TREATMENT OF SEWAGE BY THE ACTIVATED SLUDGE PROCESS

BY

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Collective Data on the Treatment of Sewage by the Activated Sludge Process

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I take this opportunity of expressing my appreciation to Professor John C. Penn for suggesting this subject and to Miss A. E. Fisher, librarian, whose assistance in the library was a great help to me in preparing this thesis.

Introduction

Until recently the medical profession has been the sole guardian of the public's health. The system it uses is to prescribe a cure for a disease, but it does not seek to prevent it. The engineering profession however, lead by the sanitary engineer, is supplanting to a certain extent the doctor and his medicine. A typical case is the fall in the death rate due to typhoid fever. This was accomplished by sanitary methods of treating drinking water. Other cases involve the disposal or treatment of sewage. The best, cheapest and most efficient method of attaining this end is a matter of much discussion. One method which has been devised recently is the treatment by the "Activated Sludge Process".

The writer has chosen this as his subject, because of its infancy and great future. The day will soon come when every city and town will have a sewage disposal plant that gives a profit and is not a deficit to the operators.

Experiments Leading to Discovery.

The method of treating sewage by the activated sluge process was first formulated by Fowler and Mumford, who were conducting experiments on sewage in Manchester, Eng., in 1913. They were investigating the action of an organism which they designated as M7. They found that, if this organism was contained in sewage, the sewage was clarified after 6 hours of aeration and that the effluent was non-putrefactive. This sludge played an important part in the results obtained, as it was noticed that if the sewage samples were aerated continuously for 5 weeks, complete nitrification was obtained. When more samples were to be tested, the clarified sewage was drawn off and the new sample was used with the old sludge. The time for oxidation was reduced to 24 hours after a number of samples were clarified without removing the sludge.

These experiments were brought about in

order to find a cheaper and more satisfactory method of treating sewage. It was known that the most costly part of modern sewage works, including the capital expenditure and often the revenue charges, was the filtration area The area and cost of filter beds depends mainly, it was found, on the amount of colloidal matter present in the sewage and much confusion of ideas was due to the fact that the ordinary sewage filter, be it contact or trickling, was called upon to do two entirely different things at the same time, for it to oxidize, granulate and finally discharge as humus the colloidal matters present and second to oxidize and nitrify substances in true solution. It was also shown that a tank effluent, well clarified by sedimentation could, by accurate distribution be very efficiently purified on filters of fine material, but even then the area and cost involved in exceptionally large works, made the problem a very serious one.

For these and other reasons the thoughts of many workers in sewage treatment were turned to the possibility of a more efficient removal of the collodial matter before the filtration process.

Before this process was evolved the only practical method was by heavy chemical precipitation. The cost of operating a plant whereby the collodial matter was removed by the addition of a chemical to the sewage was very high and was money thrown away. It was not only the cost of the enormous quantities of chemicals necessary, but the removal of the vast amount of resultant sludge that became increasingly difficult and costly.

Messrs. Fowler and Mumford sought to find a method of obtaining a thoroughly clarified efficient without the use of large quantities of chemicals and with the minimum production of sludge. By a thoroughly clarified effluent is meant one which will not eventually depos-

solid matter either on the bottom of a stream into which it flows or in the interstices of a bacterial filter.

Mr. Mumford in the coarse of research in another matter had the occasion to study the the action of an organism occuring in nature, in pit water impregnated with iron. This organism which for convenience has been designated as M7 is a true facultative organism, preferably an aerobe, and exercises a specific action on iron solutions. It was found that this bacillus precipitated ferric hydroxide from iron solutions and in order to precipitate the iron sufficiently the organism required a certain proportion of albuminoid organic matter. It was therefore natural that ordinary sewage when acted upon by this organism could be utilized in this way. Experiments, in fact, showed that a sewage effluent could be effectively clarified in this way when acted upon by this organism in the presence of small quantities

of ferric salts, and aerobic conditions being maintained in the liquid by means of a current of air. The process requires therefore that the grosser solids should be removed by sedimentation so as to have the least amount of putrefactive materials in the liquid portion of the sewage.

The ordinary methods of sewage analysis fails to reveal the change which has really taken place during this process, as they do not differentiate between organic nitrogenous material, in the colloidal and crystalloidal states respectively.

Early Experiments.

Experiments in the laboratory were made with the conditions during the process maintained as far as possible aerobic throughout, and there being always a certain amount of ferric hydrate present to oxidize offensive sulfer compounds and no offensive odor was produced.

By this method a limped sparkling and non-putrifactive effluent was obtained from domestic sewage drawn from a sewer near the laboratory. Experiments indicated that one gram of iron-salt per gallon was the maximum need and that a total of twelve hours tankage, i.e. six hours aeration and six hours settlement, was sufficient.

Another feature found out was that once the growth of organisms had been established in the tank, there appeared no difficulty in maintaining it. The one hindering feature however, was the cost of air blast; the pressure of air however, depended simply on the depth of water to

be blown through and a number of engineering conditions would naturally affect part of this problem.

The advance claimed, is the use of a specific orgainism found in nature, together with iron salts, to affect the clarification of the effluent, that is, the coagulation of the colloidal matter as distinct from the purification of the effluent taken as a whole. To use a simple illustration the addition of a little rennet does not appreciably alter the contents of milk as a whole, but separates it into a solid and liquid portion. The endeavor of the discoverers was to obtain a similar result in the case of sewage tank effluent.

Experiments at Manchester.

Further experiments were carried out on this line by Messrs. Arden & Lockett in 1914 at Manchester. The samples consisted of 80 oz. bottles of Manchester raw sewage. They were aerated until complete nitrification, by drawing air through the sewage by means of an ordinary filter pump. For the first sample five weeks was required for complete nitricication, after which the clear liquid was drawn off and another sample of 80 oz. added to the bottle containing the settled sludge and this again aerated until complete nitrification. This method of treatment was repeated several times with retention in each case of the deposited solids.

It was found that the amount of solids increased and the time required for each successive aerating deminished until it was possible to oxidize a fresh sample within twenty-four hours. The experimenters called these deposited solids "activated sludge"

With this activated sludge a further series of samples were tested. In general a proportion of one volume of activated sludge to four volumes of sewage of the preceeding experiment much smaller proportions were used.

From these tests the following conclusions were made, that an extraordinary high degree of purification can be obtained within a reasonable period of time by aeration in contact with the activated sludge. The amount of nitrification depending to a certain extent on the concentration or strength of the sewage dealt with. On the average, aeration under the conditions of the experiment for a period of six hours, with subsequent settlement, was sufficient to obtain a high percentage of purification. In all cases the resultant effluent was non-putrefactive on incubation.

These experiments were worked on the draw and fill method and it was anticipated that equally good results could be obtained by working on a continuous flow basis.

Further experiments in this line showed that the activity of the sludge is gradually diminished, when working on the fill and draw method, if it is called upon to treat futher samples of crude sewage, prior to the complete nitrification of the previous samples dealt with. The results also showed that this difficulty would be overcome by simple aeration of the sludge alone, until the free or saline ammonia content was removed.

Experiments were then carried on to determine the influence of temperature on the oxidation. From these experiments it was found that the oxidation process could be maintained within a fairly wide range of temperature. The experiments carried on for temperature less than $10^{\circ}C$ showed that an inactive sludge was produced. With a temperature of $30^{\circ}C$ it was found that the initial clarification effect was to some extent interfered with and that the effluent resulting from subsequent settlement showed a slight deterioration.

Activated sludge accumulated in this manner as described by the investigators is "quite inoffensive, dark bown in color, and flocculent in character, and despite its low specific gravity separates from water or sewage at a rapid rate. After prolonged settlement the activated sludge, however, rarely contains less than 95 per cent. of water. A remarkable separation of the water from the sludge can be readily obtained by treatment of find grade strainers, with the production of a sludge of the consistancy of a stiff jelly. Gelatine counts have shown a bacterial content of at least thirty million organisms per cubic centimeter. In addition, the sludge, by reason of its nitrifying power, must of necessity contain a large number of nitrifying organisms. It should also be noted that a fairly large number of protozoa were found". It does not, however, contain any algae growths. The chemical analysis of an average sample of activated sludge is as follows:-

Organic Matter	64.7	Per cent
Mineral "	35.3	" "
Total Nitrogen (N)	4.6	" "
Phosphate (P_2O_5)	2.6	" "
Matter extracted by Carbon Tetrachloid CCL_4	5.8	" "

Attention should be called to the abnormally high percentage of nitrogen as compared with ordinary unoxidised sewage sludge.

Experiments were carried out in the open, as compared with the previous experiments which were performed in a laboratory and the same results obtained. An air diffuser was also used instead of an air tube and the results showed and increase in the oxidation of sewage. A continuous system of flow was also tried and the result was that the amount of ammonia present in the effluent increased as the experiment proceeded and rendered it necessary to recirculate the effluent through the aeration tank again. From this it was seen that the sewage must flow very slowly through nine series of aeration tanks in order to properly purify

the sewage.

Experiments in U.S.

Similar experiments of this sort were conducted in America at Urbana, Ill. in November 1914 and then on a large scale in May 1915 by Edward Bartow and F.W.Mohlman of the State Water Survey, University of Illinois. The first experiments were made on raw sewage without activated sludge present and the results showed that complete nitrification could be obtained within the limits of 15to33 days by blowing air into the sample by way of a tube. They then used an air diffuser with a similar sample of sewage and complete nitrification accured within 15 days. In each case the free ammonia nitrogen was oxidized to nitrite nitrogen and further oxidized to nitrate nitrogen. It took 4830 cuft of air in the second case for the formation of the nitrate. At the end of seven days the free ammonia nitrogen was completely changed to nitrite nitrogen, slowly changed to nitrate nitrogen.

When a similar sample was examined in the presence of activated sludge complet nitrification was accomplished in five days and the amount of air used was only 1270 cu. ft. The supernatant liquid was then drawn off and another sample added to this accumulated sludge and aeration continued. In this treatment complete nitrification took place in two days with the use of but 720 cu.ft. of air. Treatments were continued, always deconting off the clear liquid and a new sample added to the sludge accumulated until the twelfth treatment, when theresults showed complete nitrification in less than eight hours with the use of only 128 cu. ft. In the thirty-first treatment there had already settled enough sludge that the proportion of sewage to sludge was five parts to one part. For this sample purification was obtained in less than five hours using 35 cu. ft. of air, this being about 3 cu.ft. per gallon of sewage.

Samples taken every hour of the sewage, in the operation of the last experiment named, showed

that the free ammonia is not changed to nitrite and the nitrite oxidized to nitrate but that nitrates and nitrites were formed simultaneously.

Biological examinations then made in the sludge showed the presence of a slender worm whose lenght varied from two to five mm. It is known to abound in fresh water bodies where there is an abundance of decaying organic matter and threves especially where there is much fermentation and in waters contaminated with sewage providing there is an abundance of oxygen. These worms probably destroy at least their own weight of organic matter each day. Because of their reproduction by fission extensive colonies can be produced within a short period.

These worms, no doubtedly are the main content of activated sludge. The sludge does not have an unpleasing odor, owing to the fact that it consists largely of living organisms. If kept for a long time in a moist condition without air it will putrefy. The chemical analysis of this sludge after drying first on a water bath, then for three hours in an oven at 100°C the loss of

moisture being 95.54 per cent, was:-

Nitrogen (N)	6.3 Per cent.
Phosphorous (P)	1.44 " "
Phosphate (P_2O_5)	3.31 " "
Fat	4.00 " "
Volatile matter lost by ignition	75.00 " "

The percentage of nitrogen and Phosphate are higher in this sludge than that obtained at Manchester.

Further experiments were made at Urbana in May 1915. These experiments were conducted in four large concrete tanks each having an area of 10 sq.ft. and 8ft.5in. depth above 1½ in. filtros plates which were used to diffuse the air. In two tanks, nine plates were used with spaces of one inch between them and in the third tank there were three plates covering one-third the area of the floor with a central trough sloping to the plates at an angle of 45°. In the fourth tank one plate was used in the center covering one ninth the area of the

floor and with the bottom sloping to it at an angle of 45° on all sides. Below the plates was an air space of four inches deep. These tanks could be filled in six minutes and drained in eight minutes, through two outlets which are respectively 2' 6" and 5' 7" above the porous plates. No sludge was lost through the outlets of the third tank because movable outlets were used. The first and second tanks were filled with the same kind of sewage, the sewage in the first tank being aerated continuously, and in the second tank for 23 hours, the sludge being allowed to settle and the supernatant liquid drawn off and one hour later more sewage added to the collected sludge. This cycle was repeated daily and results were recorded. After ten days one per cent of volume in the first tank was sludge and in the second tank 10%. The effluent from the second tank was clearer than that of the first tank. The operation of the second tank was continued as before and after 15 days, nitrification was complete.

The sewage was then changed every twelve hours and nitrification was complete in eight days. Changing the sewage every six hours did not show good results and it was necessary to aerate for longer periods. This comparison indicates, however, that sludge may be satisfactorily activated by changing the sewage before nitrification is completed and that the sewage may be changed at frequent intervals. The third tank gave stable effluents after five days. The fourth tank did not give stable effluents in 18 days.

Further experiments at Urband with activated sludge took place in 1916 with continuous operation and results showed that 90% of the suspended matter was removed and after 13 days of operation stable effluents were obtained.

Milwaukee Experiments.

Further experiments were carried out by T. Chalkley Hatton, chief Engineer, Milwaukee Sewage Commission at Milwaukee since 1914. The magnitude of these experiments being larger than those at Urbana. Experiments were carried out in March 1914 one a small scale so as to get an idea as to the plant necessary to experiment on a larger scale. Two glass tubes 6' long by 1¼" in diameter were used. Air was forced into one of these tubes through filtros plates and another through a tube. Results showed that after 24 hours aeration in each tube the nitrification in each of the tubes was about the same. A tank of larger capacity was then built outside. This tank measured 32' lone 108 6" wide and 10' deep. Filtros plates were set at the bottom of this tank and the effluent drawn off by means of a floating circular weir. This tank was operated under varying conditions. The results for normal conditions being, filling one hour, aerating three and one-half hours, settling one-half

and drawing one hour. Further experiments were carried on in a tank 10 ft. high 5 ft wide, one foot between sides. Glass plates were inserted at various depths to observe the action inside. The results obtained from this experimental tank showed a greater number of bacteria per c.c. for the filtros tank than for the air jet diffuser tank. Experiments were then conducted on continuous flow operation. The tank being of the same size as the one used in the second set of experiments. This tank was put into oeration after securing the activated sludge. Experiments were carried out with varying volumes of air per gallon of sewage treated, varying rate of flow and varying the volume of activated sludge. The results for this tank are as follows, the larger percentage of the sludge in the tank, the more nearly complete nitrification is obtained, that is, for percentages of sludge up to 12½% for volume.

All of the preceeding experiments were car-

ried out in relatively warm weather, so the question came up as to how the process would work in cold weather, as the bacteria did their best work in temperatures between 688 to 70°F Tests were made on the Milwaukee Sewage in Winter the temperature of the Sewage ranging from 55°F to 42°F and it occasionally dropped down to 40° These very low temperature, retarted the oxidation of the organic matter and decreased the stability of the treated liquid. Activating this sewage with 2¼ cu. ft. of air per gallon, 90 per cent of bacteria in the sewage was removed and the suspended matter reduced to about 15 parts per million.

By increasing the volume of air applied the plants could remove the suspended and colloidal matter and bacteria in a satisfactory manner. As the temperature of the sewage dropped, the oxidation of the organic matter decreased the nitrates in the effluent falling more than 100 per cent for a difference of temperatures

of 63° to 49° and the oxygen consumed was increased 75%. The decrease in oxidation was also accompanied by a decrease in the stability of the effluent. In cold weather the treated liquid contained a large percentage of dissolved oxygen and only a trace of nitrate, whereas in summer the nitrates were high and the dissolved oxygen low. This shows that the liquid seems to depend upon nitrates in summer and dissolved oxygen in winter for its stability. This shows that in winter temperature, good bacterial removal and clarification can be maintained without oxidizing the ammonical nitrogen to nitrate.

These, and the proceeding Milwaukee experiments proved that it was possible to treat the sewage of Milwaukee by the activated sludge process on the continuous flow method when the temperature of the sewage was 50°F or over at less cost than by any other process. It was then decided to build a plant having a capacity of 1,600,000 gallons a day. The estimated cost of

the plant was $68,000 but the plant was completed in January 1916 at a total cost of but $61,536 including all machinery and cost of engineering and inspecting.

The activated sludge plant is located on Jones Island, alongside a large outfall sewer of the combined system. It consists of eleven cylindrical tanks, so that if the activated sludge process should fail they could be easily converted into Imhoff tanks. Of the elven tanks, eight used in series are used for aeration of the sewage in the presence of activated sludge, one is a sedimentation tank and two are sludge, aeration tanks. The size of the tanks are as follows, they are all 30' in diameter and have side walls extending 13' above its inner bottom. The total depth of sewage and sludge is 10' and the average depth is 9' in the ten tanks used for aeration. The sewage and the sludge in the sedimentation tank is 35.2' deep. The holding capacity of each of the eight sewage aeration tanks is 45000 gallons or 360,000 for the group. The open area of

each of these tanks is 662.84 sq. Ft. and all of them 5,303 sq. ft. The sedimentation tank has a holding capacity of 33, 600 gallons, not including 2,260 gallons held by the 48" cast iron sludge pipe extending below its bottom.

The general scheme of operation is as follows: the sewage is admitted to tank 1 where it is aerated with activated sludge, it then passes succession through the first eight tanks the combined sewage and sludge passing on from one tank to another and then into the sedimentation tank 9. Here the sludge settlement and the clear liquid passes out into the lake. From the bottom of the deep well in tank 9 the sludge is discharged by gravity into either of the sludge aeration tanks 10 or 11. The aerated sludge from these two tanks passes outside the tanks to a 48" vertical cast iron pipe set 28¼' in the ground from which it is lifted by air and returned to the inlet to the sewage-aeration tank 1.

The portion of the activated sludge in excess of what is necessary to maintain the proper percentage in the aerating tanks is pumped out of the sludge tanks from time to time and dewatered and sold as fertilizer.

The normal lake level is at El.-1.4. The sewage level in tank 1 is El.+ 0.8 and the weir in the sedimentation tank is at El. + 0.5 giving a fall of 3' in water level through the series of tanks.

By means of the curved baffle or division wall the sewage travels and is subjected to aeration for a distance of 912'. Air diffusion affected by means of 12 x 12 in. filtros plates 78 in each sewage and sludge aeration tank. This gives a ratio of diffusing surface to tank surface of 1 to 8.5. The filtros plates are set in cast iron frames, which afford an air supply conduit beneath the center line of each plate. The estimated air capacity of the filtros plates in the eight sewage aerating tanks is 2 cu. ft. per minute and in the two sludge aerating tanks it is

12 cu.ft. in each case under a 2 in. water pressure.

This plant was designed to treat 1,600,000 gallons of sewage per day with a four hours period of aeration and with 25 per cent activated sludge content, a velocity of 3.8 ' per min. and 27 min. sedimentation period. It can also be run with 25 per cent activated sludge present running through at a velocity of 5 ft. for 3 hours and a 20 min. sedimentation period, the capacity for this operation being 2,160,000 gallons. A capacity of 2,304,000 gallons daily is obtained with 20% activated sludge running through at a velocity of 5 ft. per min. for 3 hours and a 19 minute sedimentation period.

The results drawn from this plant after a year of continuous operation are numerous, and many new experiments were tried there, but on a larger scale, and their results obtained.

When this plant was first put into operation it required from 30 to 35 days of aeration to obtain a sufficient quantity of activated sludge

so as to start work, and in order to maintain 25 per cent of activated sludge in the aerating tanks it had been found necessary to return from the sedimentation tank from 40 to 50 per cent of the volume of raw liquor treated, because the liquor drawn from the sedimentation tank was only about one-half sludge.

Tests for this best diffusers to use were also made. It was found that the filtros diffusers created too much frictional loss, the loss being three-fourths lb. for forcing a five lb. air pressure through. Tests were made with wood block cut from basswood across the grain and the frictional loss for these filters were only one-half pound for five pound air pressure. The wood filtros plates are cheaper and nitrification with less air could be secured by increasing the diffuser area about 35% over air required for filtros, and thus reducing the volume of air passing through each square foot of diffuser.

The aerating tank which gave the best re-

sults in Milwaukee has the following proportions: 1 sq. ft. of diffusing surface to 5.5 sq. ft. of tank surface, average depth of liquor, 9 ft. 275 gallons of raw sewage treated per day per sq. ft. of surface. One cubic foot of aerating tank capacity treats 29 gallons of sewage per day.

The results obtained from the sedimentation tank at this plant were not very good, the sludge could not find its way down the central well and therefore collected on the sloping bottom of the tank and the sludge became septic. This settling in this manner was due to an entrance velocity which was too great and adverse currents were established which held the finer flock in suspension, permitting it to pass over the weir with the effluent; the heavier sludge would settle or the sloping bottom and not slide down to the central well and it became septic there, From further experiments conducted it was found that the tank giving the best sedimentation was a tank whose ratio of the breath to the length

was as 1 to 2.3 with flow across the breath. The running velocity should not exceed 3 ft. horizontal per minute. The detention period may be from 30 to 50 minutes, according to the character of the sewage treated. Vertical-horizontal flow being more effieient than either vertical or horizontal flow. The effluent should be removed with the least velocity possible and over continuous rather than V shaped weirs the latter creating cross current just where they are most objectional.

The Sludge and Its Disposal.

After the sludge collects into the sedimentation tank it is removed, dewatered, pressed and sold as fertilizer. The fertilizer being sold for $12.50 per dry ton in 1917. The cost however, of pressing and drying the sludge which included interest charges and plant depreciation, labor and materials was about $8.75 per dry ton. The clear profit bein $3.75 per ton. An analysis of the sludge obtained is as follows:

Nitrogen	5.1% as NH_3
Fat	5.3%
Soluble Phosphoric acid	9.5%
Potash	.25%

The value of the sludge depends upon several things among which may be mentioned the percentage of available nitrogen and the quantity of fatty matter it contains. The higher the nitrogen content, the more valuable is the sludge for manure, but on the other hand, the higher the fatty content the less suitable is

the sludge for agricultural use until the fatter material has been removed. However, the more fat present, the more advisable it is to treat the sludge to recover this fat, if it is present in considerable quantities.

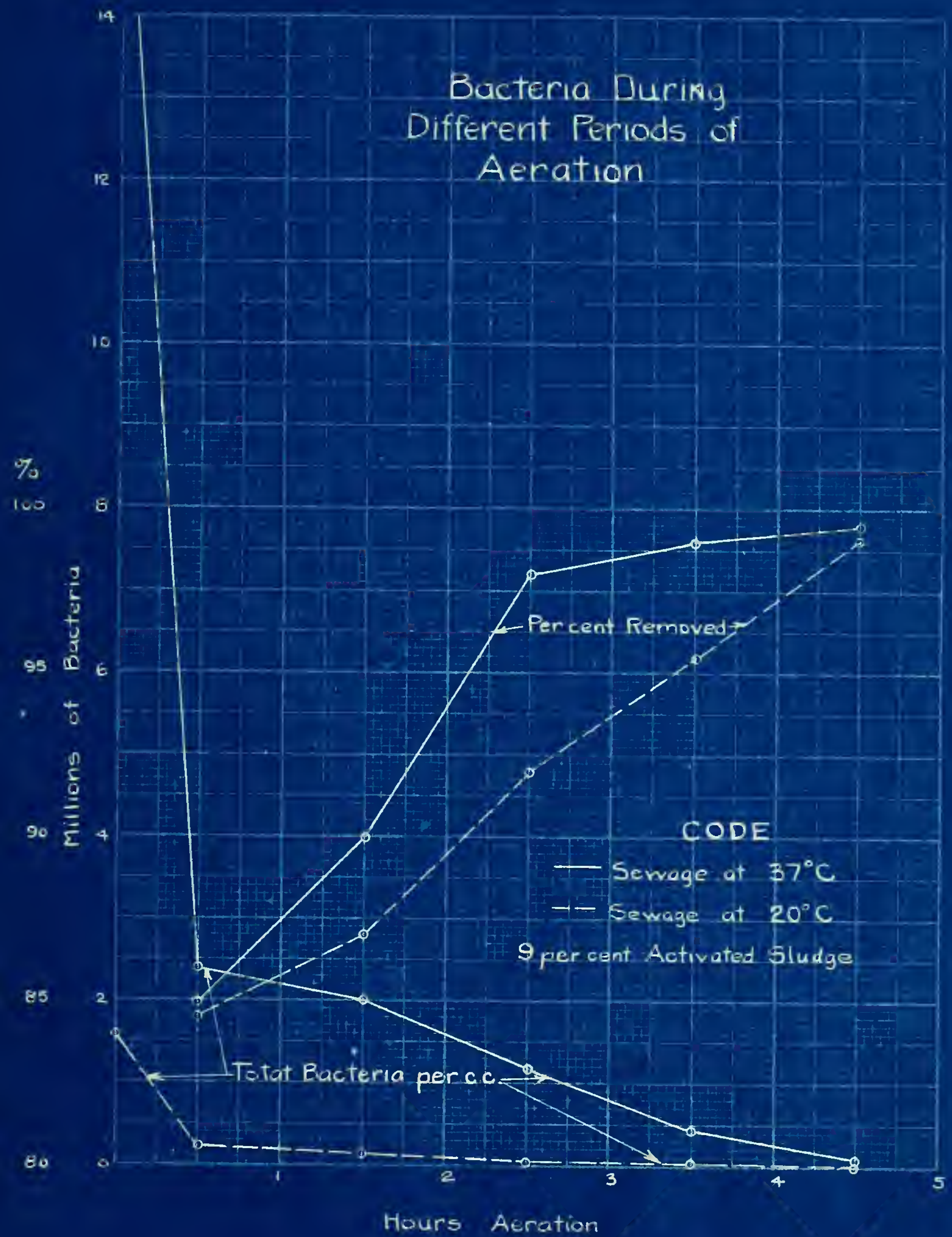
Estimating that one dry ton could be obtained from 1,000,000 gallons of sewage treated and an average daily dry weather flow of 5,000,000 gallons the net cost of disposing Milwaukee's sewage was estimated at $9.64 per 1,000,000 gallons of which 4.89 is charged to overheads and $4.75 to operating, renewals, and repairs. The net cost of operation per capita is figured out to be .53¢.

But this may not be true, The actual value of sludge manure, depends upon the ease with which it can be disposed of. For small communities surrounded by rural districts there may possibly no trouble whatever of disposing of this sludge at a payable price. But when a great center is considered, where great quantities of

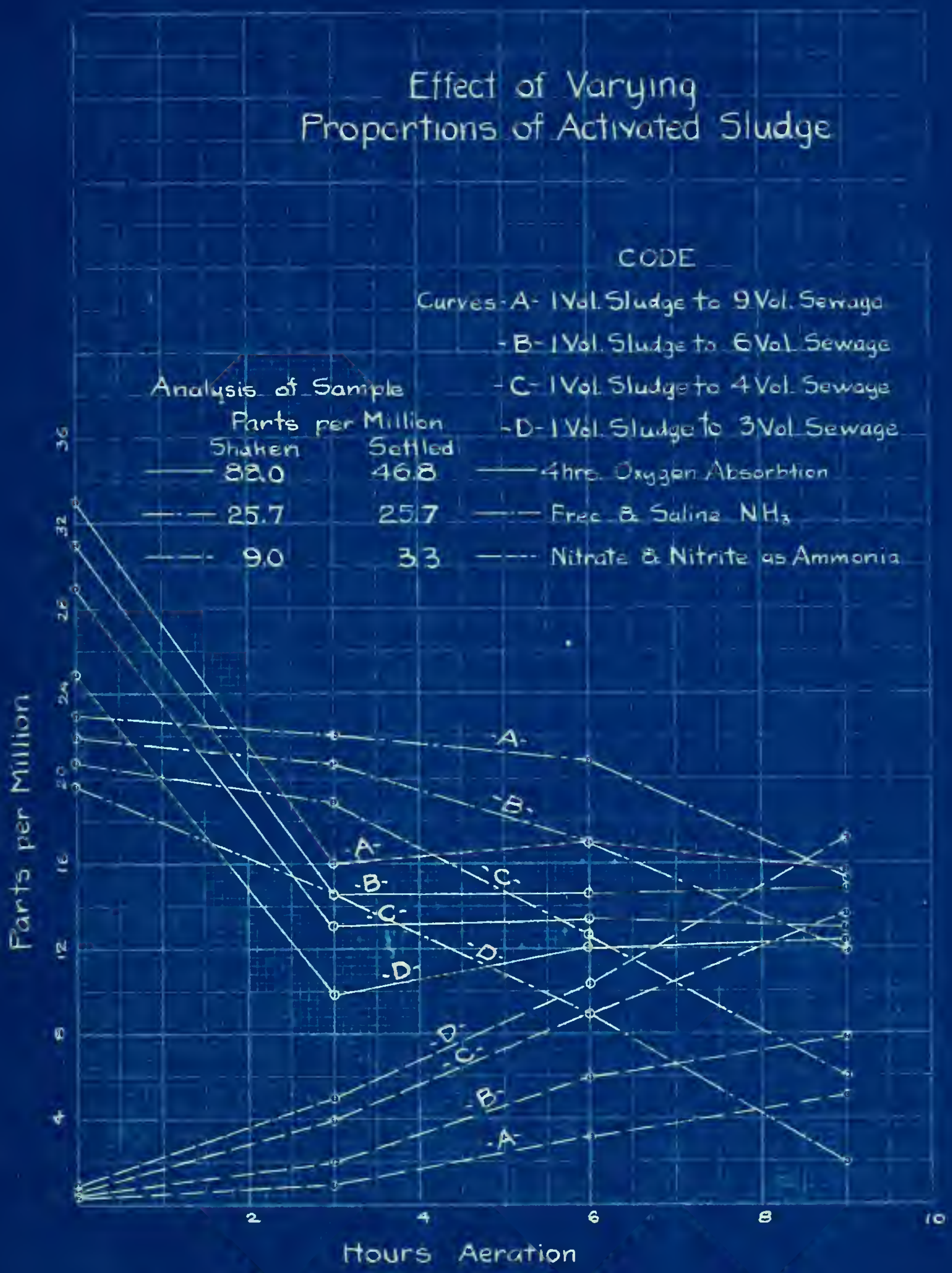
the sludge could be produced, that is more than can be used by the surrounding farmers, to get rid of it, would have to be transported a great distance and sold at a cheaper price to make up for the transportation cost. Sewage sludge, however high in available nitrogen is not such a rich manure that it can stand the cost of being carried half way across the world like the chilean nitrates. A comparatively small amount of handling and carriage kills it as an article of commerce.

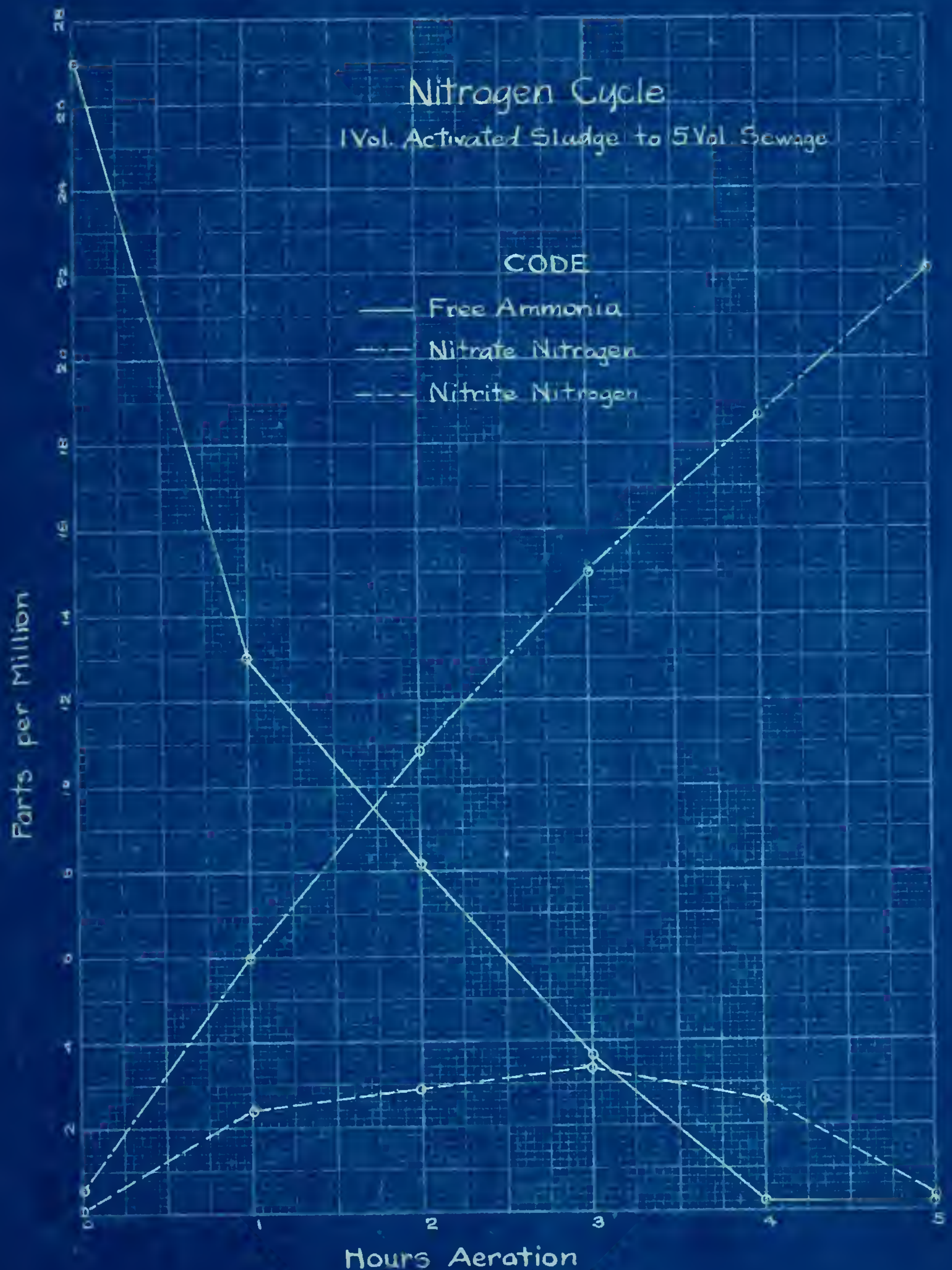
Activated sludge can be stored for a time because there is no offensive oder to activated sludge, but considerable oder may attend improper sludge reduction. Partially dewatered sludge, if exposed to the sun for a few hours gives off a highly objectional odor of hydrogen sulfate. This odor lasts for a short time only or until a dry covering is formed. Suldge placed under cover and not exposed to the sun gives off little or no odor. Flies, insects and worms do not infest the

treatment plant, even during the early fall when they are so prevalent in nearly all other types of disposal plants.

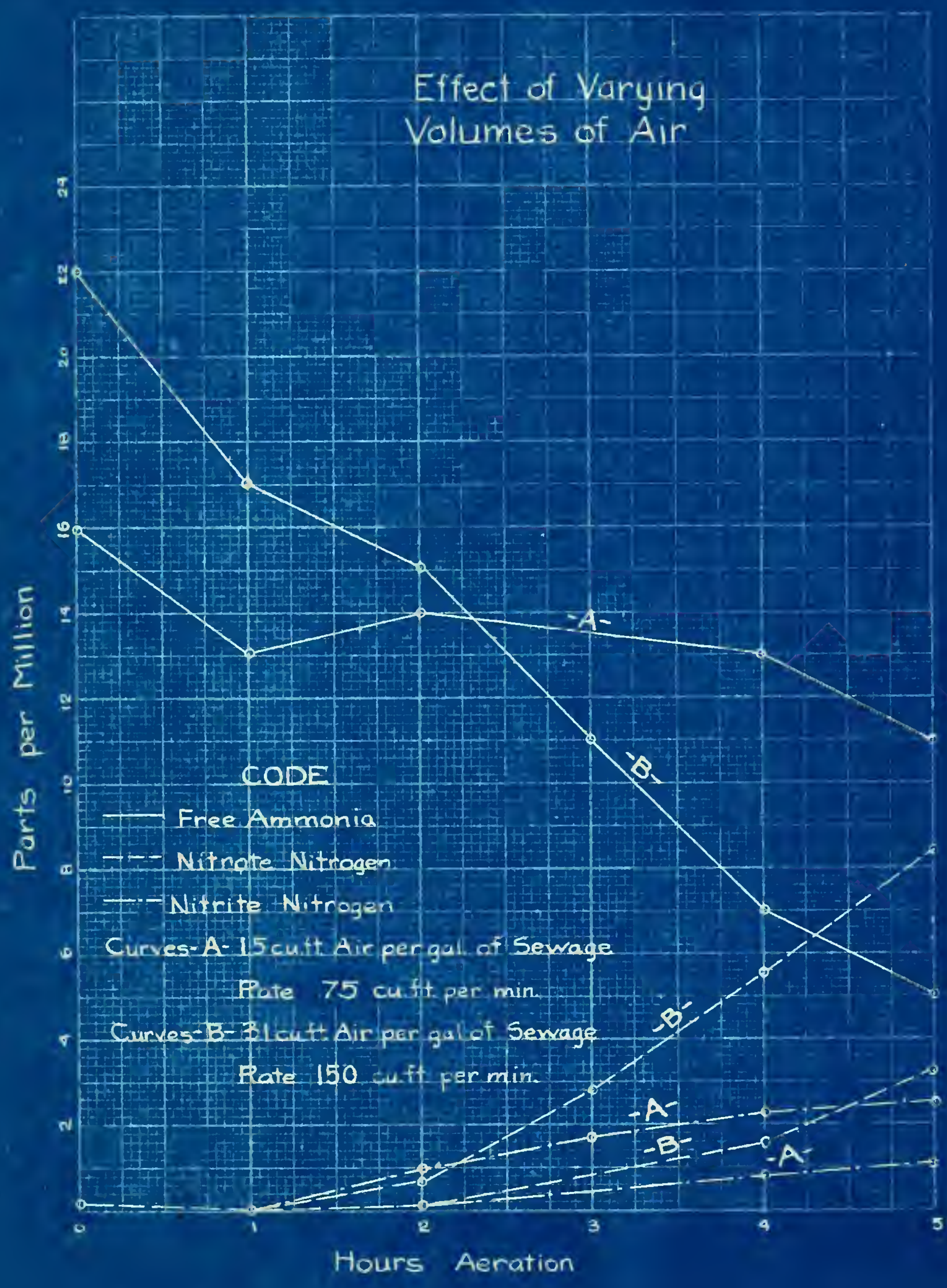


Bacteria During
Different Periods of
Aeration
%
105
95
90
85
80
Millions of Bacteria
14
12
10
8
6
4
2
0
Per cent Removed
Total Bacteria per c.c.
CODE
Sewage at 37°C
Sewage at 20°C
9 per cent Activated Sludge
1
2
3
4
5
Hours Aeration


Effect of Varying
Proportions of Activated Sludge
CODE
Curves -A- 1 Vol. Sludge to 9 Vol. Sewage
-B- 1 Vol. Sludge to 6 Vol. Sewage
-C- 1 Vol. Sludge to 4 Vol. Sewage
-D- 1 Vol. Sludge to 3 Vol. Sewage
Analysis of Sample
Parts per Million
Shaken Settled
88.0 46.8 4 hrs. Oxygen Absorbtion
25.7 25.7 Free & Saline NH_3
9.0 3.3 Nitrate & Nitrite as Ammonia
-A-
-B-
-C-
-D-
Parts per Million
4
8
12
16
20
24
28
32
36
2
4
6
8
10
Hours Aeration



Nitrogen Cycle
1 Vol. Activated Sludge to 5 Vol. Sewage
CODE
Free Ammonia
Nitrate Nitrogen
Nitrite Nitrogen
Parts per Million
Hours Aeration
0
1
2
3
4
5



Effect of Varying
Volumes of Air
Parts per Million
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
Hours Aeration
-A-
-B-
-B-
-A-
-B-
-A-
CODE
Free Ammonia
Nitrate Nitrogen
Nitrite Nitrogen
Curves-A- 1.5 cu.ft. Air per gal. of Sewage
Rate 75 cu.ft. per min.
Curves-B- 3.1 cu.ft. Air per gal. of Sewage
Rate 150 cu.ft. per min.