AN EXPERIMENTAL STUDY OF A TRICKLING FILTER

THESIS FOR THE DEGREE OF M. S.

Edward C. Schneider

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THESIS

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AN EXPERIMENTAL STUDY OF A TRICKLING FILTER

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INTRODUCTION

The purpose of this study of an experimental trickling filter is to determine the relationships existing between certain chemical and physical factors which control the efficiency of plant operation. There will be found in this work a certain amount of duplication, i.e., of work done in different parts of the United States and Canada in the past. However, in this study many of the results do not check with the work done before, and a few new factors were determined.

REVIEW OF LITERATURE

Trickling filters are a natural outgrowth of the sand filters and contact beds for sewage. In 1894, English engineers conceived the idea of passing sewage through a gravel filter so that a small film of sewage would be in contact with the stones. The "percolating" method of sewage filtration, as it was then called, seemed to give a more stable effluent than the contact bed or an intermittent sand filter.

H. W. Clark and Stephen DeM. Gage [1] in 1910 found that the uneven distribution of sewage on a trickling filter bed resulted in poor stability of effluent. One portion of the bed would be overloaded while another portion would be underloaded. By changing the type of distribution from dash plates to a rotary arm, nitrification increased 40 per cent and the distribution on the bed became more even.

Aeration studies (2) were made in Canada in 1899 to determine the amounts of air needed to oxidize the sewage as it passed through the filter bed. While no quantities were stated, it was found that the filter beds needed resting periods to restore the depleted air in the gravel.

M. W. Davenport, (3) in a study of the organisms in a trickling filter found algae near the surface of the beds and a number of infusoria protozoa in the upper layers of the bed. In the lower layers of the filter, clean living organisms were found. A number of free living organisms were found in the effluent of the filter. The temperature, quantity of food, and rate of application were found to control the fauna of the filter. At low temperatures the fauna decreased, and at higher temperatures they increased.

H. F. Mills and H. W. Clark, (4) found that the filtration of sewage that is highly colored, turbid, and contains a considerable amount of organic matter, as represented by the albuminoid ammonia, may be accomplished by coagulation with sulphate of ammonia or ferrus sulphate combined with lime.

R. McGowan,[8] in 1920 studied the oxidation of nitrogen compounds. He observed that the primary function of a trickling filter was the nitrification process.

C. B. Hoover,[9] shows the normal characteristics of a sprinkling filter effluent to be the following:

"1. From 10 to 20 per cent less total suspended matter than in the applied sewage. 2. From two to 10 times as much settleable suspended matter as in the applied sewage. 3. Oxidized nitrogen in the form of nitrites and nitrates to the extent of from one to 10 parts per million. 4. Reduction in the oxygen demand of the applied sewage of from 50 to 90 per cent. 5. A reduction in the total bacterial count of the applied sewage from 40 to 70 per cent."

J. A. Reddie,[12] found that the pH of the sewage as it passes through the filter decreases, due to the oxidation of carbonaceous and protein material in the sewage.

W. Rudolfs,[16] in a study of an experimental trickling filter found that the reduction of ammonia-N corresponds with the reduction of oxygen consumed.

W. D. Hatfield,[27] has shown that there is a relationship between temperature and filter efficiency. As the temperature increases the efficiency also increases, and vice versa.

W. Rudolfs and N. Chamberlain[33] observed from experimental filters containing crushed stone, slag, gravel, and wire mesh a loss of ammonia-N which could not be accounted for by oxidation to nitrites and nitrates or by microbial reassimilation. The quantities of ammonia-N lost were not uniform for the different levels of the various filters. The time of contact of sewage with the different media did not seem to be of much importance. The per cent loss of ammonia-N varied with the temperature. A small portion of ammonia-N is lost in the air, another portion assimilated by the flora and fauna in the filter, and another portion oxidized to nitrites and nitrates.

C. C. Homman,[22] in reporting operating results at Canton, Ohio, describes two methods of preventing clogging and pooling of trickling filter beds: (1) drying and (2) chlorination. At Canton the drying of beds has proved a successful method. The building up of nitrates was noted during the drying period.

J. A. Childs and G. J. Schroepfer,[25] in a survey of 15 trickling filter plants report that "(1) the per cent reduction in oxygen demand of any particular trickling filter plant is not, within reasonable limits, materially influenced by quite wide variations in strengths of sewage or rates of application; (2) the oxygen demand of the filter effluent is directly proportional to the strength of the filter influent."

W. E. Stanley[35] states that the primary function of a trickling filter is to satisfy the oxygen demand of the sewage. The determinations of the changes from the less stable to the more stable nitrogen compounds are useful in measuring the amount of work done by the filter. Stanley advocates more studies of the relationship between the size and gradation of stone and the loading on a filter bed.

From 1908 to 1920 the studies of trickling filters were mostly for the improvement of mechanical equipment. During this period nozzles were improved for more even distribution of sewage; and the rotating arm was also improved during this time.

There are much data from which to draw information. The above reviews are listed to indicate a part of the studies of trickling filters. In the discussion of results of this study comparisons will be made with additional previous work.

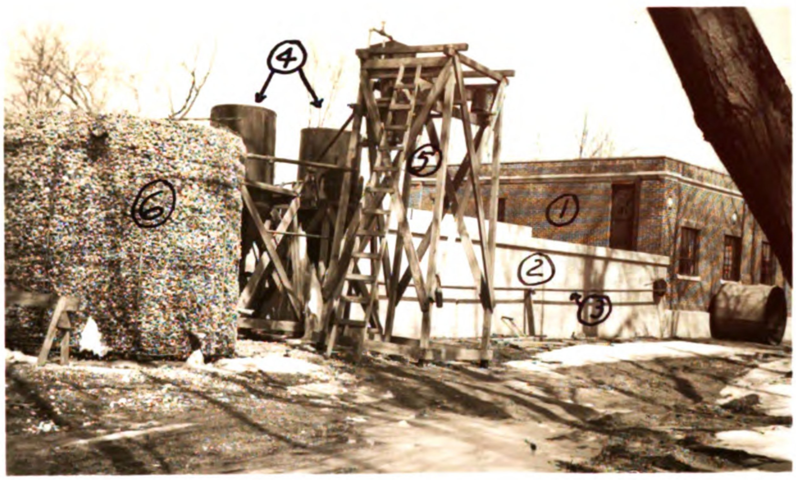


Fig. 1

1. Pump house, East Lansing Sewage Treatment Plant.
2. Imhoff Tanks, " " " " "
3. 2" take off line for Experimental Plant.
4. Not a part of this study.
5. Orifice box and dosing tank.
6. Trickling Filter.

DESCRIPTION OF EXPERIMENTAL PLANT

The first step in any research problem is to provide adequate material with which to carry on an investigation. With this in mind the Engineering Experimental Station financed the construction of a small experimental trickling filter plant; consisting of a dosing tank, trickling filter bed, and a final sedimentation chamber.

The influent of the filter is the effluent of the Imhoff tanks of the East Lansing Sewage Treatment Plant. This effluent is taken (Fig. 1) from the Imhoff tanks by tapping the effluent channel. The effluent is then pumped to an orifice box (Fig. 2) through which the rate of application to the filter bed is controlled. Orifice plates of various sizes are attached to the box for different rates of application. An overflow pipe in the orifice box permits the maintenance of a constant head for a constant discharge through the orifice plates. The overflow pipe leads back to the Imhoff tanks. The orifice box is placed directly over the dosing tank.

The dosing tank (Fig. 2) is in the shape of a frustrated cone. This shape allows some flexibility in dosing period. The dosing apparatus in the tank consists of a float attached to a plunger valve. The float can be raised or lowered as desired. The flexibility of the dosing rates, however, is controlled by certain limits in

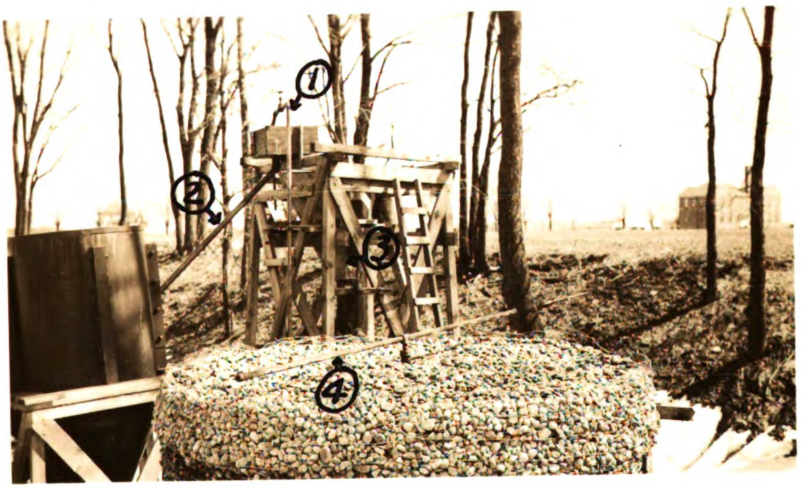


Fig. 2.

1. Sewage inlet pipe to orifice box.

2. Overflow pipe to Imhoff tanks.

3. Dosing tank.

4. Revolving arm for distribution of sewage on filter.

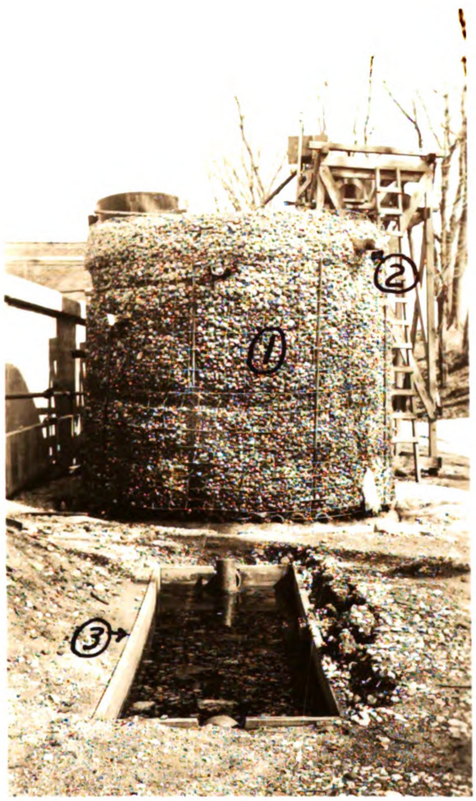


Fig. 3

1. Trickling Filter bed.
2. Eavestroughs for collecting samples.
3. Final sedimentation chamber.

the rate of application to the filter bed. The sewage flows by gravity from the dosing tank to the filter bed. The dosing is intermittent to allow rest periods.

The filter bed (Fig. 3) is 10 feet in diameter and nine feet deep. The filter medium is washed gravel varying in size from 1½ inches to 2½ inches. Wire mesh is used for holding the gravel in place. Channel tiles placed on a concrete base are used for underdrainage and aeration. Eavestroughs are placed at each foot depth for sampling.

The effluent of the filter passes through a final sedimentation chamber (Fig. 3) which is designed for a retention period of two hours. The effluent of the final settling chamber then discharges into the Red Cedar River.

The sewage is distributed over the filter bed by means of a revolving arm (Fig. 4). This arm is made of one-inch pipe with three sixteenth-inch diameter holes spaced to give even distribution over the entire bed. The arm revolves on a pivot and makes 20 revolutions per minute when distributing sewage. The minimum head on the arm is six inches. The top of the bed is one foot below the bottom of the dosing tank.

EXPERIMENTAL DATA

The following analyses were made of the influent to the filter bed (Imhoff tank effluent) and for each foot of depth filter: temperature, pH, five day bio-chemical oxygen demand, dissolved oxygen, oxygen consumed, ammonia-N, nitrite-N, nitrate-N, total solids, organic solids, suspended solids. The determinations were made by the standard methods of the United States Public Health Association.

The following rates of application to the filter were studied: 1.48, 2.15, 3.71, and 4.66 million gallons per acre per day. As the filter is nine feet deep the following rates in gallons per day per acre foot correspond to the rates given above: 164,000; 240,000; 410,000; and 520,000. The rates of application per acre foot of depth in use in this country range from 200,000 to 300,000.

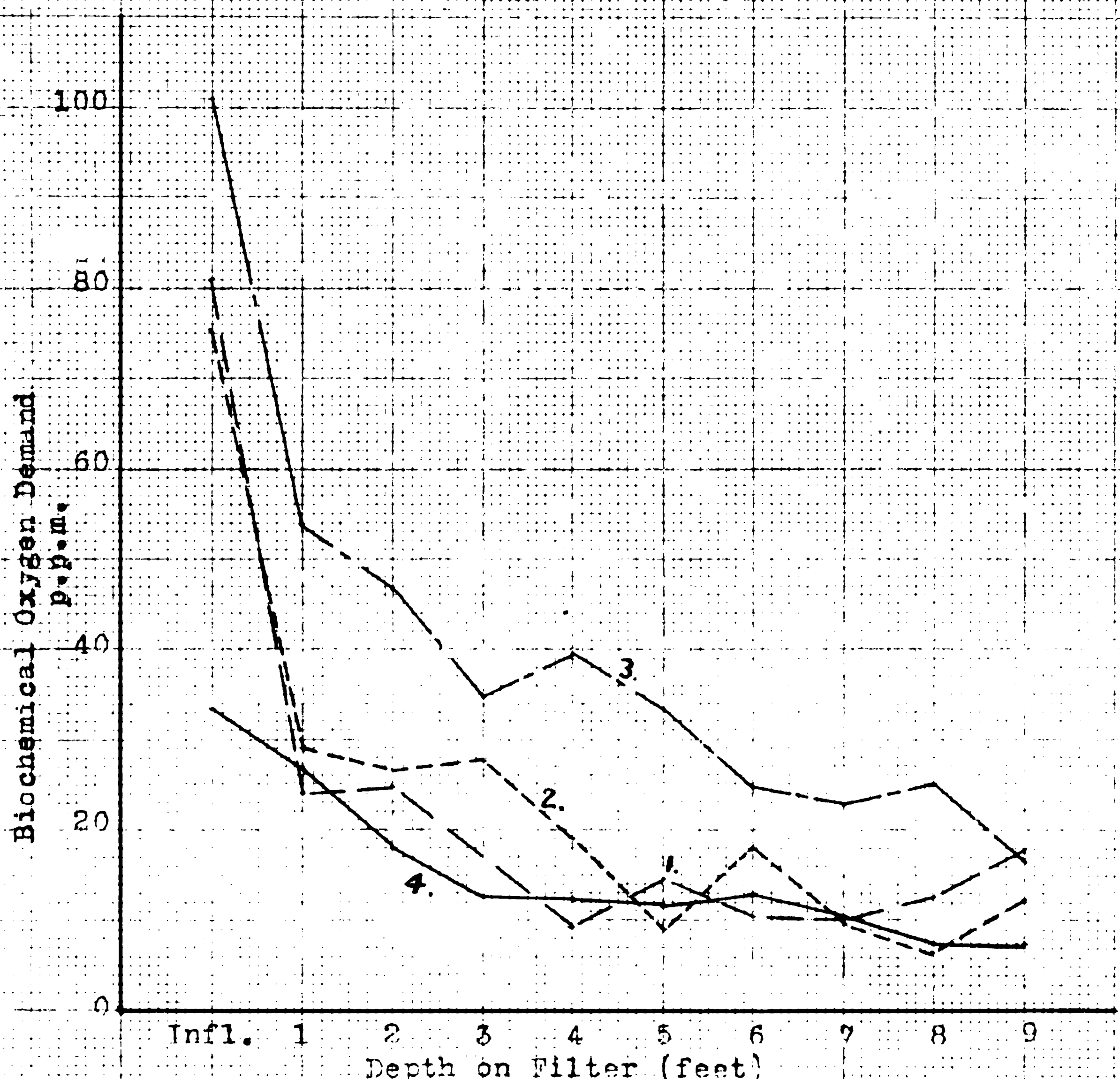
The construction of the experimental unit was completed December 2, 1931, and immediately placed in operation. The rate of 4.66 m.g.a.d. was applied to mature the bed, and relative stability tests made every few days for each foot of depth to observe the progress in maturing. On January 6, 1932, the effluent from the six foot depth of the filter showed a 10-day stability at room temperature (20° C.) or a relative stability of 90 per cent. It is interesting to note the rapidity with which the bed matured. This is probably due to the heavy rate of application on the filter bed and the mild weather which prevailed during the maturing period.

A series of tests were made for each rate of application as soon as the bed matured.

Fig. 4

Biochemical Oxygen Demand

Rates of Application:
1. 1,480,000 gal./acre/day
2. 2,150,000 "
3. 3,700,000 "
4. 4,660,000 "



DISCUSSION

Biochemical Oxygen Demand.

There are many variables in the operation of a trickling filter which affect its efficiency. The variables which are most significant are those which are physiological in nature. As an example, bacteria must have certain quantities and concentrations of food. On the filter this may be represented by the amount of biochemical oxygen demand loading. Optimum amounts and concentrations of food depend on the kind of sewage treated. The quality of food or kind of organic matter present controls the kind of organisms developed in the filter.

At the beginning of this study the sewage was applied at the rate of 4.66 million gallons per acre per day. The weather was mild and considerable precipitation occurred during this time. As the East Lansing sewerage system is of the combined type, the sanitary sewage was greatly diluted. The average B. O. D. of the influent to the filter for this period was 33.5 p.p.m. The maximum reduction of B. O. D. occurred at the eight-foot depth. At this depth there was a reduction of 78 per cent.

Fig. 5

Percent Reduction of Biochemical
Oxygen Demand

Rates of Application:
1. 1,480,000 gal./acre/day
2. 2,150,000 "
3. 3,700,000 "
4. 4,660,000 "

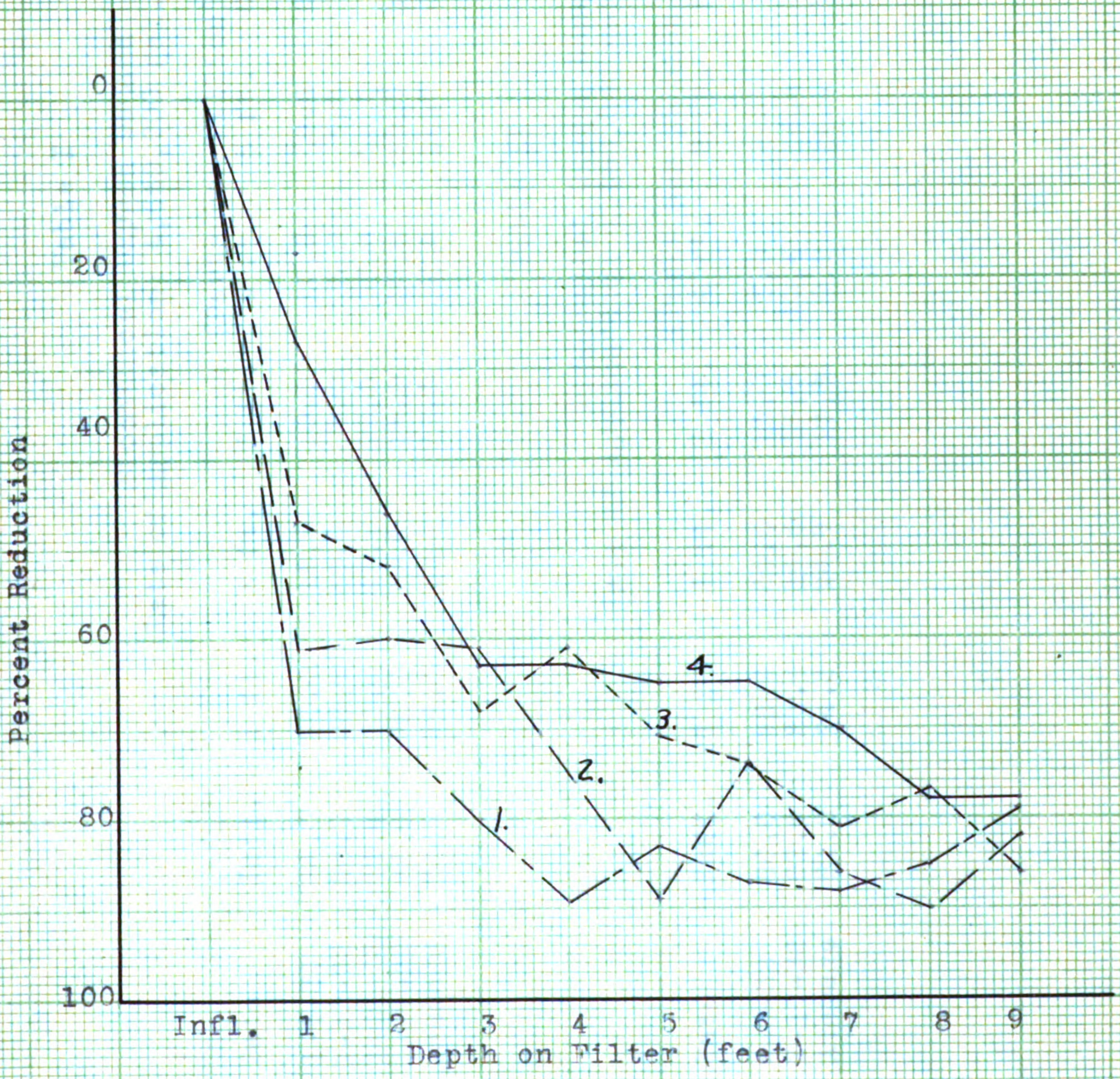


Table I

Biochemical Oxygen Demand
Rate of Application: 4,660,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	24.0	20.0	12.5	10.0	10.0	8.6	21.0	9.4	13.6	5.8
1-13-32	20.0	30.0	10.0	5.0	5.0	4.2	9.6	8.0	5.4	8.2
1-20-32	35.0	20.0	25.0	20.0	20.0	14.8	7.0	6.6	7.8	6.4
1-27-32	55.0	35.0	25.0	15.0	10.0	19.0	13.8	16.4	2.2	8.6
Average	33.5	26.3	18.1	12.5	12.4	11.7	11.8	10.1	7.3	7.3

Table II

Biochemical Oxygen Demand
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	80.0	25.0	30.0	15.0	5.0	---	8.8	4.4	14.8	21.0
2-17-32	82.0	23.6	19.4	18.6	13.4	14.4	12.6	16.0	10.2	13.2
Average	81.0	24.3	24.7	16.8	9.2	14.4	10.7	10.2	12.5	17.1

Table III

Biochemical Oxygen Demand
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	90.0	35.6	31.4	26.6	22.8	14.4	38.8	11.4	4.8	10.8
4-6-32	78.5	40.8	33.0	27.4	24.6	10.6	4.0	3.6	2.0	7.4
4-13-32	60.0	27.0	39.9	41.4	20.0	5.2	21.0	13.2	11.2	24.8
4-14-32	72.0	13.8	10.2	14.6	8.6	5.6	7.8	6.0	9.6	5.6
Average	75.1	29.3	26.1	27.5	19.0	9.0	17.9	9.8	6.9	12.2

Table IV

Biochemical Oxygen Demand
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	100.0	29.0	25.8	23.4	10.6	12.2	26.2	8.4	4.2	6.2
4-21-32	68.0	26.2	30.0	23.6	18.8	6.4	30.4	2.2	6.0	6.2
4-27-32	76.0	35.6	54.0	4.0	34.6	3.8	3.8	---	23.4	7.4
4-28-32	120.0	79.8	38.2	38.6	66.6	65.6	29.8	24.0	44.6	23.6
5-4-32	166.0	87.2	79.8	76.4	69.0	77.4	31.4	55.6	50.6	40.4
5-5-32	76.0	64.2	51.2	43.4	33.4	34.6	23.2	23.2	20.4	14.0
Average	101.0	53.6	46.7	34.9	39.6	33.3	25.0	22.7	24.9	16.8

Table V

Per Cent Reduction B. O. D.
Rate of Application: 4,660,000 gal. per acre per day.

Date	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	17	48	58	58	64	13	61	43	76
1-13-32	--	50	75	75	79	52	60	73	59
1-20-32	43	43	43	43	58	80	81	78	82
1-27-32	36	36	73	82	65	66	70	95	84
Average	27	46	63	63	65	65	70	78	78

Table VI

Per Cent Reduction B. O. D.
Rate of Application: 1,480,000 gal. per acre per day.

Date	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	69	63	81	94	--	89	95	81	74
2-17-32	71	77	78	84	83	85	81	88	84
Average	70	70	80	89	83	87	88	85	79

Table VII

Per Cent Reduction B. O. D.
Rate of Application: 2,150,000 gal. per acre per day.

Date	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	60	63	70	75	84	57	87	95	89
4-6-32	48	57	65	69	87	94	94	97	91
4-13-32	55	33	32	67	92	65	70	82	58
4-14-32	81	86	79	88	92	89	92	86	92
Average	61	60	61	75	89	74	86	90	82

Table VIII

Per Cent Reduction B. O. D.
Rate of Application: 3,700,000 gal. per acre per day.

Date	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	71	74	77	89	83	74	92	96	94
4-21-32	62	56	66	72	91	56	97	91	91
4-27-32	53	29	95	54	95	95	--	70	91
4-28-32	33	68	68	44	45	75	80	63	80
5-4-32	48	52	58	58	53	81	66	69	76
5-5-32	16	32	42	50	54	63	70	74	82
Average	47	52	68	61	71	74	81	77	86

The next rate of application of sewage to the filter was 1.48 million gallons per acre per day. The average influent B. O. D. for this period was considerably higher than for the previous run, being 81.0 p.p.m. The maximum average reduction for this period was 89 per cent and occurred at the four-foot level. From this depth on down to the nine-foot depth the B. O. D. gradually increased until the reduction was only 79 per cent.

The filter was then operated at a rate of 2.15 million gallons per acre per day. The average B.O.D. for this run was 75.1 p.p.m., and the average maximum reduction was 89 per cent and occurred at the five-foot level.

The last rate of application to the filter was 3.70 million gallons per acre per day. After this rate was started the weather began to warm up and the filter immediately began sloughing off. During this period the average influent B. O. D. to the filter was 101.0 p.p.m. Because of the unloading of the filter the maximum per cent reduction of B. O. D. in the filter was 86 per cent and occurred at the nine-foot depth.

It will be noted from these results that for different rates of application varying depths of filter will be necessary to treat the sewage. Low rates of application will require shallower depths of filters than will higher rates of application. It will also be noted from Figures 4 and 5 that there is a pronounced lag in the central portion of the filter. This lag will be discussed later with correlations.

Filter Loading.

The per cent reduction of the biochemical oxygen demand can hardly be called the measurement of efficiency of a trickling filter, because the per cent reduction is not a measure of the work done. Take for example two sewages, one containing 1,000 p.p.m. B. O. D., and the other containing 100 p.p.m. B. O. D. If the per cent reduction through two filters is 90 per cent, the final effluent of one filter will contain 100 p.p.m. B. O. D., and the other will contain 10 p.p.m. B. O. D. The filter with the effluent containing 100 p.p.m. B. O. D. will have removed 900 p.p.m., while the second filter which has an effluent B. O. D. of 10 p.p.m. will have removed only 90 p.p.m. B. O. D. The work done by the first filter is more than that done by the second filter and is, therefore, more efficient; but the per cent reduction in B. O. D. does not indicate which filter does the most work.

The rate of application of sewage to a filter is another factor to be considered in measuring the efficiency of the trickling filter. The work done

Table VIII A

Filter Loading and Efficiency

Date	Rate of Application gal./acre/day	Rate of Application gal./acre ft./day	B.O.D. Loading lbs./acre/day	Lbs. B.O.D. Removed	Maximum Reduction B.O.D.
Jan. 6 to Jan. 27,-32	4,660,000	520,000	1,300	1010	78% @ 8 ft.
Feb. 3 to Feb. 17,-32	1,480,000	164,000	1,000	890	89% @ 4 ft.
Mar. 2 to Apr. 14,-32	2,150,000	240,000	1,350	1200	89% @ 5 ft.
Apr. 20 to May 5,-32	3,700,000	410,000	3,120	2680	86% @ 9 ft.

Table IX

Temperature (° C. at 12 Noon)

Rate of Application: 2,150,000 gal. per acre per day.

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-6-32	11.0	10.0	9.0	7.5	7.0	6.0	7.0	7.0	7.0	7.0
4-13-32	8.0	7.0	3.5	2.0	0.5	2.0	4.0	4.0	3.5	3.0
Average	9.5	8.5	6.3	4.8	3.8	4.0	5.5	5.5	5.3	5.0

should, therefore, be expressed as the amount of B. O. D. removed per unit of filter surface. The results of this study indicate that the measurement of efficiency is best expressed as B. O. D. in pounds per acre per day removed by the filter. The reason for expressing the loading and efficiency in this manner is that the major portion of the B. O. D. is reduced in the first foot of the filter. By placing the loading expression on the area basis the depth of the filter has little bearing on the efficiency of the plant.

In Table VIII A is shown the loading on the filter for the different rates of application. The filter is least efficient during the lowest rate of application and most efficient during the rate of 3.7 m.g.a.d.

The reason for the first foot of the filter removing more B. O. D. than any other equal portion may be due to three things: (1) it may act as a mechanical strainer, (2) it may be due to bioprecipitation, and (3) it may be due to the flora and fauna of the filter which is influenced by the high concentration of food in this portion.

Temperature.

Figure 8 shows the correlation between per cent reduction B. O. D. and temperature. There is a marked

Table X

Temperature (° C. at 12 Noon)
Rate of Application: 3,700,000 gal. per acre per day.

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	12.0	12.0	13.0	12.0	10.5	10.0	11.0	11.0	11.0	10.0
4-21-32	12.0	15.0	15.0	12.0	12.0	11.5	12.0	12.0	12.0	12.0
4-27-32	13.0	9.0	8.0	4.0	6.0	6.0	6.5	7.0	7.5	8.0
4-28-32	13.0	15.0	12.0	10.0	11.0	9.5	10.0	11.5	10.0	10.0
5-4-32	14.0	16.0	16.0	15.0	14.0	13.0	14.0	15.0	14.0	14.0
Average	12.8	13.6	12.8	10.8	10.7	10.0	10.7	11.1	10.9	10.8

Table XI

pH Valves
Rate of Application: 2,150,000 gal. per acre per day.

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-6-32	7.6	7.5	7.5	7.5	7.5	7.5	7.4	7.5	7.5	7.4
4-13-32	7.5	7.4	7.3	7.3	7.3	7.3	7.3	7.3	7.2	7.3
4-14-32	7.2	7.4	7.4	7.5	7.5	7.5	7.5	7.5	7.5	7.6
Average	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4

relationship between these factors. As pointed out by Hatfield[27] the higher the temperature of the sewage the greater the per cent reduction B. O. D. This was not found to be the case in this study. When the temperature of the influent was 14° C. the per cent reduction was 86, and when the temperature of the influent was 12° C. the per cent reduction was 94. The effluent temperatures of the filter were proportional to the temperatures of the influents. The above comparisons were made for the same rate of application. There is a relationship, however, between the B. O. D. reduction and the internal temperature of the filter.

Alkalinity.

The pH values, Tables XI and XII, of the sewage as it passes through the filter are somewhat inconsistent. At the rate of 2.15 m.g.a.d. the average pH through the filter was constant, 7.40. The pH through the filter at the rate of 3.70 m.g.a.d. increased from 7.2 in the influent to 7.7 in the effluent.

Dissolved Oxygen.

The dissolved oxygen of the sewage as it passes through the filter increases quite uniformly in the upper layers and then follows the same lag in the central portion of the filter as does the B. O. D. During the rate

Table XII

pH Valves
Rate of Application: 3,700,000 gal. per acre per day.

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	7.3	7.5	7.5	7.5	7.6	7.7	7.7	7.7	7.5	7.8
4-21-32	7.3	7.3	7.3	7.4	7.5	7.5	7.5	7.5	7.5	7.5
5-4-32	7.0	7.1	7.3	7.4	7.6	7.6	7.6	7.6	7.6	7.7
Average	7.2	7.3	7.4	7.4	7.6	7.6	7.6	7.6	7.5	7.7

Table XIII

Dissolved Oxygen
Rate of Application: 4,660,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	0.0	6.6	8.4	9.0	9.8	10.0	10.4	8.8	11.0	13.2
1-13-32	7.4	5.6	8.0	9.4	8.4	9.0	8.4	8.8	8.8	9.2
1-20-32	2.0	6.0	8.0	9.2	8.6	9.4	9.6	9.2	10.4	9.0
1-27-32	1.0	6.4	11.2	11.8	10.6	10.0	9.8	9.4	9.2	9.6
Average	3.5	6.2	8.9	9.9	9.4	9.6	9.5	9.1	9.9	10.3

Table XIV

Dissolved Oxygen
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	1.4	5.0	6.8	8.4	8.2	7.8	9.2	8.8	11.2	9.4
2-10-32	0.0	2.0	6.4	9.6	9.6	6.8	8.0	10.4	10.4	9.4
2-17-32	2.0	5.4	9.2	10.4	11.2	10.2	10.4	11.8	12.0	11.0
Average	1.1	4.1	7.5	9.5	9.7	8.3	9.2	10.3	11.2	9.9

Table XV

Dissolved Oxygen
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	0.2	3.3	5.6	6.8	7.0	8.6	10.0	7.6	7.0	10.0
4-6-32	1.6	3.4	5.6	8.0	9.2	9.2	8.6	8.2	8.6	10.0
4-13-32	1.6	5.0	10.0	12.1	9.9	10.8	11.9	13.4	11.6	10.8
4-14-32	3.9	6.8	7.3	8.6	11.3	11.0	9.0	10.2	10.0	9.8
Average	1.8	4.8	7.1	8.9	9.4	9.9	9.9	9.8	9.3	10.2

Table XVI

Dissolved Oxygen
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	0.0	3.2	6.0	5.6	6.8	6.4	6.4	6.6	8.4	8.4
4-21-32	0.0	2.0	2.4	4.2	5.2	5.2	5.6	6.2	6.0	6.2
4-27-32	0.0	5.8	6.2	8.2	6.8	8.0	7.8	5.0	6.0	7.6
4-28-32	0.0	2.8	5.2	5.6	5.6	6.6	6.8	5.0	6.6	4.6
5-4-32	0.0	1.0	2.4	3.8	6.6	5.0	5.0	3.2	6.2	6.0
5-5-32	0.2	4.0	5.0	7.2	8.2	8.4	6.0	9.0	8.2	7.8
Average	0.03	3.1	4.5	5.8	6.5	6.6	6.3	5.8	6.9	6.8

Table XVII

Oxygen Consumed
Rate of Application: 4,660,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	27.9	17.3	15.6	15.5	15.8	14.7	16.3	15.7	13.2	13.9
1-13-32	19.2	17.0	16.6	16.6	16.2	16.4	16.3	15.7	16.4	15.9
1-20-32	24.6	19.4	18.5	15.9	16.9	16.3	15.0	15.3	15.1	14.0
1-27-32	18.5	16.9	15.9	15.5	16.8	14.7	13.9	14.1	12.7	12.0
Average	22.6	17.7	16.7	15.9	16.4	15.5	15.4	15.2	14.4	13.9

of application of 4.66 m.g.a.d. the average dissolved oxygen of the influent was 3.5 p.p.m. and increased to a maximum of 10.2 p.p.m. in the effluent. During this time the B. O. D. of the effluent was quite low and the high dissolved oxygen in the influent may be due to the large amount of storm water in the sewage. During the rate of application of 3.70 m.g.a.d. the average dissolved oxygen in the influent of the filter was less than 0.1 p.p.m. The dissolved oxygen in the influent during this rate was 6.8 p.p.m.

Oxygen Consumed.

The oxygen consuming capacity of the sewage decreases quite rapidly in the upper layers of the filter. This is probably due to the oxidation of carbonaceous material in the sewage. As the carbonaceous material is quite readily oxidized, greater reduction will take place in the upper layers of the filter due to the fact that the most oxygen is available in this portion of the filter. There is also a lag in the reduction of oxygen consumed in the central portion of the filter. The oxygen consumed value in the influent of the filter was never greater than 22.6 p.p.m. This value occurred when the strength of the sewage was low. As the strength of the sewage increased the oxygen consumed of

Table XVIII

Oxygen Consumed
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	27.7	17.4	18.1	14.0	12.8	28.4	15.1	13.6	12.6	18.6
2-10-32	18.0	19.2	15.4	15.2	12.2	21.5	20.0	19.5	18.9	26.4
2-17-32	14.9	13.2	13.3	12.6	11.3	10.8	14.7	10.3	9.8	13.0
Average	20.2	16.6	15.6	13.9	12.1	16.1	16.6	14.5	13.8	19.3

Table XIX

Oxygen Consumed
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	17.2	15.1	14.9	13.6	12.3	12.7	13.7	8.8	8.6	8.2
4-6-32	34.8	27.2	23.7	19.3	19.3	13.5	14.0	13.8	16.2	15.5
4-13-32	18.1	18.6	16.5	23.7	15.4	14.1	16.9	18.3	14.8	18.9
4-14-32	19.1	18.3	18.7	18.1	16.4	16.8	18.8	18.3	17.2	18.7
Average	22.3	19.8	18.5	18.7	15.9	14.3	15.9	14.8	14.2	15.3

Table XX

Oxygen Consumed
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	20.2	16.4	14.8	14.5	14.3	13.2	15.2	13.8	13.1	15.5
4-21-32	24.6	20.2	21.0	15.5	13.9	16.3	15.8	13.0	12.2	17.9
4-27-32	17.0	16.1	14.1	12.0	17.1	14.5	16.1	13.7	15.3	15.0
4-28-32	19.7	17.7	13.9	15.3	19.3	13.9	18.0	16.0	15.6	17.5
5-4-32	16.9	17.0	27.2	14.9	11.2	12.8	11.6	13.3	13.8	24.7
5-5-32	15.3	14.9	17.1	12.6	11.2	12.2	12.4	12.2	11.0	18.1
Average	18.9	18.0	18.0	14.2	14.5	13.8	14.9	13.7	13.5	18.2

Table XXI

Ammonia-Nitrogen
Rate of Application: 4,660,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	7.8	6.7	4.7	5.8	5.1	5.5	5.2	4.7	3.9	3.9
1-13-32	7.8	7.8	7.4	4.3	4.3	2.8	2.8	2.0	1.6	0.4
1-20-32	8.2	7.1	7.8	6.7	6.7	6.3	6.3	6.3	5.8	2.7
1-27-32	9.8	9.8	7.8	7.8	6.3	5.8	5.1	5.1	4.3	2.9
Average	8.4	7.9	6.9	6.2	5.6	5.1	4.9	4.5	3.9	2.5

Table XXII

Ammonia-Nitrogen
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	22.6	21.5	19.5	14.7	13.7	11.8	5.8	3.9	3.9	6.8
2-10-32	18.6	15.6	12.7	12.7	8.8	7.8	6.8	6.8	4.9	4.9
2-17-32	14.7	11.7	9.8	6.8	5.9	4.0	0.1	0.9	0.1	0.1
Average	18.6	16.3	14.0	11.4	9.5	7.9	4.2	3.9	2.9	3.9

Table XXIII

Ammonia-Nitrogen
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	28.7	24.4	19.6	17.6	14.7	14.7	11.8	3.0	1.0	1.0
4-6-32	8.0	7.0	7.0	5.8	7.0	2.0	1.8	1.2	0.4	0.2
4-13-32	8.0	6.0	8.0	8.0	7.0	1.6	3.0	1.6	0.2	0.2
4-14-32	4.0	3.0	2.0	1.4	1.6	0.2	1.4	0.2	1.0	0.2
Average	12.2	10.1	9.2	8.2	7.6	4.6	4.5	1.5	0.7	0.4

Table XXIV

Ammonia-Nitrogen
Rate of Application: 3,700,000 gal. per acre per day.

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	12.0	10.0	9.0	8.0	7.0	4.0	9.0	2.0	0.9	0.2
4-21-32	12.0	10.0	10.0	9.0	9.0	4.0	6.0	4.0	1.0	0.2
4-27-32	12.0	12.0	11.0	10.0	13.0	10.0	6.0	5.0	10.0	6.0
4-28-32	12.0	12.0	11.0	11.0	12.0	10.0	5.0	4.0	10.0	1.0
5-2-32	10.0	12.0	11.0	12.0	9.0	8.0	4.0	6.0	4.0	1.0
5-5-32	8.0	10.0	6.0	8.0	6.0	4.0	4.0	2.0	2.0	0.2
Average	11.0	11.0	9.7	9.7	9.3	6.7	5.6	3.8	4.7	1.4

Table XXV

Nitrite-Nitrogen
Rate of Application: 4,660,000 gal. per acre per day.

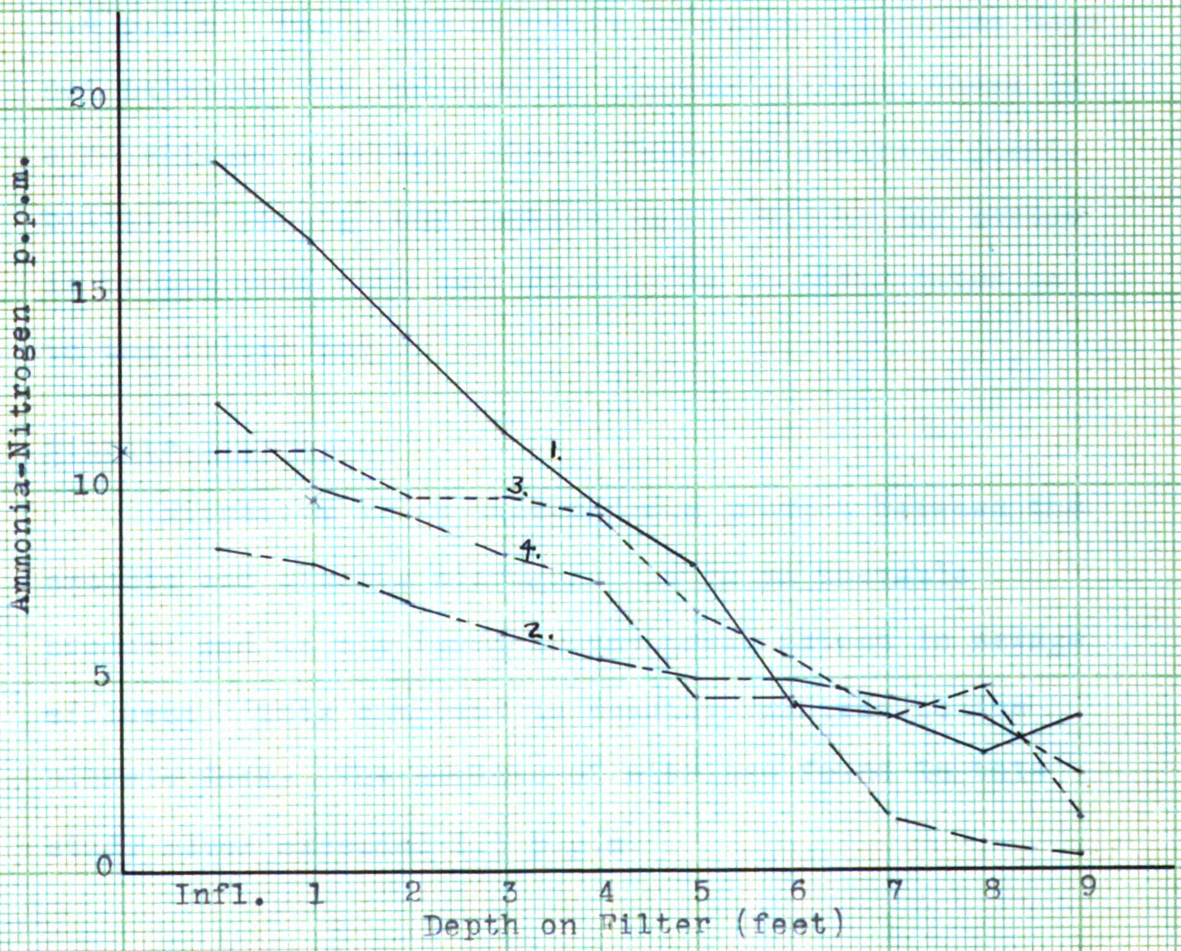
(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	0.2	0.3	0.5	0.5	0.5	0.4	0.4	0.5	0.4	0.5
1-13-32	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.7
1-20-32	0.8	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
1-27-32	0.1	0.8	0.4	0.3	0.3	0.3	0.4	0.4	0.2	0.3
Average	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.5

Fig. 6

Ammonia-Nitrogen

Rates of Application:
1. 1,480,000 gal./acre/day
2. 2,150,000 "
3. 3,700,000 "
4. 4,560,000 "



the influent decreased. This is rather surprising as the opposite would be expected.

Ammonia Nitrogen.

The reduction of ammonia nitrogen(Fig. 6) is quite uniform throughout the filter. During the low rate of application the ammonia nitrogen was highest in the influent, being 18.6 p.p.m. During the high rate of application the ammonia nitrogen was low, being 8.4 p.p.m. The effluent of the filter contained very little ammonia nitrogen. In some cases it was reduced to 0.4 p.p.m. While the decrease in ammonia nitrogen does not parallel the increase in nitrate nitrogen there is a relationship between them. There is always a possibility of losing some ammonia in the air as the sewage is broken into fine particles as it is distributed on to the filter bed.

Nitrite-Nitrogen.

Nitrite-N is an intermediate product between the ammonia and nitrate nitrogen. It is an unstable product and is not found to any great extent in sewage effluent. This compound is readily exidized to the nitrate form. The amounts of nitrites found in this study never exceeded 1.3 p.p.m.

Table XXVI

Nitrite-Nitrogen
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	0.0	0.1	0.5	0.3	0.2	0.5	0.2	0.1	0.1	0.0
2-10-32	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.1	0.1	0.1
2-17-32	0.1	0.4	0.5	0.3	0.3	0.2	0.2	0.2	0.1	0.1
Average	0.03	0.2	0.5	0.3	0.2	0.3	0.2	0.1	0.1	0.1

Table XXVII

Nitrite-Nitrogen
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	0.0	0.1	0.1	0.4	0.5	0.3	0.4	0.1	0.1	0.1
4-6-32	0.2	0.8	2.5	2.0	0.5	0.2	0.2	0.2	0.3	0.8
Average	0.1	0.4	1.3	1.2	0.5	0.3	0.3	0.1	0.2	0.5

Table XXVIII

Nitrite-Nitrogen
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	Tr.	Tr.	Tr.	0.5	0.5	0.5	0.5	0.1	0.2	0.4
4-21-32	Tr.	Tr.	Tr.	Tr.	Tr.	0.1	0.8	0.2	0.4	0.3
4-27-32	0.1	0.1	0.1	0.3	0.1	1.3	1.0	0.3	0.9	1.0
4-28-32	0.1	0.1	0.1	0.3	0.5	0.4	0.5	0.8	0.9	1.0
5-4-32	0.1	0.1	0.1	0.1	0.1	0.5	0.5	1.0	0.8	2.0
5-5-32	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.4	1.0	1.5
Average	0.1	0.1	0.1	0.2	0.3	0.6	0.6	0.5	0.7	1.0

Table XXIX

Nitrate-Nitrogen
Rate of Application: 4,660,000 gal. per acre per day.

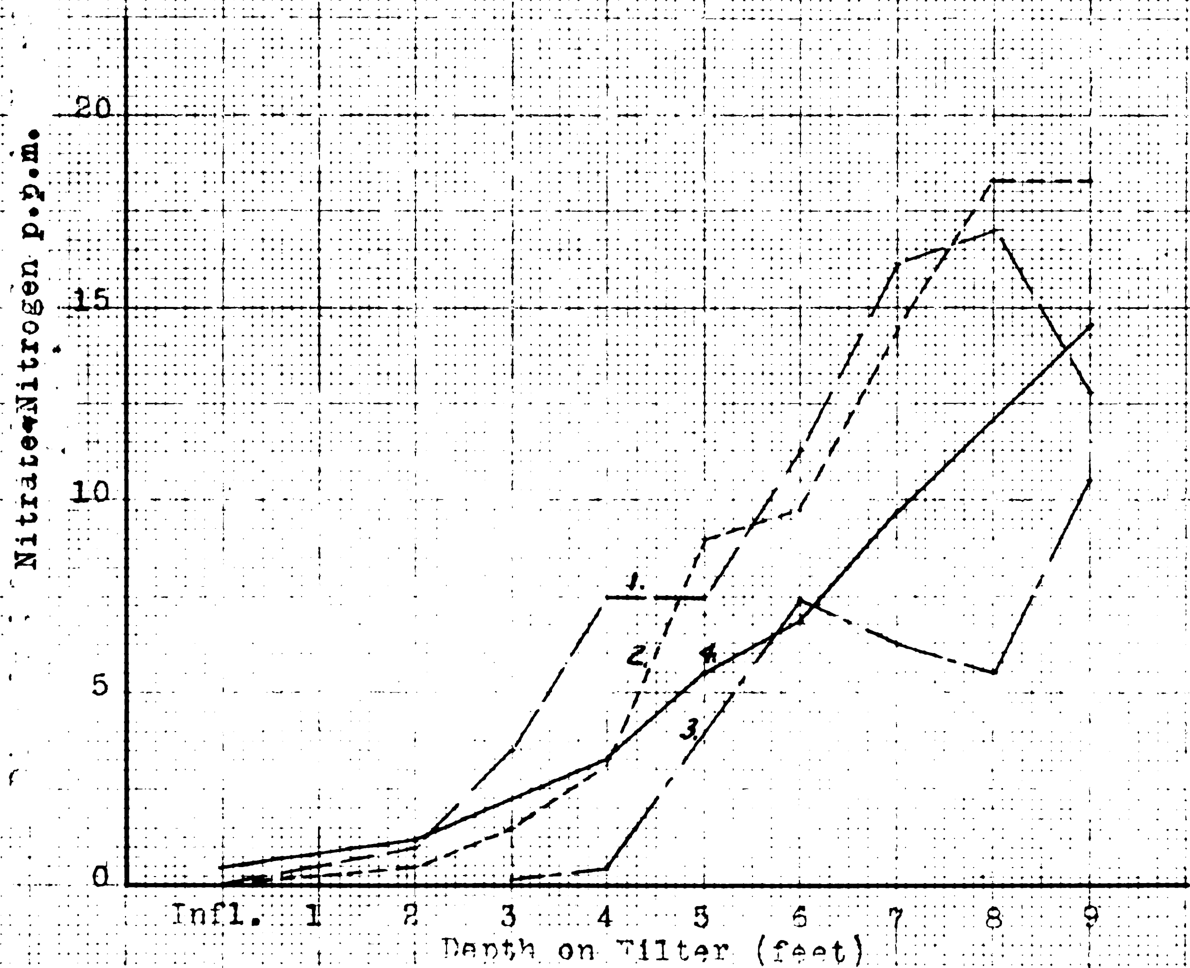
(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	0.0	0.9	2.1	3.0	4.0	9.0	9.0	9.9	12.0	15.0
1-13-32	1.5	2.0	1.6	3.0	5.0	6.0	7.0	11.0	14.0	16.0
1-20-32	0.6	0.6	1.1	1.9	1.9	4.0	6.0	9.0	11.0	13.0
1-27-32	0.0	0.0	0.5	1.5	1.8	3.0	5.0	9.0	11.0	14.0
Average	0.5	0.9	1.3	2.3	3.2	5.5	6.9	9.7	12.0	14.5

Fig. 7

Nitrate-Nitrogen

Rates of Application:
1. 1,480,000 gal./acre/day
2. 2,150,000 "
3. 3,700,000 "
4. 4,660,000 "



Nitrate-Nitrogen.

The formation of nitrates in the filter are divided into three groups: (1) the nitrification in the upper layers, (2) the nitrification in the middle portion of the filter, and (3) the nitrification in the lower layers of the filter. The production of nitrates in the upper layers of the filter is slow. Usually no nitrates were found until the sewage reached the depth of two feet. During the sloughing period the formation of nitrates did not take place until the sewage reached the depth of four feet. Denitrification occurred at intervals in the filter. It was most pronounced, however, during the beginning of the sloughing period. In the central portion of the filter there was a pronounced lag in the production of nitrates. In the lower depths of the filter the nitrate production increased rapidly. Nitrates as high as 21.0 p.p.m. were recorded during the lower rates of application. During the sloughing period the nitrates in the effluent dropped to as low as nine p.p.m.

Correlations.

Correlations were made between the dissolved oxygen, oxygen consumed, nitrate nitrogen, and the per cent reduction of B. O. D. to determine the cause of the

Fig. 8

Correlation of Percent Reduction B.O.D. and Temperature

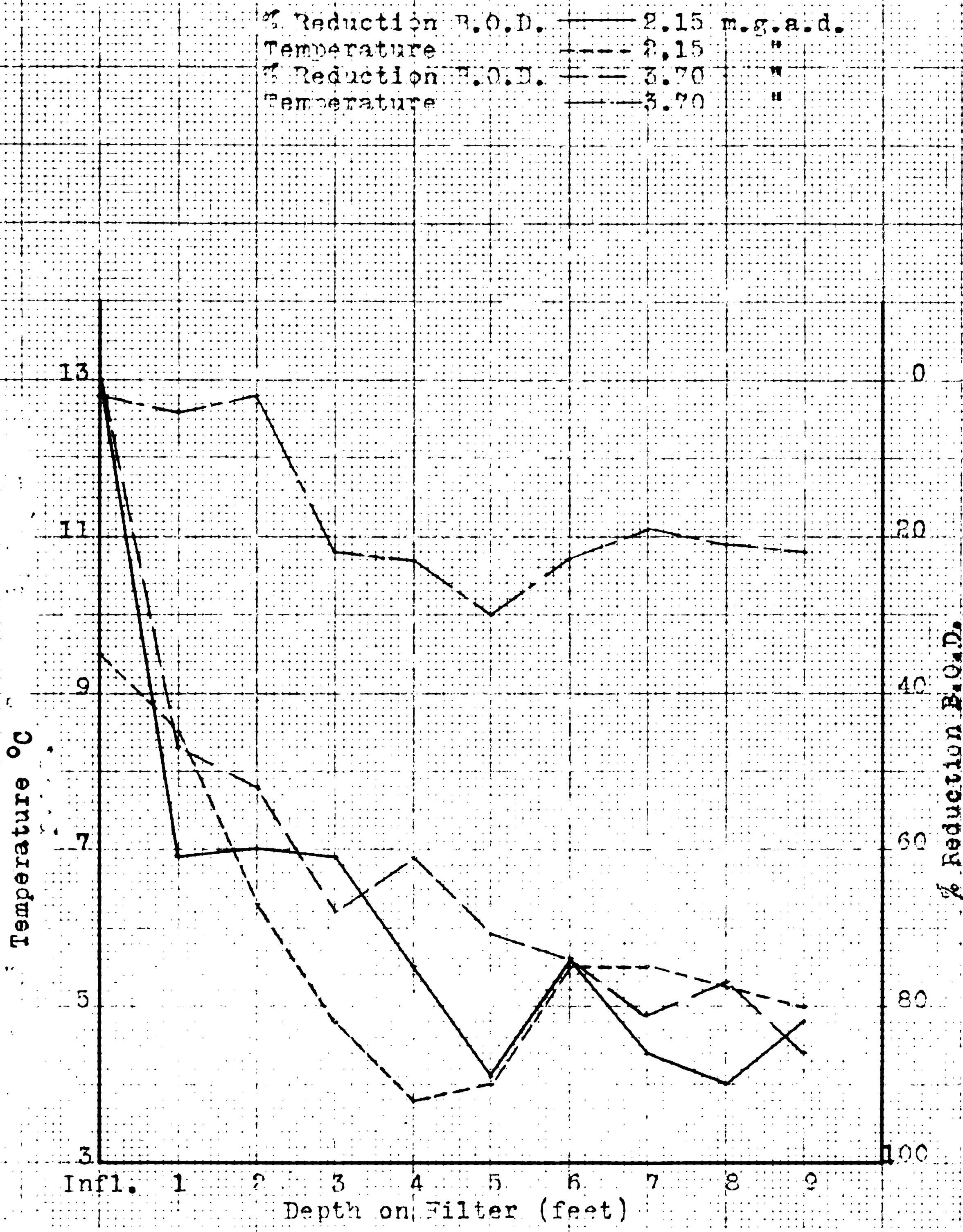


Table XXX

Nitrate-Nitrogen
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	0.0	0.0	0.0	4.0	6.0	1.6	9.0	9.9	14.0	14.9
2-10-32	0.0	0.0	0.0	0.5	7.9	9.0	11.1	19.7	16.1	5.0
2-17-32	0.0	1.6	2.9	6.1	9.0	12.0	14.0	18.1	21.0	19.0
Average	0.0	0.5	0.9	3.6	7.6	7.5	11.3	16.1	17.0	12.9

Table XXXI

Nitrate-Nitrogen
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	0.0	0.0	0.0	0.2	5.0	9.0	0.0	13.1	20.0	19.0
4-6-32	0.0	0.6	1.4	4.0	3.0	9.0	19.0	15.0	15.0	15.0
4-13-32	0.0	0.0	0.0	1.0	2.0	9.0	10.0	15.0	18.0	19.0
Average	0.0	0.2	0.4	1.4	3.5	9.0	9.7	14.4	18.3	18.3

Fig. 9

Correlation of B.O.D. Reduction, Dissolved Oxygen, Oxygen Consumed, and Nitrate-N.

Rate of Application; 4,660,000 gal./acre/day

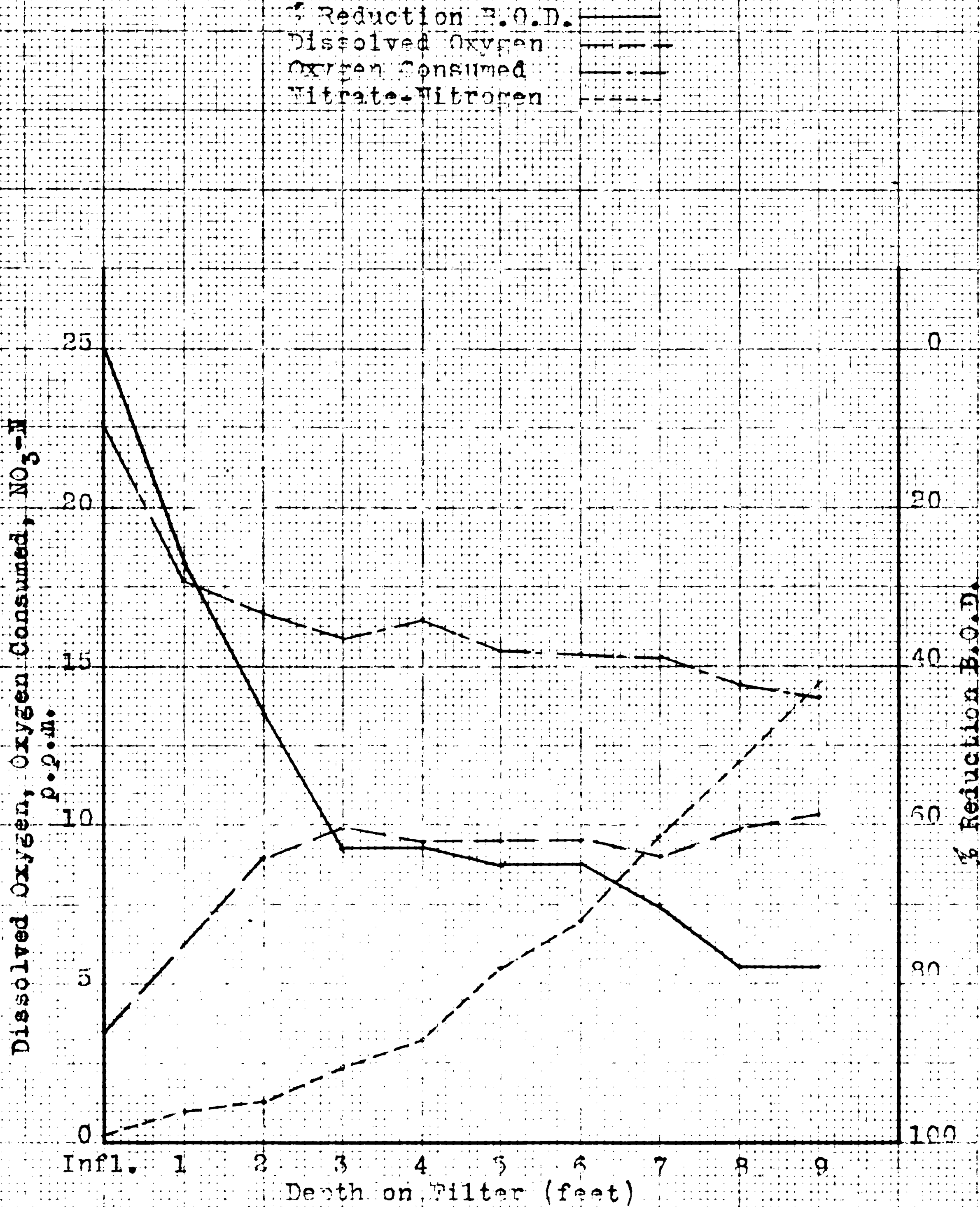


Table XXXII

Nitrate-Nitrogen
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	0.0	0.0	0.0	0.0	1.1	4.0	0.0	5.0	8.0	9.0
4-21-32	0.0	0.0	0.0	0.0	1.5	6.0	0.0	4.0	6.0	14.0
4-27-32	0.0	0.0	0.0	4.0	0.0	4.0	8.0	9.0	3.0	9.0
4-28-32	0.0	0.0	0.0	5.0	0.0	3.0	20.0	12.0	2.0	10.0
5-4-32	0.0	0.0	0.0	0.0	0.0	1.0	5.0	2.0	4.0	10.0
5-5-32	0.0	0.0	0.0	0.0	0.0	5.0	10.0	5.0	8.0	11.0
Average	0.0	0.0	0.0	1.5	0.4	3.8	7.3	6.2	5.5	10.5

Table XXXIII

Total Solids
Rate of Application: 4,660,000 gal. per acre per day.

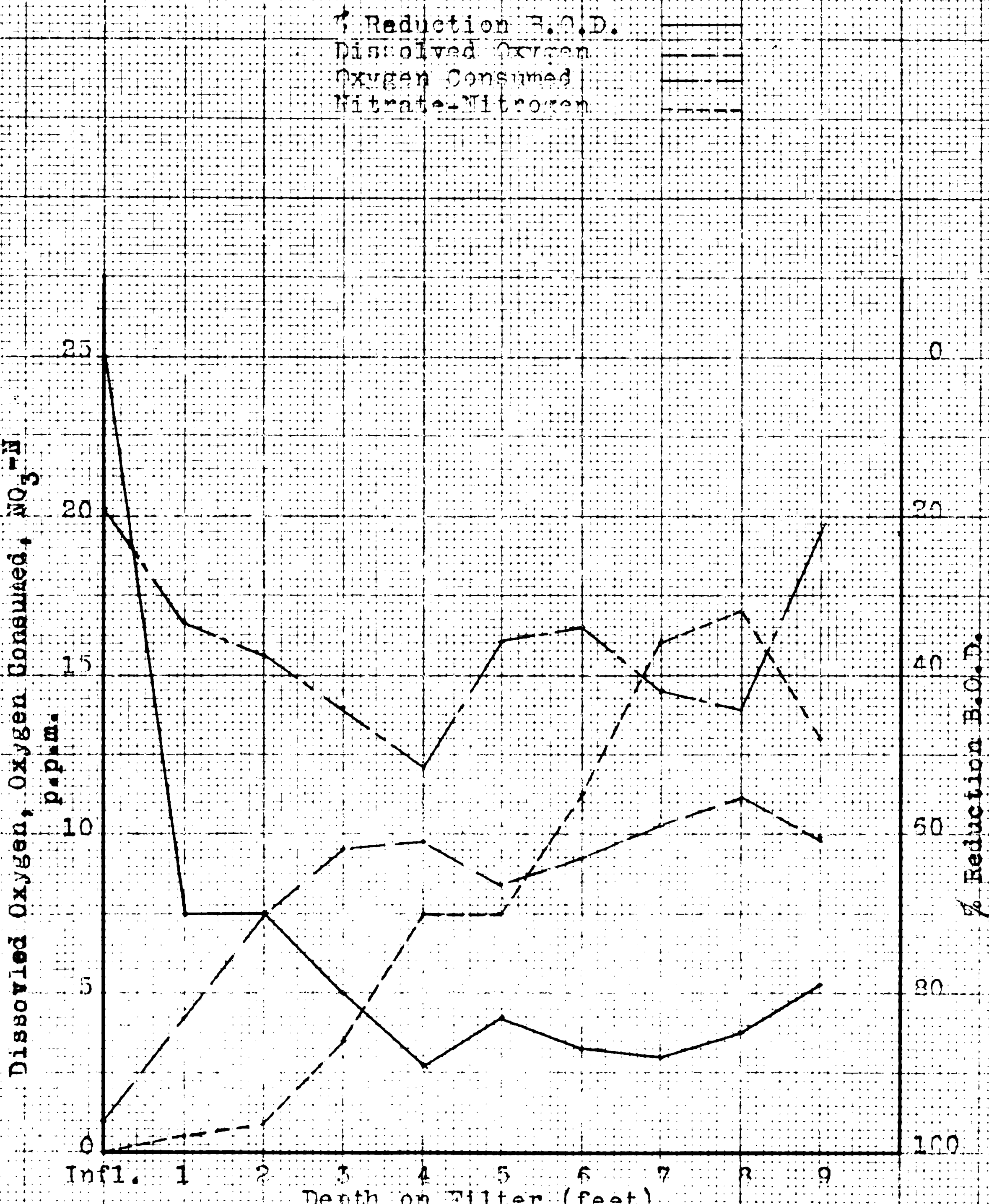
(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	864	576	640	610	580	544	660	558	620	604
1-13-32	798	600	640	605	590	700	620	678	632	660
1-20-32	926	856	798	868	840	838	924	848	788	964
1-27-32	934	690	722	798	802	718	802	780	918	896
Average	881	681	700	720	703	700	752	716	739	781

Fig. 10

Correlation of B.O.D. Reduction, Dissolved Oxygen, Oxygen Consumed, and Nitrate-N.

Rate of Application; 1,480,000 gal./acre/day



lag in efficiency in the central portions of the filter. The influence of these four factors was taken as most representative of the work done by a trickling filter. It is observed from this correlation that each of the four factors is related to the other. The lag of each of the factors occurring in the center of the filter is identical with the other three. It, therefore, appears that the center of the filter is not receiving as much air as the upper and lower layers. The reason for this deduction is that each of the factors used in this correlation needs air or oxygen to carry on the stabilizing process. There are many things which would correct this condition of lag in the center of the filter, a few of which are: shallower filter, larger stones with more voids, preaeration, different underdrainage, and using larger stones in the bottom of the filter and decreasing the size of the stones as the filter is built up. The maintenance of a higher temperature in the center of the filter would also aid in the efficiency of this portion. The sag in the temperature curve indicates that the organisms which aid in the work of the filter are made less active by the sudden drop in temperature. The rate of application has no effect on this lag in efficiency as is shown in Figures 9, 10, 11, and 12.

Fig. 11

Correlation of B.O.D. Reduction, Dissolved Oxygen, Oxygen Consumed, and Nitrate-N.

Rate of Application; 2,150,000 gal./acre/day

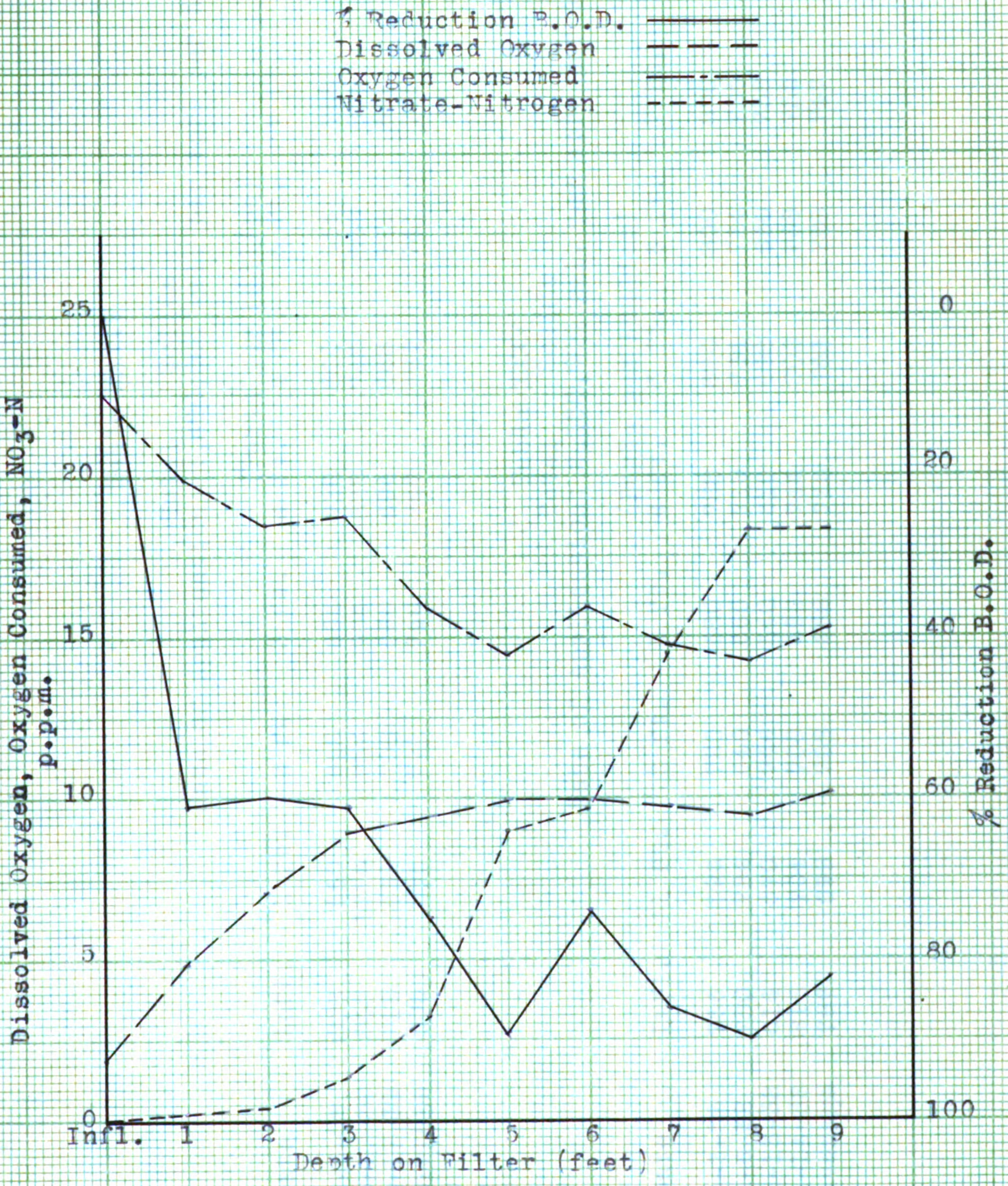


Table XXXIV

Total Solids
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	858	660	648	656	718	890	656	758	766	822
2-10-32	848	1276	956	904	838	742	838	854	796	802
2-17-32	712	632	708	660	694	668	728	652	668	694
Average	806	856	771	740	747	767	741	755	743	773

Table XXXV
Total Solids
Rate of Application: 2,150,000 gal. per acre per day.

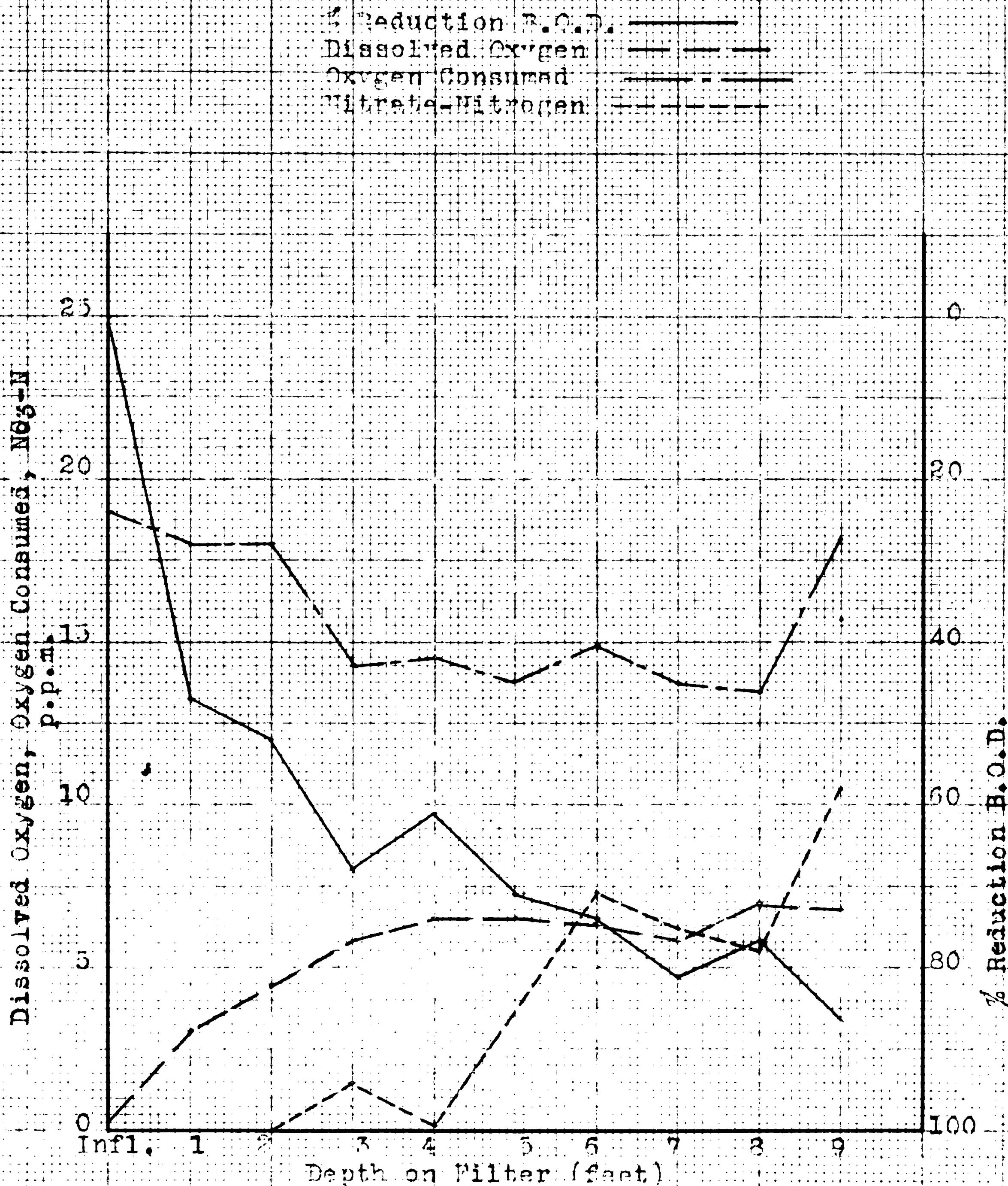
(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	756	696	720	680	788	820	800	800	754	774
4-6-32	780	724	640	660	718	734	724	724	720	760
4-13-32	614	670	746	640	610	692	620	732	752	724
4-14-32	816	704	700	690	744	802	768	732	708	840
Average	767	699	702	668	715	762	728	747	734	775

Fig. 12

Correlation of B.O.D. Reduction, Dissolved Oxygen, Oxygen Consumed, and Nitrate-N.

Rate of Application: 3,700,000 gal./acre/day



Solids.

In general, there is a marked reduction of total solids in the first foot of the filter; but as the sewage passes through the filter more solids accumulate so that there are more solids in the effluent of the filter, in some cases, than in the influent. This condition seems to indicate that the filter is continually sloughing off to a certain extent in the lower depths. The organic solids through the filter parallel the total solids. Approximately 60 per cent of the solids in effluents of the filter are organic. The average amounts of total solids in the influent average between 750 and 900 p.p.m. The amount of solids in effluent will average between 50 p.p.m. less and 50 p.p.m. more than that found in the influent. This same condition holds true for the organic solids.

The reduction of suspended solids in the filter is maximum at the four-foot depth. Approximately 90 per cent of the suspended matter is removed at this depth. As the sewage passes on through the filter, the amount of suspended solids builds up until there is only a reduction of about 50 per cent in the effluent. The average value of suspended solids in the influent was around 175 p.p.m.

Table XXXVI

Total Solids
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	824	594	652	722	640	924	784	664	2804	744
4-27-32	766	930	640	690	1150	1296	1110	912	3926	1176
5-4-32	750	780	1342	2280	1088	3120	1792	3390	2700	3200
Average	780	768	878	1231	959	1780	1229	1656	3143	1707

Table XXXVII

Loss of Ignition
Rate of Application: 4,660,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
1-6-32	400	288	180	396	280	136	160	240	404	480
1-13-32	466	378	420	398	370	352	330	380	432	520
1-20-32	594	566	452	520	540	550	534	518	474	652
1-27-32	564	420	410	460	440	370	422	406	554	572
Average	506	413	465	444	408	352	374	386	466	556

Table XXXVIII

Loss of Ignition
Rate of Application: 1,480,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
2-3-32	546	376	362	372	436	410	376	408	480	436
2-10-32	650	---	728	544	564	492	560	670	620	490
2-17-32	400	330	354	282	316	378	358	344	352	320
Average	532	353	481	399	435	427	431	477	484	415

Table XXXIX

Loss of Ignition
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
3-2-32	414	380	396	324	444	432	398	486	400	424
4-6-32	400	334	292	300	310	356	344	366	340	380
4-13-32	392	392	280	350	368	452	318	436	240	398
4-14-32	388	336	390	352	364	348	340	388	468	480
Average	399	361	339	332	372	397	350	419	362	421

Table XL

Loss of Ignition
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	360	332	320	352	300	384	342	336	726	370
4-27-32	492	528	368	400	500	486	610	352	1306	524
5-4-32	300	340	610	808	380	892	740	992	810	1100
Average	384	400	433	520	393	587	564	560	947	665

Table XLI

Suspended Solids
Rate of Application: 2,150,000 gal. per acre per day.

(Parts per Million)

Date	Infl.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-6-32	148	100	152	68	8	40	60	16	56	16
4-13-32	46	62	20	28	10	30	42	18	32	66
4-14-32	52	0	2	0	4	2	4	34	88	64
Average	82	54	58	32	7	24	35	23	59	49

Table XLII

Suspended Solids
Rate of Application: 3,700,000 gal. per acre per day.

(Parts per Million)

Date	Infl	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
4-20-32	140	42	22	18	20	74	96	46	2016	36
4-27-32	460	304	46	40	506	800	308	156	3310	522
5-4-32	120	224	664	1460	690	2140	1080	670	1592	2394
Average	240	190	244	506	405	1005	494	257	1306	984

Bacteria.

A few tests were made to determine the numbers of total bacteria and B. Coli in the influent and effluent of the filter. These few tests indicated that there is an increase in the number of total bacteria and a reduction of about 75 per cent in the B. Coli.

CONCLUSIONS

In drawing conclusions for a study of this kind it must be borne in mind that local conditions are largely a controlling factor in the results obtained. The results obtained on this experimental unit would indicate the following conclusions:

(1) The maximum B. O. D. reduction per foot of depth takes place in the first foot of the filter.

(2) The efficiency of a trickling filter is best measured by the reduction of B. O. D. loading expressed as pounds per acre per day.

(3) The reduction in B. O. D. varies with the internal temperature of the sewage in the filter.

(4) There is a tendency for an increase in alkalinity of the sewage as it passes through the filter.

(5) The carbonaceous material oxidizes more readily in the upper layers of the filter.

(6) The reduction in ammonia-N is proportional to the increase in nitrate-N.

(7) The production of nitrate-N does not as a rule take place in the upper layers of the filter.

(8) There is a relationship in the filter between the dissolved oxygen, oxygen consumed, nitrate-N, and B. O. D. reduction.

(9) There is no appreciable reduction of total or organic solids in this filter.

(10) Suspended solids in the effluent of this filter are reduced to 50 per cent of those in the influent.

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