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REPORT

of an Experimental Investigation of the Value of a Process
for Purifying Sewage by Means of Artificially
Aerated Bacterial Filters.

BY

GEO. E. WARING, Jr., M. Inst. C. E.

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The Purification of Sewage by Forced Aeration.

A STUDY OF THE RESULTS OF ARTIFICIALLY STIMULATING BACTERIAL ACTION IN SEWAGE.

We are accustomed to think of all things material as divided into three great kingdoms — Animal, Vegetable and Mineral. Viewed superficially, these divisions seem clearly defined and, at least to a great extent, permanent. The truth is that matter is constantly passing from one division to another, and that in none of them, save the mineral, is any stability to be found. Certain elements have never been discovered in organic form, but all vegetable structures are built of materials borrowed from the mineral world, which must, sooner or later, be returned to it. All animal tissues are drawn from the vegetable, directly or indirectly, and, in due time, back to the dust must they go.

Until about 1890 the theories concerning the destruction of waste organic matters were in a state of speculation and development, but much positive knowledge on the subject has been gained within the last five years.

Foremost in importance are the results of the experiments made by the Massachusetts State Board of Health at its station at Lawrence. The detailed records of these experiments and the deductions of the eminent scientists in charge of them, as published in the Reports of the Board, constitute the most valuable addition yet made to sanitary science. It is sufficient, for the purposes of this paper, to say that these experiments prove beyond question the fact that organic matter in sewage is reduced to its original mineral elements — absolutely destroyed as organic matter — by the action of living organisms; and that they clearly indicate — if not the precise manner in which the work is done — at least the conditions which favor or retard its accomplishment. The experiments consisted in passing sewage at intervals through tanks filled with various filtering materials. The simplest and most striking illustration of the process was obtained in the use of two tanks, one filled with gravel-stones none of which were less than one-eighth of an inch nor more than three-eighths of an inch in diameter, and the other filled with stones varying from three-quarters to one and a quarter inches in diameter. In both cases the material was carefully washed, that no sand or soil might remain attached to it. Concerning the results obtained from these tanks, Mr. Hiram F. Mills, who was then in charge of the station, says:

"The experiments with gravel-stones give us the best illustration of the essential character of intermittent filtration of sewage. In these, without straining the sewage sufficiently to remove even the coarser suspended particles, the slow movement of the liquid in thin films over the surface of the stones, with air in contact, caused to be removed for some months 97 per cent. of the organic nitrogenous matter, a large part of which was in solution, as well as 99 per cent. of the bacteria, which were, of course, in suspension, and enabled these organic matters to be oxidized or burned, so that there remained in the effluent but three per cent. of the decomposable organic matter of the sewage, the remainder being converted into harmless mineral matter.

"The mechanical separation of any part of the sewage by straining through sand is but an incident, which, under some conditions, favorably modifies the result; but the essential conditions are very slow motion of very thin films of liquid over the surface of particles having spaces between them sufficient to allow air to be continually in contact with the films of liquid.

"With these conditions, it is essential that certain bacteria should be present to aid in the process of nitrification. These, we have found, come in the sewage at all times of the year, and the conditions just mentioned appear to be most favorable for their efficient action, and at the same time most destructive to them and to all kinds of bacteria that are in sewage."

We see, therefore, that the process that is called "filtration" is not filtration, but a mere exposure of the sewage, in the presence of air, to the action of destructive bacteria, which, so far as known, are the only agents that can oxidize and destroy the organic impurities of sewage. The presence of air (oxygen) is absolutely essential to the inoffensive decomposition of organic wastes. In its absence certain forms of putrefaction and disintegration will be set up, but such processes are offensive and, to the best of our knowledge, they are usually dangerous. When sewage is delivered into porous, open-jointed absorption drains, laid in surface soil, it soaks away into ground which is sufficiently permeated with air to induce bacterial oxidation. When sewage is spread over the surface of the ground, the process of destruction is essentially the same, but exposure to the air is more complete and oxidation is, at proper temperatures, proportionately more active. In each of these cases, however, as well as in the case of the filters at Lawrence, described above, complete and inoffensive purification is obtained only by the intermittent application of sewage. The liquid applied must be allowed to drain away and be followed in its descent through the interstices of the soil by the air necessary to facilitate the bacterial destruction of the impurities adhering to its particles.

The experiments herein described, in the treatment of sewage in artificially aerated filters, were undertaken with a full understanding of the facts stated above, and after a careful study of the researches of the Massachusetts Board of Health. They illustrate no new theory; they deal with no purifying process but the natural one of bacterial oxidation, which has been in constant operation since the first appearance of life upon the earth. Their aim has been to find a way of artificially producing conditions more favorable to natural bacterial action than can be found under ordinary circumstances.

The process consists in the mechanical straining out of all solid matters carried in suspension in sewage, and their subsequent destruction by forced aeration, and the purification of the clarified sewage by bacterial oxidation of its dissolved organic matters in an artificially aerated filter.

The results accomplished in the experiments herein described exceeded the most sanguine expectations. Sewage, loaded with grease, dirt, excreta, and the putrid overflow of cesspools, escaped from the tanks clear, white, and limpid. The impurities were not passed through in disguise, the foul smell was not masked by other odors; the effluent water was actually clean,—a good drinking water.

This complete regeneration continued through five months, and when the filters by which it had been performed were taken apart, they too were clean. The filth had not accumulated in them; it had completely disappeared.

The process is not only valuable as an economical and efficient means of purifying sewage. It is equally applicable to the cleansing of liquid wastes from slaughter houses, glue factories, fertilizer factories, garbage disposal works, silk and woolen mills, —in short, it will purify all water that has been soiled by organic matter.

Described briefly, the apparatus and the mode of operation are as follows:—

The sewage, after passing through suitable screens, which withhold large solids, such as rags, paper, lemon-rinds, etc., flows slowly, horizontally, through or over a shallow bed (say 6 inches deep) of coarse broken stone or similar material, which serves to catch and retain the coarser floating particles which have escaped the screens.

These broken-stone beds should be provided in triplicate, each to have ample capacity to receive the entire flow for a certain period; and they are to be used in alternation, allowing to each twice as much time for rest and recuperation as for active service. When one of these areas is thrown out of use, it is drained and its accumulation of filth is exposed to the action of air, which results in its speedy destruction, leaving the bed in condition again to receive its quota of sewage when its turn comes.

Leaving this area of broken stone, the sewage, freed from its coarser solids, passes to a straining tank filled with fine broken stone, coarse gravel, locomotive cinders, coke, or similar porous material. This tank is divided into two compartments by a diaphragm, which extends nearly to the bottom of the tank. The sewage passes down through one of these compartments, flows under the diaphragm and rises through the other compartment, overflowing at its top. The rate of flow through the tank must be sufficiently slow to allow the deposition upon the surfaces of the filtering medium of the solid particles suspended in the sewage. If the speed be properly regulated, practically all of the suspended impurities are retained in this tank, and the sewage leaves it as a slightly opalescent but clear liquid, with a perceptible odor. At this stage it compares favorably with the effluent of chemical precipitation works.

When one of these straining tanks has been in operation for a considerable time, the accumulation of sludge at the surface of the filtering material clogs the pores of the filter and decreases its capacity, although the quality of the effluent is in no wise impaired. When this condition is reached, the flow is turned to another tank of similar construction, where the straining process begins anew. The filter tank which has just been thrown out of use is drained, and an abundant supply of air, under light pressure, is forced by a blower into the bottom of the tank (where means for its even distribution are provided), rising through the filtering medium in a strong current which penetrates into all its voids and pores. Under these conditions, rapid bacterial oxidation is set up and the retained impurities are speedily consumed, leaving the tank in a clean condition, ready for further use.

It will probably be best to provide four of these straining tanks, to be used in alternation, allowing to each a period of aeration three times as long as its period of use. The filters which were in use at Newport during the whole time of the experiment (over five months) without any renewal of material, showed no signs of deterioration, but were practically as clean at its termination as when they were new, and were capable of producing as good results.

The degree of purification attained at this stage of the process is, in many cases, sufficient to satisfy all requirements. When purification to a drinking-water standard is necessary, it may be obtained by further treatment, as follows:

After passing the straining tanks, the sewage, which has been relieved of all matters in suspension, but which still contains nearly or quite all of the dissolved impurities originally in it, flows to an aerating tank. This is similar in construction to the straining tanks, save that it has no dividing diaphragm, the sewage passing in at the top and escaping, as purified water, through a trapped outlet at the bottom. It must also be considerably larger than the straining tanks, for the sewage, instead of passing through the filter in a solid column, as in the former case, trickles down in a thin film over the surfaces of the particles of coke or other filtering material; while, through the voids between the particles, and in immediate contact with the trickling films of liquid, a current of air is constantly rising, being introduced at the bottom of the tank by a blower.

After the filter has been a short time in use, the nitrifying organisms, which have entered with the sewage, develop, and, in the presence of abundant food supplied by the sewage, and abundant oxygen furnished by the blast, multiply with great rapidity, until their number has reached a point at which the average food supply is only capable of feeding the existing colony, and further multiplication is checked. When a sufficient colony of organisms has become established, the consumption of the organic matter in the liquid passing through the tank will be practically complete, so long as the quantity is reasonably uniform. Any sudden and marked increase or diminution in the rate of flow will make it necessary for the colony of organisms to adapt itself to the new conditions, and this it will do, within reasonable limits, in a short time.

As these nitrifying tanks are constantly aerated, *they are used continuously*, and one area, of sufficient size to care for the flow, is all that need be provided.

The process by which the impurities of the sewage are removed is the purely natural one on which depends the ultimate destruction of all organic matter. When sewage is spread over the surface of the ground, as in irrigation, it is exposed to the atmosphere in thin broad sheets, and the bacteria which reduce its putrescible matters are active because air is abundant. The process in the aerating tank described above is essentially the same, but in this case the earth is massed in cubical form, and the atmosphere is made to pervade the mass, so that every conceivable plane within it presents — so far as bacterial activity is concerned — the conditions of a natural surface.

The same is true with regard to the straining tanks. While the sewage is passing through them, the action is merely mechanical sedimentation. When the liquid has been drained off and the aeration has begun, the process and the result are the same as they would be if the accumulated sludge were spread in extremely thin sheets over the surface of a large area of soil.

The construction of the experimental plant at Newport was begun in April, 1894. By special permission of the authorities

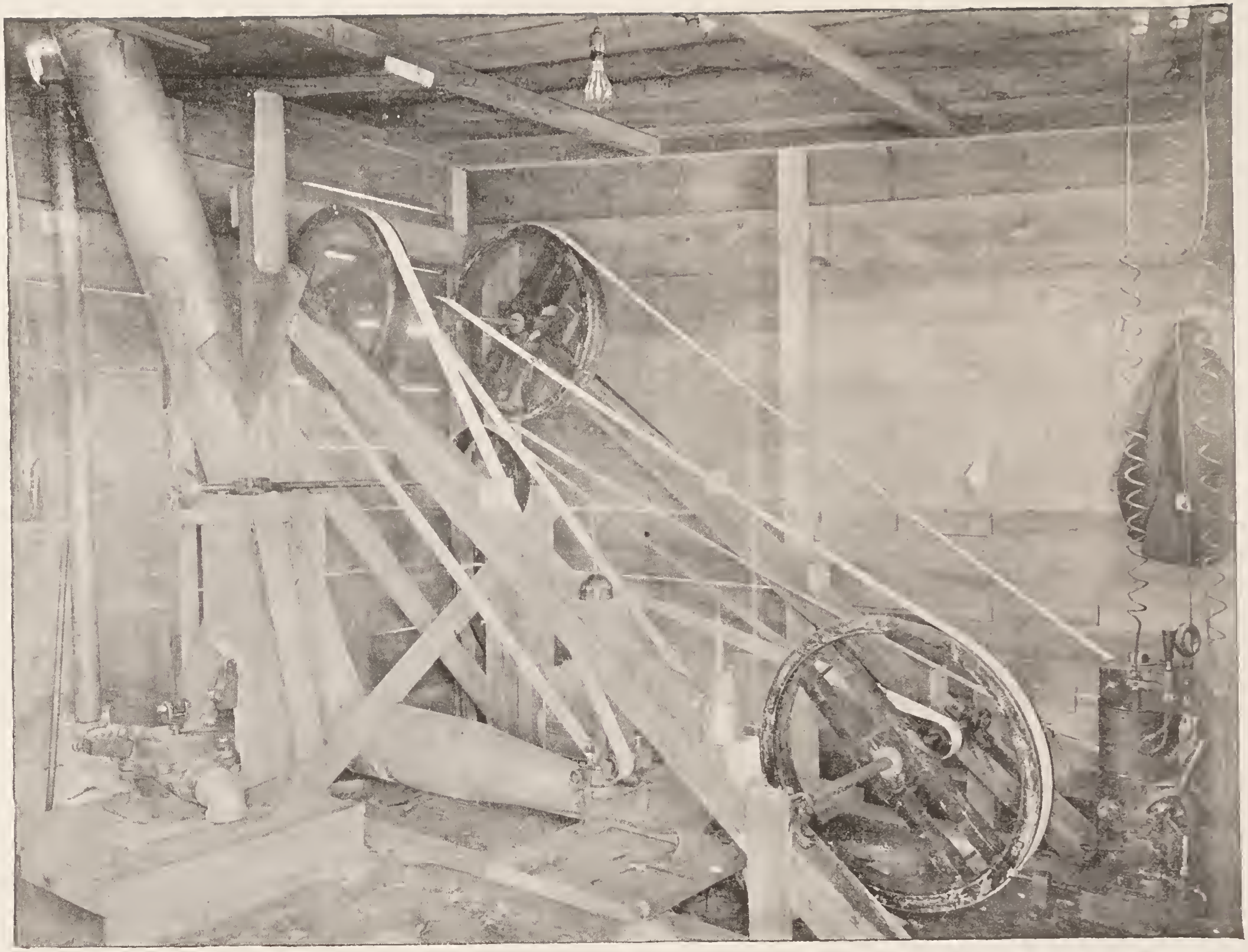

FIGURE 1.

of the city, a building 14 feet square was erected upon city property on Briggs Wharf, directly over the main outlet sewer and enclosing one of its manholes. The sewer at this point is  in section, 5 feet wide and 5 feet deep and with a grade of 1 to 2000. At the end of the wharf, 104 feet beyond the point selected, the sewer delivers into a large settling chamber, and from this an iron pipe, laid on the bottom of the inner harbor, leads beyond the breakwater and discharges into the main channel. A storm overflow in the settling chamber (a weir in the sea wall) allows the direct discharge of sewage into the inner harbor at times when the flow is unusually large. This overflow is provided with low tide-gates, but very high tides sweep over these and flood the settling chamber with salt water. The city is sewered according to the combined system. The street inlets deliver into large catch-basins, which in dry weather are little better than cesspools. Many of the sewer connections are merely overflows from old cesspools, receiving only liquid which is stale and putrid. The main sewer, which of necessity has very little fall, is a sewer of deposit, in which putrefaction is constantly going on. Because of these conditions, the sewage used in the experiments was often far from "fresh," although the analyses showed it to be of normal composition and fair average strength. It contained practically no manufacturing wastes, although at times there was evidence of the presence of gas liquor. The invert of the sewer at the manhole covered by the experiment station was 1.05 feet above low tide. The average flow of the sewer at low tide, when the outlet was free, was about 9 inches deep, but at high tide the water was backed up until it was from 2 to 2½ feet deep, and the current either entirely checked or reversed. Exceptionally high tides, which entered the settling chamber through the storm overflow, invaded the sewer, so that at times the pump drew nothing but slightly fouled salt water, and the work had to be suspended in consequence. This was partially remedied by placing a dam, about 28 inches high, in the sewer, but at times the salt water swept over this.

Within the building, upon a platform built over the manhole, a 10-inch diaphragm pump was placed, with a 3-inch galvanized iron suction running to within about 8 inches of the bottom of the sewer.*

The mouth of this suction was open — full bore — so that a fair sample of the sewage, — solids as well as liquids, — might be had. The large rubber flap-valves of the pump, although occasionally choked, passed solid substances well, and objects of considerable size, — dead rats, halves of lemon, pieces of shoe leather and towels, cabbage leaves, etc., — were delivered on the screen. The capacity of the pump at full stroke was .81 gallons, but its average throw during the experiment was about .28 gallons, and its average speed was 5 to 8 strokes per minute. It was driven by an offset crank-pin so attached to a face-plate on a shaft that the stroke could be made of any length from 0 to 4 inches. A revolution counter, attached to the connecting rod, recorded the number of strokes. A 3-inch galvanized iron force-main ran from the pump to the screen overhead, which will be described later. This pipe was tapped close to the pump and a pet-cock inserted, from which the samples of sewage for analysis were taken.

A 28-inch exhaust fan, made by the Boston Blower Company, furnished the means of aerating the tanks. It ran, during the experiment, at speeds varying from 1500 to 4800 revolutions per minute, and delivered into a 12-inch galvanized iron blast pipe, which distributed the air through branches to the tanks. A pressure gauge attached to this pipe indicated the air pressure in ounces and in inches (of water).

Both pump and blower were driven, through suitable shafting, by a 3 H. P. Edison electric motor, supplied with current from the Newport Illuminating Company's station. But 1½ H. P. was needed for the work, and the current was reduced, first by a rheostat, which after a time burnt out one of its coils, and later by a lamp resistance of twelve 32- and eight 50-candle-power lamps, arranged in series of two.

Figure 1 shows the arrangement of pump, counter, blower, air-guage, shafting and motor.

A chemical laboratory was provided, suitably equipped for the determination of free and albuminoid ammonias, consumed

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* Later, during the dry weather, this was lowered to within 3½ inches of the bottom.

FIGURE 2.

oxygen, dissolved oxygen, chlorine, etc., and for the recording of meteorological conditions.

The screening apron, straining tanks, aerating tanks and effluent tank were located in a yard outside of the building, and their general arrangement is clearly shown in Figure 2. The force-main from the pump delivered near the top of the building, under the large air-pipe, and, by means of a loose elbow and short nipple, the flow could be turned at will to either side of a partition which divided into two sections (for alternate use) a shallow bed of coarse broken stone, supported on a trestle. The function of this bed was to catch and retain the coarser solids contained in the sewage, before passing it to the tanks below. Each of these sections contained 20 square feet (4 x 5) of stone 8 inches deep. In practice it was found that this area was insufficient for convenient working. It was effective in that it retained practically all of the coarser matters, but they accumulated so rapidly that one section soon choked and the flow had to be turned upon the other. The impurities in the section thrown out of use disappeared rapidly in its interval of rest, but before its cleansing was complete the other section would be choked and in need of attention. For this reason it became necessary to wash out these beds from time to time, though their work was much lightened later by placing a wire screen of ½-inch mesh under the force-main delivery. Three of these sections should have been provided, and each should have been of twice the actual size. This would have allowed ample time for the exercise of their self-cleansing properties.

At one time one of these sections was filled with fine broken stone (¾ to ⅜ inch). Its performance in withholding matters in suspension was admirable, but it choked too quickly and became so filled with pasty sludge that its aeration and recuperation were very slow. Without doubt the best results would be obtained by constructing straining aprons of sufficient size and in triplicate, and grading the size of the stone so that the coarsest shall be nearest to the delivery of raw sewage and the smaller sizes near the outlet.

From the straining apron, the sewage, freed of its coarser solids, but still containing much fine matter in suspension and all that it originally had in solution, passed to the straining

L. of C.

tanks. Of these there were originally four (Nos. 1,* 2, 3 and 4), similar in construction, but filled with different materials. Each tank had a total capacity of about 985 gallons. The top of No. 1 was about 4 inches below the delivery of the straining apron, and each succeeding number was 6 inches lower than the one next before it, so that the tanks could be used in series if desired, the overflow of No. 1 delivering into No. 2, its overflow, in turn, passing to No. 3, and so on. The internal arrangement of one of these tanks is shown in Figure 3. *A* is a false bottom

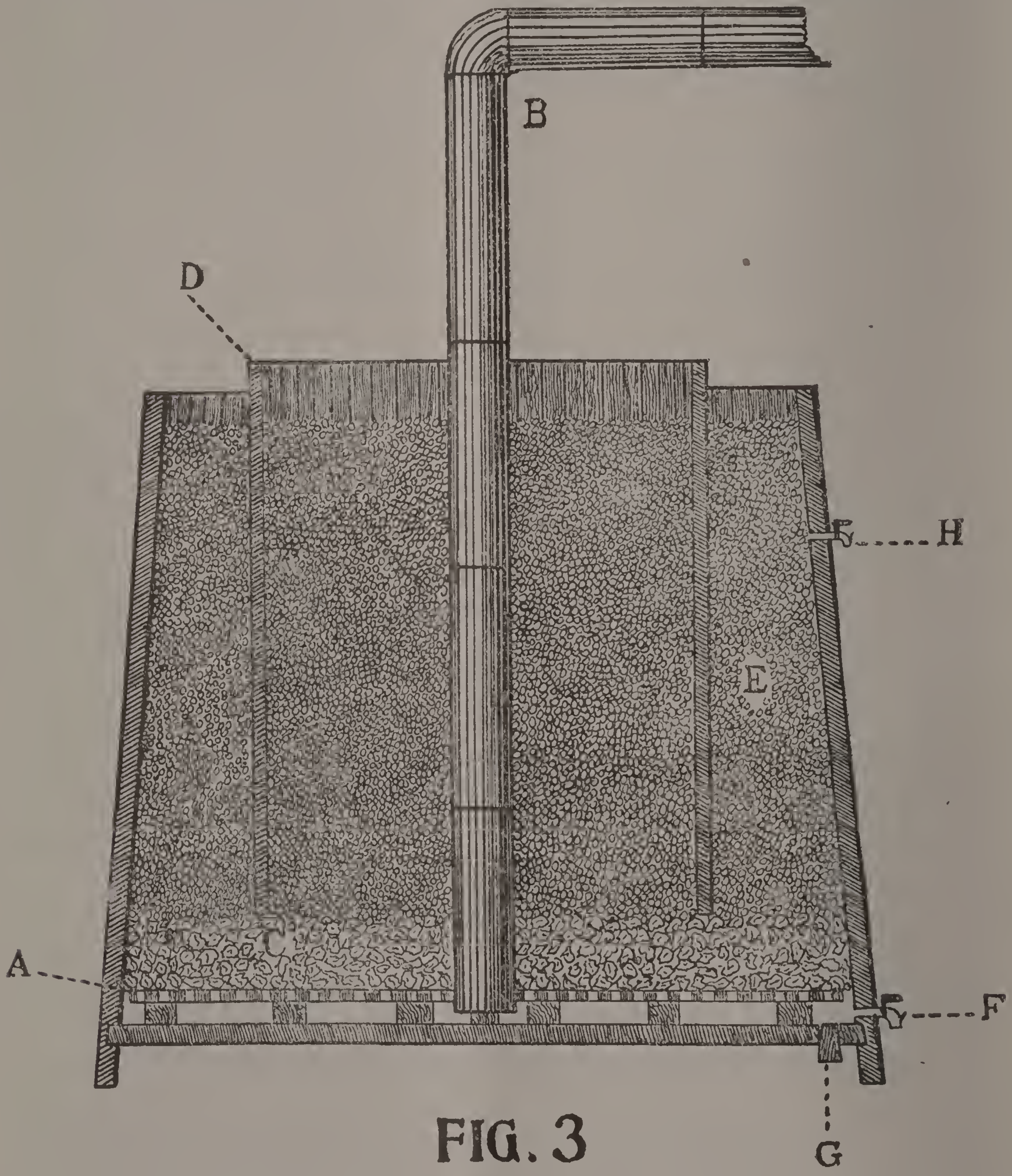

FIG. 3

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* Afterwards No. 1 A.

of plank, perforated with $\frac{3}{4}$-inch holes about 4 inches apart and supported a few inches from the bottom on cleats. *B* is a galvanized iron air-pipe, 6 inches in diameter, branching from the 12-inch air main, and delivering through the false bottom into the open space below. *C* is a layer of coarse broken stone (1 to $2\frac{1}{2}$ inch) 6 inches thick. In tank No. 1, this material was used for filling the whole tank. *D* is a cylindrical diaphragm, of hooped staves, resting upon the broken stone *C*, and dividing the surface of the tank into a circle and a ring of equal area. *E* is the material with which the main body of the tank,—inside and outside of the diaphragm,—was filled. In No. 2 it was fine broken stone ($\frac{3}{8}$ to $\frac{3}{4}$ inch); in No. 3, round pebbles, of diameters ranging from $\frac{3}{8}$ to $\frac{5}{8}$ inch; and in No. 4, coarse white gravel, of very uniform size, free from sand, each grain being about $\frac{1}{8}$ inch in diameter. Each of these four tanks was fitted with a drainage cock *F* near its bottom, and a hole bored through the bottom and closed with a wooden plug *G* provided means for the rapid and complete emptying of any tank when desired. In draining a tank at the close of a run, when it had accumulated its quota of sludge and was about to be aerated, the liquid was drawn off slowly through the cock, to prevent such disturbance of the sediment deposited upon the particles of the stone as a rapid flow would have caused. A smaller cock *H* was placed near the top of each tank, just below the overflow line, and from this samples were taken for analysis and examination. The partially strained sewage from the apron was delivered on the surface of one of these tanks in the circle enclosed by the diaphragm. It passed down through the central cylinder of filtering material and under the diaphragm, and rose again through the annular space outside of the diaphragm, overflowing through a spout into a gutter* leading to the central circle of the next straining tank, when two or more of these tanks were used in series, or to the aerating tank, for further treatment.

As has been stated, the function of these four "strainers" was mere mechanical sedimentation. The liquid flowed slowly

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* Short lengths of hose were used at first to conduct the flow from tank to tank, as shown in Figure 2. Shallow wooden gutters were afterwards found to be more convenient.

through them and the suspended matters, which were more or less fibrous or gelatinous in their nature, attached themselves to the particles of the filter, the coarser of them being deposited near the surface of the central cylinder and the finer progressing further and further into the mass. Samples drawn from the drainage cocks at the bottom proved nearly as clear as those taken from the sampling cocks near the point of overflow, showing that practically all of the solid matters were deposited in the central core during the downward flow of the water, and that very little work remained to be done as the liquid rose in the outside ring. This was the case when the sewage was applied at the maximum rate attained in the experiment, 8,950,194 gallons per acre, the water moving through the tank at the rate of about 3 feet per hour. It is reasonable to suppose that the deposition of the suspended matters of sewage would be more rapid and complete when the liquid is slowly rising than when it is descending, and it is probable, therefore, that at least twice this maximum amount could be passed through a similar filter without materially impairing the quality of the effluent. The periods of operation of each filter would, of course, be shortened, but the power of recuperation would not be impaired. While these tanks were in operation, the contained liquid effectually trapped the air pipe *B*, but as soon as a tank was drained, its water seal was broken and air from the blower poured into the open space beneath the false bottom, and, the drainage cock having been closed, rose through the contents of the tank, its pressure ensuring a distribution throughout the whole mass. This abundant supply of oxygen stimulated into activity the germs of decomposition which lay dormant in the tank. They speedily attacked the stored organic matter and reduced it to its mineral constituents, part of it being rendered soluble and passing off in the next flow of liquid through the tank and part escaping in gaseous form into the atmosphere. The substance of the deposited matter was completely destroyed and the filter was restored to a clean condition, ready for further use.

The original plan provided for the use of these strainers in series, the flow from the apron passing in succession through Nos. 1, 2, 3 and 4; or, as a possible alternative, their employment in pairs, Nos. 1 and 3, for instance, being in operation while Nos. 2 and 4 were aerating. It was soon found, however, that, in the use of four strainers in succession, the sewage was detained so long in the tanks that it began to putrefy, the effluent from the fourth tank and sometimes that from the third being worse than their respective affluents. Even when two tanks were run in series, the improvement caused by the second was not sufficient to justify its use, and, during the latter part of the experiment, the flow was passed through but one strainer.

The comparative efficiencies of the various strainers are clearly shown in the tables accompanying the report of the chemical work. The results obtained in the use of No. 1 were excellent, but this tank was found somewhat more difficult to clean than the others, because the larger voids between the stones permitted the accumulation of sludge in larger masses, which were not so easily disintegrated by the action of the air as the more divided masses which gathered in the other tanks. The use of No. 1 as a strainer was therefore abandoned, and the tank was converted into an aerator, No. 1 A, as is described below.

Suspended matter having been removed from the sewage, mechanically, in the strainers, to be afterwards destroyed by forced bacterial action, the clarified, but still foul, liquid was led to the aerating tank, shown in section in Figure 4. This tank was of the same size as the others, and was set 6 inches lower than strainer No. 4. It had a perforated false bottom, with an 8-inch air-pipe delivering into the space below it. On this bottom was placed 6 inches of coarse broken stone, which was packed at the top with smaller stone, so as to support firmly the finer filling material, which was clean white gravel, similar to that used in No. 4, and 3 feet 9 inches deep. On this was placed another 6 inches of coarse broken stone *K*, packed with finer stone at the top, and the whole was covered with 6 inches of fine beach sand *L*. Two vent pipes *M M*, made of single lengths of round 4-inch agricultural tile, pierced the covering of sand and communicated with the upper layer of broken stone beneath it. This tank had no diaphragm. The effluent from the strainer entered at its top, trickled down over the broken stone and gravel and ran out at the bottom through the pipe *R*, which discharged into an upright length of vitrified pipe *S*, closed at one end, effectually trapping the outlet and preventing air from escaping with the effluent. This trap overflowed into a rectangular wooden tank of about 350 gallons capacity, sunk in the ground, which collected the effluent and allowed convenient inspection of it in bulk, giving a better general idea of the transparency and whiteness of the water than the laboratory samples or the turbidity-testing apparatus.

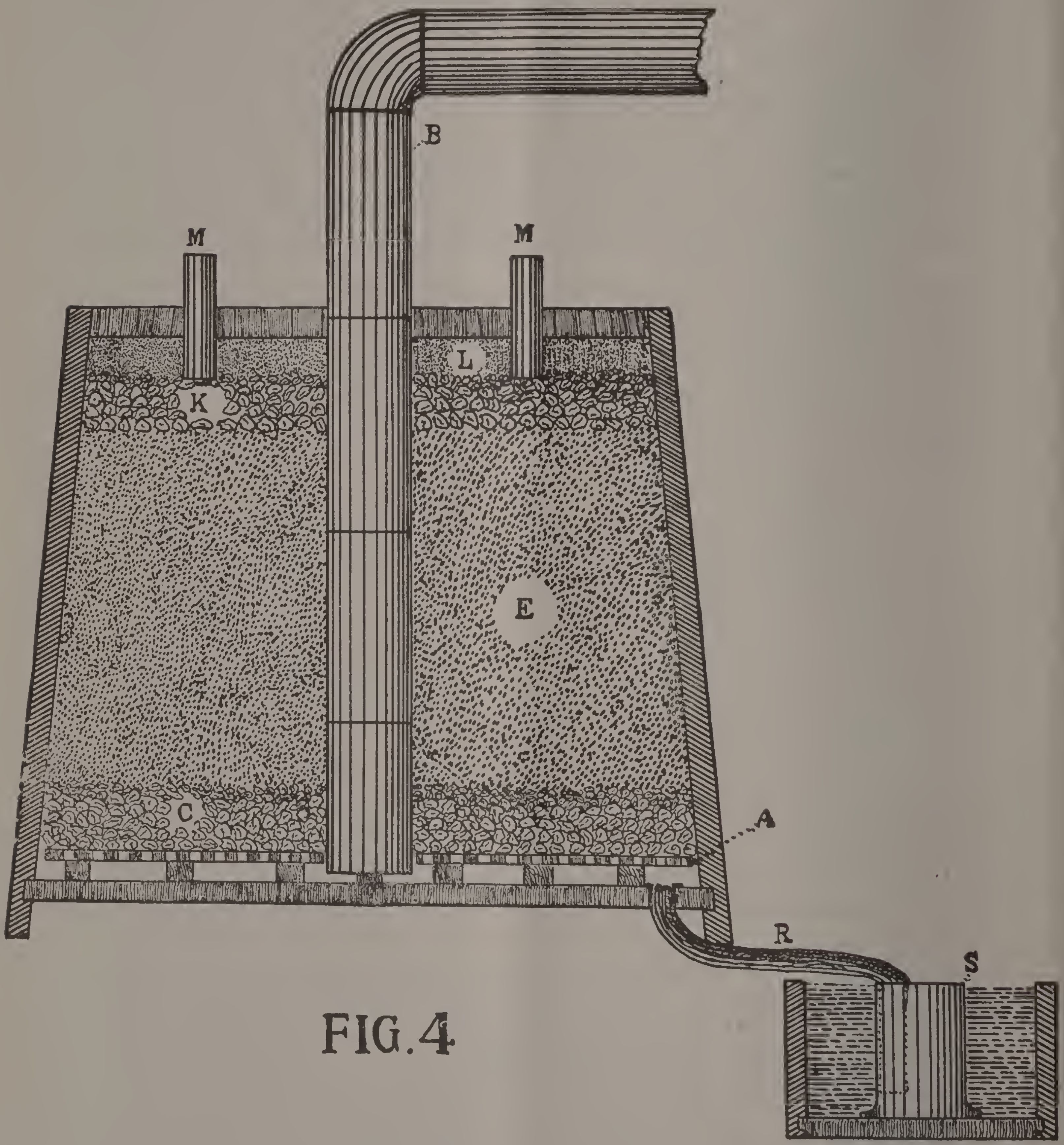

FIG. 4

In tank No. 5 the forced aeration was constant. Air was delivered at its bottom, and, being prevented by the trap from passing out with the water, rose through the gravel to the upper layer of broken stone, and thence escaped, by means of the vent pipes, to the outer air. At times the discharge through these vents was sufficiently strong to carry with it good sized pieces of the broken stone in which their lower ends were embedded. At other times the current was scarcely perceptible. The liquid which was constantly trickling down in thin films over the surfaces of the broken stone and gravel was always in immediate contact with a current of fresh air passing in an opposite direction through the voids between the particles of stone. When the sewage was first applied, it sank through the layer of sand within a few inches of the point at which it was delivered and passed quickly through the tank, showing little or no improvement as it escaped. Gradually, however, the surface of the sand became partially clogged and the sewage was distributed over a wider area, until at length the whole surface of the tank was covered with liquid 2 or 3 inches deep. This secured uniformity of distribution throughout the tank. Gradually, also, the organisms of nitrification began to multiply and to seize upon the dissolved impurities, destroying their organic character and transforming them into nitrites and nitrates, in which unobjectionable mineral form they escaped with the effluent. The first signs of this action were shown on June 12th. Once started, it increased rapidly, and by June 27th the average working rate of nitrification was reached. From this time to the end of the experiment the operation of this tank was practically constant,—occasionally influenced by changed conditions, as is shown in the tables of analyses, but quickly adjusting itself to these conditions.

After the abandonment of No. 1 as a strainer, this tank was lowered to the level of No. 5, reconstructed as an aerator and known thereafter as 1 A. The construction was exactly like that of No. 5, save that the main body of the tank was filled with coke, crushed to the size of coarsely ground coffee. The outlet pipe was trapped by submersion in a tight wooden box of about 5 gallons capacity, which overflowed, through a wooden trough, into the large effluent tank. Samples of the effluent of 1 A for examination and analysis were taken from this box. The tank was first applied to this use August 11th.

Nitrification appeared August 16th and rapidly increased until August 21st. From this time to the end of the experiment the operation of this tank was practically constant. The results obtained in its use are fully set forth in the report of the chemical work. Its general performance was somewhat better than that of No. 5, and, on comparison, its effluent seemed to be whiter,—that is, more blue-white.

In a strainer, during its period of use the voids of the material were completely filled by the flow of sewage. In an aerator, the voids were mainly filled by a constantly moving current of air, the liquid passing down, not in bulk, but in thin films, which worked their way over the surfaces of the particles of gravel or coke. The capacity of an aerator was, therefore, much less than that of a strainer of the same size. The effluent from the strainers was led to a distributing box, from which it escaped over a level weir, the flow being divided by movable knife-edge gates, which regulated the amounts applied to the aerators. Ordinarily No. 5 received one-fifth of the total flow from the strainers, and 1 A from one-fifth to three-tenths, the balance being returned to the sewer. At times two-fifths was turned into 1 A and satisfactorily purified. The amount of sewage actually passed through each tank daily, and the total flow in gallons per acre, are clearly shown in Tables A and E. The average daily flow through the strainers was at the rate of 3,787,200 gallons per acre (the maximum was 8,950,194 gallons), and through the aerators at the rate of 1,064,213 gallons (the maximum, after nitrification began, being 4,826,112 gallons).

The total flow applied to a strainer passed down through the central cylinder enclosed by the diaphragm, whose area was one-half that of the whole tank surface, and rose through the ring outside of the diaphragm. In effect, the sewage passed through a cylinder of filtering material about 10 feet deep and with a section equal in area to the circle within the diaphragm. So far as the filtering capacity of the tank was concerned, it might have been constructed in this form, the speed of flow being regulated by an adjustable gate in the pipe at the bottom, from which, in this case, the effluent would have escaped. The rate of application, which is figured in the tables on the area of the whole tank—circle and ring, was, therefore, actually twice the amount stated, or an average of 7,574,400 and a maximum of 17,900,388 gallons per acre.

The average percentage of purification, as represented by the removal of organic nitrogenous matter, accomplished by the strainers alone, was 51.2, and by the strainers and aerators together 92.5. At one time a purification of 99.08 per cent. was reached.

The sole function of the forced aeration was to supply oxygen to the interior of the tanks in sufficient quantity to excite and maintain the maximum activity of the bacteria of decomposition. It is probable, however, that, although the constant presence of oxygen is necessary for constant purification, the amount actually consumed in the reduction of the organic matter is small and no additional benefit is derived from the supply of an excess. Towards the close of the experiment, the air-pipe of No. 5 was throttled by the insertion of a diaphragm, pierced with $\frac{3}{4}$- and $\frac{3}{8}$-inch holes, which could be closed at will with corks. These holes were plugged, one or two at a time, until the amount passing through one $\frac{3}{4}$-inch hole was the sole supply of the tank. Later this was closed and a $\frac{3}{8}$-inch hole opened, reducing the supply, theoretically, by three-fourths. No further change was made and the tank was operated with this amount of air until the close of the experiment. The effluent showed no signs of deterioration and the supply was probably ample. Whether or not any further reduction would be possible remains to be determined by future experiment. Probably a vigorous aerating of the filter for say five minutes in each hour, thoroughly changing the air in all its voids, would store sufficient oxygen to keep the bacteria active until the next period of aeration. This course would probably be wiser than an attempt to furnish a constant supply at a lower pressure, for, in the latter case, the air would escape in the lines of least resistance, and the more remote or compact portions of the filter would not be penetrated by it; while intermittent aeration at a higher pressure would force the air into every crack and corner, and secure the efficient operation of all parts of the mass. By means of light partition walls or diaphragms the filtering material could be divided into sections, which could be aerated vigorously in turn. Assuming that the above suggestion of five minutes aeration in each hour should prove practical, the entire filter could thus be satisfactorily operated with one-twelfth of the air and power which would be used if the aeration were constant.

The station was dismantled and the tanks taken apart within the week following the close of the experiment (October 17th–24th). The upper foot (approximately) of the central compartment of each of the straining tanks showed more or less accumulation of silt, probably the result of the few heavy rainfalls during which pumping was continued bringing much gutter mud to the tanks Below this, the material was apparently as clean as when first put in, the pebbles and white gravel looking as though they had just been taken from their native beach. In no part of the tanks was there any sign of organic matter or any suggestion of the hundreds of thousands of gallons of sewage which had been passed through them. The thin layers of sand on top of the aerators were black with sulphides, but all the material below this was sweet and clean. No impurities had been *stored* in any of the tanks. They had been detained and destroyed. All the conditions clearly indicated that the usefulness of the filters had become in no wise impaired, that they were capable of performing their functions indefinitely, and that, under proper management, no renewal of the filtering medium would be necessary.

GENERAL SUMMARY.

The operation of the experimental plant and the results accomplished are set forth in detail in the annexed report of the chemist in charge and the accompanying tables. Briefly summarized, these results demonstrate that:—

1. The suspended matters of sewage (sludge) can be mechanically withheld by straining slowly through suitable material.

2. The filth accumulated by this straining material can be destroyed and the straining medium restored to a clean condition by mere aeration.

3. The successive alternate operations of fouling and cleansing can be carried on indefinitely, without renewal of the straining material.

4. The purification obtained by this straining process practically equals that accomplished by chemical precipitation, and

is sufficient to admit of discharge into any considerable body of water not used as a source of domestic supply or for manufacturing purposes requiring great purity.

5. Practically, all of the dissolved organic matter in sewage can be removed and purification to a drinking water standard can be obtained by the use of suitably constructed bacterial filters.

6. Such filters can be maintained in *constant and efficient* operation by suitable aeration.

7. The erection of a plant capable of purifying large volumes of sewage upon a relatively small area calls for no costly construction. Repairs and renewals are merely nominal. The attendance required is but slight. There is no outlay for chemicals, etc. The only expense of mechanical operation is the driving of the blower or air-compressor.

8. The process admits of wide variation in the selection of filtering material, and nearly every community can find, in its local resources, something suitable for the purpose.

The chemist in charge of the work, Mr. George W. Rolfe, was selected for the purpose by Prof. Thomas M. Drown, of the Massachusetts Institute of Technology and consulting chemist of the Lawrence experiments. He was specially fitted for it by a practical study of sewage purification at the Lawrence experiment station of the Massachusetts State Board of Health. He was assisted by Mr. Lorenzo Manuell.

The plant was erected under the supervision of Mr. G. Everett Hill, who also directed its general operation.

Acknowledgments are due to Prof. Thomas M. Drown, Prof. William T. Sedgwick, Mr. George W. Fuller and Mr. Allen Hazen for visits of inspection, for advice and for their cordial expressions of approval.

REPORT

OF CHEMICAL WORK AND GENERAL NOTES ON AN EXPERIMENTAL INVESTIGATION OF THE VALUE OF A PROCESS OF PURIFYING SEWAGE BY FORCED AERATION.

INVENTED BY COL. GEO. E. WARING, JR.

MAY 18 - OCTOBER 18, 1894.

BY

GEO. W. ROLFE, A. M. (Harv.)

Report of Chemical Work and General Notes.

The figures tabulated in this report express the results of an investigation covering five months, and having two specific objects: (1) To determine the efficiency of a new system of sewage purification; (2) To determine the duration of this efficiency.

Means at our disposal limited the chemical work of this research to a study, made on the sewage and purified effluents, of the transformation of nitrogenous matters, an approximate estimate of carbonaceous matter by an indirect method of oxidation, the determination of dissolved oxygen and the determination of chlorine.

For aid in planning the chemical work I am indebted to Prof. T. M. Drown and his staff of able assistants of the Massachusetts State Board of Health laboratories, who have not only favored me with valuable advice on points of detail, but have furnished means of verifying the accuracy of our chemical standards by direct comparison with those in use in the Board of Health laboratories. I am also under obligations to Prof. Sedgwick, of the Biological Department, for advice.

In the detail work of the experiment I have been assisted by Mr. Lorenzo Manuell.

MEASUREMENT OF SEWAGE AND EFFLUENTS.

The sewage applied was measured as follows. Determinations of the volume delivered at each pump stroke were made by averaging a sufficient number of actual measurements taken during the twenty-four hours. The number of strokes was recorded by a revolution-counter, the occasional defective working of this being checked by a calculation based on regular observations of the strokes per minute. Rates in gallons per acre were then calculated from these figures by factors expressing the actual proportional filtering areas of the tanks.

As the aerators were proportioned for a relatively smaller flow than the strainers, a fraction of the effluents of the latter, measured by a special adjustable apparatus, was applied, the rest being thrown away.

CORRECTION FOR DRAININGS.

The construction of the straining tanks required them to be drained through the bottom just before aeration. In this experiment it was not thought important to recover the drainings, hence corrections for this loss have been made in rates of tanks affected thereby.

CONTROL OF FLOW OF SEWAGE AND EFFLUENTS.

The amount of sewage applied could be controlled only to a limited extent by (1) altering the discharge of the pump by a crank adjustment, (2) varying the speed of the machinery by increasing or decreasing the electrical resistance. The flow of strainer effluents passing into the aerators could be absolutely controlled by adjustment of the distributing apparatus.

CIRCUMSTANCES AFFECTING FLOW OF SEWAGE AND EFFLUENTS.

The flow of both sewage and effluents was, however, subject to wide daily variations, due to (1) changes in electromotive force, (2) occasional stoppages from breakdowns of machinery, (3) rains, (4) very high tides. These circumstances, in great part, could neither be foreseen nor provided for, and necessitated much complication of records.

The more important data of pumping and blowing will be found conveniently arranged in *Table A*. This table is valuable for interpreting all rate figures, as calculations are made from the sewage actually pumped in twenty-four hours, regardless of stoppages.

NOTES ON SEWAGE AND THE CONDITIONS AFFECTING ITS QUALITY.

The sewage of Newport, besides being largely influenced by storm-water, is affected by the following peculiar conditions. (1) Variations in flow caused by fluctuation of back pressure at outlet, due to tides. (2) Occasional invasions of salt water caused by very high tides (over four feet rise) which back salt water up the main sewer for a long distance. (3) Dilution and disturbance caused by extensive washing of streets and catch-basins with city water at frequent and irregular intervals. (4) Partial putridity, due to overflows from cesspools and deposits in the sewers.

The effects of rain and salt water have been, in most cases, eliminated by stopping the pump at times when the state of the weather or tidal calculations indicated the probability of abnormal conditions. The periodic reversal of flow, caused by the tides, fills the large sewers along the level shore streets for long distances, and mixes the sewage, so that it is doubtful whether there is any regular variation in strength from hour to hour at the sewer outlet. The prevalent use of cesspools of course contributes to the same result. Samples taken at different hours in the day showed no marked differences when analyzed. In one instance (August 27) a representative sample was taken at intervals covering the twenty-four hours, except between 1 and 5 a. m. This sample practically agreed with the regular samples of the week taken about 9 a. m.

There are good grounds, therefore, for assuming that the analyses, in the main, represent the quality of the sewage entering the tanks. Probably this was somewhat stronger than the average flow, as the suction pipe was but a few inches above the bottom of the sewer, the stream being sluggish at all times except at low tide.

Disturbances due to flushing catch-basins, which occurred almost daily in some part of the city during dry weather, and were occasionally evidenced in the sewage, could not be provided against, nor could their influence be calculated. Probably they did not affect the result seriously.

In the latter part of June, signs of gas-liquor appeared, but its presence was not proven. Noticeable quantities of dissolved oxygen were found in the sewage of June and July. This disappeared August 10th, not to reappear until October 6th. The general characteristic appearance of the sewage was quite uniform, being greyish and milky. This was principally varied by silt and fibrous matter, which rapidly subsided on standing. As a rule, the odor was faint in samples just taken, often that of stale urine, although at times, noticeably on Mondays, there was a distinctly soapy smell.

SAMPLING.

Many circumstances prevented the control of conditions necessary for a uniform system of sampling. In every case the aim has been to await opportunities most favorable for getting data fairly representing the working of the system in actual practice, rather than to accumulate many figures obtained under doubtful conditions.

All samples of sewage for general analysis were taken from the discharge pipe of the pump while pumping.

As the purpose of the apron was simply to remove coarser stuff, such as paper, leaves, cloth and clotted matter of a gelatinous and greasy nature, which tended to form an impervious scum on the surface of the tanks, and as the amount of matter retained was very variable, since the stones were often disturbed by raking, no analyses of the apron effluent were made. Its work was reckoned in with that of the tank into which it delivered.

Samples of strainer effluents, except when otherwise specified, were taken from the faucet *H*, about six inches below the overflow pipe.

Sampling of the aerator effluents was done at the traps of their discharge pipes.

Attempts were made to trace sewage of the definite composition represented by the sample from tank to tank by determination of the chlorine in the effluents. This was usually unsuccessful, because of diffusion in the three or four hundred gallons held in the tank, and the rapid fluctuation of chlorine salts due to small quantities of salt water getting into the sewer in spite of precautions. In one case, where the experiment was carefully conducted with special reference to the point of tracing the sewage, great discrepancies were found in the chlorine, only to be accounted for by diffusion.

The straining tanks were drained very gradually from the small faucet *F*, to avoid dislodging matter deposited upon the stones. Analyses show that the loss was so small as to be negligible (e. g. No. 4 regular sample effluent: albuminoid ammonia = .025; drainings = .037).

METHODS OF ANALYSIS.

In general, the practice of the Massachusetts State Board of Health was followed.

As a rule, all samples were analyzed immediately after collection.

The distilling apparatus was, in its main features, patterned after the one in use at the Lawrence experiment station, but necessarily modified for kerosene stoves. About .01 gram of ammonia-free sodic carbonate was added to the sample to be distilled.

Nitrites were determined by the naphthylamine method of Griess; nitrates by the phenoldisulphonic process. Samples were evaporated at a very gentle heat on asbestos paper placed over incandescent lamps glowing at a dull red. Owing to the presence of chlorine, these nitrate figures are perhaps too low, but are useful as comparative tests.

"Oxygen consumed," useful as a comparative estimate of carbonaceous matter, was made by the Kübel "hot acid" method. Dissolved oxygen was determined by Winkler's method, corrections being made for nitrites present; chlorine by process recommended by Hazen.

OTHER LABORATORY DATA.

Temperature records were kept, covering most of the sampling.

Measurements of rainfall were made by weighing the precipitation in grams and tenths on an area of 100 square centimeters. This was done by means of a copper rain-gauge of approved construction, which was placed on the laboratory roof. The results are given in millimeters.

"PER CENT. OF PURIFICATION" FIGURES OF EFFLUENTS.

The offensive nature of distillates, showing large amounts of free ammonia, has led to the belief that this test really represents not only ammonia and its salts, but also many unstable organic compounds possibly of the nature of amines, which, though they may evolve ammonia when heated, are really intermediate products of putrefaction.

It was decided, therefore, to estimate purification by measuring the removal of all nitrogen obtained in the form of ammonia. In the absence of any established factor for calculating absolute total albuminoid ammonia from "albuminoid ammonia" as obtained by the Wancklyn method, the following formula for reckoning total nitrogen as ammonia was adopted:—

Total nitrogen as ammonia = "Free Ammonia" + 2 ("Albuminoid Ammonia"). This holds good for most surface waters and is approximately correct for sewage;* at least, it furnishes a fairer basis of comparison, it is believed, than the "albuminoid ammonia" figures alone.

"Per cent Purification," therefore, in columns marked "Total," is the direct ratio of the total nitrogen of the effluent of the tank named to the total nitrogen of the *sewage*, and represents the total purification of the *sewage* as shown by that effluent. "Per cent. Purification," in columns marked with number of tank, is the ratio of the total nitrogen of the effluents specified to the total nitrogen of the *affluent* of that tank, and indicates the amount of purification accomplished by the tank independently.

METHODS OF INVESTIGATION OF MATTER RETAINED BY FILTERS.

Owing to lack of facilities, as previously stated, but little work was done in investigating the amounts of organic matter retained by the strainers and destroyed by aeration.

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*Recent study of a number of Kjeldahl determinations and "albuminoid ammonias" made on artificial sewages places this factor at about 2.4.

Great difficulty was met in sampling the filtering material properly. Apparatus fitted to each tank for this special purpose proved inefficient. Sampling, which was, therefore, done with an ordinary shovel, was limited to shallow depths. For the rough comparative tests which could be made, the filtering material was dug into carefully to a depth of one foot. About one litre of the gravel at that depth was transferred to a large saucepan with an equal volume of distilled water, and vigorously stirred with a glass stirring rod for exactly five minutes. At the end of that time all matter visible to the eye was removed from the stones by the washing. The turbid liquid was quickly poured off, before it had time to settle, and, with the same precautions, was diluted to $\frac{1}{10}$ or $\frac{1}{100}$, according to circumstances. Ammonia determinations of this were then made in the manner of testing sewage.

The few results obtained are arranged in *Table D*. The only complete series of tests for a single period of aeration was made of the gravel of No. 4. This was done at the one time when circumstances were especially favorable for the work.

MICROSCOPICAL AND BACTERIOLOGICAL WORK.

No bacteriological cultures were attempted because of lack of facilities. The very few desultory microscopical examinations which were made of sewage and effluent of strainer No. 4 are hardly worthy of record. A very characteristic bacterium noticed in the sewage, plump, very motile and usually doubled, corresponded closely to the description of *B. cloacae*, of the Lawrence reports. On the surfaces of the stones in the top of the outer compartment of No. 4, in August, amoebae were noticed feeding on numerous algae, among which were recognized *scenedesmus* and *protococcus*. There were also present multitudes of large speckled *spirilla*, exceedingly motile. About 20 per cent. of dissolved oxygen was present in these upper layers, although none was found in the body of the tank.

NOTES EXPLANATORY OF *TABLES C* AND *E*.

In *Table E* are given all data necessary for understanding the work done by each tank and the resulting purification, figured from analyses of sewages and effluents as previously explained.

The first two sets of pumping and aerating periods, extending from May 17th to June 2d, were not arranged with special reference to state of effluents or condition of tanks, but were merely trial trips, as it were, made to gain familiarity with the working details. No systematic chemical tests were made at this time, the laboratory arrangements being incomplete. Rate figures were taken, but their accuracy is somewhat impaired by the numerous leakages caused by the dry woodwork of the new spouts and tanks.

On May 18th, a heavy thunder-storm, precipitating 21.9 mm. of rain in two hours, washed considerable silt into the tanks, especially into No. 1. A repetition of this was guarded against, as *Table A* shows. *Table A* will also sufficiently explain most of the irregularities in times of testing samples.

July was practically lost to our investigation on account of numerous difficulties with the pumping machinery. At such times the laboratory became an improvised machine shop. Repairs of apparatus also compelled the omission of chemical work for ten days at the end of August.

The regular chemical work closed October 13th. Pumping continued till October 18th, when the tanks were taken apart and the experiment station dismantled.

WORK DONE BY APRON.

The two compartments of the apron were used alternately, each working as long as it could pass sewage. This time depended largely on the amount of silt in the sewage and on conditions discussed in the next section. Notes giving data of the working of the apron will be found in *Table B*.

The stones were frequently raked and when badly clogged were washed, the washings going into the harbor. In a large plant, where the arrangements were better, raking alone would no doubt suffice for removing the coarser and more fibrous matters. The finer impurities in the mass would be destroyed by natural aeration during a period of rest.

The efficiency of the apron was greatly increased by the use of a screen of coarse wire netting, which was added in the early fall.

Considerable swill was among the matter caught by the apron.

NOTES ON WORK OF STRAINERS.

At first the sewage was passed through the whole series of tanks. The analyses soon made it clear that the bulk of the work was done by the first strainer. Indeed, not infrequently an *increase* in nitrogenous matter was shown in the effluent after leaving the first tank, especially when the rate of flow was slow. This seemed to be due to putrefaction of stored nitrogenous matter, resulting in the production of soluble compounds. It naturally manifested itself as "free ammonia."

The use of two straining tanks, in series, proved more satisfactory, but the filtering surface of the second tank was out of all proportion to the purification obtained. From August 13th to the end of the experiment but one strainer was used at a time, the others meanwhile aerating.

PERIODIC USE OF STRAINERS. (See *Table E.*)

It was intended to establish definite periods for passing sewage and for aerating, but it was found impracticable, in part from causes affecting the regularity of the work. (*Table A.*)

As a rule, sewage was passed through a strainer until the resistance was so great that the gradual accumulation in the inner compartment overflowed the diaphragm. This resistance resulted from the collection of matter of a gelatinous or greasy nature in the interstices of the stones, and also from a practically impervious drab scum, which formed on the surface to a depth of about half an inch. The rate at which this clogging matter gathered was very variable and depended upon obscure conditions of the sewage. It was noticed that an admixture of salt water materially increased it, evidently from precipitation of soap; and that putrefaction, as has been indicated, tended to decrease it by making soluble compounds.

The running period of a tank could be increased, perhaps a day, by frequent raking of the scum on top of the stones. Once or twice, as shown in the notes of *Table B*, the sewage was drained down below the stones and the scum scraped off. This did not extend the period of operation materially. Deep raking (about 6 inches) and a stirring up of the stones with an iron bar to a depth of more than 3 feet, as was tried a week or more with No. 2, proved of no marked benefit. The latter feature would be impracticable on a large scale. A deep raking, it is true, immediately lessened the resistance, but the relief was only temporary.

This fact makes it evident that the clogging was caused principally by material retained in the upper layers, and suggests that oxidation, if not the escape of carbon-dioxide, may be influential in forming the scum. This supposition is strengthened by the fact that it forms equally on tanks receiving strained effluent and also that effluents drawn from the interior of a tank increase their cloudiness perceptibly while standing a short time. Unfortunately, no tests for dissolved oxygen were made in these upper layers, except in one case, where its presence could be explained by algae. *Three inches below* the upper surface of the stones no dissolved oxygen was present, as was proved by many tests.

STRAINING-TANK EFFLUENTS.

The effluents of all the strainers had the same characteristics. In appearance they were greyish and translucent, resembling water to which a very small quantity of milk had been added. This cloudiness varied considerably in different specimens, and in the same sewage, when passed through successive tanks, showed a gradual decrease. Salt water, as would be expected, increased it. Effluents which had passed slowly through a series of tanks often showed a darkening from putrefaction.

All strainer effluents darkened and began to putrefy in about twenty-four hours. When taken from the bottom of a strainer they were always partly putrid, and contained slightly more albuminoid as well as free ammonia. These effluents deposited no sediment after long standing. The odor was usually marked, and of stale urine. Dissolved oxygen was invariably absent, except in one case cited in the next section.

No relation could be traced between the condition of the filtering material or size of stones and the quality of the effluents, except in one case, where, after a long aeration, there were evidences of oxidation products washed out of the stones.

MEASUREMENTS OF TURBIDITY.

From time to time rough determinations of the turbidity of sewage and effluents were made by an apparatus contrived to measure the maximum depth of liquid through which the markings of a millimeter scale, printed in black on a white ground, could be read, when illumined by a good light (daylight).

Two examples, — strainers running in series, — will sufficiently illustrate the method: —

	No. 1.	No. 2.
Sewage,	30 mm.	45 mm.
Effluent from Apron,	42 "	42 "
" " No. 1,	81 "	144 "
" " No. 2,	165 "	213 "
" " No. 3,	331 "	390 "
" " No. 4,	400+	600+

AERATION OF STRAINERS.

Before aerating, the black scum which practically sealed the top of the filter was either broken up or scraped aside. The foul odor given off at the beginning of aeration, which was hardly noticeable except to one standing directly over the tank, disappeared in three or four hours. In this odor there was often recognized a faint smell resembling the "sludge-acid" of the oil refineries, and it is probable that it was caused by traces of light petroleum oil, presumably kerosene.

After about a day's aeration, the scum dried up into thin clay-like cakes, and the stones, which were at first covered with a black slime, began to take on the ordinary greyish-white appearance of dusty gravel, the black color probably being due to ferrous sulphide.

Immediately below the surface, where the stones remained moist, and in spots where the clotted matter opposed the passage of air, there would be, at times, a vigorous growth of white mould. This mould, however, never extended downward more than three inches, and soon disappeared as the aeration progressed. Below this the stones were thinly coated with a transparent jelly-like slime, practically odorless, or, at most, having a faint fishy smell. This feature remained, with no perceptible change, during the entire period of aeration.

The air-pressure varied from 2 to 4 inches, water-column, in the main air-pipe. The air current coming out of the stones was usually barely perceptible to the moistened palm held just above the stones.

LENGTH OF AERATION.

In general, the time of aeration of any strainer depended solely on the running period of the others, each tank aerating till its turn to run came in regular rotation.

In one instance, the aeration of No. 2 was prolonged for a month. In another, No. 3, after passing over 15,000 gallons (nearly 30,000,000 to the acre), had only four days aeration, and then took 41,000 gallons (81,000,000 to the acre) before clogging. In neither of these cases did the effluents, as a whole, show any sign of the great difference in length of aeration periods. The effluent of No. 2, however, *when the tank was just starting again*, was unique in having (1) an enormous quantity of nitrites, (2) a large amount of dissolved oxygen and (3) a slight amount of nitrates, all of which, of course, came from the material in the tank.

Careful study of the results clearly showed that the time necessary for aeration depends largely on the thoroughness of the exposure of the *upper* layers of the filtering material to the action of the air. If the scum is removed or piled loosely in heaps after partial drying, and the matter between the stones thoroughly disintegrated to a depth of about six inches, by raking or plowing on the second day, the time of aeration is reduced to three or four days, while double this time does not suffice without such treatment. Further experiments are necessary to establish the minimum period of aeration for practical work.

AERATORS.

No. 5 aerator received sewage throughout the whole experiment, except (1) during removal of scum from the surface of the sand, (2) a few hours on June 22nd, when the shallow layer of fine sand on top was replaced by coarser sand, and (3) September 5th to 7th, during repairs to the upper air-space of broken stone.

No. 1 A was constructed during the early part of August by removing the coarse stone and wooden diaphragm from No. 1 strainer, and converting it into an aerator on exactly the same plan as No. 5. Coarsely powdered coke was used as the main filling, instead of fine beach gravel. No. 1 A was started August 8th, and continued in use for the rest of the experiment, except when stopped for removal of scum.

In the early part of September, very little air passed out of the flues of No. 5, showing, apparently, that the air-space was clogged. September 5th, the flow was stopped and an investigation made. The broken stone of the air-space and the gravel beneath were found to be absolutely clean, and the trouble was traced to the unequal sizes of the stones, which had become packed together in the air-space. This was remedied, and the tank gave no more trouble for the rest of the experiment.

EFFLUENT OF NO. 5.

The effluent of No. 5 was somewhat milky at first. This continued, to a slight extent, even after nitrification was established, but gradually disappeared. About the middle of July it was as clear as ordinary pond water, and had the characteristic color of the public water supply (.7 to .8 Nessler).

At times, after any considerable disturbance of the sand by deep raking (2 to 3 inches), as practiced in July and early August, the effluent showed milkiness for a few hours. This was attributed to the opening of channels through the sand, through which the liquid passed rapidly in streams, descending through small areas of gravel instead of being distributed over the stones in thin films.

An extensive growth of *crenothrix*, which suddenly appeared in the effluent on June 24th, and which disappeared in twenty-four hours, never to return, is attributed to this same cause, — the passage of a large amount of liquid through a small portion of the tank, with consequent imperfect aeration.

The use of a rake, specially constructed so that the scratchings could not exceed half an inch in depth, removed this trouble, the only recurrence of cloudiness in the effluent following the starting of the tank September 7th, after repairs. This was obviously due to defective distribution, for when the soakage of the sand was sufficiently increased by partial clogging, the cloudiness quickly disappeared.

Often, in August, large quantities of white thread-like worms, about a quarter of an inch long, and particles of water plants were carried out of the tank by the effluent. These quickly settled to the bottom of the trap, and did not seem to affect the quality of the water. Being obviously growths of the air-spaces, they were not reckoned as part of the effluent.

From the beginning, the effluent was odorless, or rarely had a faint loamy smell, such as may be noticed in a greenhouse.

EFFLUENT OF NO. 1 A.

The effluent of No. 1 A, which showed nitrification within four days, was in general better than that of No. 5, and was practically free from suspended organic matter, save for infrequent white flocculent masses of zoögloea. No worms were ever noticed. The fact that the trap was covered accounts for the absence of higher water plants. Deep raking of the sand on top produced, as in No. 5, cloudy effluents. The trouble disappeared after using the special rake before described.*

In other characteristics the effluent resembled that of No. 5, but at first was somewhat lighter colored from the decolorizing action of the coke.

On August 19th two large minnows were placed in the 350 gallon tank, which received the effluents from Nos. 5 and 1 A. These fish apparently thrived till September 2nd, when one died, the other surviving till September 4th. It is possible that they died of starvation.

EFFICIENCY AND DAILY CAPACITY OF AERATORS.

Assuming normal sewage and nitrification established, the satisfactory operation of an aerator, similar in principle to those used in this experiment, apparently depends on (1) the efficiency of the means for distributing the sewage in thin films to the

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* The following analyses illustrate the variable effects of disturbance of sand on aerator effluents : —

	Free Ammonia.	Alb. Ammonia.
No. 5, just after raking,	.025	.094
No. 5, about two hours later,	.012	.082
No. 1 A, just after raking,	.070	.250
No. 1 A, about two hours later,	.006	.040

The high ammonias of No: 5 on August 25th and September 21st can also be traced to the same cause.

action of the nitrifying organisms, (2) an air supply sufficient to maintain the activity of these organisms, (3) a flow slow enough to ensure a sufficiently long exposure of the sewage to the purifying organisms within the filter, and (4) favorable temperature.

In the case of Newport sewage, the only really abnormal conditions were caused by the occasional influx of salt-water, in quantity sufficient to check nitrification. This occurred infrequently.

The air supply was always in great excess, as was shown by the following experiment with No. 5. About October 1st, the amount of air going through this tank was reduced by placing in the 8-inch air-pipe an air-tight wooden diaphragm, perforated with holes of different sizes. These holes were closed a few at a time, until, on October 6th, the opening was reduced to a diameter of $\frac{3}{4}$ inch. On October 8th, this was diminished to $\frac{3}{8}$ inch. The tank continued giving an effluent of undiminished purity for the rest of the time it was in use. It is to be regretted that lack of time prevented further experiments in this direction.

Temperature conditions were beyond our control, but there is no reason, in the light of present knowledge, for believing that they were not most favorable during the whole period that the work was going on. It must not be overlooked that the problem of working an aerator on this plan, when exposed to a severe northern winter, has not yet been solved experimentally. The chilling effect of the outside air forced through the tank would be a serious consideration.* In the majority of cases, however, this difficulty could probably be obviated by suitable arrangements for drawing the air supply from the sewers themselves.

In the experiment at Newport, the air supply and temperature being constantly favorable for the highest efficiency, and sewage practically normal, there remain to be considered the questions of distribution throughout the filter and rate of flow.

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*It is interesting to note that in some later experiments (January, 1895), I have found good nitrification in an effluent leaving the tank at a temperature of 35° F., and probably at no time in its passage having a temperature greater than 45°.

The means at first employed for distributing the strainer effluent throughout the aerator was a 6-inch layer of sand, of such fineness that the liquid passing through it soon wetted the whole area. For a time this worked very well, but the sand soon became covered with a scum and much clogged by material of the same nature as that which choked the gravel of the strainers, but in much less quantity. Raking the sand about 2 inches deep produced irregular distribution by the channeling mentioned in the discussion of aerator effluents. Use of the special rake, before referred to, stopped this, but it was then found that the sand would not pass sufficient strainer effluent for the capacity of the tank. A coarser sand was then substituted, which did not distribute satisfactorily at first, the liquid sinking into it within a few inches of the point at which it was delivered. The most satisfactory remedy proved to be fine sand sprinkled over the surface of this coarse sand.

The best method found for preserving the constant and maximum operation of the aerator was — to stop the tank when it showed signs of clogging and scrape off the dirty sand on top, repeating this at successive cloggings till the thickness of the sand was so reduced that a fairly constant equilibrium would be established between the amount of sewage the sand would pass and the quantity the tank could purify in a given time, as shown by quality of the effluent. This established the rate for the maximum efficiency. The further treatment necessary was periodic removal of scum, shallow scratchings with the special rake, and occasional renewal of a worn place with a little sand.

Only two kinds of sand were used. These were both fine, with not very uniform grains. As stated above, the coarser worked well, although it is my opinion that a still coarser sand would have been more satisfactory. Probably any fairly coarse sand, within quite wide limits of variation in size and uniformity of grain, will make a satisfactory distributor, provided that in the beginning a temporary layer of fine sand is used. In a short time this can be removed, as the clogging will impart sufficient capillarity to ensure even soakage. The next step is to determine the thickness of the layer which will allow sufficient strainer effluent to pass for the maximum capacity of the aerator, when producing the required degree of purification. Apparently this depends more on the nature of the sewage than on the size of sand. Speaking generally, coarse sand will give the best satisfaction and will require the minimum amount of attention if worked on the lines indicated.

It is also advisable to divide the surface of the aerators into sections of comparatively small area, by partitions extending a few inches below it, so that a section can be raked or scraped without interfering with the work of the rest of the aerator. With an aerator working continuously at its maximum capacity, purifying sewage similar to that of Newport, scraping would have to be done at least every other day.

The rate of maximum efficiency of No. 5, assuming a required purification of 96 to 98 per cent., I place between 800,000 and 1,000,000 gallons per acre. That of No. 1 A between 1,200,000 and 1,500,000 gallons. The actual daily average of sewage applied was considerably less, owing to irregularities in pumping and frequent stoppages for experimenting with raking, removal of scum, etc. The working rates of the aerators were also largely reduced at times of changing straining tanks, as the drainings were lost and the flow to the aerators ceased until the new strainer was filled to the overflow point, say for three or four hours. In actual practice, these drainings should be delivered to the aerators while the strainer just started is filling up.

The figures given in the tables show the actual performance of the tanks under the unsettled conditions of experimental work. Hence, as a whole, they obviously cannot be taken as representing the full capacity of a plant constructed in the light of knowledge acquired and regularly operated under conditions of actual practice.

I attribute the greater efficiency of the coke tank to the greater distributing surface of its irregular masses and their porous nature. The gravel masses, being approximately spherical, would have for their size a minimum amount of surface.

A DETERMINATION OF TIME OF PASSAGE OF LIQUID THROUGH AN AERATOR.

June 19th an attempt was made to determine the time of exposure of the liquid to the action of the aerator, under the conditions then existing.

On the afternoon of that day No. 5 was receiving strainer effluent at the rate of .43 gallons per minute, — equivalent to 1,195,000 gallons per acre per day, — and giving a purification, as shown by test the next morning, when conditions were practically the same, of 71.0 per cent., carrying the total purification to 80.1 per cent. Nitrification was not fully established at this time.

At 3.08 p. m., 1.54 gallons of salt water were thoroughly stirred into the affluent standing on top of the tank, estimated at nearly 56 gallons, and having a chlorine content of 7.60 parts per 100,000. The salt water raised the chlorine in the mixture to 55.0 parts, as shown by test. The chlorine in the effluent leaving the aerator at trap was

at 3.14 p. m.	7.70 parts	at 4.08 p. m.	27.50 parts
3.24	7.35 “	4.11	23.50 “
3.29	10.20 “	4.14	23.50 “
3.31	12.30 “	4.17	25.50 “
3.34	16.00 “	4.23	26.00 “
3.36	17.00 “	4.27	25.00 “
3.38	18.50 “	4.31	25.25 “
3.40	19.50 “	4.34	25.00 “
3.42½	21.00 “	4.39	25.00 “
3.45	21.50 “	4.41	25.00 “
3.48½	22.00 “	4.44	24.50 “
3.52	22.50 “	4.53	24.50 “
3.55	23.25 “	5.06	24.50 “
3.59	24.00 “	5.33	24.40 “
4.02	24.50 “	5.47	16.75 “
4.05	26.00 “		

The only determinations of chlorine made on the mixture on top of aerator were

at 3.08	7.60 parts
after mixture	55.00 “
4.50 p. m.	17.50 “

A study of the figures shows that within twenty minutes salt water appeared in the effluent, the amount assuming a practically constant proportion at the end of fifty minutes, reaching a maximum (42 per cent.) ten minutes later, but showing, during the whole subsequent period of over seventy minutes that the experiment was followed, less than 7.5 per cent.

variation. Putting the results in another way:—After about 21 gallons of the mixture, approximately equivalent to 7.5 per cent. of the voids in the wetted gravel, had entered the tank, the diffusion was practically uniform throughout the entire effluent, which if then sampled would best represent the original affluent.

This experiment, of course, only illustrates the work of the tank under one fixed set of conditions. By itself, it is valuable as evidence that the distribution in No. 5 was very good, and that like results might be expected in aerators of similar construction. It also proves that, when the rate was about 1,000,000 gallons per acre, the effluent of No. 5 passed through the tank within an hour, with good purification. It further indicates that the amount of liquid distributed through the tank over the surfaces of the filtering material was between 20 and 25 gallons, or about 45,000 gallons per acre.

SUMMARY.

Careful study of the accumulated evidence leads to the following conclusions:—

(1). A straining tank, constructed on the plan herein described, can be depended upon to remove at least forty per cent. of the nitrogenous matter in ordinary sewage, if this sewage, rough strained and free from mud, is applied continuously at the minimum rate of three million gallons per acre in twenty-four hours.

(2). The gross amount of sewage which such a strainer will take before clogging depends principally on variable constituents of the sewage, but also, to some extent, on the size of the voids of the filtering medium. For ordinary materials, with voids of not less than 30 per cent., and with particles larger than .20 inch, the minimum can be placed at 20,000,000 gallons per acre [redacted], when the sewage is applied continuously.

(3). If the thick sludge is removed and the upper 6 inches of the filtering bed opened up by raking or plowing after the filter is drained, an aeration period not exceeding five days is sufficient to quite restore the strainer to its original efficiency.

(4). Further experiments are necessary to determine the smallest efficient air-supply for the cleaning of the strainers. It is much less than that used in the investigation.

(5). The efficiency of a strainer is little affected by the increasing amount of matter retained, up to the time of clogging; nor, within wide limits, is it influenced by the size or shape of the particles of the filtering medium.

(6). The strainer will preserve its efficiency indefinitely.

(7). An aerator, constructed on the plan herein described, after nitrification is established, and the methods of distribution properly adjusted, will remove over ninety-five per cent. of the organic nitrogen of a strainer effluent, applied at a rate of at least 800,000 gallons per acre per day. It will continue to do this for an indefinite period, providing suitable arrangements are made for removing sludge at frequent intervals.

(8). A reduction of at least 75 per cent. can be made in the air-supply to the aerators, as used in this investigation, without impairing their efficiency.

(9). Of coke and gravel, of practically the same size, used in aerators of similar design, the coke purified over 20 per cent. more sewage than the gravel.

ANALYTICAL TABLES.

TABLE A. — RECORD OF PUMPING AND AERATING.

Date.		Gallons pumped in 24 hours into straining tanks.	% time pumping.	% time aerating.	Remarks as to stoppage.	Aerator No. 5.		Aerator No. 1 A.	
						Gallons applied.	% time running.	Gallons applied.	% time running.
		2243.3				2243.3			
May	18	4411.3	97.6	97.6	Repairs, pump	4411.3	97.6		
"	19	3392.3	93.4	93.4	" " power turned off	3392.3	93.4		
"	20	2808.7	76.0	76.0	" machinery	2808.7	76.0		
"	21	2261.3	68.5	100.0	" effluent tank	2261.3	68.5		
"	22	2707.1	100.0	"		2707.1	100.0		
"	23	1519.3	100.0	"		1519.3	"		
"	24	565.3	38.2	93.0	Rain	565.3	38.2		
"	25	183.4	20.0	100.0	"	183.4	20.0		
"	26	0	0	"	"	0	. .		
"	27	0	0	"	"	0	. .		
"	28	863.0	62.5	"	"	863.0	62.5		
"	29	3513.0	89.8	"	"	3513.0	89.8		
"	30	0	0	58.1	Aerating tanks	0	. .		
"	31	0	0	63.4	" "	0	. .		
June	1	0	0	0	" "	0	. .		
"	2	516.4	35.4	63.0	Low sewage (losing suction at low tide)	516.4	35.4		
"	3	281.3	17.4	100.0	" "	281.3	17.4		
"	4	1145.5	75.1	41.9	" "	1145.5	75.1		
"	5	626.4	76.0	100.0	Salt water (high coast tide)	626.4	76.0		
"	6	1159.1	52.0	"	" "	1159.1	52.0		
"	7	2699.9	68.8	"	" "	2699.9	68.8		
"	8	2620.5	66.3	"	" "	2620.5	66.3		
"	9	3355.1	83.5	"	" "	671.0	83.5		
"	10	3515.3	91.6	"	" "	703.1	91.6		
"	11	2061.3	64.8	"	" "	412.3	64.8		
"	12	2554.1	72.9	"	" "	573.0	72.9		
"	13	2458.5	73.5	"	" "	614.6	73.5		
"	14	2808.4	100.0	"		619.7	100.0		
"	15	2987.8	"	"		597.6	"		
"	16	2859.6	"	"		571.9	"		
"	17	2386.9	"	"		477.4	"		
"	18	2577.4	"	"		515.5	"		
"	19	2775.5	"	"		555.1	"		
"	20	2694.0	"	"		187.2	34.7		

" 21	472.0	16.9	"	All tanks drained	0	. .		
" 22	1988.8	76.4	"	Changing sand on No. 5	1988.8	76.4		
" 23	2513.6	100.0	"		2513.6	100.0		
" 24	2158.6	"	"		2158.6	"		
" 25	1754.9	"	"		1754.9	"		
" 26	2268.5	97.9	"	Stopped to clean pump	1075.1	97.9		
" 27	1955.8	100.0	"		391.2	100.0		
" 28	2442.3	"	"		488.5	"		
" 29	2279.7	99.2	"	Stopped to clean pump	455.9	99.2		
" 30	74.4	2.6	"	Rain	14.9	2.6		
July 1	2326.6	95.8	"	"	465.3	95.8		
" 2	2028.6	81.3	"	"	405.7	81.3		
" 3	1882.9	87.9	"	Muddy sewage	376.6	87.9		
" 4	584.3	25.0	25.0	Trouble with the belts	116.8	25.0		
" 5	1769.2	100.0	100.0		353.8	100.0		
" 6	692.4	36.6	"	Lost suction. Salt water	138.5	36.6		
" 7	203.0	15.3	73.5	" " frequently	40.6	15.3		
" 8	0	0	0	Low sewage. Salt water	0	0		
" 9	1854.2	84.4	100.0	Trouble with pumping apparatus	370.8	84.4		
" 10	1140.4	93.5	92.1		228.1	93.5		
" 11	810.3	12.0	20.1		162.1	12.0		
" 12	374.4	17.4	17.5		69.5	17.4		
" 13	497.0	12.6	40.6		99.4	12.6		
" 14	0	0	41.8	Repairing pump and electrical apparatus	0	. .		
" 15	0	0	18.9		0	. .		
" 16	0	0	0		0	. .		
" 17	0	0	0		0	. .		
" 18	0	0	0		0	. .		
" 19	497.0	11.0	100.0		50.6	11.0		
" 20	0	0	"	Low sewage	0	. .		
" 21	824.6	37.2	"	Rain	164.9	37.2		
" 22	913.6	52.1	"	"	182.5	52.1		
" 23	1495.7	94.6	"	Suction pipe clogged	299.1	94.6		
" 24	445.6	27.3	"	Low sewage	89.1	27.3		
" 25	258.8	15.3	"	" "	51.8	15.3		
" 26	896.5	22.4	"	" "	179.3	22.4		
" 27	1891.0	58.0	"	" "	378.2	58.0		
" 28	2951.9	57.6	94.7	" "	590.4	57.6		
" 29	95.5	2.4	0	" "	19.1	2.4		
" 30	4520.3	100.0	100.0		904.0	100.0		
" 31	3092.5	70.8	"	Lowered suction pipe	618.5	70.8		
August 1	2335.5	100.0	"		507.1	100.0		

TABLE A. — RECORD OF PUMPING AND AERATING (*continued*).

Date.		Gallons pumped in 24 hours into straining tanks.	% time pumping.	% time aerating.	Remarks as to stoppage.	Aerator No. 5.		Aerator No. 1 A.	
						Gallons applied.	% time running.	Gallons applied.	% time running.
August	2	1186.5	100.0	100.0		237.3	100.0		
“	3	630.1	20.5	“	Salt water and rain	126.0	20.5		
“	4	2295.6	67.7	“	“ “ “ “	459.1	67.7		
“	5	760.4	68.1	“	Belt off	152.1	68.1		
“	6	2333.9	100.0	“		466.8	100.0		
“	7	2793.8	“	“		558.9	100.0		
“	8	2320.0	“	“		464.0	100.0		
“	9	2246.4	95.2	“	Rain	449.3	95.2		
“	10	1331.5	73.6	74.8	Changed pulleys	266.3	73.6		
“	11	1653.4	100.0	100.0		330.7	100.0	760.8	92.7
“	12	1189.7	71.8	“	Rain	237.9	71.8	594.8	71.8
“	13	1176.4	49.4	“	Trouble with the pump	245.3	49.4	965.2	49.4
“	14	1880.0	100.0	“		376.0	100.0	1504.0	100.0
“	15	1366.5	87.3	“	Belt slipped off	273.2	87.3	1007.8	87.3
“	16	1874.1	100.0	“	“ “ “	29.2	3.1	645.0	97.2
“	17	2024.8	97.4	“	Trouble with the pump	405.0	97.4	375.2	87.6
“	18	1979.2	94.1	95.1	Fan belt broken	383.8	94.1	389.6	94.1
“	19	1862.5	100.0	100.0		210.1	100.0	219.0	100.0
“	20	1511.8	97.2	“	Trouble with belting	298.8	96.5	393.9	95.8
“	21	1749.5	100.0	“		275.6	77.1	442.4	100.0
“	22	2288.1	95.1	“	No. 2 badly clogged	353.6	74.3	480.2	86.5
“	23	2019.6	100.0	“		310.4	73.3	419.5	79.2
“	24	2368.5	89.5	“	Lost suction	263.7	75.4	484.0	86.4
“	25	2654.4	100.0	“		530.9	100.0	471.9	93.7
“	26	1875.3	98.2	“	No. 4 badly clogged	282.1	98.2	370.8	96.4
“	27	2157.6	86.8	“	Pump out of order (Renewed diaphragm)	405.5	80.9	327.9	71.4
“	28	2625.2	100.0	“		70.2	24.7	525.0	100.0
“	29	2791.9	“	“		558.4	100.0	558.4	100.0
“	30	2557.4	“	“		175.4	33.3	568.0	95.8
“	31	2005.7	65.7	“	Salt water	401.3	65.7	429.6	65.7
Sept.	1	1633.1	65.3	“	“ “	235.1	47.9	235.1	47.9
“	2	1290.4	60.4	“	“ “	258.1	60.4	258.1	60.4
“	3	2417.0	66.8	“	“ “	483.4	66.8	483.4	66.8
“	4	2667.7	77.1	“	Pump clogged	533.5	77.1	533.5	77.1
“	5	2394.3	97.7	“	“ “	35.7	6.6	400.6	90.0

"	6	2144.6	100.0	"		0	0	428.9	100.0
"	7	2584.7	"	"		389.7	74.3	452.0	87.5
"	8	2453.3	81.1	"	Rain	1164.4	81.1	383.0	81.1
"	9	2411.5	100.0	"		1205.8	100.0	723.4	100.0
"	10	1070.6	55.9	"	Rain	404.5	47.6	519.3	55.9
"	11	1415.7	98.2	"	Removed sludge from 4	359.1	87.2	663.5	91.7
"	12	2329.8	100.0	"		303.4	76.9	758.3	76.9
"	13	2193.4	"	"		412.1	93.9	854.5	100.0
"	14	1684.9	81.3	"	Rain	337.0	81.3	505.5	81.3
"	15	2249.3	94.7	"	"	442.0	93.2	1104.8	93.2
"	16	1900.3	85.4	"	Salt water	380.1	85.7	950.2	85.4
"	17	1291.1	66.7	"	Rain	257.2	66.4	503.5	66.7
"	18	2151.2	100.0	"		430.2	100.0	645.4	100.0
"	19	200.0	9.2	"	Salt water (rain)	40.0	9.2	61.0	9.2
"	20	1672.7	68.0	"	Cleaned suction pipe	334.5	68.0	501.8	68.0
"	21	2739.2	100.0	"		547.8	100.0	821.8	100.0
"	22	2607.9	98.2	98.6	Fan belt broken	449.3	88.8	673.9	88.8
"	23	1616.1	97.9	98.0	" " "	321.3	97.9	484.8	97.9
"	24	3092.1	100.0	100.0		392.1	100.0	694.0	100.0
"	25	1522.1	"	"		271.7	"	456.6	"
"	26	1138.4	76.4	"	Salt water	227.7	76.4	341.5	76.4
"	27	1340.5	58.0	"	Cleaned suction pipe. Salt water	258.1	58.0	670.3	58.0
"	28	1137.5	62.4	"	" " " " "	352.5	62.4	568.8	62.4
"	29	1343.9	51.0	"	" "	205.7	45.5	448.7	45.5
"	30	0	0	0	Rain	0	0	0	0
Oct.	1	807.1	36.1	100.0	Salt water	195.4	36.1	172.7	30.5
"	2	1378.2	80.0	"	" "	95.7	38.5	286.2	38.5
"	3	1412.9	60.5	61.3	Fan belt broken	282.6	60.5	423.9	60.5
"	4	1199.8	58.6	100.0	Rain	240.0	58.6	360.0	58.6
"	5	1546.3	78.4	"	"	309.3	78.4	463.8	78.4
"	6	1665.8	100.0	"		647.9	100.0	814.5	100.0
"	7	1665.8	"	"		666.3	"	832.9	"
"	8	1273.1	51.7	"	Rain	255.8	37.8	357.3	37.8
"	9	1349.0	77.7	"	"	269.8	77.7	405.6	77.7
"	10	1322.2	47.2	"	"	264.4	47.2	396.7	47.2
"	11	2198.1	97.9	"	Trouble with the pump	420.6	93.7	630.9	93.7
"	12	2060.8	96.8	"	" " " "	395.8	92.7	593.6	92.7
"	13	1352.0	47.9	"	Rain	123.2	21.9	204.6	21.9
"	14	0	0	"	Took suction pipe off	0	0	0	0
"	15	2402.3	94.6	"	Suction pipe clogged	262.9	84.4	478.7	84.4
"	16	2158.1	86.4	"	Salt water	215.8	86.4	431.6	86.4
"	17	2177.8	85.4	"	" "	217.8	85.4	435.6	85.4

TABLE B.—ANALYTICAL DATA OF SEWAGE AND EFFLUENTS.

SEWAGE. PARTS PER 100,000.

Date.	Rainfall.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
	m. m.	Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
May 20–23	.74									
" 23	. . .	. . .	. . . .	. .	. .	. .	. . .	. . .	54	
" 24	14.83	. . .	. . . .	. .	. .	. .	. . .	. . .	54	
" 25	. . .	. . .	. . . .	. .	. .	. .	. . .	8.10		
" 26–30	34.42									
June 1	5.69									
" 2	. . .	1.360	1.200	. .	. .	2.40				
" 4	. . .	1.600	.640	. .	. .	4.38	. . .	19 65		
" "(Apron)	. . .	1.475	.750							
" 5	. . .	1.260	.950							
" 6	. . .	1.600	.728	. .	. .	. .	. . .	10.40		
" 7	.96	1.560	.840	. .	. .	3.75	. . .	12.00		
" 8	. . .	1.820	.756	. .	. .	3.85	. . .	7.60		
" 9	. . .	. . .	. . .	. .	. .	. .	. . .	14.00		
" 11	. . .	2.222	.920	. .	. .	. .	. . .	11.50		
" 13	. . .	1.868	.558	. .	. .	3.52				
" 15	. . .	1.360	.700	. .	. .	3.60	17.30	. . .	58	
" 16	. . .	. . .	. . .	. .	. .	. .	. . .	. . .	59	
" 18	. . .	. . .	. . .	. .	. .	. .	. . .	. . .	59	
" 20	. . .	1.800	.830	00	00	3.75	8 25	16 25	60	
" 21	.24	1.800	1.240	. .	. .	. .	. . .	16.00	61	
" 25	. . .	2.400	1 286	. .	. .	6.10	000	12.50	61	
" 27	. . .	. . .	. . .	. .	. .	. .	. . .	13.50		
" 30	3.33	3.120	.890	. .	. .	. .	. . .	. . .	63	
July 3	2 58	2.500	1.120	. .	. .	7.80	. . .	. . .	65	
" 6	. . .	.520	.340	. .	. .	1.20	8.30	188.50	64	Salt-water mixture.
. . .	. . .	. . .	. . .	. .	. .	. .	. . .	. . .	. .	Lengthened suction pipe about 6 inches.

July 8	. . .	. . .	. . .	. .	. .	. .	. . .	35.25		
" 14	14.98									
" 24	3.16									
" 28	. . .	2.500	.880	. .	. .	7.20	. . .	. . .	68	
" 31	. . .	. . .	. . .	. .	. .	. .	. . .	. . .	. .	Lowered suction pipe 1½ inches.
Aug. 3–4	33.17									
" 7	. . .	.920	1.288	. .	. .	5.50	. . .	10.00	67	
" 9	2.73	4.000	2.120	. .	. .	9.20	8.11	15.50	68	
" 11	. . .	2.222	1.200	. .	. .	5.20	0.00	19.50	68	
" 13	10.60									
" 14	. . .	2.128	.420	00	00	6.00	. . .	13.50	67	
" 16	8.44									
" 17	. . .	2 500	1.338	. .	. .	8.80	000	17.25	67	
" 20	. . .	1.080	.544	. .	. .	6.70	. . .	15.00	68	
" 22	. . .	2.176	.686	. .	. .	7.30	000	13.50	68	
" 25	. . .	2.560	2.060	. .	. .	. .	. . .	14.50	69	
" 27	. . .	2.222	1.020	. .	. .	9.20	000	26.50	—	Representative sample.
Sept. 4	. . .	2.500	1.080	. .	. .	3.40	. . .	24.50	67	
" 6	. . .	2.380	1.020	. .	. .	8.80	000	10.50	67	
" 7	. . .	2.222	1.100	. .	. .	5.40	000	28.00	67	
" 11	2.84	2.700	.810	. .	. .	5 30	000	30 50	67	
" 13	. . .	2.380	2.400	. .	. .	13.80	000	16.00	67	
" 15	5.50			. .						
" 17	4.10	2.640	1.000		. .	6.80	000	15.00	68	
" 18	.08			. .						
" 20	54 69									
" 21	. . .	1 700	.612		. .	5.80	000	18.50	67	
" 24	. . .	2.500	1.190	. .	. .	7.50	000	11.50	67	
" 26	. . .	2.100	.420	. .	. .	3.10	000	16.50	65	
" 28	. . .	2.500	1.240	. .	. .	4.00	000	23.50	66	
" 30	18.20			. .						
Oct. 3	16 05	1.500	.540		. .	2.80	000	17.00		
" 6	. . .	1.900	.640	. .	. .	3.10	9.38	11.50	63	
" 8	(8-10) 45.60	2.220	.810	. .	. .	3.90	00	21.50	64	
" 11	. . .	1.440	.700	. .	. .	2.50	13.43	17.00	61	
" 13	37.95	2.500	.850	. .	. .	2.30	13.73	9.60	61	
				. .						

TANK No. 1.

TABLE B (*continued*).

IN USE FROM MAY 16 TO JUNE 29.

PARTS PER 100,000.

Date.		From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
			Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
May	23	Apron (coarse stone)	. .	. .	. . .	. .	. . .	. . .	. .	55	
June	4	"	. .	. .	. . .	. .	. . .	. . .	76.35		
"	5	"	. .	. .	. . .	. .	. . .	. . .	13.10		
"	7	"	. .	. .	. . .	00	. . .	. . .	11.60		
"	8	"	. .	. .	. . .	. .	1.40	. . .	17.00		
"	9	"	.960	.436	00	. .	. . .	. . .	10.00		
"	11	"	.780	.372	. . .	. .	. . .	. . .	9.50		
"	12	"	1.000	.324							
"	25	"	1.660	.383	. . .	. .	1.70				
"	27	"	. .	. .	. . .	. .	. . .	00	8.50	64	

TANK No. 2.

TABLE B (*continued*).

IN USE FROM MAY 16 TO OCT. 18, 1894. PARTS PER 100,000.

Date.	From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
		Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
May 23	1	. .	. .	. . .	. .	. . .	. . .	. .	57	
June 8	“	. .	. .	. . .	. .	. . .	. . .	62.25		
“ 9	“	1.024	.420	. . .	. .	1.29	. . .	11.00		
“ 11	“	. .	. .	. . .	. .	. . .	. . .	8.50		
“ 13	Apron (coarse stone)	.900	.240	. . .	. .	.80				
“ 14		. .	. .	. . .	. .	. . .	00			
“ 15	“ Raking about once a day.	. .	. .	. . .	. .	.96	00	. .	59	
“ 16	“	. .	. .	. . .	. .	. . .	00	. .	60	
“ 18	“	. .	. .	. . .	. .	. . .	. . .	. .	64	
“ 20	“	1.000	.290	. .	. .	1.35	. . .	7.25	61	
“ 21	“	1.880	.340	00	000	. . .	. . .	10.00	61	
July 3	“	1.610	.290	. . .	. .	1.85	. . .	. .	. .	July 2 and 3 Raked surface.
“ 6	“	3.330	.262	. . .	. .	2.40	. . .	. .	66	July 24 Removed sludge on surface.
“ 9	“	. .	. .	. . .	. .	. . .	. . .	. .	66	
“ 10	“	. .	. .	. . .	. .	. . .	. . .	. .	65	
Aug. 14	Apron (fine stone)	2.380	.190	.250	.05	3.90	51.60	18.00	68	
“ 17	Aug. 17 (coarse stone) “ 18 (fine “) “ 21 (coarse “) “ 23 (fine “) “ 27 (coarse “)	2.000	.240	.030	. .	. . .	. . .	66 00		
“ 20		1.136	.210	.018	000	2.00	. . .	12.50	68	
“ 22		2.380	.280	.032	000	1.40	00	13.50	64	
Sept. 4	. . . .	2.000	.200	. . .	. .	. . .	. . .	20.50	68	Surface clogged.
“ 6	(fine stone)	1.316	.190	.024	. .	1.80	00	9.00	68	
“ 7	“	1.711	.340	. . .	. .	2.40	. . .	12.50	68	
“ 24	“	1.470	.240	.004	. .	1.70	. . .	9.50	68	
“ 26	(fine stone, with screen)	2.200	.250	.000	. .	2.10	. . .	10.50	—	
“ 28	“	2.500	.306	.002	. .	2.60	. . .	32.00	—	

TANK No. 3. TABLE B. (*continued*).

IN USE FROM MAY 16 TO OCT. 18, 1894. PARTS PER 100,000.

Date.	From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
		Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
June 5	1 + 2	1.350	.400							
" 8	"	. .	. .	. . .	. .	1.06	. . .	13.00		
" 11	"	. .	. .	. . .	. .	. .	. . .	12.50		
" 13	"	1.000	.180	. . .	. .	.80	00			
" 15	"	. .	. .	. . .	. .	.96	. . .	. . .	58	Black scum on surface (gas liquor ?).
" 16	"	. .	. .	. . .	. .	. .	. . .	. . .	61	
" 20	"	1.250	.260	000	. .	1.26	. . .	8.35	65	
" 21	"	1.080	.320							
" 23	"	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Air entering tank, 78° F.
July 3	2	1.250	.290	. . .	. .	1.90	. . .	. . .	65	
" 6	"	2.083	.300	. . .	. .	2.20	. . .	. . .	65	
" 24	"	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Removed sludge.
" 28	Apron (coarse stone)	.970	.280	. . .	. .	4.60	. . .	. . .	70	
August 7	"	1.470	.208	. . .	. .	3.80	00	29.00	68	Green growth on surface of the outer compartment.
" 9	"	2.000	.488	. . .	. .	3 40	. . .	15.00	70	
" 11	"	2.380	.296	. . .	. .	2.40	. . .	14.50	68	
" 13	Apron (fine stone)	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Raked surface and removed sludge.
" 26	"	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Began to use screens.
" 28	(coarse stone)	. .	. .	.025	00					
Sept. 7	"									
" 13	(fine stone)	1.320	.256	000	. .	2.80	00			
" 17	"	1.666	.394	. . .	. .		00	46.50	69	
" 21	Apron (coarse stone, with screen)	1.000	.360	.007	. .	2.50	. . .	11.00	68	
Oct. 8		1.560	.485	000	. .	. .	. . .	. . .	68	
" 11		.500	.196	.100	. .	1.00	. . .	11.00	59	
" 13	"	2.000	.210	.013	. .	1.10	. . .	9.00	59	

TANK No. 4. TABLE B. (*continued*).

IN USE FROM MAY 16 TO OCT. 18, 1894. PARTS PER 100,000.

Date.	From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
		Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
May 23	1, 2+3	. .	. .	. . .	. .	. .	. . .	. . .	57	
June 8	“									
“ 9	“	1.176	.376	. . .	. .	. .	. . .	17.00		
“ 11	“	. .	. .	. . .	. .	. .	. . .	13.75		
“ 13	“	.588	.284	000	00	1.28	00			
“ 14	“	. .	. .	. . .	. .	. .	. . .	. . .	61	
“ 15	“	. .	. .	. . .	. .	.84	. . .	. . .	59	
“ 16	“	. .	. .	. . .	. .	. .	. . .	. . .	62	
“ 25	1	1.110	.265	. . .	. .	1.25				
August 6	3	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Removed sludge.
“ 7	“	1.724	.184	. . .	. .	3.60	00	34.00	68	
“ 9	“	1.666	.184	. . .	. .	2.60	. . .	19.50	70	Green growth on surface of outer compartment.
“ 11	“	1.333	.190	. . .	. .	1.90	. . .	15.50	69	
“ 13	“	. .	. .	. . .	. .	. .	. . .	. . .	. .	Raked surface (removed sludge).
“ 24	(fine stone apron)	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Surface badly clogged.
“ 25	Apron	2.170	.430	.024	. .	2.30	. . .	17.00	. . .	Removed sludge.
Sept. 7	(coarse stones)									
“ 11	Apron	1.667	.184	000	. .	1.80	. . .	14.50	68	Took sludge off surface.
Oct. 3	Apron	1.250	.270	000	. .	1.50	. . .	25.50	63	
“ 5	(fine stone apron,	. .	. .	. . .	. .	. .	. . .	. . .	. . .	Removed sludge.
“ 6	with screen)	1.570	.250	000	. .	1.50	. . .	12.00	60	
“ 8	“	1.110	.370	000	. .	.90	00	9.00	60	Sample taken from drainings.

TANK No. 5.

TABLE B (*continued*).

IN USE FROM MAY 16 TO OCT. 18, 1894. PARTS PER 100,000.

Date.		From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
			Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
May	29	Tank No. 1, 2, 3 & 4	.620	.130	. . .	. . .	.620				
June	7	"	1.032	.270	. . .	000	. . .	. . .	86.00	. .	
"	8	"	. . .	. . .	. . .	. . .	. . .	. . .	417.50	. .	
"	9	"	.750	.352	. . .	. . .	. . .	. . .	26.00	. .	
"	11	"	.780	.246	. . .	. . .	. . .	. . .	54.75	. .	Cloudy effluent but odorless.
"	12	"	.420	.132	. . .	. . .	. . .	. . .	. . .	. .	
"	13	2, 3 & 4	.560	.142	. . .	.285	. . .	. . .	. . .	62	
"	14	"	. . .	. . .	. . .	.316	.660	85.25	. . .	59	
"	15	"	.193	.150	.040	.454	.860	93.06	. . .	62	
"	16	2 & 3	. . .	. .	.120	.666	. . .	. . .	. . .	64	
"	18	"	. . .	. . .	. . .	.625	. . .	. . .	. . .	66	
"	19	"	. . .	. . .	. . .	.480					
"	20	"	.450	.120	.070	.300	.640	. . .	7.75	65	
"	23	1 & 4	. . .	. . .	. . .	.250	. . .	. . .	. . .	. . .	Put new sand on top (6 inches).
"	24	"	. . .	. . .	. . .	. . .	. . .	62.12			
"	25	"	. . .	. . .	. . .	.550	.750	. . .	. . .	65	Sand on top not completely wetted. Extensive growth of crenothrix in effluent box.
"	26	"	.330	.120	. . .	1.200					
"	27	"	.045	.082	. . .	1.000	. . .	85.96	. . .	66	
"	28	"	. . .	. . .	. . .	1.250	. . .	. . .	. . .	. .	Cloudy effluent.
"	29	2 & 3	. . .	. . .	. . .	1.180	. . .	. . .	. . .	. .	
"	30	"	.0125	.116	. . .	2.500	. . .	55.55	. . .	70	
July	2	"	. . .	. . .	. . .	.900	. . .	66.66	. . .	70	
"	3	"	.0170	.060	. . .	1.000	.660				
"	5	"	. . .	. . .	.070	.800					
"	6	"	.033	.076	.011	.330	.700				
"	7	"	. . .	. . .	. . .	2.000					
"	9	"	. . .	. . .	. . .	. . .	. . .	92.52	. . .	65	
"	27	3 & 4	. . .	. . .	. . .	.400					
"	28	"	.250	.092	. . .	.700					
August	1	"	. . .	. . .	. . .	.300					

August 6		3 & 4		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Raked sand owing to clogging from green growth.
“ 7		“		.020	.120	.021	.160	1.150	69.11	20.00	70	Took off top sand owing to clogging.
“ 8		“		. . .	. . .	. . .	.140					
“ 9		“		.060	.167	.022	1.250	.700	76.02	17 25		
“ 10		“		. . .	. . .	. . .	2.220					
“ 11		“		.150	.076	.027	1.430	.600	81.89	12.00		
“ 12		“		. . .	. . .	. . .	1.250					
“ 13		“		. . .	. . .	. . .	.700	.600	. . .	14.50		
“ 14		2		.375	.105	.033	2.000	. . .	88.70	15 50	68	
“ 15		“		. . .	. . .	. . .	1 000					
“ 16		“		. . .	. . .	. . .	1.000					
“ 17		“		.048	.044	.030	.500	. . .	2 minnows living in effluent tank. . . .	34.00	. . .	Raked sand.
“ 18		“	Raked sand on surface once or twice a day according to sewage.	. . .	. . .	. . .	.800					
“ 20		“		.160	.065	.096	1.430	.600	. . .	15.50	70	
“ 21		“		. . .	. . .	. . .	.600					
“ 22		“		.070	.040	.064	.900	.660	52.96	10.75	62	
“ 24		4		.250	.094	.060	1.200	.900	. . .	. . .	. . .	Took off layer of sand on surface.
“ 25		3		. . .	. . .	. . .	. . .	. . .	. . .	. . .	67	
“ 28		“		. . .	. . .	. . .	1.200	. . .	. . .	. . .	. .	Evidence of clogging of air space below sand.
“ 29		“		. . .	. . .	. . .	.800	. . .	. . .	. . .	. .	
“ 30		“		. . .	. . .	. . .	.340	. . .	. . .	. . .	. .	
“ 31		2		. . .	. . .	. . .	.550	. . .	. . .	300.00		
Sept. 2		“		. . .	. . .	. . .	.750	. . .	. . .			
“ 4		4		020	.070	. . .	1.000	.600	. . .	17.00		
“ 5		“		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Reconstructed air space as trouble was due to packing of stone and not clogging by sewage.
“ 7		“		. . .	. . .	. . .	2.200	.860	. . .	30 50		
“ 11		“		.036	.048	.100	. . .	.880	80.92	14.00	62	
“ 13		3		.014	.026	.012	.800	.600	91.40	9.35	60	Surface badly clogged.
“ 17	Clear effluent.	“		.012	.063	.0008	1.100	.880	92.20	40 00	69	Sept. 15 Removed 1½ inches of sand.
“ 20		“		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Took off surface of sand about ½ inch.
“ 21		“		.500	.120	.095	1.000	1.220	82.39	13.50	68	Faint cloudiness.
“ 24		2		.006	.048	.006	1.400	.480	90.93	13.50	63	
“ 26		“		.007	.048	.000	1.200	.560	97.79	10.00	56	
“ 28		“		.012	.084	.024	1.400	.800	87.60	28.50	64	Took off about ½ inch of sand.
Oct. 3		4		005	.086	000	1.500	.600	84.46	23.00	59	
“ 5		“		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Took off scum on surface.
“ 6		“		.004	.076	000	1.600	.620	93.17	11.50	59	Reduced air supply to ¾ inch hole.
“ 8		“		.004	.018	.023	1.200	.560	84.26	9.50	59	Cut off air supply to ⅜ inch hole.
“ 11		3		.003	.031	.007	1.000	.280	87.98	23 50	56	
“ 13		“		.002	042	.015	1.000	.670	91.57	10.00	58	

TANK No. 1 A.

TABLE B (*continued*).

IN USE FROM AUG. 8 TO OCT. 18, 1894.

PARTS PER 100,000.

Date.	From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
		Free.	Albuminoid	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
Aug. 12	Tank No. 2	...	...	Aug. 14 .135	.015	Aug. 14 1.100	Aug. 14 69.77	...	Aug. 14 70	Cloudy effluent.
" 15	"	1.250	.092	...	.000	...	...	...	...	" "
" 16	"	...	...	...	.225	.300	...	...	...	" "
" 17	"	.840	.092	.600	.300	...	2 minnows living in effluent tank. ...	16.30	...	Surface clogged.
" 18	"	...	...	...	.600					
" 20	" Raking surface about once a day.	.112	.049	.136	1.250	.420	...	...	69	Clear effluent from this time.
" 21	"	...	...	...	1.400	...	...	...	...	
" 22	"	.006	.026	.120	1.600	.400	67.17	11.75	61	
" 25	4	.006	.030	.036	1.400	.420	...	...	67	
" 28	3	...	...	...	1.200	...	...	13.50	...	Surface clogged.
" 29	"	...	...	...	1.000					
" 30	"	...	...	...	.840					
" 31	"	...	...	...	1.200	...	...	345.00		
Sept. 2	2	...	...	...	.800					
" 4	"	.010	.051	...	1.540	...	...	100.00		
" 5	"	...	...	...	..	...	...	29.25	66	
" 6	"	.015	.036	...	.800	.600	90.75	16.00	66	
" 7	"	.010	.040	...	1.400	.400	83.76	12.50	66	
" 11	4	.036	.048	.080	2.200	.320	79.17	13.50	64	
" 13	3	.024	.040	.014	1.320	.500	89.39	12.50	Sept. 12 61	
" 15	"	...	...	...	..	...	...	...	...	Took off 1 inch of sand.
" 17	"	.010	.054	.008	.670	.700	95.82	42.50	65	
" 20	"	...	...	...	..	...	...	...	...	Scraped the surface.
" 21	"	.040	.059	.015	.800	.840	84.51	14.00	67	
" 24	2	.006	.048	.008	1 600	.420	83.77	13 50	65	
" 26	"	.006	.033	.003	1.000	.440	95.53	9.50	57	
" 28	"	.006	.040	.018	1 400	.440	91.37	28.50	65	Took off 1 inch of sand.
Oct. 3	4	.006	.046	.000	1.400	.520	92.52	24.50	57	
" 5	"	...	...	...	..	...	...	...	...	Removed sludge on surface.
" 6	"	.028	0.42	.002	1.000	.440	95.60	12.50	63	
" 8	"	.048	0.46	.004	1.400	.520	84.26	9 50	60	
" 11	3	.002	0.22	.007	1.200	.420	89.23	20.00	56	
" 13	"	.022	0.30	.012	.800	.500	86.96	10.00	58	

TABLE B (*concluded*).

CITY WATER FROM LABORATORY.

Date.	From.	Ammonia.		Nitrogen as		Oxygen.		Chlorine.	Temperature. Degrees Fahrenheit.	Remarks.
		Free.	Albuminoid.	Nitrites.	Nitrates.	Consumed.	Dissolved. % saturation.			
June 18	Tap	. .	. .	. . .	.018					
" 23	"	.001	.058	00	. .	.41				Color, greenish yellow.
August 22	"	.001	.021	00	.003	.24	50.40	2.00	70	

ANALYSES ARRANGED BY DAYS.

TABLE C.

(Aerators marked *.)

PARTS PER 100,000.

Date.	Rate per acre for 24 hours in gallons calculated from gallons actually pumped.	Sample from	Ammonia.		Nitrogen as		Chlorine.	Oxygen.		% purification by removal total N as NH_3.		% time pumping in the last 24 hours.	Air pressure (inches of water).	Rainfall (last 24 hours). m. m.
			Free.	Albuminoid.	Nitrites	Nitrates.		Con-sumed.	Dissolved. % saturation.	Reckoned from sewage.	Reckoned from affluent.			
June 9	. . . . .	S	1.820	.756	. . . .	00	7.60	3.85						
	5,188,590	1	.960	.436	. . . .	00	10.00	1.40	. . .	45.6				
	"	2	1.024	.420	. . . .	00	11.00	1.29	. . .	44.1	—2.8			
	"	3	1.350	.400	. . . .	00	13.00	1.06	. . .	35.5	—13.3			
	"	4	1.176	.376	. . . .	00	. . .	. . .	. . .	42.1	10.8			
	"	* 5	.750	.352	. . . .	June 7 00	26.00	. . .	. . .	56.7	24.6	66.3	1	
June 13	. . . . .	S	1.860	.558	. . . .	. . . .	. . .	3.52						
	5,057,118	2	.900	.240	. . . .	. . . .	. . .	.80	00	53.5				
	"	3	1.000	.180	. . . .	. . . .	. . .	.80	"	54.3	11.46			
	"	4	.588	.284	. . . .	. . . .	. . .	1.28	"	61.2	15.00			
	1,100,160	* 5	.560	.142	. . . .	.285 {June 15 .454}	. . .	.66	. . .	71.6	27.00	72.9	2⅜	
June 20	. . . . .	S	1.800	.830	. . . .	. . . .	16.25	3.75	8.2					
	5,495,500	2	1.000	.290	. . . .	. . . .	7.25	1.35	00	54.3				
	"	3	1.250	.260	. . . .	. . . .	8.35	1.26	00	48.8	—9.89			
	1,065,800	* 5	.450	.120	. . . .	.300	7.75	.64	. . .	80.1	61.00	100	1¼	
June 23	City water	. . .	.001	.058										
June 25	. . . . .	S	2.400	1.286	. . . .	. . . .	12.50	6.10						
	4,264,000	1	1.660	.383	. . . .	. . . .	. . .	1.70	. . .	51.3				
	"	4	1.110	.265	. . . .	. . . .	. . .	1.25	. . .	67.0	32.4			
	"	* 5	.330	.120	.070	.550	. . .	.75	June 24 62.1	88.5	65.25	100	1½	
July 3	. . . . .	S	2.500	1.120	. . . .	. . . .	. . .	7.80						
	4,016,000	2	1.610	.290	. . . .	. . . .	. . .	1.85	. . .	53.8				
	"	3	1.250	.290	. . . .	. . . .	. . .	1.90	. . .	61.4	16.44			
	778,944	* 5	.017	.060	. . . .	1.000	. . .	.66	July 2 66.6	97.1	92.51	81.3	1¼	
July 6	. . . . .	S	.520 diluted with	.340 salt water.	. . . .	. . . .	188.5	1.20						
	3,503,000	2	3.330	.262	. . . .	. . . .	. . .	2.40						
	"	3	2.080	.300	. . . .	. . . .	. . .	2.20						
	679,296	* 5	.033	.076	.011	.330	. . .	.70	. . .	. . .	. . .	100	1¼	

July 28	. . . . .	S	2.500	.880	00	00	. . .	7.20						
	3,744,000	3	.970	.280	00	00	. . .	4.60	. . .	64.1				
	726,144	* 5	.250	.092	. . . .	.700	. . .	. . .	. . .	89.8	71.63	58.0	1	
Aug. 7	. . . . .	S	.920	1.288	00	. . . .	17.50	5.50	10.6					
	4,721,122	3	1.470	.208	00	. . . .	29.00	3.80	00	46.1				
	“	4	1.724	.184	00	. . . .	34.00	3.60	00	40.2	—10.9			
	896,256	* 5	.020	.120	.021	.160	20.00	1.05	69.1	92.6	87.6	100	1½	
Aug. 9	. . . . .	S	4.000	2.120	00	. . . .	15.50	9.20	8.1					
	4,593,600	3	2.000	.488	00	. . . .	15 00	3.40	0	63 9				
	“	4	1.666	.184	00	. . . .	19.50	2.60	0	75.3	31.60			
	890,800	* 5	.060	.167	0.023	1.25	17.25	.70	76.0	95.2	80.63	100	1½	
Aug. 11	. . . . .	S	2.222	1.200	00	. . . .	19.50	5.20	00					
	2,636,370	3	2.380	.296	00	. . . .	14 50	2.40	“	35.7				
	“	4	1.333	.190	00	. . . .	15.50	1.90	“	62.9	42.36			
	511,296	* 5	.150	.076	0.027	1.43	12.00	.60	88.7	93.5	82.40	73.6	2¾	
Aug. 14	. . . . .	S	2.128	.420	00	00	13 50	6.00	00					
	2,329,272	2	2.380	.190	.250	.05	18.00	3.90	51.6	9.8				
	1,753,500	* 1 A	1.250	.092	.135	00	14.50	1.10	69.7	51.7	48.50			
	470,976	* 5	.375	.105	.033	2.00	15.50	.60	88.7	80.3	78.80	49.4	3½	10.60
Aug. 17	. . . . .	S	2.500	1.338	00	. . . .	17.25	8.80	00					
	3,710,700	2	2.000	.240	.030	. . . .	64.00		. . .	52.1				
	1,232,000	* 1 A	.840	.092	.600	.30	16.50	.30	. . .	81.2	58.71			
	56,000	* 5	.048	.044	.030	.50	34.00	.50	. . .	97.4	94.51	100	1¾	8.44
Aug. 20	. . . . .	S	1.080	.544	00	. . . .	15 00	2.70	.					
	3,687,750	2	1.136	.210	.018	. . . .	12.50	2.00	. . .	28.2				
	418,200	* 1 A	.112	.049	.136	1.26	16.50	.42	. . .	90.5	86.5			
	403,200	* 5	.160	.065	.096	1.43	15 50	.60	. . .	86.7	81.37	100	1½	
Aug. 22	. . . . .	S	2.176	.685	00	00	13.50	6.70	00					
	3,464,000	2	1.190	.140	.032	00	13.50	1 40	“	58.6				
	844,900	* 1 A	.006	.026	.120	1.60	11.75	.40	67.1	98.4	96.06			
	529,200	* 5	.070	.040	.064	.90	10.75	.66	52.9	95.8	89.80			
	City water	. . .	.001	.021	00	.003	2.00	.24	50.4	. . .	. . .	100	1½	
Aug. 25	. . . . .	S	2.560	2.060	00	. . . .	14 50	7.30	00					
	4,689,600	4	2.170	.430	.024	. . . .	17.00	2.30	. . .	54.6				
	924,500	* 1 A	.006	.0296	.036	1.40	13.50	.42	. . .	99.0	97.85			
	506,300	* 5	.250	.094	.060	1.40		.90	. . .	93.3	85.54	89.5	1½	

ANALYSES ARRANGED BY DAYS.

TABLE C. (*concluded*).

(Aerators marked *.)

PARTS PER 100,000.

Date.	Rate per acre for 24 hours in gallons calculated from gallons actually pumped.	Sample from	Ammonia.		Nitrogen as		Chlorine.	Oxygen.		% purification by removal total N as NH_3.		% time pumping in the last 24 hours.	Air pressure (inches of water).	Rainfall (last 24 hours). m. m.
			Free.	Albuminoid.	Nitrites	Nitrates.		Con-sumed.	Dissolved. % saturation.	Reckoned from sewage.	Reckoned from affluent.			
Sept. 4	. . . . .	S	2.500	1.080	00	. . . .	24.50	3.40	. . .					
	4,785,600	2	2.000	.200	. . . .	. . . .	20.50	3.20	. . .	48.5				
	923,300	* 1 A	.010	.051	. . . .	1.54	29.25	.60	. . .	97 6	95.30			
	928,200	* 5	.020	.070	. . . .	1.00	17.00	.86	. . .	96.6	93 34	66.8	1¾	
Sept. 6	. . . . .	S	2.380	1.020	. . . .	. . . .	10.50	8.80	00					
	4,740,700	2	1.316	.190	. . . .	. . . .	9.00	1.80	00	61 6				
	765,200	* 1 A	.015	.036	. . . .	.80	16.00	.50	90.7	98.0	94.86	97.7	1¾	
Sept. 7	. . . . .	S	2.222	1.100	. . . .	. . . .	28.00	5.40	00					
	4,246,308	2	1.711	.340	. . . .	. . . .	12 50	2.40	00	45 9				
	819,200	* 1 A	.010	.040	. . . .	.140	12.50	.40	83.7	98.0	96.24	100	1⅝	
Sept. 11	. . . . .	S	2.700	.810	. . . .	. . . .	30.50	5.30	00					
	2,119,800	4	1.667	.184	00	. . . .	14.50	1.80		52 9				
	991,800	* 1 A	.036	.048	.080	2.20	13.50	.32	79.1	79.2	93.48			
	776,700	* 5	.436	.108	.400	2.20	14.00	.88	80.9	80.1	68.45	55.9	1¼	2.04
Sept. 13	. . . . .	S	2.380	2.400	00	00	16.00	13.80	00					
	4,613,000	3	1.320	.256	00	0.020	6.40	1.20	00	74 50				
	1,448,400	* 1 A	.024	.040	.014	1.32	12.50	.50	89.3	98.50	94.33			
	582,500	* 5	.014	.026	.012	.80	9.35	.60	91.4	99.08	96.40	100	1½	
Sept. 17	. . . . .	S	2.640	1.000	00	. . . .	15.00	5.80	00					
	3,762,594	3	1.666	.394	00	. . . .	46.50	2.80	"	47.7				
	1,814,900	* 1 A	.010	.054	.008	.67	42.50	.70	95.8	97.4	95.9			
	729,800	* 5	.012	.063	.0008	1.12	40.00	.88	92.2	97.0	94.38	85.4	1½	
Sept. 21	Rain water		000	.002	.0004	.040	. .	. . .	. . . .					
	. . . . .	S	1.700	.712	00	00	18.50	5.80	17.8					
	3,311,946	3	1.000	.360	.007	. . . .	11.00	2.50	00	44.9				
	958,500	* 1 A	.040	.059	.015	.80	14.00	.84	84.9	94.9	90.79			
	642,300	* 5	.500	.120	.095	1.00	13.50	1.22	82.3	76.3	56.98	68.0	2	54.69

Sept. 23	. . . . .	S	2.500	1.190	. . . .	. . . .	11.50	7.50	00					
	5,163,700	2	1.470	.240	.004	. . . .	9.50	1.70	"	60.0				
	862,700	* 5	.006	.048	.006	1.40	13.50	.48	83.7	97.9	94.77			
	1,287,200	* 1 A	.006	.029	.008	1.60	13.50	.42	90.9	98.7	96.76	98.57	2	
Sept. 26	. . . . .	S	2.100	.420	. . . .	. . . .	16.50	3.10	00					
	3,013,800	2	2.200	.250	00	. . . .	10.50	2.10	00	9.2				
	521,700	* 5	.007	.048	00	1.20	10.00	.56	97.7	96.5	96.10			
	872,100	* 1 A	.006	.033	.015	1.00	9.50	.44	95 5	97.5	97.31	100	2	
Sept. 28	. . . . .	S	2.500	1.240	00	. . . .	23.50	4.00	00					
	2,654,190	2	2.500	.306	.002	. . . .	32.00	2.60	"	37.5				
	514,800	* 5	.012	.084	.024	1.40	28.50	.50	87.6	96.4	94.22			
	1,280,273	* 1 A	.006	.040	.018	1.40	28.50	.44	91.3	98.3	97.24	58.0	1½	
Oct. 3	. . . . .	S	1.500	.540	00	. . . .	17.00	2.80	00					
	2,728,836	4	1.250	.270	00	. . . .	25.50	1.50	"	30 6				
	183.744	* 5	.005	.086	00	1.50	23.00	.60	84.4	93.1	90.11			
	546,642	* 1 A	.006	.046	00	1.40	24.50	.52	92 5	96 2	94.53	80	4½	
Oct. 6	. . . . .	S	1.900	.640	. . . .	. . . .	11.50	3.10	9.3					
	3,061,700	4	1.570	.250	00	. . . .	12 00	1 50	00	38.00				
	593,900	* 5	.004	.076	00	1.60	11.50	.62	93.1	95.1	92.47			
	885,900	* 1 A	.028	.042	.002	1.00	12.50	.44	95.6	96.5	94.59	78.4	5¼	
Oct. 8	. . . . .	S	2.222	.810	00	. . . .	21.50	3.90						
	3,298,300	3	1.560	.485	00	. . . .	. . .	. . .	. . .	34.1				
	"	4	1.110	.370	00	. . . .	9 00	.90	. . .	51.8	26.88			
	1,279,300	* 5	.004	.018	.023	1.20	9.50	.56	84.3	98.9	97.84			
	1,590,900	* 1 A	.048	.045	.004	1.40	9.50	.52	90.5	96.3	92.54	100	4	
Oct. 11	. . . . .	S	1.440	.700	00	.10	17 00	2.30	13.4					
	2,617,900	3	1.000	.196	.100	. . . .	11.00	1.00	00	51.0				
	507,700	* 5	.003	.031	.007	1.00	23.50	.28	88.0	97.7	95.33			
	757,700	* 1 A	.002	.022	.007	1.20	20.00	.42	89.2	98.4	96.70	47.2	3¾	3.65
Oct. 13	. . . . .	S	2.500	.850	. . . .	. . . .	9.50	2.50	13 7					
	4,078,384	3	2.000	.210	.013	. . . .	9.00	1.10	00	42.3				
	759,900	* 5	.002	.042	.015	1.00	10 00	.67	91.6	97.9	96.40			
	1,133,776	* 1 A	.022	.030	.012	.80	10.00	.50	87.0	98.0	96.61	96.8	4	37 95

TABLE D.

PARTS PER 100,000.

ROUGH AMMONIA DETERMINATION OF MATTER HELD BY FILTERING MATERIAL OF STRAINERS.

From.	Number of days aeration.	Date of analysis.	Where taken.	Ammonia.		REMARKS.
				Free.	Albuminoid.	
Tank No. 3		June 29	Original gravel from heap	1.56	2.24	Samples taken from different parts of heap.
" " 3		" 29	" " " "	1.40	3.76	
" " 4		July 2	" " " "	.56	6.90	
" " 4		" 15	" " " "	1.20	4.80	
" " 4	3 days	" 2	Top	1 60	88.60	One continuous aeration period.
" " 4	3 "	" 2	1 foot below surface	6 00	42.00	
" " 4	15 "	" 14	" " "	8.08	16.00	
" " 4	19 " (and 3 days tank empty, but not aerating).	" 21	" " "	13.36	2.60	
" " 2	9 " (and 5 days tank empty, but not aerating).	" 27	" " "	1.40	49.40	
" " 3	16 "	" 15	" " "	4.00	31.24	
" " 3	2 "	Aug. 15	" " "	4.00	30 40	
" " 4	2 "	" 15	" " "	0.00	24.00	

TABLE E. — SUMMARY OF RESULTS.

[All the figures are corrected for loss due to draining straining tanks before aeration. The "% purification" is figured from ammonia figures, and represents (in columns marked "Total") the percentage of all nitrogen present in the sewage which has been removed at that stage of the process. In columns marked with *number of tank* is given the percentage of nitrogen removed from the *affluent* entering the tank. The first, therefore, is a measure of the total purification of the original sewage after leaving the tank. The second set of percentages is a measure of the purification by the tank designated of the *affluent* as received.]

TANK No. 1.

(Strainer.) Filtering surface = $\frac{1}{1980}$ of acre. Filled with coarse broken stone. Voids of stones after drainage = 43 %. Capacity for sewage 450 gals.,* being allowance for drainage.

From	Started.	Stopped.	Total gallons pumped.	Average % of time pumping.	Average air pressure (inches of water)	Total gallons per acre.	Daily average rate.	Aeration.		Av. % Purification.	
								Started.	Stopped.	Total.	No. 1.
Apron	May 17	May 25	20,092.0	74 2	$1\frac{3}{4}$	39,782,000	4,420,000	May 26	June 2		
"	June 2	June 12	18,046 4	63 9	$1\frac{1}{2}$	35,732,000	3,572,000	June 12	" 21	50.4	50.4
"	" 21	" 29	16 311.1	96.7	$1\frac{5}{8}$	32,296,000	4,037,000	" 29	July 20	47 6	47.6
Total days pumping 26			Tot. 54,449.5	Av.77.2	Av. $1\frac{5}{8}$	Tot. 107,810,000	Av. 4,147,000	Tot. days aeration 37		Av. 49.2	Av. 49.2

Reconstructed with coke filling as an aerator (1 A) and started August 8.

TANK No. 2.

(Strainer.) Filled with fine crushed stones. Filtering surface = $\frac{1}{1980}$ of acre. Capacity for sewage 450 gals.,* being allowance for drainage. Voids of stones after draining = 44.1 %.

From	Started.	Stopped.	Total gallons pumped.	Average % of time pumping.	Average air pressure (inches of water)	Total gallons per acre.	Daily average rate.	Aeration.		Av. % Purification.	
								Started.	Stopped.	Total.	No. 2.
No. 1	May 17	May 25	19,642.0	74.2	$1\frac{3}{4}$	38,991,000	4,332,000	May 26	June 2		
" 1	June 2	June 12	17,596 4	63.9	$1\frac{1}{2}$	34,841,000	3,484,000			54 7	8.6
Apron	" 12	" 21	24,103.6	94.0	$1\frac{1}{8}$	47,725,000	5,303,000			54.8	54.8
"	" 29	July 13	15,648.8	53 8	$1\frac{3}{8}$	30,985,000	2,300,000	June 21	June 30	41.9	41.9
"	Aug. 13	Aug. 23	17,106.9	92.8	$1\frac{1}{2}$	33,872,000	3,387,000	{ July 13 { " 19	{ July 15 { Aug. 13	40.0	40.0
"	Sept. 1	Sept. 7	12,581.5	81.0	$1\frac{1}{2}$	24,911,000	4,151,000	Sept. 7	Sept. 22	52.0	52 0
"	Sept. 22	Oct. 2	14,407.1	76.0	$2\frac{3}{8}$	28,526,000	3,169,000	Oct. 2	Oct. 13	39.2	39.2
"	Oct. 13	" 17	7,953.4	78.6	4	15,748,000	3,937,000				
Total days pumping 71			Tot. 129,039.7	Av. 63.2	Av. $1\frac{1}{2}$	Tot. 255,599,000	Av. 3.045,000	Tot. days aeration 69		Av. 46.3	Av. 38.5

* These figures are necessarily only approximate, as they represent not only the sewage actually filling the tank up to the overflow pipe, but also that retained in inner compartment by the frictional resistance at time of draining. The error, however, is small.

TABLE E (*concluded*).

TANK No. 3.

(Strainer.) Filled with coarse beach gravel. Filtering material surface = $\frac{1}{1980}$ of acre. Capacity for sewage 350 gals.,* being allowance for drainage. Voids of stones after draining = 32.1 %.

From.	Started.	Stopped.	Total gallons pumped.	Average % of time pumping.	Average air pressure (inches of water).	Total gallons per acre.	Daily average Rate.	Aeration.		Av. % Purification.	
								Started.	Stopped.	Total.	No. 3.
No. 1, 2	May 17	May 25	19,192.0	74.2	1½	38,040,000	4,230,000	May 26	May 28		
Apron	“ 28	“ 30	4,376.0	76.2	1⅜	8,664,000	4,332,000	“ 30	June 2		
No. 1, 2	June 2	June 21	41,295.0	77.7	1⅛	81,764,000	4.304,000	June 21	“ 29	49.9	9.7
“ 2	“ 29	July 13	15,198.8	53.8	1⅜	30,094,000	2,210,000	July 13	July 15	56.6	25.4
Apron	July 19	Aug. 13	40,535.2	64.1	1⅞	80,260,000	3,280,000	Aug. 13	Aug. 27	54.6	54.6
“	Aug. 27	Sept. 1	11,815.8	90.5	1¼	23,395,000	4,679,000	Sept. 1	Sept. 12		
“	Sept. 12	“ 22	18,592.3	90.4	1¾	36,812,000	3,681,000	“ 22	Oct. 8	61.8	61.0
“	Oct. 8	Oct. 13	8,340.4	74.3	4	16,514,000	3,303,000	Oct. 13	“ 18	41.8	41.8
Total days pumping 88			Tot. 159,345.5	Av. 75.1	Av. 1½	Tot. 315,543,000	Av. 3,584,000	Tot. days aeration 61		Av. 53.0	Av. 36.8

TANK No. 4.

(Strainer.) Filled with fine beach gravel. Filtering surface = $\frac{1}{1980}$ of acre. Capacity for sewage 350 gals.,* being allowance for drainage. Voids of gravels after draining = 34.4 %.

											No. 4.
No. 1, 2, 3	May 17	May 25	18,842.0	74.2	1½	37,307,000	4,145 000	May 26	May 28		
“ 3	“ 28	“ 30	4,026.0	76.2	1¼	7,971,000	3,986,000	“ 30	June 2		
“ 1, 2, 3	June 2	June 16	29,455.5	78.6	1¼	58,322,000	4.022,000	June 16	“ 22	46 1	7.5
“ 1	“ 21	“ 29	15,861.1	96.7	1⅝	31,405,000	3,925,000	“ 29	July 15	64.0	32 4
“ 3	July 19†	July 29	10,174.7	39.8	1	20,146,000	2,120,000	July 28	“ 30	64.3	16.9
“ 3	“ 30	Aug. 13	24,535.2	84 1	2⅛	48,579,000	3,470,000	Aug. 13	Aug. 23		
Apron	Aug. 23	“ 27	9,214.4	94 9	1¾	18,244,000	4,060,000	“ 27	Sept. 7	54.6	54.6
“	Sept. 7	Sept. 12	9,840.0	89.2	2½	19,483,000	3,896,000	Sept. 12	Oct. 1	53.4	53.4
“	Oct. 2	Oct. 8	8,868.8	75 6	4	17,460,000	2,910,000	Oct. 8	“ 18	40.5	40.5
Total days pumping 71			Tot. 130,817.7	Av. 77.1	Av. 1¾	Tot. 258,917,000	Av. 3,646,000	Tot. days aeration 78		Av. 56.2	Av. 24.5

TANK No. 5.

(Aerator.) Filled with fine beach gravel. Filtering surface = $\frac{1}{1920}$ of acre. Voids of gravels after draining = 34.4 %. No. 5.

No. 1,2,3,4	May 17	May 25	18,492.0	74.0	1½	35,504,000	3,945,000	May 17			
" 3, 4	" 28	" 30	3,676.0	72.2	1¼	7,058.000	3.529,000				
" 1, 2, 3, 4	June 2	June 12	10,398.6	63.9	1¼	19,965,000	1,996,000			65.1	24.0
" 2, 3, 4	" 12	" 16	2,265 0	89.3	1¾	4,349,000	965,000			77.0	56.7
" 2, 3	" 16	" 21	1,283.9	87.0	1⅜	2,465,000	618,000			82.2	60.6
" 1, 4	" 21	" 29	9,744.4	96.7	1⅛	18,709,000	2,338,000			91.5	76.3
" 2, 3	" 29	July 13	2,324 3	53.8	1⅞	4,462,000	354,000		July 15	96.4	91.6
" 3, 4	July 19†	" 29	1,635.9	39.8	2	3,139,000	331,000	July 19		91.8 }	82.1
" 3, 4	" 30	Aug. 13	5,140.0	81.4	2⅛	9,869,000	707,000	(Repairing	machinery).	93.6 }	
" 2	Aug. 13	" 23	2,247.4	77.9	2⅛	4,315,000	431,000			91.7	86.0
" 4	" 23	" 27	1,468.4	86.7	1⅞	2,820;000	630,000			93.4	85.6
" 3	" 27	Sept. 1	1,546.4	55.4	1½	3,020,000	640,000				
" 2 {	Sept. 1	" 5 }	1,528.9	52.7	1¾	2,935,000	587,000		Sept. 5	96 6	93.4
" 4 {	" 7	" 12 }	3,528.1	78.0	1¾	6,774,000	1,355,000	Sept. 7		83.3	68.0
" 3	" 12	" 22	3,519 4	77.5	1¾	6,757,000	675,000	(For	repairs)	93.7	83.7
" 2	" 22	Oct. 2	2,644 1	70.4	3	5,076,000	568,000			97.0	95.0
" 4	Oct. 2	" 8	2,241 8	79.5	4	4,304,000	717,000			96.1	93.5
" 3	" 8	" 13	1,633.8	69.8	4	3,137,000	627,000			97.9	96.4
" 2	" 13	" 17	792.3	69.6	4	1,520,000	380,000		Oct. 18		
Total days pumping		138	Tot. 76,110.7	Av. 71.1	Av. 2⅛	Tot. 146,178,000	Av. 1,060,000	Tot. d's aeration 148		Av. 90.3	Av. 77.2

TANK No. 1 A.

(Aerator.) Filled with coke (screening ½). Filtering surface = $\frac{1}{1910}$ of acre. Voids of coke = 38 9 %. No. 1 A.

No. 2, 3	Aug. 11	Aug. 13	1,152.4	71.3	2¼	2,201,000	900,000	Aug. 14			
" 2	" 13	" 23	5,375.5	94.3	2⅛	10,267,000	1,090,000			80.3	67.5
" 4	" 23	" 27	1,749.9	88 9	1⅛	3,342,000	836,000			99 0	97.9
" 3	" 27	Sept. 1	2,422.1	86.6	1½	4,626,000	925,000				
" 2	Sept. 1	" 7	2,346.5	73.7	2⅛	4,482,000	747,000			97.9	96.0
" 4	" 7	" 12	2,728.9	83.2	1¾	5,212,000	1,042,000			96.9	93.4
" 3	" 12	" 22	6,754.8	78.1	1¾	12,901,000	1,170,000			97.9	95.5
" 2	" 22	Oct. 2	4,451.8	62.2	3	8,503,000	955,000			98.3	97.1
" 4	Oct. 2	" 8	3,181.3	79.5	4	6,076,000	1,013,000			96.7	94.5
" 3	" 8	" 13	2,425.3	69 8	4	4,632,000	900,000			98.2	97.0
" 2	" 13	" 17	1,509 3	69 6	4	2,882,000	760,000		Oct. 18		
Total days pumping		67	Tot. 34,097.8	Av. 78.2	Av. 2½	Tot. 65,124,000	Av. 972,000	Tot. days aeration 65		Av 94.7	Av. 90.8

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* See foot note on p. 65.

† No sewage actually passing through this tank till July 21.

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