undergoing at once a very dangerous process of decomposition, in the presence of moisture, heat and darkness—all conditions known to be particularly favorable to the growth of dangerous bacteria or germs of disease. In dealing with sewage, a cardinal principle, always to be observed, is to avoid all stagnation. In the leaching cesspool we have the worst possible example of stagnation and of accumulation of putrefying filth on our premises. The great objection to a leaching cesspool is not only that it constitutes in itself an abominable nuisance, comparable to a powder magazine, which merely needs a single spark to create destruction, but that it unavoidably and invariably pollutes the subsoil in the neighborhood of dwellings, contaminates the water supply, and renders the air which we breathe obnoxious by its exhalations. If we consider for a moment that such isolated country dwellings and farm houses, which are not in reach of sewers, also do not usually enjoy the benefit of a public water supply, but must derive their potable water from wells, cisterns or springs on the premises, the full extent of the evil and the force of our objections become

more apparent. It is, indeed, of the utmost importance that the local water supply of isolated dwellings be kept as clear and free from contamination as possible ; but even supposing that water is introduced from a street or public supply, the enormous evils of soil pollution and air contamination remain. Two thousand years ago, an old philosopher, Hippocrates, preached a sanitary formula, which has not been improved up to the present day. Recognizing the dangers to health resulting from neglect of sanitary precautions, he expressed his advice in the words, "pure air, pure water, and a pure soil." What, then, shall we say if some of our best architects of the present day persist in suggesting as the most convenient and ready means of getting rid of the sewage of a country house the adoption of a leaching cesspool?

I admit that in sparsely populated country districts a leaching cesspool, located at a great distance from, and at a lower level than, the house, may sometimes be used without causing any harm to the occupants of the house. As a matter of principle, however, sanitary science must condemn such devices in every case. If the principle is true that we should speedily return all organic dirt and filth to the earth, it should be carried out in such a manner that the soil may accomplish the complete destruction of organic filth. We shall see, further on, that this can be done only near the surface of the soil, and by application of the sewage before it becomes putrid.

In pouring our sewage into leaching cesspools, on the contrary, we bury all matter deep in the ground; remote from the cleansing, oxidizing effect of the atmosphere, of the purifying action of plant life, and of the help which is rendered by some of the low organisms, or so-called bacteria, in the process of nitrification and destruction of organic matter.

Then, again, another important consideration should not be lost sight of, namely, that often where a leaching cesspool cannot work any danger to our own house, our own well or spring, it may pollute shallow or deep wells belonging to adjoining estates. It is, therefore, evident that as habitations are grouped closely together, leaching cesspools become more and more inadmissible. If we are selfish enough to locate such a cesspool in the remotest and lowest corner of our own garden, entirely forgetful of its immediate proximity to our neighbor's drinking-water well, it is but perfectly proper that our health authorities should remind us that we have some obligations to fulfill against our neighbors.

Occasionally, such cesspools are built with the sides solid, leaving

only the bottom loose for the escape of sewage, or in cases where they are originally open on the sides, the pores soon clog, and the removal of the liquid then takes place in a very imperfect manner.

3. The house drain may deliver the sewage into a tightly built cesspool, provided with an overflow pipe carried into some ditch or watercourse. Such an arrangement may be considered a direct outcome of the leaching cesspool. Desiring to avoid the pollution of the soil, the architect or owner built the cesspool with tight sides and bottom, but, finding that it would rapidly fill up, and that frequent pumping out would be expensive, an overflow was taken from the cesspool, and the surplus of liquid sewage carried away. While such a tight cesspool with overflow located far away from the house, and with the overflow carried into some large volume of rapidly flowing water, may be unobjectionable, where but little water is used in a house, the arrangement constitutes in the case of larger houses a fearful nuisance, for the sewage is already putrid when removed.

4. The alternative is to empty the sewage into a cesspool built absolutely tight, and without overflow. Such a cesspool avoids the pollution of the water supply, and also the contamination of the subsoil. It is, therefore, an arrangement much to be preferred to a leaching cesspool, and permissible under certain circumstances. Perhaps I should rather call it a sometimes necessary evil, for it should be borne in mind that it involves a long temporary storage, and does not effect an immediate or nearly immediate disposal. Hence it cannot be approved from a sanitary point of view, and its objections are many and serious ones. Since it is the object of all good drainage to get rid of filth from the premises at once, or else to dispose of it on the premises while *fresh*, so as to be completely taken up by vegetation and purified by the soil, it is evident that a vast receptacle of accumulated filth cannot be considered a sanitary device. The stagnating sewage within the walls of the cesspool undergoes a process of decomposition, and the gases generated are extremely unwholesome, often causing, by improper escape, or by entrance into houses through the sewer pipes, a nuisance. To ventilate such a cesspool successfully is rather a difficult, and often an impossible, matter.

To overcome some of these objections, it is the habit of some architects to use two cesspools for a single house, delivering into the one all water-closet wastes, while the other one is intended for the reception of kitchen and laundry water. I do not approve of such an arrangement. Practically, it is found that after awhile both cesspools do not differ materially, as regards the degree of putrefaction

and offensiveness of their contents; nor can I see any sense in duplicating or multiplying the dangers which adhere to all cesspool arrangements.

There are some cases where no good feasible way of dealing with sewage may be advised other than to run it into a tight cesspool. In that case, the following precautions are to be observed: The cesspool should be located as far away from the house as possible, and there should be proper disconnection between the house and the cesspool. The latter should be built in two compartments, the first of which constitutes an intercepting chamber for the solids, while the second and larger chamber will receive the liquids. Both chambers should be built thoroughly tight, of hard-burned brick, laid in hydraulic cement, preferably of a circular shape, and the walls should be well rendered inside and outside with Portland cement. Each chamber should be arched over and topped with a manhole, covered with a tight iron cover. The cesspool should be as well ventilated as it is possible to do, and it should be emptied, cleaned and disinfected at frequent intervals. The separation of the liquid from the solid matter facilitates much the disposal of both. The liquids may be bailed, or better, pumped out, and used to sprinkle and irrigate the lawn, or kitchen garden, shrubbery, vine trellis or apple orchard. The solids should be removed and dug as fertilizers under the soil. The oftener this is done the better, and the less offense will be caused by the application of sewage to land.

Some objections to a cesspool always remain. If it is built, as it should be, *absolutely* tight, and of moderate size only, to avoid the retention of too large a volume of sewage, then the necessity of frequent pumping arises, and with it the annoyance of constant attention and of manual labor. If we enlarge the dimensions of the cesspool to avoid the frequency of pumping out, we increase the dangers alwaps resulting from stagnant sewage, and create, as it were, a large gasometer for noxious gases.

5. If a stream of running water, either a brook, river, canal or tidal estuary is available, at not too great a distance, a single house may sometimes discharge its sewage into it, trusting to the dilution of the sewage and to the self-purification of the stream to render the sewage innocuous. This method, simple and convenient as it may appear, cannot be regarded as permissible in all cases. It is a method which, especially if the current is not rapid, and the volume of water in the stream not large, may cause serious annoyance and offense, and hence must be condemned as crude and imperfect; for,

by pouring the filth into the nearest water course, we simply remove the evil from one place to another, without attempting to abate the nuisance. Again, it should be remembered, that what may be feasible and unobjectionable for a single house, is not practicable in the case of a number of adjoining isolated country houses. The pollution of creeks, rivers and streams must be avoided, especially of those water courses serving as a source of supply of potable water for villages and towns located along the banks of these streams, and from which canal boats or river craft draw their drinking and cooking water. Riparian dwellers always suffer by direct discharge of unpurified sewage into water courses. The watering of cattle, and washing and bathing in the river are thereby often rendered impossible; while more or less damage is done to fish culture, particularly where the sewage is discharged in a putrid condition. While it is a well-known fact that some kinds of fish feed on *fresh* sewage matter, others, particularly salmon and trout, appear to be very delicate, and usually suffer from the pollution of streams.

Channels with tidal flow, finally, should not receive sewage, for much of the solid matter discharged into them will repeatedly float up and down with the ebb and flow of the tide, instead of being at once removed. Offensive odors pervade the air, the banks will become defiled, the river beds silt up, and the channels gradually become obstructed.

6. Houses located at or near the seashore have, sometimes, no other available outlet for the discharge of their sewage than the ocean; but, although at first blush a ready means of getting rid of sewage, such a discharge is seldom permissible. Experience has demonstrated the unpleasant fact that floating sewage matter, discharged into the sea, may return to the shore with the tide, or through the action of eddies, currents, winds and waves. The sandy beaches become polluted, and the damage inflicted may seriously interfere with the use of the beach for bathing or recreation purposes. The direct discharge into the sea is only practicable where the sewage outfall from houses on the cliffs or near the beach is carried far out into deep water, and all sewage matter carried away by some strong currents setting in at right angles to the sewage outfall, or about parallel to the line of the beach.

7. It is obvious, therefore, that in the majority of instances, house sewage cannot be directly admitted into water courses or streams of any kind, nor into the sea, without creating a nuisance to sight, smell, or a danger to health. As far as practicable it should first be purified

by removing the suspended impurities, and at least a part of the matters in solution. The purification may be effected by various methods, such as artificial filtration, chemical treatment, or by the application of sewage to land. After being purified by mechanical or chemical processes, sewage can sometimes be admitted directly into streams, in other cases, however, it becomes desirable that it be further purified or utilized on land.

I shall not stop to consider the question of artificial filter-beds, for, to my knowledge, such a system has never been used in the United States, in connection with the sewage from houses. I desire only to refer to a very ingenious mechanical filter, invented in England, and recently introduced into this country. It is known as the Farquhar-Oldham filter. The chief characteristic of this machine is the revolving cutter, which is so arranged that whenever the surface of the filtering medium clogs up with sewage sludge, it can be removed by said cutter in a few moments, whereby practically a new filter is established. This operation may be repeated as often as found necessary. While I have not personally made use of this filter for purifying the sewage from isolated country houses, I understand that it is in successful use at a country house at Seabright, New Jersey, and elsewhere. Wherever no system of sewage purification by application to land is possible, I believe this method will form a successful solution of the problem, although many will hesitate to adopt it, owing to its cost. The best filtering material for such apparatus is sawdust, which, when removed, can be readily utilized, to fire up the boilers needed for the sewage pumps.

8. Sewage from isolated country houses may be purified on the premises by chemical treatment. By this method the suspended and a part of the dissolved impurities are precipitated by means of chemicals. Quite a large number of chemical processes have been invented, but none of them have attained any very extensive use. One of the most common processes consists in the addition of milk of lime to sewage. Much more effective than this are solutions of sulphate of alumina, or of perchloride of iron. Such chemical precipitation, while not accomplishing a very thorough purification, removes the impurities to such an extent as to permit a discharge into a tidal river or a large stream. Occasionally, however, as stated above, the clarified liquid is applied to land for further rarification.

In selecting a precipitant, preference should be given to one which accomplishes the process of subsidence with rapidity; at the same time it should be remembered, in choosing a precipitant, that it

should produce a sludge of minimum bulk with maximum amount of solid impurities. In both respects, milk of lime is inferior to the other chemicals mentioned above.

A difficulty adhering to all chemical precipitation processes is the disposal of the sewage sludge. It usually contains, after precipitation, from 90 to 95 per cent. of water, and unless the latter is removed it soon decomposes and becomes offensive. It has been suggested to evaporate this water by artificial heat, but such a process is expensive. Others have proposed the separation of the liquid matter from the solid in centrifugal machines. In some instances, sludge is pumped directly from the precipitation tanks to land, where it is left exposed to the air, and when comparatively dry is dug into the ground. In some patented processes, such chemicals are added as enable the manufacture of brick or of cement from the sludge. More recently, powerful filter-presses have been used, which offer great advantages. By means of these the sludge is quickly pressed into cakes, which may be sold as manure to farmers, and not being bulky, enable a better transportation for long distances.

Chemical treatment must sometimes be adopted where land is not available for purification purposes, or where its high price precludes any efforts to obtain an area sufficiently large for irrigation. It may, at times, become necessary to resort to it, where the soil is underlaid with rocks. Again, chemical precipitation may be combined with the application of sewage to land, in which case a much smaller irrigation or filtration area is sufficient. But all this refers more to the sewage from large institutions or from villages or towns.

Chemical treatment is not well adapted to single, isolated dwellings. The process implies the construction of tanks, the provision of suitable chemicals, the careful and thorough mixing of the sewage with the chemicals, all of which calls for considerable expense. Apart from this consideration, such a manipulation of sewage is not desirable on the premises, and in the vicinity of dwelling-houses.

It may be said in general, that whatever the chemical treatment may be, it will be wise not to have too much faith in the realization of a large commercial profit from the sewage treatment. Far better to make the ultimate purification of the sewage the chief end in view. It is also well to remember that in certain chemical processes, the effluent water is of such a character that, if discharged into brooks or rivers, it may kill fish and cause an injury to fish culture. Chloride of lime is particularly objectionable. Sulphurous and hydrochloric acids are also said to be very hurtful.

9. Wherever a sufficient area of land is available, and the layout of the land and the character of the soil are favorable, sewage may be disposed of, and purified on the premises by applying it to the land. Generally speaking, the application of sewage to land forms the best solution of the problem of sewage disposal. Not that it enables us to derive much profit from its utilization—this should always be a secondary consideration, in the case of larger institutions or towns not less than in the case of single houses—but by applying sewage to land it is always possible to effect its purification to such an extent as to avoid the usual fouling of surface or subterranean water courses. While chemical precipitation and mechanical filtration may be considered *artificial* processes, the purification of sewage by the soil is a natural process, completing one of the constant rounds or circulations going on in Nature. The water on the globe furnishes an example of such a circulation going on forever. Arising as a vapor from the ocean, and from large exposed surfaces of flowing water, it is carried along in the upper strata of the atmosphere by currents of air, and forms clouds, from which it is again precipitated upon the surface of the earth in the form of rain, snow, hail, or dew. A part of this storm water is immediately evaporated and returns to the clouds, another part flows off on the surface forming successively springs, brooks, rivers, streams—all flowing toward the great ocean, while a third part soaks into the ground, and is partially absorbed by vegetation, and partly forms underground streams of water with an inclination toward some stream, or else forms springs, which finally come out at the surface.

Another example of a constant round in Nature is afforded by the circulation going on between animal and vegetable life. Plants are nourished, and grow upon decomposed animal matter, effecting a change of those substances which might become dangerous to animal life, into harmless food substances for the roots of plants. The same plants, perhaps, form the nourishment for man and animals, and are again discarded to feed vegetation.

The whole process of water circulation has never been better described than in the words of Mr. F. O. Ward, at the General Congress of Hygiene, at Brussels, in 1856. These words, quoted by Mr. Edwin Chadwick, the nestor of sanitary science in England, in an address on "Circulation or Stagnation," are as follows:

"The water which falls on the hills in a state of purity undergoes a natural process of filtration through sand, enters the rural collecting

pipes, and passing through the aqueduct to the metropolitan distribution pipes, finds its way to every story of every house in the town; whence again, after having supplied the wants of the inhabitants, it runs off, enriched with fertilizing matter, which it carries away before allowing it time to ferment. This manure, driven along irrigation pipes, is deposited in the soil, leaving the water to pass into drainage pipes, and flow on to the rivers. The rivers conduct it to the ocean, where it rises as vapor under the heat of the sun, to redescend as rain on the hills, enter again the collection pipes, and recommence its vast and useful course of circulation."

But let us return to the consideration of the application of sewage from isolated country houses to land. The conditions of successful application are a sufficiently large area of suitable, absorbent, well aërated, properly prepared and thoroughly under drained soil. I should, perhaps, add to these a few other conditions, namely, the proper and judicious management, careful and equal distribution, and, before all, the *intermittent* application of sewage to the soil, which latter is so needed to insure its aëration.

The land selected for the purification of the sewage should not be located too near a dwelling. In particular, if wells are used, it should be kept at a safe distance from them, the exact distance depending not so much on the configuration or slope of the surface as upon the inclination of the underground geological formation and strata.

We may distinguish several systems, namely, broad sewage irrigation, intermittent downward filtration and sub-surface irrigation. The Report of the Royal Commission on Metropolitan Sewage Discharge, published in 1884, defines broad irrigation as "the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation, consistent with due purification, for the amount of sewage supplied." The same report speaks of intermittent downward filtration as "the concentration of sewage at short intervals on an area of especially chosen porous ground, as small as will absorb and retain it, not excluding vegetation, but making the produce of secondary importance." In the first system, the sewage flows principally *over* the land, in the latter system it passes *through* the land. Sub-surface irrigation is a modification of the filtration system, in which the sewage is distributed in a network of tile pipes, close under the surface of the ground, whereby all offense to sight or smell is at once overcome. It is obvious that this is an important consideration wherever sewage irrigation is to be practiced close to a dwelling-house.

Broad irrigation requires very large areas of land. The land must not be continuously flooded, so that in order to manage an irrigation farm successfully, it is, at least, advisable to have pieces of fallow land, and to distribute the sewage on different portions on alternating days. By passing sewage through a properly prepared filtration area, we are enabled to effect the purification of a much larger volume, provided we maintain an intermittent discharge, so as to secure thorough aëration.

In all methods of application of sewage to land, it is advisable to intercept, at least, the coarser suspended organic matters contained in sewage, which should be dealt with separately. The irrigation field must in all cases be properly and thoroughly under drained. The preparation of the surface of the land should be simple and inexpensive, and must depend somewhat on the general topography of the field, as well as upon the kind of vegetation which it is intended to raise from sewage. It is important that the sewage be distributed evenly and in as fresh condition as possible. Much the best plan to secure an intermittent discharge and to avoid an irregular and trickling flow, is to collect the sewage from the house in a self-acting flush-tank. Wherever possible the sewage should be conveyed to the latter by gravitation, and the location of the irrigation field should be selected accordingly. Occasionally, however, pumping becomes a necessity, and this may be accomplished either by a steam pump, a gas or hot air engine, or a windmill.

I shall, hereafter, dwell more at length upon the sub-surface irrigation system, and shall explain some of its details, because I regard it as the best available system for the disposal of liquid and semi-liquid wastes of isolated country houses. Before doing so, it may be well to sum up what I have said about the methods available for disposing of sewage of isolated country houses.

Such houses as are not in reach of sewers can dispose of their liquid sewage in some cases by a direct discharge into a stream (taking this word in its widest significance) or into the sea. As a rule, however, it is absolutely necessary, and vastly better to adopt some system of purification on the premises. Of systems of sewage purification, application to the soil is preferable to mechanical filtration, or to chemical precipitation. The latter methods should only be resorted to where no land suitable for disposal is obtainable. Of the methods of applying sewage to land, broad irrigation is least favorable, as it requires a large area of land, and in cases where the field is located close to the house, it becomes objectionable. Intermittent downward

filtration, while requiring a much smaller surface, is yet open to the second objection made to surface irrigation. Far preferable, for single houses and isolated institutions, is the sub-surface irrigation system. Leaching cesspools are absolutely inadmissible, and the same is true of tight cesspools with overflows into a ditch or water course. In a few cases it may be necessary to adopt a perfectly tight cesspool without overflow, and to pump the liquid out at frequent intervals, distributing it on the land. This alternative should be resorted to only where all other methods prove objectionable or impracticable.

In the following I shall dwell more at length upon the *disposal of sewage by sub-surface irrigation*, for, in my judgment, this is the most available system for the disposal of liquid and semi-liquid wastes of isolated country houses. The system has long ago attracted public attention, and has, in recent years, been taken up by the foremost sanitary engineers, for more than any other method, it promises the entirely successful solution of the problem of sewage disposal for isolated houses. It certainly recommends itself, owing to the peculiar facilities for disposing of sewage *without creating an offense to sight or smell*, for it is only too well known that open or surface irrigation becomes, in many cases, exceedingly objectionable in close contiguity to mansions or dwellings.

The origin of the sub-surface irrigation system is usually attributed to the Rev. Henry Moule, Vicar of Fordington, the inventor of the earth-closet. He looked upon it as the best solution of the slop-water disposal question for cottages which adopted the earth-closet system. But according to Mr. Edwin Chadwick, sub-surface irrigation had previously been tried independently and systematically on a large scale by M. Charpentier, a French vine-grower, near Bordeaux. Mr. Chadwick states that the results which the latter obtained with vines and fruits, as well as with market-garden produce, were most satisfactory. The system would probably never have grown to its present popularity had it not been for Mr. Rogers Field, Mem. Inst. C. E., who, recognizing the desirability of intermittent action, invented his automatic flush-tank, which he applied successfully to the disposal of liquid household wastes. His first experiments were made at some laborers' cottages, belonging to his own estate at Sheffield, in Essex. Since then the system has been adapted to all possible conditions, and has given such satisfaction that it is now considered admirably suited to isolated houses not in reach of a sewer, but having sufficient porous or well-drained ground about them, with favorable lay of the land. Col. Geo. E. Waring, Jr., was the first to try the

system in this country, about fifteen years ago. Finding that it worked satisfactorily in the case of his own residence in Newport, R. I., then not in reach of a sewer, he adopted it afterward with success for the disposal of sewage of cottages and suburban residences, and on a larger scale for the purification of sewage at the women's reformatory prison at Sherburne, Mass., the Keystone Hotel, at Bryn Mawr, Pa., and at Lenox, Mass., for the sewage of the whole village. Since a number of years the system has been extensively applied by many sanitary and landscape engineers, and by a few progressive architects, for the disposal of sewage of isolated country houses or institutions not within reach of sewers, but liberally supplied with water and plumbing appliances.

The system is based upon the well-known fact that the aërated layers of soil *next to the surface,* the sub-surface as it were, possess in a high degree the power of destroying organic substances buried in them, by nitrification and oxidation, aided during a part of the year by vegetation, and assisted at all times by minute organisms or bacteria. The latter play an important part in the round of changes in Nature. "They are," says Tyndall, "by no means purely useless or purely mischievous in the economy of nature. They are only noxious when out of their proper place. *They exercise a useful and valuable function as the burners and consumers of dead matter, animal and vegetable,* reducing such matter with a rapidity otherwise unattainable to innocent carbonic acid and water. Furthermore, they are not all alike, and it is only restricted classes of them that are really dangerous to man. One difference in their habits is worthy of special reference here. Air, or rather the oxygen of the air, which is absolutely necessary to the support of the bacteria of putrefaction, is, according to Pasteur, absolutely deadly to the vibrios which provoke butyric acid fermentation."

I lay particular stress upon the importance of distributing the sewage close to the surface of the soil, at a depth not exceeding 10 or 12 inches. Aëration is a *conditio sine qua non* of the whole system. At greater depths oxidation and purification become very much slower, until they finally cease altogether. The *subsoil* is not able to effect a complete purification of sewage, as the oxidizing influence of the atmosphere does not so freely reach it. It is the layer of earth next to the surface, the *sub-surface,* which acts on the sewage. Hence the name of the system is derived, and it is an error, committed quite frequently, and to which I have more than once called attention, to call the system "subsoil" irrigation.

We see, then, that only where sewage is distributed close to the surface, where sufficient oxygen attaches to the particles of the soil, are the organic matters in it taken up as nourishment by the roots of plants, and reduced or destroyed by the bacteria in the soil. The liquid sewage, freed of its coarser impurities, soaks away into the porous ground, and thus becomes still more clarified by filtration, so that when removed by deep under-drains, it is generally found to be quite clear, colorless, free of taste or smell. By arranging an *intermittent* discharge, the upper layers of the soil are enabled to take up oxygen during intervals between discharges, and to prepare for the next volume of sewage, while the ground is prevented from becoming saturated, wet and swampy.

There is a radical difference between such a system and a loose or leaching cesspool. With the latter the area of soil used for purification is quite small as compared with the former, where the surface can be chosen in proportion to the amount of sewage to be disposed of, which is not a feasible thing to do with a cesspool. We all know that even in the case of a leaching cesspool, newly built and first put to use, some purification of the sewage which oozes out at its pores is accomplished by mechanical filtration. After some use, however, its pores clog up, and the soil around the cesspool becomes saturated with sewage matter, undergoing, in the absence of oxygen, a very slow process of decomposition. The sewage soaks away unpurified, polluting springs and wells, and the unwholesome gases generated taint the ground air, and, being given off at the surface, frequently enter our houses. It is for these reasons that all sanitarians look upon a leaching cesspool as a nuisance and a standing danger to health.

Briefly described, the sub-surface irrigation system consists of two parts: *First*—An absolutely tight receptacle, or sewage tank for liquid household wastes, including the contents of water-closets. *Second*—A network of common distribution drain tiles, laid a few inches below the surface of the ground, with *open joints*, so as to permit the liquid to ooze out at numerous points. This network of pipes, buried in the ground, constitutes the irrigation field.

As stated heretofore, it is an important condition to insure the successful working of the system, that the discharge of sewage from the sewage tank to the irrigation field be *intermittent*, and that, instead of a constant, dribbling stream from the tank, there be a powerful rush of sewage in a large volume, so as to secure an even distribution and the perfect filling up of all pipes. It is, to say the least, desir-

able that the discharge should not occur more frequently than *once a day,* that is, every twenty-four hours, and the size of the tank should be governed hereby.

The soil of the field should, preferably, be gravelly and porous. All tight clay soils, and ground liable to dampness, should be properly under drained by deep land drains. The sub-irrigation field should not be located too near a house, wherever there is abundance of land favorably located, permitting the sewage to flow away by gravity. As a matter of precaution, it is well that some attention be paid, in locating the irrigation field, to the direction of the prevailing winds, although as a matter of fact, a properly working irrigation field is quite inodorous. So much is this the case that the tiles may be, and in practice often are, laid under the well-kept lawns adjoining summer residences, without ever causing an offense. Another precaution to be observed where the water supply of a country house is derived from wells or springs, is, that the field should not be located near them.

The preparation of the sub-surface of the field is accomplished in the following manner: Common unglazed agricultural tiles, two inches inside diameter and one foot in length, are laid 8 or 10 inches below the surface on continuous boards, or, better, in gutters of earthenware, laid accurately in the trenches at the uniform grade required. Should the tiles ever clog up, it thus becomes an easy task to take them up, to clean them and to relay them in the gutters, an operation readily performed by a common laborer. It is quite important that there should be between the tiles at each joint, a space of about ¼ inch to facilitate the oozing out of the sewage. Small earthen caps about 3 inches long are placed over the ends of tiles at each joint to protect it from dirt or earth falling from above. It is not necessary to give the absorption tiles a greater fall than about two or three inches per 100 feet, for if laid at too steep a grade the sewage would rush to the lowest level and saturate that part of the irrigation field. It should be noted that much of the success of the system depends upon the accuracy with which the distribution tiles are laid. They should branch out from the bottom of the main carrying conduit, and special T or Y branches are manufactured for this purpose. The main drain should be laid at least two feet deep, and the 2-inch branches should be cemented until they strike the proper depth of 8 or 10 inches. The main drain conducting the sewage from the flush-tank to the irrigation field should be 4 inches in diameter, except in the case of large institutions, when the size of the flush-tank often

requires a 6-inch main conduit. It can be laid with as much fall as the layout of the land will require, but where it approaches the absorption field its fall should be limited to 4 or 6 inches in 100 feet, to prevent the sewage from running to the lower part of the field, overcharging the lower lines of drains. The distance between the lines should average about 5 feet. The ramification and the general layout of the lines will depend on the contour lines of the land. In the case of level ground the lines may be parallel to each other.

The number of feet of tiles which it is necessary to lay will depend upon the quantity of sewage delivered each day. It will vary, moreover, for like quantities of sewage, with the general character and porosity of the soil of the absorption field. Wherever the soil consists of a heavy clay or is liable to be wet or swampy, it is absolutely necessary to thoroughly under drain the field by a complete system of agricultural tiles, laid at a depth of from 4 to 5 feet, removing and discharging the purified sewage as well as any excess of soil moisture.

The flush-tank is usually built of hard-burnt brick, laid in hydraulic cement mortar, and made perfectly water tight.

An important and most necessary precaution to prevent the clogging of the siphon, which empties the tank, or of the distribution tiles, is to build in connection with the flush-tank, and between the house and the latter, an intercepting chamber or grease trap, intended to intercept all solids, undissolved paper and fatty waste matters from the kitchen. Such a chamber is, in a certain sense, a cesspool, although it differs from the ordinary objectionable device of this kind in having its liquid contents frequently changed, and in being built of small size. Its emptying and cleaning must, of course, by no means be neglected. Much of the solid matter and paper, etc., is reduced by maceration and decomposition, and flows dissolved by water into the liquid sewage chamber. The overflow pipe connecting both must dip well below the surface of the water level in the first chamber to prevent scum or grease from over-flowing into the flush-tank. The flush-tank proper should, generally, be built circular in shape, and of a size to hold one day's volume of sewage. The liquid wastes from the household are retained in this tank until it is filled, when its whole contents are suddenly delivered into the main drain, and thence into the irrigation tiles, whereby all the rows of tiles are *uniformly* charged, and the whole of the absorption field is brought into use each time the tank is emptied. If the sewage is discharged suddenly in a large volume, it oozes out, not only at the bottom, but also at the sides and top of each joint. The purification begins at

once. The clarified liquid soaks away into the ground, the impurities being retained by the earth, where they are quickly destroyed. Air enters the pores of the soil and prepares it for future use, while the tank is gradually filling for the next discharge.

The interval required between two consecutive discharges, the exact proportion between capacity of tank and size of house, between size of tank and number of feet of drain tiles, etc., are details requiring judgment, skill and experience, and which must be left to be determined in each individual case separately.

To discharge the flush-tank, recourse may be had to various mechanical appliances. The simplest arrangement, but one that requires daily attendance and some manual labor, is to place a gate valve at the outlet pipe leading from the bottom of the tank, which valve is opened or closed by hand whenever the tank becomes filled. This arrangement may answer for smaller country houses, in which the amount of water used is limited, being usually pumped into the tank by hand. An *automatic* device is preferable in many respects. This may be either a tumbler or tilting tank, or one of several siphon devices now in the market. I have, so far, found none better nor cheaper than the annular siphon, as devised by Mr. Rogers Field, C. E. If space would permit, I should illustrate and describe the manner in which I usually arrange it, but this is not possible.

My description of the system of sewage disposal by sub-surface irrigation is, I trust, sufficiently definite to give a correct general idea of it. Having spoken so much in its favor, it is but proper that I should notice and mention the objections which are, at times, brought forward both by professional and by laymen against the system.

1. It is sometimes feared that the land into which sewage is continually poured will, after some years, become saturated with sewage, its surface wet or swampy, and the whole of the irrigation field a large cesspool, spread out laterally instead of downward. There is, however, absolutely no reason for apprehending such trouble. Wherever the soil is not naturally loose and porous, *under drainage* is essential and must be provided for. If properly carried out, all superfluous moisture in the ground will be removed. *Aëration* is another essential condition, and wherever it is neglected the soil may become saturated with sewage matters. Finally, *intermittency of discharge* is required, with intervals of at least twenty-four hours between consecutive emptyings of the flush-tank. Under drainage of the soil and intermittent action of the flush-tank secure the much desired aëration of the sub-surface. This secured, oxidation and nitrification,

and the destruction of the organic particles attaching to the earth will follow with regularity.

2. Much apprehension is often felt lest such a system will not work properly in winter time, and fear is expressed about the freezing up of the ground about the absorption tiles. Experience with the system in the coldest parts of the New England States has fully removed any doubts on this point. Where the system has been in continuous use, summer and winter, it is found by practical experience that the warmth of the sewage is sufficient to keep the ground at the disposal field from freezing.

3. It is often objected that the necessary intercepting chamber for solids is in reality a cesspool. This is true to some extent; nevertheless, I always advise to build this chamber in connection with the flush-tank, but I use the utmost precaution in its construction to make it perfectly tight. As regards this intercepting chamber, it should be remembered that the liquid sewage in it is constantly changed, for a large volume of water passes through it every day. Although the chamber retains organic waste matter partially putrefied, the amount cannot be compared with that in a cesspool. Some of the solid matter is undoubtedly reduced by maceration, and being dissolved, passes into the liquid chamber, from where it is discharged into the absorption drains, to be finally oxidized and rendered innocuous. By cleaning the intercepting chamber once a month, the amount of solid putrid matter may be kept down to a minimum; consequently there will be little if any exhalation of gases of putrefaction, and inasmuch as the water level remains constant—the intercepting chamber being always filled to the overflow level—gases are not forced out as in the case of ordinary cesspools. By means of proper ventilation the intercepting chamber may be kept quite free from offense.

Perhaps I should mention here that owing to these objections attempts have repeatedly been made to do away with the intercepting chamber. But in all cases where water-closets are used and their contents discharged into the tank, it becomes imperative to prevent the solid portions of the sewage from clogging the tiles, and the siphon which discharges the flush-tank.

I well remember an attempt made some years ago to do entirely without intercepting chamber by simply surrounding the siphon (a Field annular siphon) with a double cylindrical wire screen of both coarse and fine mesh. In less than six months the tiles were entirely choked. The only alternative would seem to be to strain the solids.

English sanitary engineers, among them such well-known authorities as Mr. Rogers Field and Mr. Wm. Eassie, prefer a straining chamber. To quote Mr. Field: "The distinguishing feature of this arrangement is that there is no tank or depression for the sewage to collect in, but that the bottom of the chamber is on the same level as the bottom of the drain, so that liquid sewage passes through the chamber without any obstruction. The interception of the solids is effected by two strainers, which consist of small iron rods fixed in an iron frame, and so arranged as to be movable. The bottom of the chamber is constructed of concrete, smoothly cemented and rounded, so as to form a sort of channel for the passage of the liquid, and to enable the solids to be more readily cleaned out. This bottom also has a rapid fall from the inlet to the outlet, which still further facilitates the rapid passage of the liquid. The sides are usually formed of brick-work, and the whole is covered by a light wooden lid, opening on a hinge." With such an arrangement a man can easily remove the solids by scraping them up by means of a hoe over the edge and mixing them with dry earth. To prevent such a chamber from becoming offensive, the solids should be removed daily.

A different arrangement from the above, which has also been repeatedly suggested, is that of having in a straining chamber a perforated pail or movable iron basket, which intercepts all the solids and which must be emptied and cleaned every day.

Of the two devices, the plain strainer appears to me to be far preferable. Personally, I have not yet tried either of the arrangements described. I should be willing to substitute the straining chamber for the intercepting chamber if I could rely explicitly upon *daily* removal. The trouble involved is not large, it is true, but servants are proverbially neglectful, and the arrangement suggested certainly robs the system of one of its best features, namely, that of being automatic. If daily attendance is required, it might be just as well to require the help to empty the sewage tank daily by opening a stop-valve; and thus do away with every kind of automatic siphon or other device, while retaining the features of intermittent discharge, and of a discharge of a large volume suddenly distributed over the whole of the irrigation field.

4. Owners of country residences find an objection to the system in the necessity of frequent emptying of the intercepting chamber just referred to, which, they claim, causes more or less of a nuisance. As an answer to this objection, I would say that of the two evils of cleaning out a large, ordinary open cesspool and the comparatively speak-

ing small intercepting chamber, the latter is far preferable. But in doing so I probably overlook the fact that the same people who raise such an objection would probably never see to it that their large cesspool is cleaned, paying no attention to it as long as the sewage runs off, no matter where to.

5. It is sometimes objected that the tiles will choke and must be taken up and relaid. I cannot deny the possibility of such an occurrence, although this may only become necessary about every three years on the average. They will choke sooner if they lack the cleansing effect of a flush delivered at intervals from the sewage tank. Even supposing for a moment that the tiles would have to be cleaned and relaid every year, how little amount of labor, trouble and expense is involved in doing so, owing to their being laid in permanent gutters and close to the surface. Compare this with the trouble and annoyance of having to empty and clean a disgusting overflowing cesspool!

6. The system is objected to because the ground where the tiles are buried cannot be plowed, nor can heavy wagons drive over it without risk of breaking or displacing the pipes. This objection cannot be denied, but it is a slight one, if one at all.

7. Many people object to the cost of the automatic siphon. However expensive this may be, it cannot be considered a valid and sound objection against the system. As a matter of fact, the annular siphon, at least in the case of isolated suburban and country houses, does not cost very much. But, where this expense is objected to, the mistake should not be made of providing only one large overflow pipe from the liquid sewage tank, from which a constant small stream dribbles toward the irrigation field. This is a very imperfect and faulty arrangement. Only a short length of the tiles would receive an almost constant trickling flow of sewage, saturating the ground around it to the surface and keeping it in unwholesome condition. Moreover, the tiles would rapidly choke up with such an arrangement. Aëration, intermittent action, oxidation, powerful flushing, the uniform and entire filling of the tiles, all these conditions essential to the success of the system, would be absent.

As indicated heretofore, a stop-valve in the outlet pipe, worked by hand, may take the place of an automatic siphon. The only other admissible arrangement, and one which I have adopted with perfect

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NOTE.—Since writing the above the author has constructed such a straining chamber as is described in the preceding pages in connection with a 30,000 gallon flush-tank for sewage disposal at the State Homeopathic Asylum for the Insane, at Middletown, Orange county, New York.

success, for smaller country houses, where the owners objected to the cost of an automatic flush-tank, is a sewage tank, provided with a large number of overflow pipes, all placed exactly *at the same level* in the tank—not a very easy thing to do, by the way—and all discharging simultaneously equal or nearly equal portions of the sewage into the various lines of absorption drains, thus securing a better distribution of the sewage. In this arrangement the tiles are likely to choke sooner than in the system with intermittent flush-tank, since they lack the cleansing effect of a sudden rush of water from the tank.

8. Another objection is the cost of the system. The first expense is, of course, more than that for a cesspool of moderate dimensions, but the frequently recurring expense of cleaning and emptying the latter, soon renders the sub-surface irrigation system cheaper than the ordinary cesspool. For a small country house its whole expense should not exceed $250, and for a larger country residence the system ought not to cost more than $500, which prices include the royalty on some of the better class of patented automatic flush-tanks.

9. It is sometimes stated that the sub-surface irrigation system is impracticable in the case of level ground, or where the lawn rises at the rear of the house, or where the main soil-pipe leaves the house at a depth below the cellar floor. To this I answer that some concessions must, under such circumstances, be made. For instance, in places where the available fall from the house to the irrigation field is slight, no plumbing fixtures should be placed in the basement, and the soil-pipe should leave the house as near the surface as practicable. In some cases it may even become necessary to build the flush-tank in embankment, hiding it in a sort of artificial terrace at the side of the house. By making the tank of a shallow depth it is usually possible to effect a suitable arrangement. In extreme cases it may become necessary to lift the sewage, after straining, and this may be accomplished by a variety of mechanical devices. Where a small air compressor may be operated in the cellar of the house, Shone's sewage ejector appears to offer a simple solution of the problem. Where steam is available, a pulsometer pump could be used for lifting the sewage. If gas is laid on to the house, or a gasoline gas machine is in operation, a gas engine or hot-air engine may prove economical. Finally, the motive force of the wind may be used for such purposes by erecting a windmill with suitable pumping apparatus. Whatever the special difficulties may be in each case they can usually be overcome at a slight sacrifice. Certainly they should not be considered objections to the system as such.

10. The objection that the sub-surface irrigation system poisons wells, may be removed by simply locating the field away from wells, or where it must necessarily be close to a house, by abolishing wells, and depending on rainwater collected in tight, underground cisterns, as a source of water supply.

11. Some think that it is impossible to purify sewage by turning it into agricultural drains located at a depth below the roots of the plants. It is hardly worth while to consider this objection, as many years of successful working of the system seem to amply contradict it.

12. The system has received condemnation because "sub-irrigation is a process faulty in principle, as it feeds vegetation by the upward rising of moisture, accompanied by evaporation, with all the chilling influences which are so injurious to vegetation as well as to human beings." I can only answer that, so far as my personal observation goes, practically no harm has ever been done to vegetation; on the contrary, it stimulates the growth of grass, of shrubbery and of fruit trees, which statement, I am confident, is borne out by the experience of other sanitary engineers.

13. Where the irrigation field is under drained, it frequently happens that at first the sewage leaks away too quickly and without being purified, at the points where the distribution tiles cross the lines of agricultural tiles. This can be remedied after a while, when the earth in the deep trenches for the land tiles settles down and solidifies.

This, I believe, comprises all the criticisms raised against the sub-surface irrigation system. While I do not wish to be understood as claiming this method of sewage disposal as a panacea for all the evils incident to country house drainage, I hold that the system is an excellent one wherever suitable land, of suitable character and of sufficient area, properly located, may be obtained. For a further detailed discussion of the whole subject I may be permitted to refer to a small volume, soon to be issued, entitled "The Disposal of Household Wastes."

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