Waring (G. E.)

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PROTECTION OF STREAMS USED AS SOURCES OF WATER SUPPLY.

BY

GEORGE E. WARING, Jr.,
NEWPORT, R. I.

EXTRACTED FROM THE
TRANSACTIONS OF THE COLLEGE OF PHYSICIANS OF PHILADELPHIA,
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ONE of the most important questions now claiming attention, in connection with the sanitary condition of houses and towns, relates to the manner of getting rid of the foul constituents of the liquid effluent in such a way as to prevent annoyance from odors, danger from the development of infection, and the contamination of water-courses and harbors. The difficulties presented have always existed, and the ill effects of ordinary methods have always been known. It is only since attention has been called to the relation of the foul effluent of house and town drainage to the spread of diseases that the difficulty has been generally recognized, and only since the modern growth of the larger towns that its dangers have been fully apprehended.

In a few fortunate cases, such as those of towns discharging their effluent into great rivers like the Mississippi, the remedy is provided by the volume of the stream to which the sewage is added. In London, the Thames has become so foul that the Royal Commission which recently investigated the matter, pronounced the system of outflow there established to be "a disgrace to the metropolis and to civilization." In Paris, the discharge of the great collecting sewers into the Seine has produced a condition that is no longer tolerable. Were the houses and streets of Philadelphia drained in accordance with modern ideas of decency and efficiency, the condition of the Delaware would perhaps become little better than that of the Schuylkill. The great addition to the tidal volume of the harbor of New York, due to the inpouring through the East River of the higher tide of Long Island Sound, mitigates, but does not remedy the foul condition due to the discharge of the city's wastes along its whole border. In short, all considerable communities in this country and in Europe are confronted to-day by a problem which it is absolutely necessary to solve. In one way or another, the waste organic matter of our domestic life and of our industries must be withheld from the waters into which our sewers discharge.

I propose to notice, only in passing, what may be called the more artificial means for accomplishing this result; that is, the chemical and mechanical methods of precipitation, decantation, and distillation. There are instances in Great Britain and on the Continent of Europe, where the difficulty of securing a sufficient area of land for what we may regard as the more natural treatment is so great, that there is no choice but to resort to these more costly and less efficient processes.

It is possible, by an addition of the salts of iron and other salts, of milk of lime, of comminuted clay, etc., to cause the deposition of nearly or quite all of the suspended impurities of sewage. The deposit or sludge thus formed is sometimes treated by filtration, drying, filter-pressing, etc., in such a manner as to become available as manure for use on lands not too far removed.

In connection with the Liernur. system of pneumatic removal in Holland, an ingenious plan has been devised by which the solid parts of the slightly diluted effluent are recovered by evaporation *in vacuo.* In Germany, other more elaborate processes, including the distillation of the purified effluent, have been measurably successful in the production of the salts of ammonia for commercial use, and of a residuum of some manurial value.

It seems hardly worth while, in the short space here at my disposal, to do more than to refer to these processes, which, however important under favoring circumstances, are not suited to conditions prevailing almost universally in this country. There is probably no town in the United States where any treatment of sewage is desirable, where it will not be cheaper and more simple to overcome the difficulty by the aid of surface or subsurface irrigation or by more concentrated filtration—filtration, in greater or less degree, being an essential element of all irrigation. This application to the soil is not only cheaper and more simple, but is also more effective. No chemical or mechanical treatment has thus far been devised which produces an effluent so entirely free from organic impurity and from the lower forms of life as that which is produced by properly regulated agricultural disposal.

We have been, until recently, quite in the dark as to the processes by which organic wastes are destroyed after application to the ground. We seem now to have some positive knowledge on the subject—knowledge due largely to the investigations of Dr. Frankland in

England, and of Schloesing and Muntz in Paris—these investigations being an application of knowledge derived from the biological investigations of late years.

It may now be accepted as a demonstrated fact, that the various processes of oxidation and nitrification by which organic impurities in the soil are reduced to their mineral elements or to elementary salts, are due to, or are largely aided by, the reproduction and growth of bacterial life. This was especially well demonstrated in the Paris experiments, by the fact that, while sewage filtered through a suitable soil confined in a cylinder two metres high, the liquid being applied with intervening periods for aëration, was deprived of its impurities and allowed to pass out at the bottom of the column as pure water, the process being accompanied by a great increase of bacterial growth; the impregnation of the soil with the fumes of chloroform was sufficient, by arresting bacterial activity, to allow the sewage to be discharged as impure as it was received. Ample confirmation of the obvious conclusion was found in the fact that after the chloroform had entirely escaped from the pores of the soil the purifying effect was fully restored.

Roughly speaking, or rather practically speaking, the process is this: When sewage is applied to the soil its impurities are filtered out and are attached to, or involved with the particles of the soil. The water thus purified descends to the lower strata—to the underdrains or other means of outlet. As the water descends, fresh volumes of air enter and furnish oxygen, which it is the office and the means of life of the *bacterium termo* to combine with the retained impurities. The resultant product is fully decomposed matter available for the use of plants or for innocuous removal in solution. There is much in the way of detail concerning the processes involved yet to be discovered, and investigation is active in this direction. Enough is now known to constitute the basis of a rational theory applicable to the practical processes we are considering. These processes have long been employed with more or less completeness and with corresponding perfect or imperfect results.

It would be a fair summing up of the whole case to say that we now know, by well-established theory and by ample practice extending over more than twenty years, that we have in the soil a universally available agent for the safe, inoffensive, and complete destruction of everything in the way of organic waste that we may deliver to it in a proper manner.

As we look over the field of practice, beginning with the Craigentinney Meadows at Edinburgh, which have been irrigated with sewage for more than a century, and ending with the most complete modern examples, we find the greatest conceivable variety of conditions and a great variety of results. There are more than one hundred sewage farms in England to which are applied the effluent of as many towns, large and small. Some of them have been carefully arranged and are fed by sewers which deliver the sewage to them in a very early stage of decomposition, and where the great bulk of the storm water is diverted to other outlets. On these the best results are obtained. In other cases the attempt is made to purify the whole outflow, storm water and all, with the natural result that floods of storm water deluge the land at those times when it is already drenched by the heavy downfall and is incapable of absorbing more water. Here the result is far from satisfactory.

In Germany, sewage irrigation farms connected with the city of Berlin, with Dantzic, and with Breslau, arranged in accordance with modern ideas on the subject, are all instances of notable success.

At Gennevilliers, where about one-fifth of the whole outflow of the sewers of Paris, about one-half of the dry-weather midsummer flow, is distributed over a very large area of thirsty and hitherto almost valueless sand and gravel, the result is excellent.

In our own country, we have as yet no instance, save the recent one of Pullman, Illinois, of a general system of sewage irrigation. The result there, according to all reports, is as good as it has been elsewhere.

I have recently had an opportunity of carrying out a rather complete system of sewage disposal in your near vicinity, in connection with the State Asylum for the Insane at Norristown. As I have endeavored there to work according to the best indications of modern experience, and as my efforts have been freely sustained by the Trustees of the Asylum, I know of no way in which I can better set forth what seems to me the best method for disposing of sewage than by describing, somewhat in detail, the work that has there been done and the result thus far achieved.

The Asylum is situated on high land in the north-eastern suburbs of the city, on the water-shed of Stony Creek. The buildings include eight large pavilions, with the necessary administration buildings, kitchens, laundries, etc. The population of the institution is now not far from 1600. The consumption of water is not far from 150 gallons per head, daily, and all manner of organic waste, except the garbage, which is fed to swine, must necessarily be disposed of through the system of house drains and sewers with which the institution is amply supplied.

As at first constructed, the system of drainage, delivering not only foul wastes but roof and surface water as well, discharged its contents through a large main sewer running in a southerly direction, entering a brook which delivers, in a short distance and with a steep incline, into Stony Creek near the hospital station of the railroad.

Although the ample facilities for the drainage of such an institution afforded by Stony Creek had been a chief inducement offered by the city of Norristown for the location there of the Asylum, the buildings had not long been occupied before complaints were made of the gross fouling of the creek due to the hospital drainage.

Following the erroneous idea which is so prevalent, that the chief source of defilement in sewage is fecal matter, two immense settling tanks were established in the grounds for the retention of these solids only, the effluent enriched by the products of their putrefaction, overflowing into the sewer and running into the creek. As urine and kitchen wastes are quite as bad in their ultimate condition as is fecal matter, and much more serious in amount, this process did not long satisfy the complainants and an injunction was threatened to prevent the discharge of any sewage from the hospital into the stream. In consequence of this threat, the authorities engaged me to devise and carry out some other system of relief. What has been done is as follows:

The old system of drains and sewers has been left as it was, to carry off roof-water and surface-water from the courts, walks, etc., these finding their way into Stony Creek through the old channel. A separate system of sewers, six inches in diameter, has been constructed in connection with all of the foul wastepipes of the building, so that they carry all kitchen and laundry waste, bath and toilet waste, closet discharges, and dining-room and pantry sink waste, everything, in short, which contains foul refuse. For lack of sufficient appropriation some changes that it was thought desirable to make in the interior plumbing of the buildings were not made. It was attempted to substitute water-closets with traps for the untrapped closets already in use. These latter have their outlets connected with ventilation pipes in which a strong current of air is maintained by the use of steam—a very expensive process. They are also flushed by automatic cisterns in such a way as to consume a very large volume of water. The trapped closets with independent flushing cisterns, to be worked by the use of the seat, would have effected considerable economy; but it was found that the odor produced during their use, especially in the morning when used in rapid succession, could not be kept out of the wards without the introduction of a new system of apartment ventilation. This experiment was therefore abandoned as too costly in construction, and the old method of forced downward ventilation continues, in spite of the cost of its maintenance.

The dining-room sinks were subject to the usual difficulty from the accumulation of grease. Such sinks as are to be retained were supplied with a flushing outlet, which is accomplishing a most satisfactory result. The same system was applied on a very large scale to the kitchen sink, which is so arranged that its outlet is ordinarily kept plugged. When discharged, from 50 to 100 gallons are delivered at a time through a 4-inch pipe; this sweeps all grease and other refuse rapidly forward and constitutes an effective flush for the kitchen drain, which formerly gave trouble even with a large grease trap and with the occasional introduction of a jet of steam.

The system of sewers described is brought together to a single main outlet 6 inches in diameter, constructed like the branch sewers of vitrified earthenware pipe. This main sewer delivers into one corner of an open tank 40 feet square and about 6 feet deep, built of brick laid in and coated with Portland cement, and having a Portland cement concrete floor. It is probably absolutely tight. Immediately in front of the inlet (the mouth of the main sewer) there is a vertical iron screen, with one-half inch openings, for holding back paper, rags, a small part of the fecal matter, and the miscellaneous rubbish delivered from the buildings. In the corner of the tank, diagonally opposite the inlet, there is a vertical Rogers' Field annular siphon, the overflow of its discharging limb, 8 inches in diameter, being 5 feet above the floor of the tank. About a foot below the overflow level, and through the south wall of the tank there is a 4-inch opening which is ordinarily kept plugged. At the bottom of the tank and connected with the main discharging chamber outside, there is a pipe through the wall closed by a screw-gate.

This flushtank, the largest I believe that has ever been constructed, has a capacity between its floor and its overflow point of 60,000 gallons. It occupies about two hours in discharging, and during this time about 15,000 gallons more flow in from the main sewer, so that the total amount discharged at each operation averages about 75,000 gallons.

The discharging siphon is so arranged that when sewage begins to overflow at the top of its discharging limb its outlet becomes sealed, its contained air is soon withdrawn, and it discharges, full bore, until the tank becomes empty, when air is taken, first at the inner end and then at the outlet end; the siphon "breaks" and nothing more can be discharged until the overflow begins again. The discharging chamber delivers into an 8-inch pipe which leads to the irrigation field.

In the course of the main drain, above the tank, there is a gate by which the flow can be diverted from the tank and sent through a by-pass directly to the 8-inch pipe. Below the tank there is another gate by which its discharge may be diverted to a truck-patch near by whenever sewage is required for irrigation there. Higher up in the truck-patch there is a sewage carrier which is connected with the 4-inch hole near the top of the tank. By a proper adjustment of these different arrangements sewage can be sent from the buildings directly to the irrigation field without going through the flush-tank, or can in like manner be diverted to the lower carrier of the truck-patch. By opening the gate at the bottom of the tank sewage is allowed to flow out as it flows in, and can be sent in uniform moderate quantity to the irrigation field or to the truck-patch. By removing the plug near the top of the flushtank, the upper carrier of the truck-patch can be made to receive sewage for four or five hours, but as the entering stream is too large to be completely removed at this point, it in time reaches the overflow and starts the siphon, and the whole accumulation is discharged through this.

These truck-patch carriers, the by-pass and the various gates, are incidents of the system and are intended only for occasional use; ordinarily, the discharge is in a strong flow through the main 8-inch pipe connecting with the irrigation field.

Around the whole interior of the tank, near its top, there is a perforated brass pipe connected with the main water supply by a float-cock at the bottom of the tank. This sends a spray over the walls of the tank during about an hour, partly before the discharge is complete and partly during the earlier filling of the tank. Its purpose is to wash down accumulations of slime which might in hot weather become offensive. This part of the apparatus is to be removed during the winter season.

The irrigation field proper is about 1000 feet distant, and its upper side is $27\frac{1}{2}$ feet lower than the outlet of the flushtank. This field is separated from the hospital grounds by a public road and by Stony Creek. Its lowest side is nearest to the grounds, and its higher or further side is bounded by a mill-race a little above its highest level. The area of the field available for irrigation is about 12 acres. Lying to the north of it is a piece of waste land 2 or 3 acres in extent, which has been arranged for use as a relief area in emergencies. Along the upper side of the irrigation field bordering the mill-race, is a deep trench with sloping grassed sides and with a planked water-way at the bottom, for catching and carrying away the infiltration or overflow of the mill-race. Immediately inside of this ditch is the main sewage carrier, which extends from one end of the field to the other, and has a fall of 1 to 600 from its highest point, which is in midway of the field. At this highest point there is a circular well, 6 feet in diameter and 7 feet deep, measuring from the top of its wall, which is a little higher than the surface of the ground. The 8-inch discharge pipe delivers into the bottom of this well, which thus serves to check the velocity due to the rapid fall of the connecting sewer. At its top there are three semicirçular openings two feet wide and one foot deep. One opens into the north carrier and one into the south. The third opens into another carrier which leads directly toward the middle of the field. Ordinarily, only one of these openings is used at a time, and one is sufficient to deliver the whole flow. The north and south carriers, the banks of which are lower toward the field than toward the mill-race, overflow with much uniformity and deliver the sewage at the top of a well-graded inclined surface over which it runs until absorbed. In no case does the sewage run quite the whole distance across the field. Movable gates being set at one point or another, the whole tankful of sewage may be delivered at pleasure over any area of from 2 to 4 acres, according to the inclination of the surface, and its condition of saturation by rain, or its dryness.

The carrier which runs toward the centre of the field delivers into a level ditch which surrounds a level tract about 2 acres in area. This is crossed by a series of parallel ditches 3 feet wide and 2 feet deep, separated by beds or banks 8 feet wide. These beds are to be used for the cultivation of vegetables, forage, osiers, or whatever may be thought most advantageous. They receive their sewage solely by lateral absorption.

This level tract constitutes a relief bed capable of receiving several tankfuls of sewage in succession, and resembling somewhat the "intermittent filtration" beds used in England.

The whole of the field outside of the level tract is now sowed with rye and grass and is already well covered. It is intended to use it as grass land only, and with the relief that can at all times be afforded by the level tract, by the emergency field to the north, and by the truck-patch, it need never be overflooded, and the sewage may at any time be kept off from any part of it long enough for harvesting. Judging from the experience of similar fields in England, it will be necessary to crop it three or four times during the season.

A considerable element of the cost of the work was due to the very unfavorable character of the ground, which, like that of the whole neighborhood, is a very heavy, stony, argillaceous deposit, underlaid by a stratified limestone sometimes at a depth of 2 feet or more, sometimes lower than it was necessary to excavate. A sort of swale ran through the field from end to end, the land being higher at the bank of the creek than here. It was crossed with ditches, largely occupied by a tussock swamp due to a heavy underlying stratum of clay, and its old fence rows and ditch rows were overgrown with willows and other trees.

The cost of the preparation of the land was not less than $8000, including underdraining, grading, uprooting trees, etc.; that is to say, it cost this amount to put it into the condition of a reasonably well graded, cleared, and naturally well-drained field. That part of the cost would be avoided where land of proper character is available.

One item of the preparation consisted in the laying of over 20,000 feet of draining tile at a depth of from 5 to

8 feet, more than half of which required rock cutting from a few inches to 2 feet in depth. It should be said that the rock is so fractured that water easily finds its way down to the level of the tiles. The underdrains are generally 25 feet apart.

The surplus water of the soil was substantially all removed by the digging of the ditches, so that when the tiles had been laid and covered, during dry weather, they discharged a very small stream. It took a long time to get the stony filling of the underdraining ditches so compacted and solidified as to prevent the direct flow of water from the surface to the tiles. Even now, there are some voids which have not been detected and filled, and some water flows directly from the surface to the tiles during the application of sewage. It soon ceases and the effluent is clear within half an hour after the tank ceases discharging. In a short time this difficulty will be corrected and it will always be clear.

The above is a brief and rough description of the general arrangement of the work. Its operation, so far as observed, may be thus explained:

All of the water-closets in the wards are flushed out at intervals of 4 or 5 minutes with a copious discharge from automatic tanks. This flow runs directly to the new sewers and is sufficient in amount to maintain, day and night, a constant cleansing flow. The water-closets in the administration buildings and officers' quarters are operated by hand. They are all in direct communication with the same sewers. So, also, are the urinals (automatically flushed) and the wash-sinks and baths of the whole establishment; also, the sinks in the various dining halls. Such of these as are not to be abandoned on the completion of the new refectory buildings have been provided with flush-pots, by which their wastes are held back until accumulated to the amount of 6 or 7 gallons, and then they go forward, with a rush and in mass, to the sewers.

The whole series of kitchen sinks are connected with a similar apparatus, by which, as above stated, from 50 to 100 gallons at a time are discharged into the sewers through a 4-inch outlet. The laundry apparatus from time to time contributes its very copious flood to the volume of the sewage.

Probably, in no case, does more than 15 minutes elapse between the emptying of any vessel in the establishment and the arrival of its discharge at the flush-tank. Within certainly less than 12 hours and often less than 8 hours, the tank becoming full, discharges the whole accumulation into the main outlet-sewer leading to the irrigation field. The stream, running out through one or other of the carriers leading from the well, overflows its banks and spreads over the land. This complete process may take two and a half hours, so that if we add together the extreme limits of time, we have less than 15 hours between the discarding of waste matter and its application to the surface of the irrigation field.

It is safe to say that putrefaction exists nowhere, at any time, throughout the whole system, and there is never at any point the least suggestion of the putrid odor inseparable from common sewers and cesspools. The only element of the mass which, in its fresh condition, is malodorous is the fecal matter; as this is distributed through and drowned by not less than 2000 times its volume of water, it counts for nothing as a source of exhalation. The whole flow might be discharged on the lawn in front of the administration building without offence save to the eye.

A few small coprolites withstand the rough usage of the current and are carried on to the ground, but they are so few and so very far between as not to be noticeable. Whatever solid matter passing through the screen is lodged on the surface of the field is destroyed by natural processes everywhere active. In no case is the amount of such matter or the effect from it worth noticing.

The real filth of the sewage—its dissolved and finely divided suspended matters—is carried into the ground, is retained there, and is destroyed by oxidation, and, through the activity of bacteria, by nitrification. As filth, it cannot pass through the soil nor very far into it. If the products of its resolution are not consumed by plants, they pass off with the underdrainage, as soluble salts devoid of all organic character and unaccompanied by the lower forms of organic life.

After a few days' use of a single tract, the sewage is turned to another tract and again to another and another, being allowed nowhere to run long enough for the closing of the ground against infiltration by clogging, or for the gorging of its interior spaces with impurities. In short, the process of purification is complete and continuous. Experience elsewhere indicates that the soil will in time improve in its purifying power from year to year for a long time.

There are larger examples of the purification of sewage by irrigation elsewhere in the world, and examples of which the lesson is enforced by long experience; there is, so far as I know, no example in existence more carefully arranged as to its details, involving the overcoming of greater natural difficulties, or better illustrating the more modern technical methods of the art.

I may be excused for suggesting that this example, so near to your own doors, points out the way in which the sewage of the towns now draining into your own water supply may practically, and without too great cost, withhold their filth from their drainage, making the Schuylkill once again a fit source from which to draw household water.

Another method of disposal by application to the land which is especially applicable to isolated houses and to establishments, where the discharge cannot be removed and must be concealed, is what is known as "Subsurface Irrigation," a process invented by the Rev. Henry Moule, for use in connection with the earth-closet, and first applied systematically by Rogers Field, Esq., an English engineer, in connection with the drainage of some cottages at Shenfield, in Essex. Its use in England has never extended very much.

In this country its first application was in connection with my own house at Newport, in 1869. After ample experience and observation of its efficiency, I began to use it in my private practice as an engineer, in disposing of the sewage of isolated houses. In 1876 I had become so confident of its success that I applied it to the sewage of the whole village of Lenox, Mass. In 1879 it was applied on a still larger scale at the Woman's Prison, at Sherburne, Mass., and in 1881 to the hotel at Bryn Mawr. The details of this system have been very materially perfected, and its use is now common in many parts of the country, there being hundreds of examples in New England and probably as many within a radius of ten miles about Orange, N. J.

The Lenox work being the oldest of the larger ones and the one longest in use, may be taken as an illustration of the system generally.

Lenox was a scattering village with less than 1000 persons living in reach of the sewers. The fund available for sewage was small, not enough to lay an outlet-sewer to the river, over two miles distant, to say nothing about work in the town. Indeed, a discharge into the river would not long have been tolerated. At that time (1876) much less was known than now as to the efficiency of sewage irrigation. As the most promising means for overcoming the difficulty, I decided on the adoption of subsurface irrigation, using 10,000 feet of distribution pipes, underlying a well-graded area of about one and a half acres. The pipes were laid a little more than one foot below the surface. They were common 2-inch agricultural sole tiles laid directly on the earth. They were divided into 20 lines, with as many connections with the main pipe leading from the flushtank. The manner of connection was never very satisfactory, and the general arrangement was never entirely successful from the point of view of an expert. However, although the field was but a few hundred feet distant from the village, there was never any serious complaint from it, and there was generally great satisfaction with it, although, as the flushtank had no settling basin for holding back solids—only a strainer—there was always more or less trouble from obstructions, and, as the population increased, these obstructions increased, until now the whole affair is in such condition that it seems necessary to reconstruct parts of the work in accordance with methods since universally adopted. At the same time, with all its drawbacks, it has been essentially successful and satisfactory, no nuisance having arisen from it that was perceptible at any distance from the field, and no attention having been called to it by reason of its condition. It has been much quoted and visited, as an instance of a great advance in the disposal of the sewage of a village, and it only needs slight improvements to make it available for perfect work for years to come, provision being made for distribution over the surface of the field, at times, during the short period when the village is full of visitors.

At the Woman's Prison the system was much more correctly constructed and has been correspondingly more successful, though it is seriously overtaxed with an effluent of about 30,000 gallons per day; the more especially as the contributing pipes lie in a bed of muck and heavy silt, one of the least successful materials for this use.

At the Bryn Mawr Hotel the same system has always worked satisfactorily since it has been sufficiently extended to deal with the large volume of sewage; but, mechanically considered, this is not a test case, for all of the sewage is received and retained in large cesspools, the absorption drains taking care only of the putrid liquid discharged from them.

After large experience with this method of distribution, I should not hesitate to use it for a community of any size if it were a mere question of mechanical arrangement and of purification. I should hesitate to use it except where the distribution ground is in the immediate vicinity of houses, simply because it is much more costly and much less simple than a discharge over the surface which, as has been amply proven before and is amply proven now at Norristown, answers every requirement of simplicity, safety, and decency.

I cannot better close this paper than with extracts from a report made on the 25th day of July, 1885, to the Chamber of Deputies of France by M. Bourneville, a deputy, submitted in the name of the committee appointed to examine the proposed law having for its object the agricultural utilization of the sewage of Paris and the purification of the Seine.

I adhere as closely as possible to the original text, thinking that, as former statements about this work have been disputed, a close translation is more important than a freer rendering in English. M. Bourneville says:

"The vast experiment at Gennevilliers comes in its turn to confirm the great laws of natural purification and agricultural restitution, attested by the numerous examples that we have collated.

"It was in May, 1869, that is, sixteen years ago, that the sewage first reached the land of the plain of Gennevilliers. There had already been for two years (1867 to 1869) several thousand cubic metres distributed by irrigation or treated by chemical reagents at Clichy on an experimental field, where the pumps now stand; a certain number of vegetable products had been obtained on about two-thirds of an acre. The experiment transported to the other side of the Seine, at the beginning of the plain of Gennevilliers, began in 1869 on six hectares (fifteen acres) bought by the city of Paris and retroceded by it to several well-disposed cultivators. The disasters of the war came and destroyed the first installations; they were put into condition again at the commencement of 1872 and since then the service has been regularly performed. On the 3d of June your commission visited in detail the pumping station of the city of Paris and the plain of Gennevilliers. We have gathered together, on the ground and in the documents placed at our disposal, the most circumstantial information on the results obtained."

The report then describes the character and arrangement of the pumps, connecting pipes, distribution pipes, etc., and continues:

"The volume of sewage sent into the plain of Gennevilliers, which was only 1,765,621 cubic metres in 1876, was 15,000,000 in 1880, and finally 22,493,992 cubic metres in 1884. From 1872 to 1885 there have been spread on the plain of Gennevilliers 157,000,000 cubic metres.

"The irrigated surface has undergone a corresponding development. Beginning with 57 hectares in 1872, it reached 121 hectares in 1874, 200 hectares in 1875, 450 hectares in 1880, and finally 616 hectares on the 1st of January, 1885. The sewage is distributed over the tracts by about 20 laborers, each of whom is charged with the supply of from 25 to 30 hectares and with the management of about 30 outlets. In view of the extreme division of the property and the diversity of culture, the volume of sewage delivered into the plain is distributed so uniformly as to require no reservoir and no 'regulator;' simple standpipes placed near the steam pumps and at different points along the pipes regulate the pressure.

"During the season of active vegetation, the cultivators are present on the fields during nearly the whole day to the number of about 1500 men, women, and children; they lead the water into the ditches from the distribution outlets with a care and a skill which would leave nothing to be desired in the best irrigations of the south of France. During the three or four months of winter, vegetation is only partial; the laborers then interfere more directly; they cause the sewage to flow in the gutters and trenches in such a way as to insure purification by oxidizing action; the solid portions remain in the gutters and form a paste which the peasants afterward incorporate with the earth in the first plowing of spring. This is the case especially for cereals; the vegetable products utilize the winter deposits in the form of a top-dressing of the beds.

"At Paris, as at Berlin, this formation of the deposits and the irrigation continue during the greatest cold, sewage water having always a temperature of at least 5° or 6° (40° to 44° Fahr.) This was realized in the severe winter of 1879 and during the three weeks of continuous frost of last winter. During great floods of the Seine the pumps are generally stopped, leaving to its flow the removal of the entire discharge of the main sewers."

Then follows a table, showing that in 1884 the volume of sewage used in irrigating, per month, varied from 1,205,358 cubic metres in February, to 2,766,782 cubic metres in July. The monthly average for the year was 1,874,491 cubic metres.

"At the time of the visit of your Committee, the volume delivered to the cultivators each day reached from 130,000 to 140,000 cubic metres for every twenty-four hours. More than one-half of the sewage of Paris was purified and utilized by the plain of Gennevilliers during the heated term and during low water of the

Seine. That is to say, at the time when the discharge of sewage into the Seine is specially objectionable.

"The results obtained in the plain, from the point of view of cultivation, are most remarkable. Your Commission traversed, during more than two hours, fields covered with products of the greatest variety and abundance; vegetables of all sorts, cereals, grass, and nurseries.

"They obtain generally 20,000 to 40,000 head of cabbage per hectare, 60,000 heads of artichokes, 10,000 kilogrammes (over 100 tons) of feeding beets, and five or six cuts, yielding from 80 to 100 tons of green forage. The gross product obtained per hectare varies from 3000 to 10,000 francs ($600 to $2000) and even more for crops.

"It has been said, in the presence of the Commission, that the horticultural products of Gennevilliers were of bad quality. It has been written that *the vegetables produced by this soil, surcharged with infected water, are bad to the taste, and the forage offered to live stock is not nutritive, and is, besides, rejected by them.* On this point here is the opinion formulated in a special report to the Agricultural Society of France by M. Michelin."

Then follows a table showing that the 616 hectares were occupied for the growth of cabbage, artichokes, potatoes, asparagus, salads of various sorts, peas, carrots, beans, parsley, onions, beets, luzerne, grass, sundry vegetables, nursery stock, trees, and cereals. M. Michelin says:

"The Society has, through its committees, always observed the results obtained in the horticultural experiments which have shed light on this question, which we in the horticultural world of Paris regard as solved from the practical point of view, with reference to the beauty of the products, their quality as to taste, the success of the production and the certainty of sale. In affirming the quality of the vegetables to be proper for the nutrition of men as well as of animals, it should be explained that the liquid ought not to be put in contact with those parts of the plant which are above ground, but only with their roots."

The Committee asserts that "all the vegetables of Gennevilliers are advantageously sold in the *Halles*, as well as in the markets of the Environs. They carry off the first prizes at the horticultural exhibitions of Paris, and even of Seine-et-Oise. About 800 cows are fed with the aid of the irrigated grass and plants. The average dose of sewage used by a hectare, divided over the whole surface dedicated to irrigation, is about 40,000 cubic metres a year. It is really, if we include what is not used directly, about 50,000 cubic metres. Certain parcels, specially treated, under an arrangement with the cultivators and by way of experiment, with high doses, have been receiving for three years 80,000 cubic metres by regular irrigation summer and winter. They are covered with a luxuriant vegetation.[1]

"The rental value of land which was formerly from 90 to 150 francs a hectare ($7.20 to $12 per acre)—we speak, of course, of the cultivated land—is now from 450 to 500 francs ($36 to $40 per acre) in all the irrigated area. As to the selling value, it is from 10,000 to 12,000 francs ($800 to $960 per acre). All leases now accepted by the cultivators carry the provision that the high rent is not consented to, except on the condition of sewage being disposable for the leased land.

[1] At this rate, one acre would purify the sewage of over 500 persons (at 40 gallons per day).

"The commune of Gennevilliers asked and obtained, by the treaty of 1881, that for a period of twelve years the sewage should remain at the disposition of its inhabitants as freely as they should desire, whatever might be the projects and works of the city of Paris for the extension of irrigation (elsewhere).

"Irrigation with sewage has, therefore, brought wealth to Gennevilliers. Notwithstanding the evidence of these results, there is among the adversaries of the present project one who maintains that this wealth is an illusion, and that in reality the irrigation has caused to Gennevilliers an irreparable wrong, because no one seeks this locality for the construction of villas. The answer is simple; we take it from M. Francisque Sarcey: 'The population, which was not dense,' says he, 'cultivated more or less well a rebellious soil. They had only to scratch the ground to meet the sterile sand and the arid gravel. A few country houses had pushed in here and there around Gennevilliers itself; but it was by exception, *for the emigration of the Parisian Bourgeoisie in search of villas passed to one side and pushed generally further on.* Those who had stopped there could have been seduced only by the cheapness of the land. It seemed that this country, struck with a sort of malediction, was never to lift itself from this condition, when, in 1869, the sewer commission of Paris selected it as the theatre of an experiment which was to produce a happy change in its appearance.'

"The purity of the subsoil water, which receives all of the water filtering from the irrigated land is perfect. M. Pasteur has testified to this with his high authority before the Committee.

"All may judge of this as your Committee has done by the examination and the tasting of the water that flows out of the 5 lines of drains 18 inches in diameter which surround the village of Gennevilliers and discharge into the Seine about 1 kilometre from each other. These drains, having a total length of about 8 kilometres (5 miles) have been established at a depth of 4 metres (12 feet) at the normal level to which it was desired to reduce the subsoil water; in the case of floods, or of very heavy irrigation, these drains facilitate the outflow of the water and prevent the invasion of quarries and cellars.

"As M. Marie-Davy, Director of the Observatory of Montsouris, testified before the Committee, the water of the drains is chemically pure. It contains barely 0.001 of a gramme of organic nitrogen to the cubic metre even at those points, as in the experimental basins of the gardens belonging to the city of Paris, where the annual or continuous dose reaches and passes 80,000 cubic metres per annum. With Liebig's boullion which shows 62 micro-germs in a cubic centimetre of water of the Vanne, 1410 for the Seine at Bercy and 20,000 for the sewage, there are found only a dozen inoffensive micro-germs in the water of the drains, which thus sustains the opinion of M. Pasteur. At the same time, the large content of chlorine, 0.07 of a gramme per litre, indicates the presence in the subsoil water of a large proportion of purified sewage which has passed through the ground.

"The sanitary condition of the commune of Gennevilliers leaves nothing to be desired; the Mayor and his Adjuncts, Doctors Thobois and Cornilleau, testified before the Committee at its visit to Gennevilliers, and it is enough to walk about in the plain and see the vigor and good health of the hundreds of men, women, and children who are working eagerly [avec ardeur] in the midst of the irrigated fields to understand the true state of the case. The *general mortality* in 1865 was 32 per 1000. In 1876 and 1881 it was only 25 and 22. No epidemic of typhoid fever has existed for long years, although the irrigations were continued on a large scale during the cruel epidemic which attacked Paris in 1882. Not a single case of cholera occurred in 1884. Never from 1869 to this day, although the inhabitants eat their own vegetables, even uncooked, has there been observed a single case of *anthrax* or *septicæmia.* In fact, all of the information that we have gathered from most of the physicians who have had occasion to be called to Gennevilliers proves that intermittent fever shows itself very rarely, and that the number of cases does not exceed that of localities more or less remote, and of which the fields are not subjected to irrigation.

Still another argument pleads in favor of the excellent sanitary condition of Gennevilliers: that is, the increasing growth of population as shown by the following table:

1st of January, 1869	2186	inhabitants.
" " " 1872	2218	"
" " " 1880	2389	"
" " " 1885	3245	"

"Such are the facts that your committee has established in the plain of Gennevilliers; it has been constantly accompanied by the authorized representatives of the population of the plain and its suburbs: MM. Pommier, Mayor, and Retrou, Adjunct, of Gennevilliers, Berthou, Mayor of Saint Ouen, Hennape, Mayor of Puteaux, our friend M. Bailly, Mayor of Courbevoie, Honorary Inspector-General of Public Assistance. A deputation of the cultivators of the plain gave the committee all the information as to details that it needed. No discordance was developed; the unanimity was complete concerning the excellence of the results obtained and the absolute innocuity of the system. The majority of your commission cannot refrain from expressing to you the confidence that these demonstrations give it in proposing to you the continuation and extension of sewage irrigation."

The publication of this report must have been most gratifying to M. Durand-Claye, the champion, and the wise and eager director of the work at Gennevilliers, who has fought its battles against prejudice, ignorance, and malice from the days of its struggling infancy to this hour of its complete triumph, and his own.

At Gennevilliers as at Croyden, Berlin, Dantzic, Breslau, and the Norristown Asylum, complete evidence is set before us of the absolute efficiency of the system of purification by application to the soil, which, it seems to me, on the score of economy and of completeness, as well as by reason of the conditions generally prevailing in this country, has such advantages over the best of the chemical systems that it is, in at least a very large majority of cases, better suited to our needs.

Nor can it be doubted that this system will enable us to restore and to maintain the purity of our water-courses, especially when these are used as the source of water for domestic use.