EFFECTIVENESS OF A DEEP NATURAL SAND FILTER FOR FINISHING OF A SECONDARY TREATMENT PLANT EFFLUENT

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ABSTRACT

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When the Lake George Sewage Treatment Plant was constructed in 1939 it was described as a complete treatment plant. This was because the treated effluent was discharged onto natural sand seepage beds which were "at least 25 feet deep". In recent years, an increase in nutrient concentration has been noted at the south end of Lake George near Lake George Village. The object of this study was to determine if the treatment plant effluent had any effect on this increased nutrient concentration.

The original plan was to locate the ground-water table near the treatment plant and by use of a dye, trace the flow through the ground. It was found that the ground-water table was deeper than 56 feet and the natural sand beds were also greater than 56 feet in depth. Due to limited funds for well drilling exploration, the project scope was revised.

The new objective was to determine the removal efficiency of the sand beds with respect to coliforms, BOD, chlorides, and the nitrogen and phosphorus compounds.

It was found that when beds were dosed, they were no longer saturated at 15 feet. Ten feet of sand was found to remove coliforms by 99% and BOD by 96%. However, nitrates, phosphates, and chlorides remained in significant concentrations after filtration through 10 feet of sand.

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INTRODUCTION

When the Lake George Sewage Treatment Plant was constructed in 1939, it was described as a "complete treatment" plant (1). This is because the effluent after secondary treatment by trickling filtration followed by secondary sedimentation is discharged onto natural sand seepage beds which are "at least 25 feet" deep. (In this study one well was drilled to 56 feet where the same sand was still encountered).

Considerable efforts have been taken to preserve the natural purity of the waters within Lake George. It was for this reason that the extra effort was taken to provide this finishing treatment for the secondary treatment effluent from the Lake George Sewage Treatment Plant. The objective of this study was to determine the removal efficiency of the sand beds with respect to coliforms, BOD, chlorides, and the nitrogen and phosphorus compounds in order to try to determine whether or not any of these constituents could reach Lake George which is downstream surface-wise from the treatment plant.

GENERAL FIELD INFORMATION

Figure 1 shows the general layout of the treatment plant and the location of the sand beds and sampling wells. The plant consists of two primary settling and digestion tanks of the Imhoff type, three dosing tanks, three trickling filter beds, one rectangular with fixed nozzles which is covered in winter, and two circular with rotating arms, two circular and one rectangular secondary settling tanks, 20 natural sand seepage beds, a sludge pump house and three sludge drying beds. The effluent from the secondary settling tanks is not chlorinated before discharge onto the sand beds.

The services of a well driller were engaged to install the sampling wells in bed #11. Using a 6" auger, five holes were augered to depths of 5, 10, 15, 20 and 25 feet. (Fig. 1). A 1 1/4" galvanized steel well point (36" long, mesh #60, mesh length 30") was placed in each hole and the hole packed with sand.

Well points were driven manually to depths of 5 and 10 feet in beds #7 and #13 to compare their filtering efficiencies with bed #11. According to the plant operator who had been at the plant since its construction, bed #11 was a "fast bed" in that the water percolated away in a day or two. Bed #7 was extremely slow and once loaded would take more than a week to dry. Bed #13 was chosen because it had had only limited use since the plant was built. This was because the control valve to load this bed is accessible only through a manhole. Valves for the other beds are operated from above ground.

The plan was to saturate the bed with sewage effluent and then pump the wells and determine the filtering efficiency of the sand with depth. Bed #11 was used continuously for over two weeks. Normally it is loaded weekly from Friday through Sunday. It was possible to obtain samples from only the 5 and 10 feet wells, which indicates that the bed is no longer saturated at 15 feet.

METHODS AND PROCEDURES

A. Sample Collection

After well points had been installed and a filter bed flooded, the wells were developed to remove the fine sand from the area around the point. This was accomplished by pumping the wells at the maximum rate for about 60 minutes.

Samples were collected by pumping a well at its maximum rate (approximately 4.5 gpm for a 5 foot well and 1.3 gpm for a 10 foot well) for about

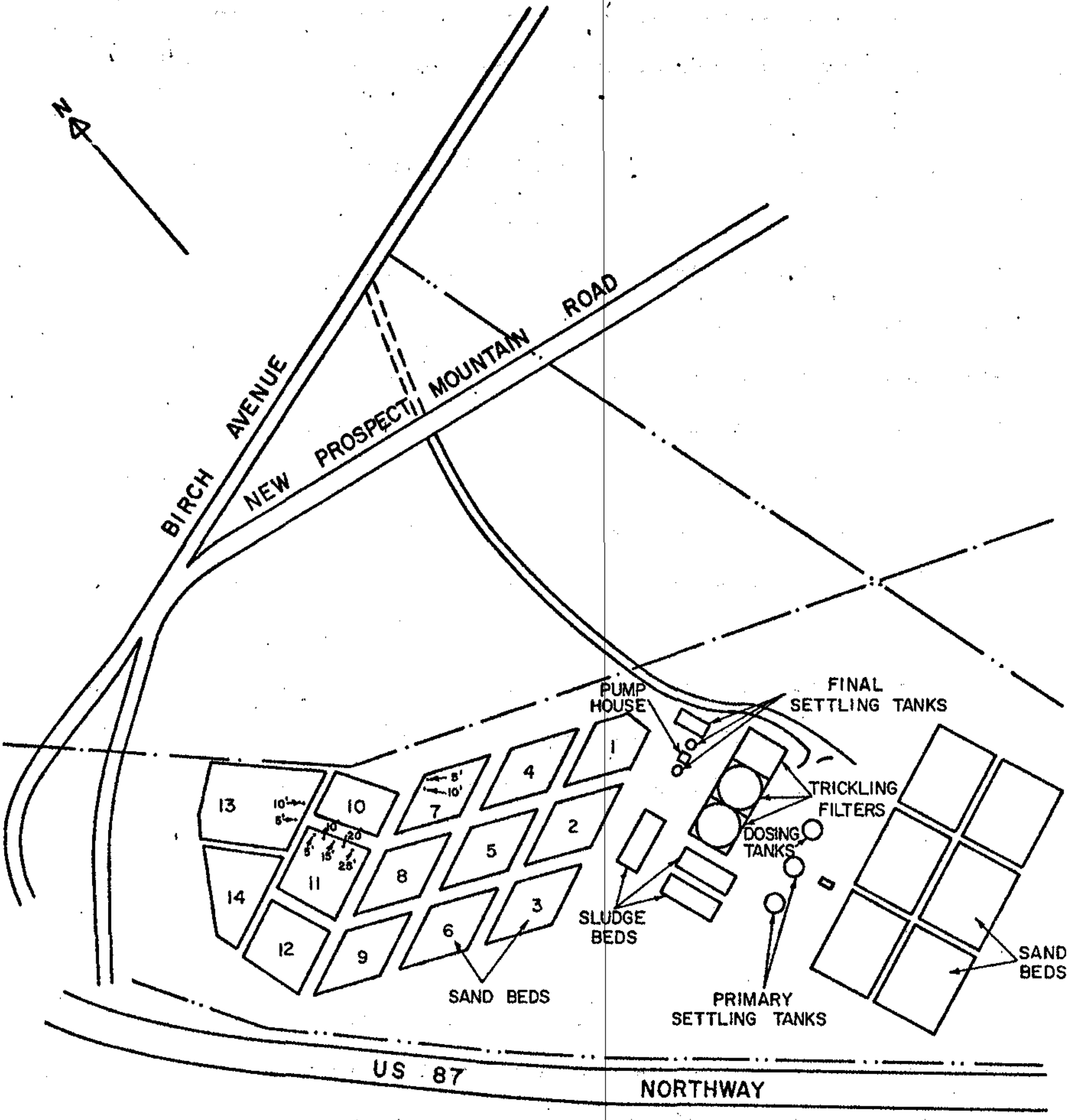

N
BIRCH AVENUE
NEW PROSPECT MOUNTAIN ROAD
PUMP HOUSE
FINAL SETTLING TANKS
TRICKLING FILTERS
DOSING TANKS
SLUDGE BEDS
PRIMARY SETTLING TANKS
SAND BEDS
SAND BEDS
1
2
3
4
5
6
7
8
9
10
11
12
13
14
8'
10'
10'
8'
5'
10
15'
20
25'
US 87
NORTHWAY

FIGURE 1

10 minutes and then collecting the sample in a clean polyethylene gallon bottle. The bottles were rinsed several times with the well water before taking the sample. The bottles were then taken to the laboratory where they were refrigerated until analyzed. Normally the analysis was completed within two days.

The collection of samples had to be incorporated with the daily operation of the treatment plant. Normally the beds were used only once a week and sometimes only once every two weeks. Cooperation of the treatment plant personnel was obtained so that bed #11 was flooded from June 14 through July 1, and beds #11 and #13 from July 18 through July 25.

B. Laboratory Analyses

The analyses for coliforms, BOD, chloride, organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, and orthophosphate were performed in accordance with Standard Methods (2). The method used in the determination of total phosphate and polyphosphate is described on page 719 of International Journal of Air & Water Pollution (3).

EXPERIMENTAL RESULTS AND DISCUSSION

No water samples were ever obtained from bed #7. It was covered with effluent for over two weeks, yet the bed never became saturated to a depth of 5 feet and thus no samples could be obtained. This bed is reported by the plant personnel to contain considerable amounts of clay. This could explain the slow percolation rate of the bed and the subsequent inability to obtain water samples.

No attempt was made to determine the volume of effluent placed on the beds. The plant had a master meter which indicated a flow of 250,000 to 750,000 gpd during the period of this study.

No samples were able to be secured from the 15, 20 and 25 feet depths in bed #11. This is because the sand was no longer saturated beyond this depth. Therefore, even though the bed was loaded for over two weeks with water standing on the surface, the water broke up into droplets between the 10 and 15 feet depth, and the bed was aerobic below that depth.

The number of samples analyzed did not allow for a comprehensive statistical analysis. Some sample analyses showed a wide range of variation and the mean value would not give a true representation of the data. It was felt that the median value (the magnitude of the middle observation of an array) would be the most representative value in making comparisons and drawing conclusions.

A. Coliform Removal

The results of the coliform analyses are tabulated in Table 1. Figure 2 indicates that the median coliform concentration drops off rapidly in the first 5 feet of sand. In bed #11 the coliform reduction is from 970 to 46/100 ml, while in bed #13 the reduction is from 1260 to 20/100 ml.

A good comparison between beds #11 and #13 can be seen in Figure 3, where the median percent removal is plotted vs. depth of the filter beds. Bed #11 which is used routinely, removed 95.3% of the coliforms in 5 feet. Bed #13 which is used rather sparingly, removed 98.4% of the coliforms in first 5 feet. The total percent removal for the two beds in 10 feet is 99.3% (bed #11) and 99.9% (bed #13). Although bed #11 has slightly less capacity for coliform removal in the first 5 feet, its overall removal in 10 feet approaches that of bed #13, with both beds having greater than 99% removal.

The results here agree with similar findings by Calaway, et al. (4), who state that the greatest number of coliforms occur in the surface level of the sand, with this being best explained by the character of the sand at this level. The surface sand screens out the larger organic particles during filtration and this organic matter forms a matted layer which acts as a highly retentive filter and aids in coliform removal. However, in addition to this mat that forms, the sand filtering capacity itself has an appreciable effect on coliform removal.

There appears to be no appreciable effect on the overall coliform removal efficiency when a bed is used for extended periods of time. Bed #11 was in continued use from June 14 through July 1 with the efficiency being 98% for the July 1 sample. Bed #13 was used continually from July 18 through July 25 and the removal efficiency remained greater than 99%.

TABLE I

Coliform Concentration (#/100 ml) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	86	19	78.0	<1	>99.0
6/20	11	900	240	73.3	4	99.6
6/26	11	50	46	8.0	8	84.0
7/1	11	1040	33	96.8	20	98.0
7/8	11	1320	160	88.0	9	99.3
7/23	11	*	160	--	*	--
7/25	11	1200	20	98.3	10	99.2
(Median)		970	46	95.3	8	99.3
7/8	13	1320	2	99.8	<1	>99.9
7/15	13	2400	24	99.0	<1	>99.9
7/19	13	600	6	99.0	<1	>99.8
7/23	13	*	240	--	*	--
7/25	13	1200	20	98.3	6	99.5
(Median)		1260	20	98.4	<1	>99.9

*Count was outside the recommended range.

FIGURE 2

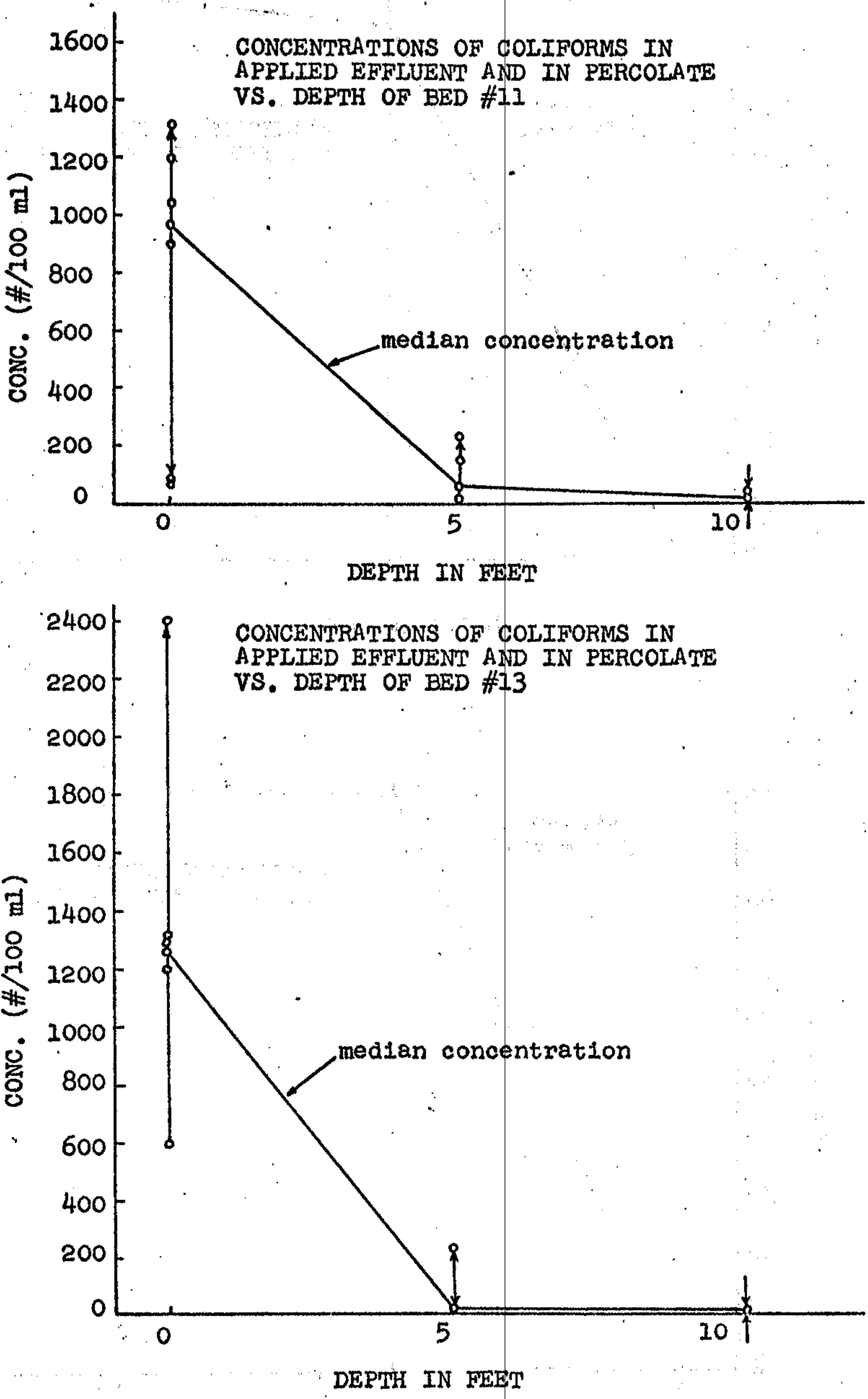
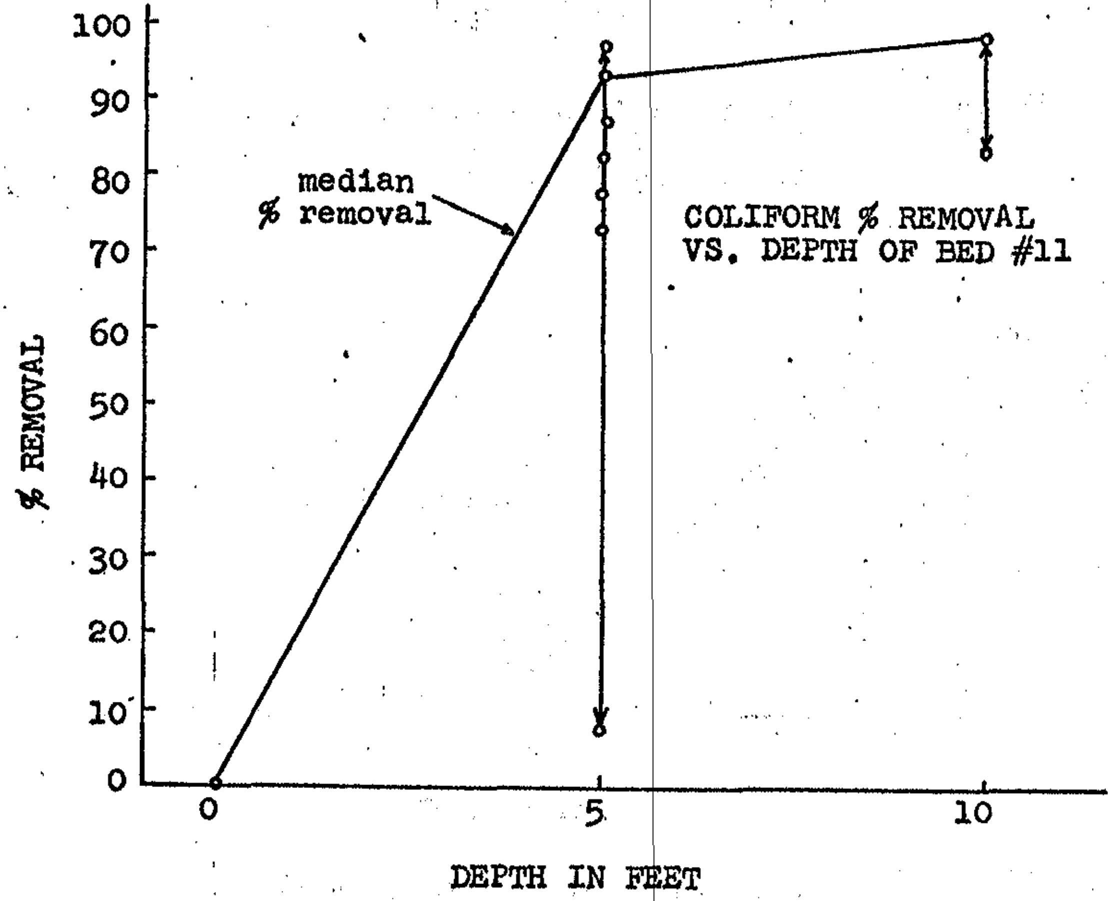
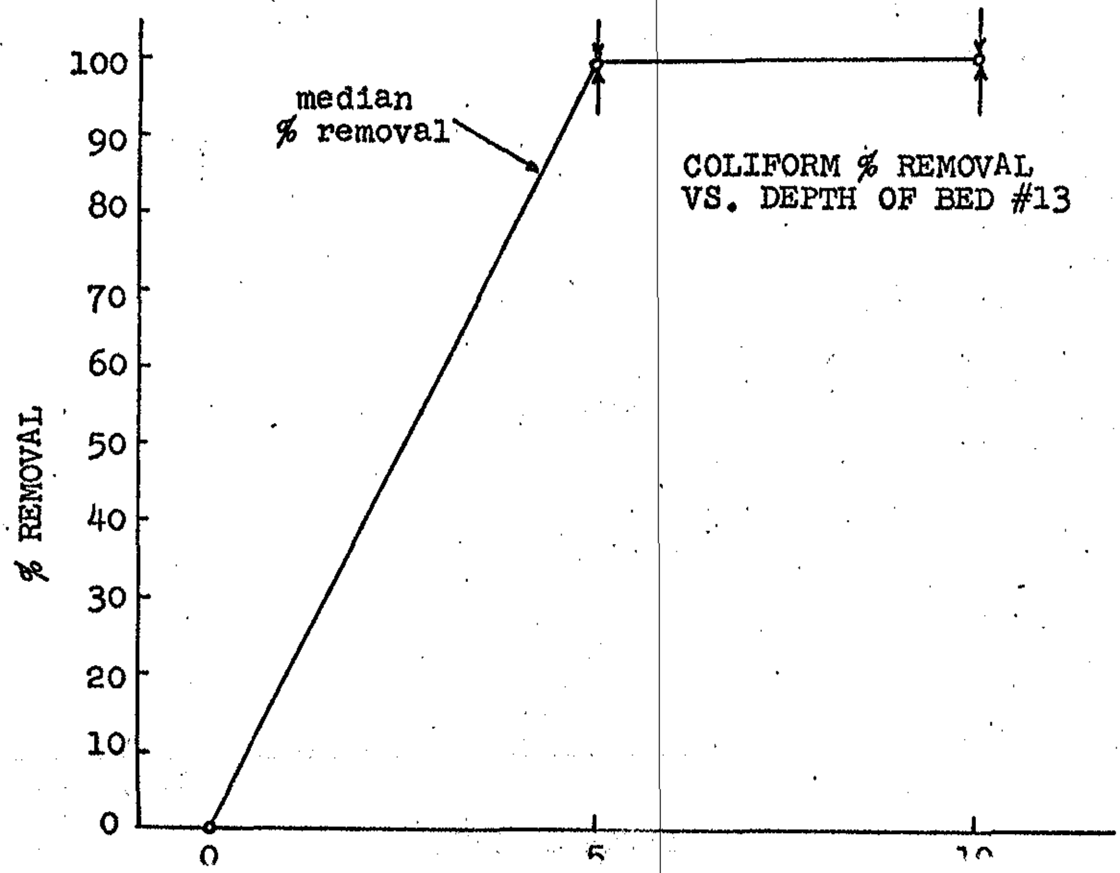

CONCENTRATIONS OF COLIFORMS IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11
CONC. (#/100 ml)
1600
1400
1200
1000
800
600
400
200
0
median concentration
0
5
10
DEPTH IN FEET
CONCENTRATIONS OF COLIFORMS IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13
CONC. (#/100 ml)
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
median concentration
0
5
10
DEPTH IN FEET

FIGURE 3


100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
median
% removal
COLIFORM % REMOVAL
VS. DEPTH OF BED #11
0
5
10
DEPTH IN FEET


100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
median
% removal
COLIFORM % REMOVAL
VS. DEPTH OF BED #13
0
5
10

Almost all coliform organisms were removed from the percolate in the vertical travel through 10 feet of sand. The applied effluent was not chlorinated which demonstrates that a sand bed removes coliforms very well and assumedly other bacteria of fecal origin. In all probability, coliforms would be further removed by deeper percolation, therefore, the sand bed proves to be an effective method for removing coliform organisms.

B. BOD Removal

The results of the BOD analyses appear in Table II. Figure 4 shows that the median BOD concentration drops sharply in the first 5 feet and continues to drop, at a slower rate, in the next 5 feet. The decrease is 38.5 to 7.5 to 1.45 mg/l BOD in bed #11 and 46.0 to 6.8 to 1.2 in bed #13. Figure 5 indicates the median percent removal for the two beds. Overall removal in 10 feet is just about the same for both beds, namely 96.2% for bed #11 and 97.4% for bed #13. As in the case of coliform removal, there is no noticeable effect upon BOD removal due to continuous loading of the beds. Furman, et al. (7) reported similar results. In their study they found that even though the organic loading rate was sufficient to clog the interstices of the surface sand, they were able to obtain 80 to 95% removal. Since there is no difference in degree of removal between the two beds studied, the bed efficiency is apparently not a function of their use over the past years.

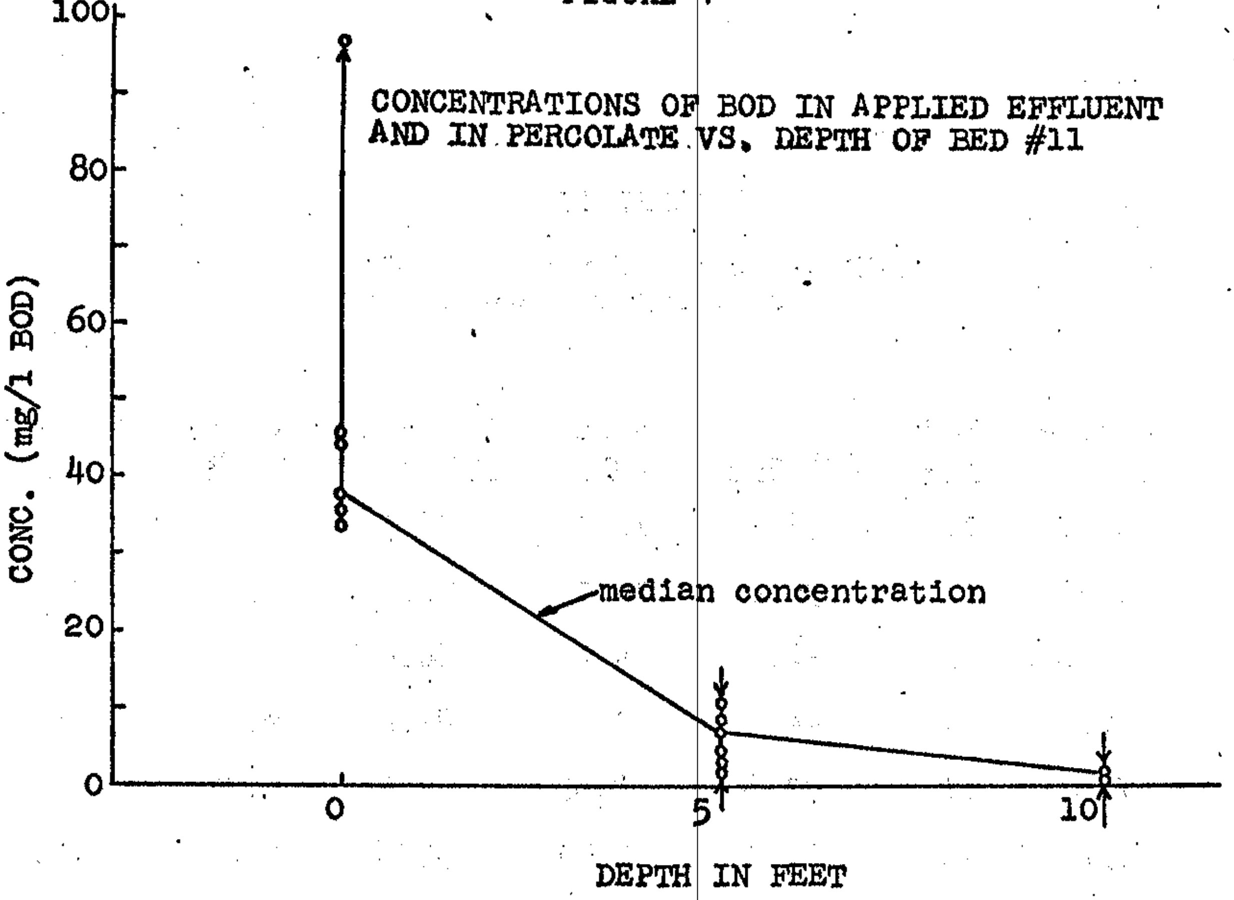
Sawyer (6) defines BOD, biochemical oxygen demand, as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. It is anticipated that the BOD removal will primarily be a function of biological activity, which is mainly dependent on nutrient concentration, number of organizms present, and temperature. Of secondary importance will be the physical characteristics of the bed. If physical removal were a primary factor, clogging of the filters would occur. However, no clogging problems have ever been encountered with these two beds. Biological metabolism by the microorganisms keeps clogging material to a minimum. Further, if the removal were more a filtering process, nearly all the reduction would occur on the surface of the filter. The physical

TABLE II

BOD Concentration (mg/l BOD) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	38.5	11.0	71.5	0	100.0
6/20	11	36.8	10.7	71.3	1.95	94.7
6/26	11	34.2	4.8	86.0	1.0	97.0
7/1	11	44.9	7.5	83.2	2.35	94.7
7/8	11	97.8	8.43	92.4	2.37	97.6
7/23	11	37.9	2.41	93.6	0.8	98.0
7/25	11	46.0	3.1	93.2	1.45	97.0
(Median)		38.5	7.5	80.5	1.45	96.2
7/8	13	97.8	2.10	98.0	1.21	99.0
7/15	13	46.1	10.5	77.1	0.60	98.5
7/19	13	30.1	12.1	59.7	0.25	99.2
7/23	13	37.9	6.81	82.0	3.13	92.0
7/25	13	46.0	4.34	90.7	1.83	96.0
(Median)		46.0	6.81	85.2	1.21	97.4

FIGURE 4


CONCENTRATIONS OF BOD IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11

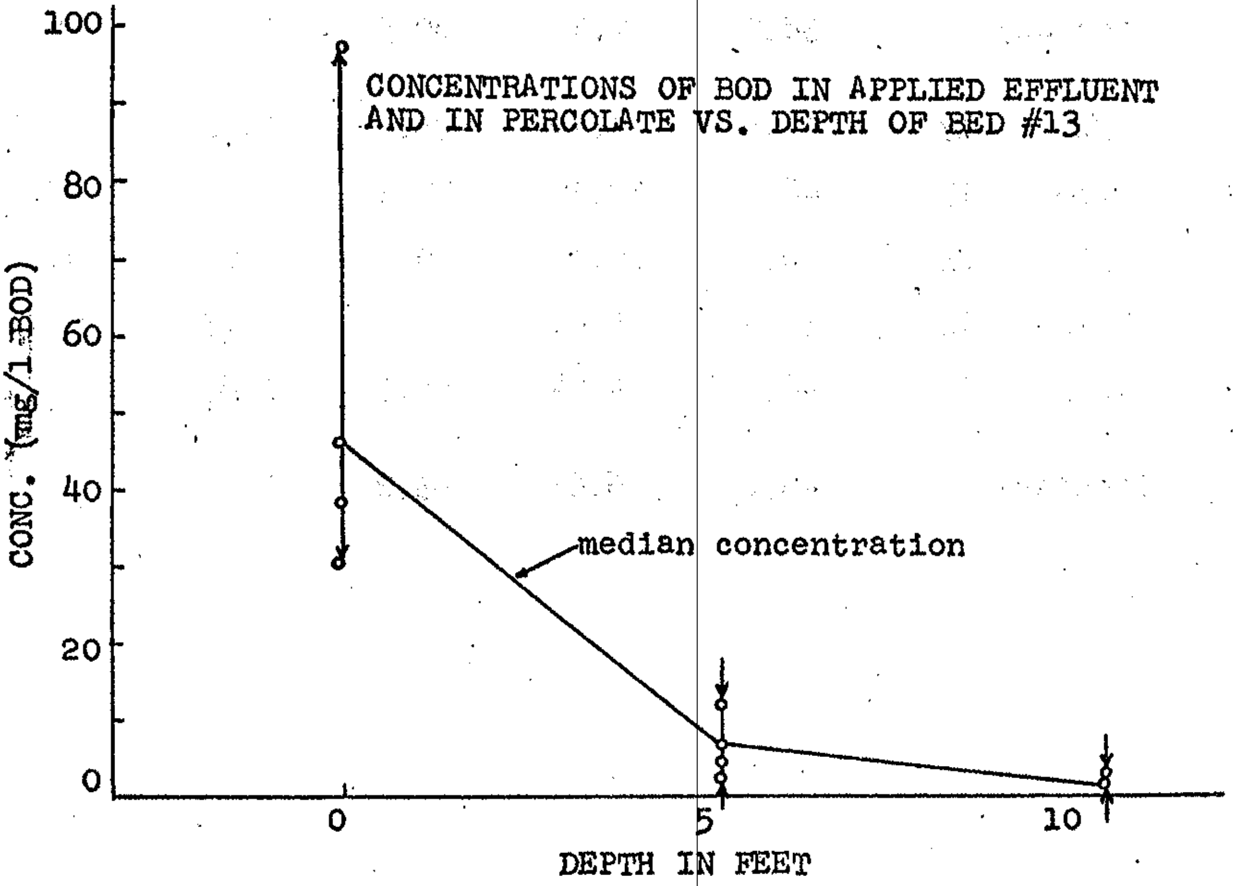
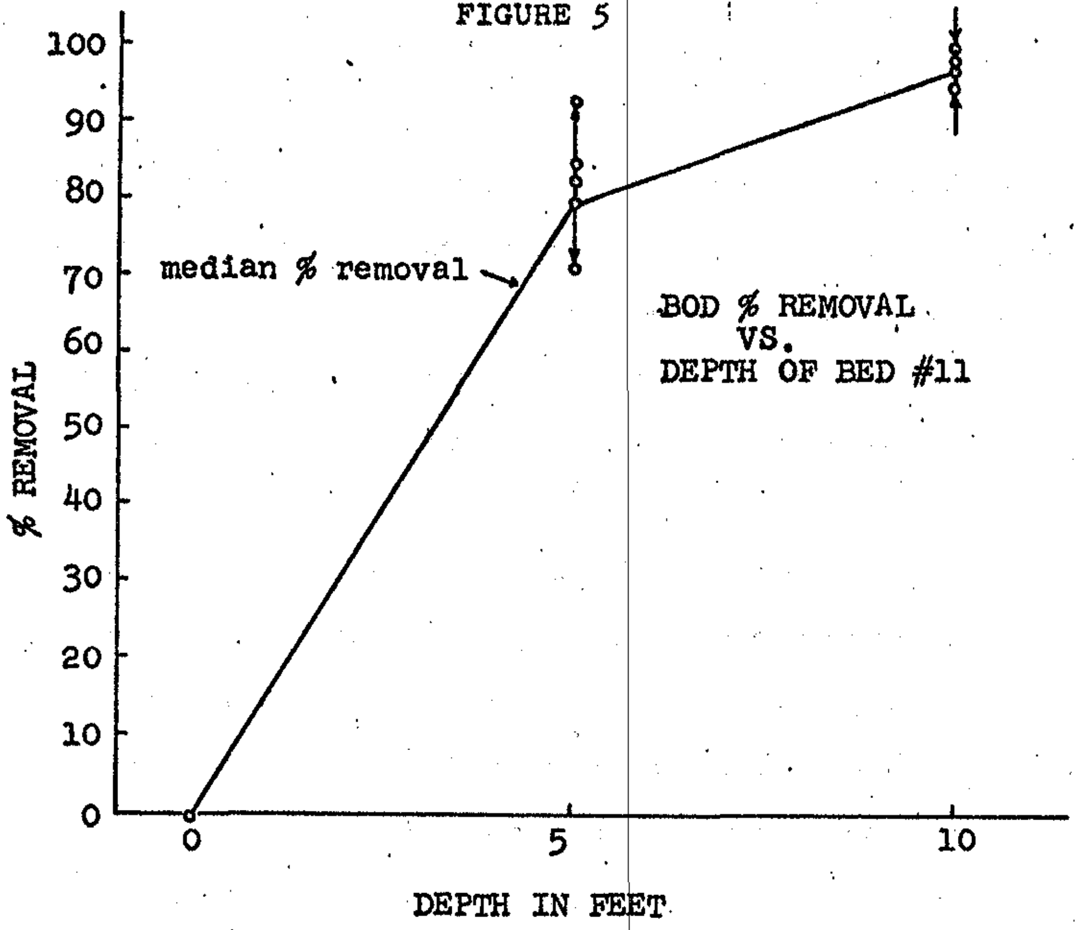
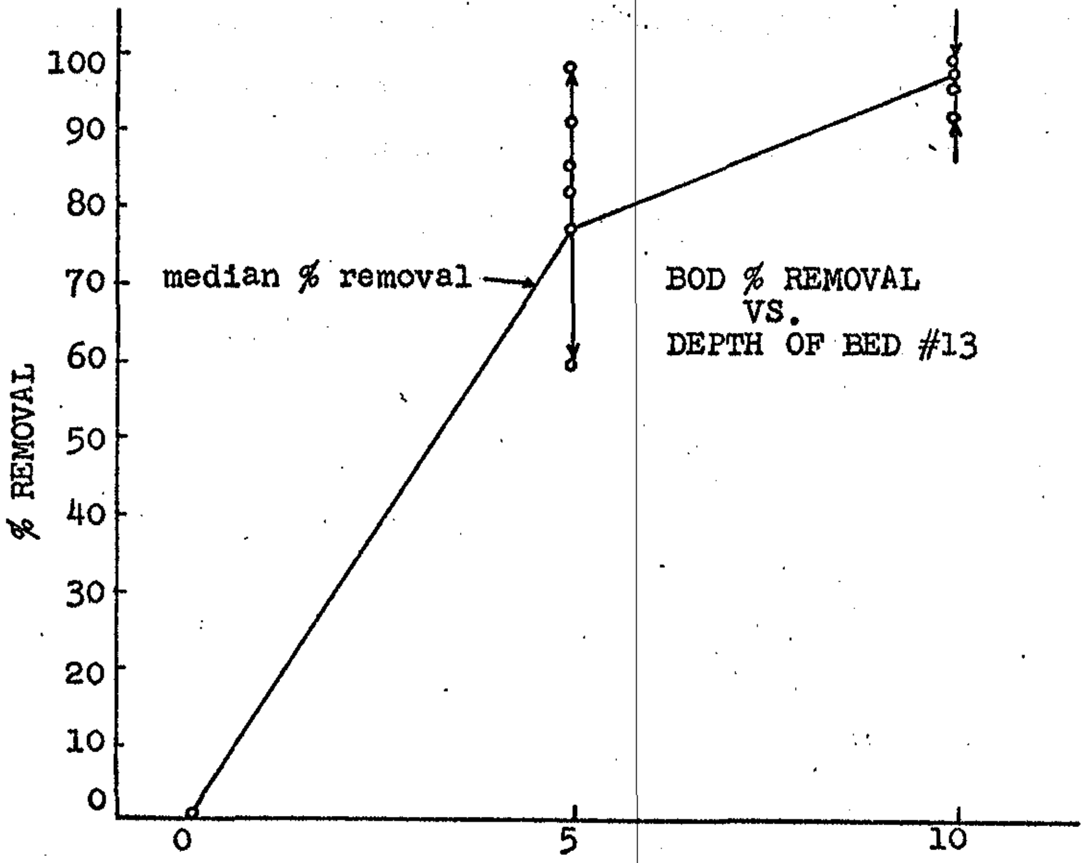

CONCENTRATIONS OF BOD IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13

FIGURE 5


100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
0
5
10
DEPTH IN FEET
median % removal
BOD % REMOVAL
VS.
DEPTH OF BED #11


100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
0
5
10
median % removal
BOD % REMOVAL
VS.
DEPTH OF BED #13

characteristics of the sand are important in that the sand adsorbs or traps the organic matter and provides the habitat on which organisms can live while they decompose the organic matter.

Since BOD removal is primarily an aerobic process and the majority of BOD removal was in the upper layers of the filter bed, there must be a source of oxygen available. D.O. studies at depths of 2, 4, 6 and 8 feet at the Rio Hondo test basin (6) on similar sand showed that oxygen was available in the percolate throughout the sampling depth. Although dissolved oxygen tests were not performed in this study, there are two possible sources of oxygen. One would be the initial D.O. of the effluent; the other would be the air in the bed before loading. Upon loading, the air is dissolved by the water and becomes available for the organisms to use in their metabilism. Since the beds were not saturated with water at 15 feet and below, there is some supply of air available to move upward into the upper water saturated area. This air may possibly come underground from adjacent beds which are not being loaded. It would also enter the beds when they are not being dosed, thereby indicating the desirability of alternate dosing and resting of the beds. Thus the void spaces between sand grains are essential to air movement. To prove the above hypothesis, D.O. determinations should be made at various depths to determine the D.O. levels.

C. Chloride Concentrations

The results of the chloride analysis are shown in Table III. Figure 6 shows that the median chloride concentration varied only slightly as the percolate moved through the filter beds. There was no distinguishable difference between beds #11 and #13 with respect to chloride concentration at the 5 and 10 feet depths.

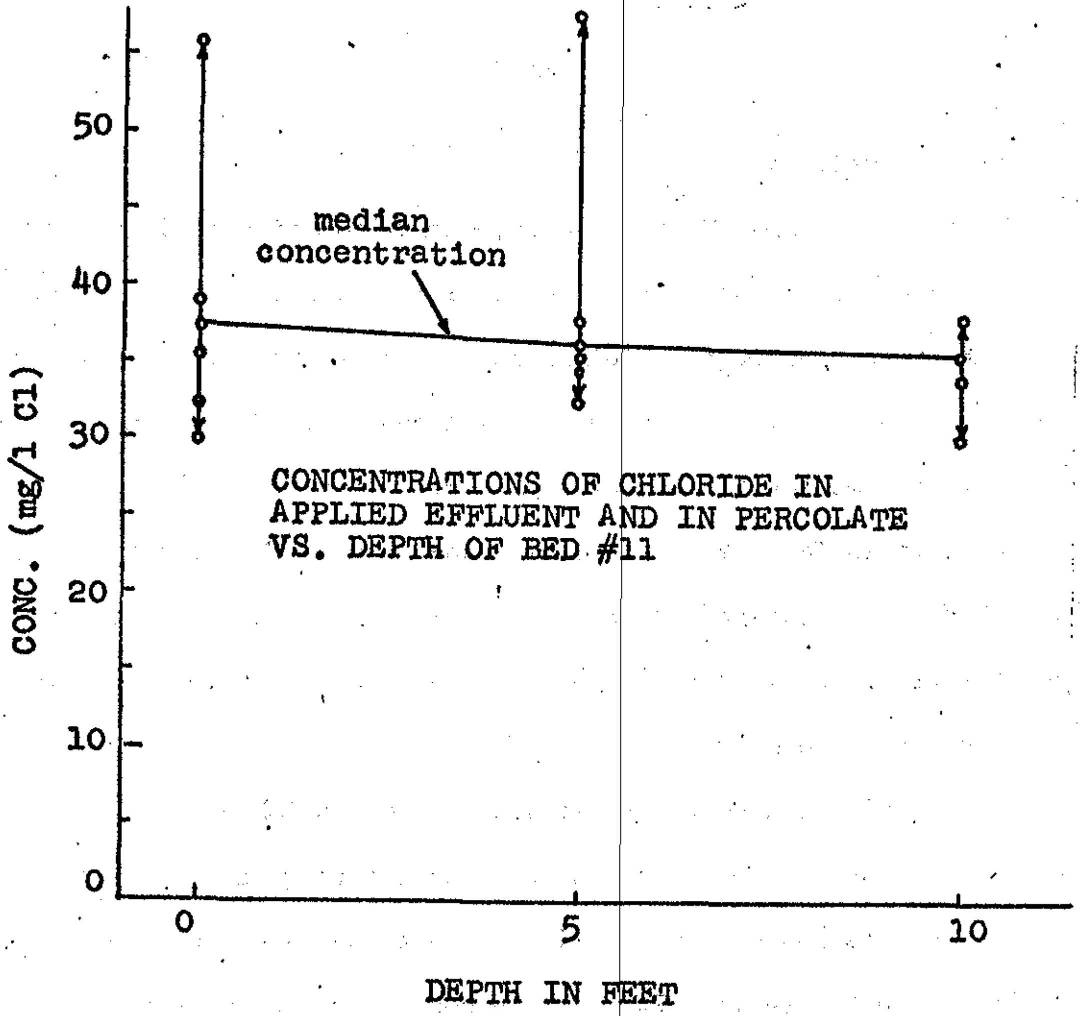
These results confirm those of others (8,9), namely that chlorides are not removed from water that percolates through soil or sand. Where vegetation is present, once can expect some chloride removal by absorption through the roots of vegetation.(8) However, there is no vegetation present in these sand beds.

TABLE III

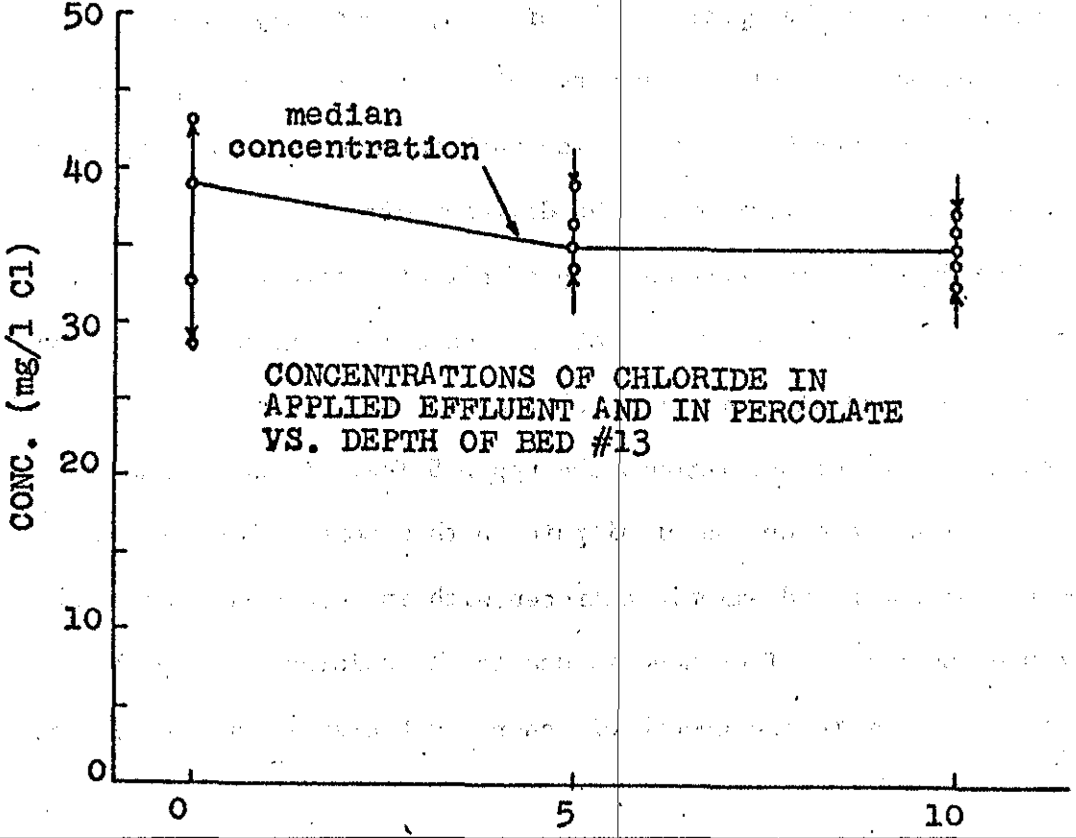
Chloride Concentration (mg/l Cl) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	38.0	36.5	4.0	35.5	6.6
6/20	11	37.5	37.5	0	30.0	20.0
6/17	11	35.5	36.5	- 2.8	38.0	- 7.0
6/20	11	30.0	37.5	-25.0	37.5	-25.0
6/26	11	56.0	32.5	42.0	35.5	36.6
7/1	11	32.5	58.0	-78.5	34.0	- 4.6
7/8	11	39.0	35.5	9.0	34.0	12.8
7/23	11	39.0	38.0	2.6	37.0	5.1
7/25	11	32.5	35.0	- 7.8	37.5	-15.4
(Median)		37.5	36.5	2.8	35.5	5.3
7/8	13	39.0	33.5	14.1	37.0	5.1
7/15	13	28.5	35.0	-22.8	32.5	-14.0
7/19	13	43.0	35.0	18.6	36.0	16.3
7/23	13	39.0	39.0	0	35.0	10.2
7/25	13	32.5	36.5	-12.3	34.0	- 4.6
(Median)		39.0	35.0	10.3	35.0	10.3

FIGURE 6



CONCENTRATIONS OF CHLORIDE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11



CONCENTRATIONS OF CHLORIDE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13

D. Nitrogen Analyses

The data in Table IV show the concentrations of organic nitrogen in the applied effluent and in the percolate at 5 and 10 feet. Figures 7 and 8 show that organic nitrogen is diminished by more than 82% in percolation through the upper 5 feet of sand beds #11 and #13. Further percolation to 10 feet increases the total median percent removal to 100%.

The data in Table V and Figures 9 and 10 show that ammonia nitrogen is diminished in the two beds by more than 19.5% in percolation through the upper 5 feet of sand. Further percolation to 100 feet increases the total median percent removal to 79%.

Nitrite nitrogen concentrations are shown on Table VI. The values are very low and can be considered insignificant throughout the depth of sampling.

The results on the nitrate nitrogen analyses are tabulated in Table VII and plotted in Figure 11. The nitrate content varied appreciably from day to day. Although in several of the samples there was a decrease of nitrate nitrogen through the upper 5 feet of sand, especially in bed #11, nitrification was the predominant effect in percolation from the 5 to 10 foot depth. As there is no measurable reconversion back to ammonia nitrogen, it can be assumed that nitrification is the dominant effect.

The decrease in concentration of nitrate nitrogen through the upper 5 feet of sand can be due to the absence of a large number of nitrifying bacteria in this zone and also, to the fact that the BOD seems to be exerted within a few hours in seepage through the upper 5 feet of sand. Adsorption could also help in the decrease of nitrate in this zone. The overall decrease of organic nitrogen and ammonia nitrogen with increased concentrations of nitrates through the 5 to 10 feet zone is due to the existence of aerobic conditions in this zone or to the growth of anaerobic bacteria capable of nitrification.(10

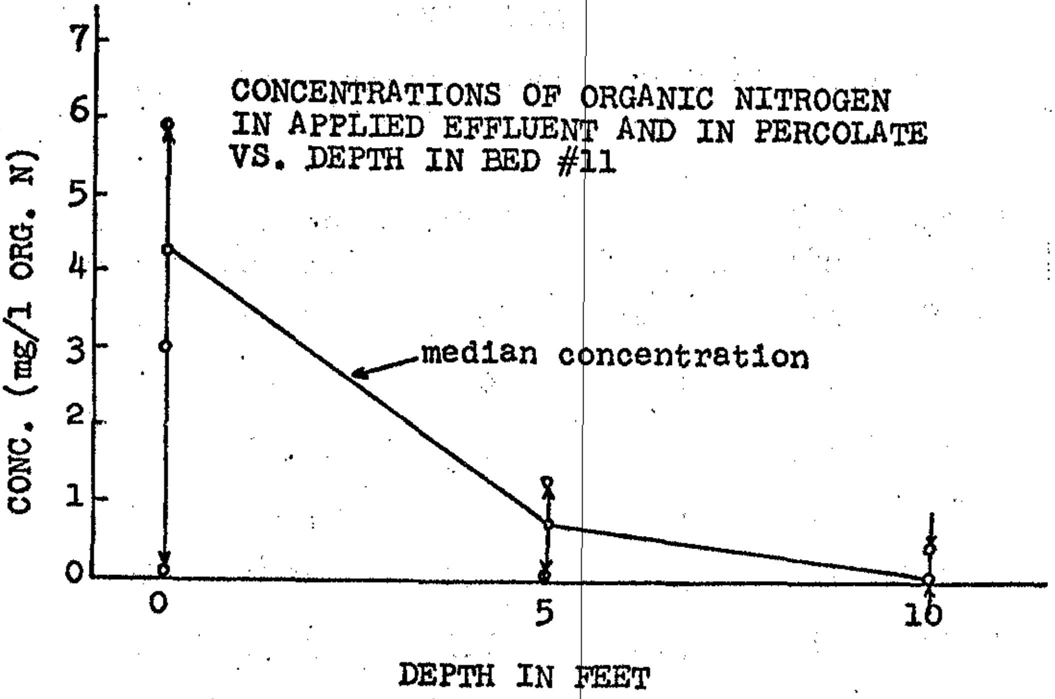
TABLE IV

Organic Nitrogen Concentration (mg/l org. N) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	4.25	0	100.0	0	100.0
6/20	11	0	0	--	0	--
6/26	11	3.0	0	100.0	0	100.0
7/1	11	0	0	--	0	--
7/8	11	5.6	1.12	80.0	0	100.0
7/23	11	5.5	1.3	76.5	0	100.0
7/25	11	5.9	0.75	87.0	0.47	92.0
(Median)		4.25	0.75*	82.6	0	100.0
7/8	13	5.6	0	100.0	0	100.0
7/15	13	5.6	0	100.0	0	100.0
7/19	13	3.5	0.28	92.0	0	100.0
7/23	13	5.5	1.5	72.5	0.47	91.5
7/25	13	5.9	0.75	87.2	0.19	97.0
(Median)		5.6	0.28	95.0	0	100.0

*6/20 and 7/1 not included in determining median.

FIGURE 7


CONCENTRATIONS OF ORGANIC NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #11
CONC. (mg/1 ORG. N)
0
1
2
3
4
5
6
7
median concentration
0
5
10
DEPTH IN FEET

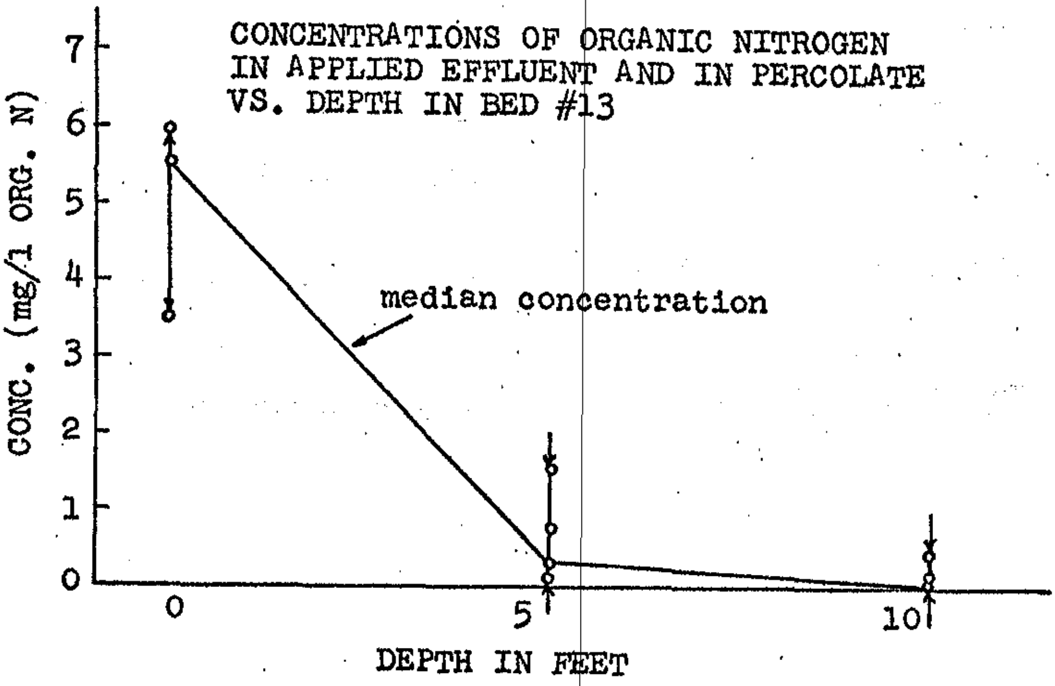

CONCENTRATIONS OF ORGANIC NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #13
CONC. (mg/1 ORG. N)
0
1
2
3
4
5
6
7
median concentration
0
5
10
DEPTH IN FEET

FIGURE 8

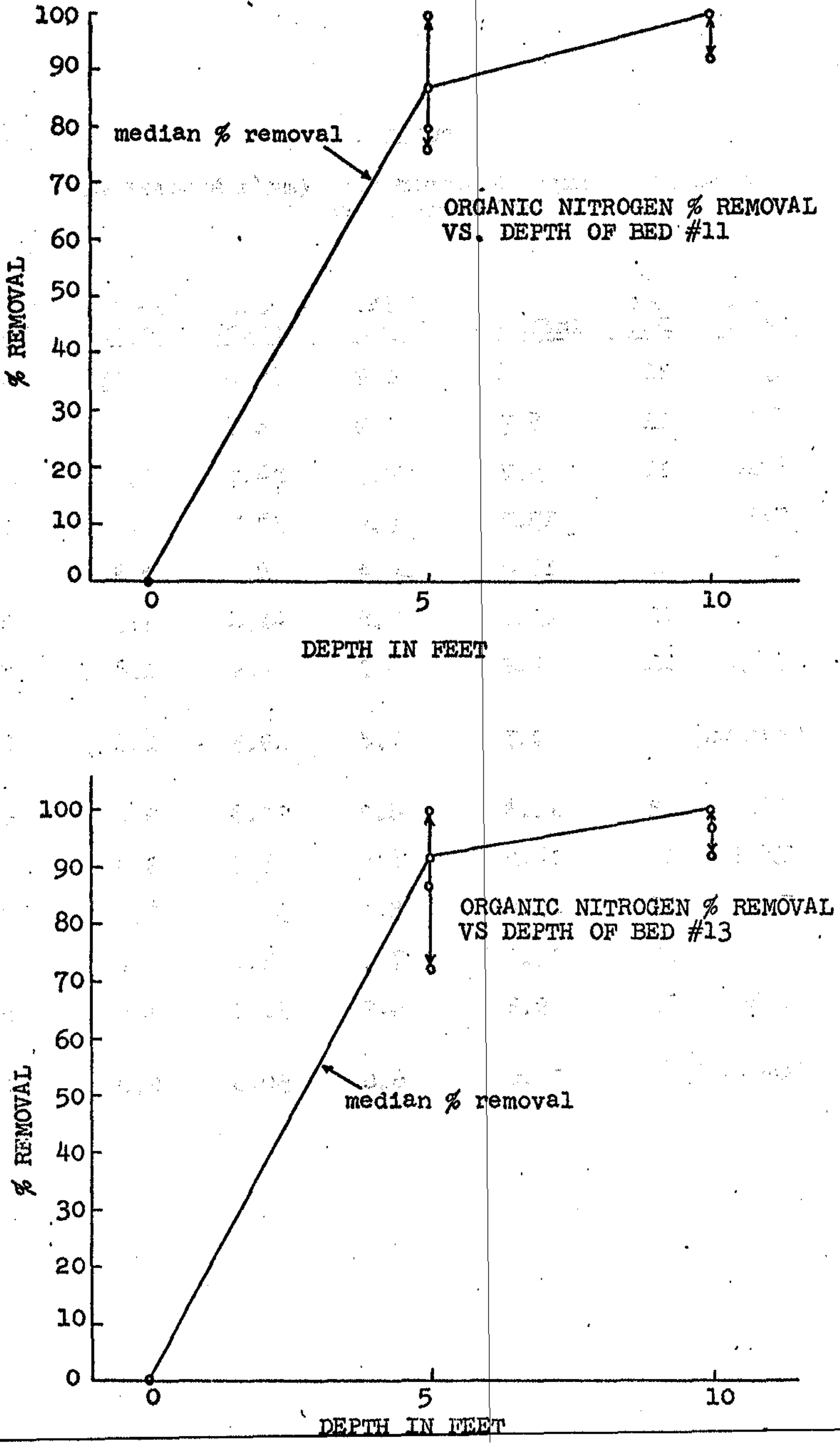
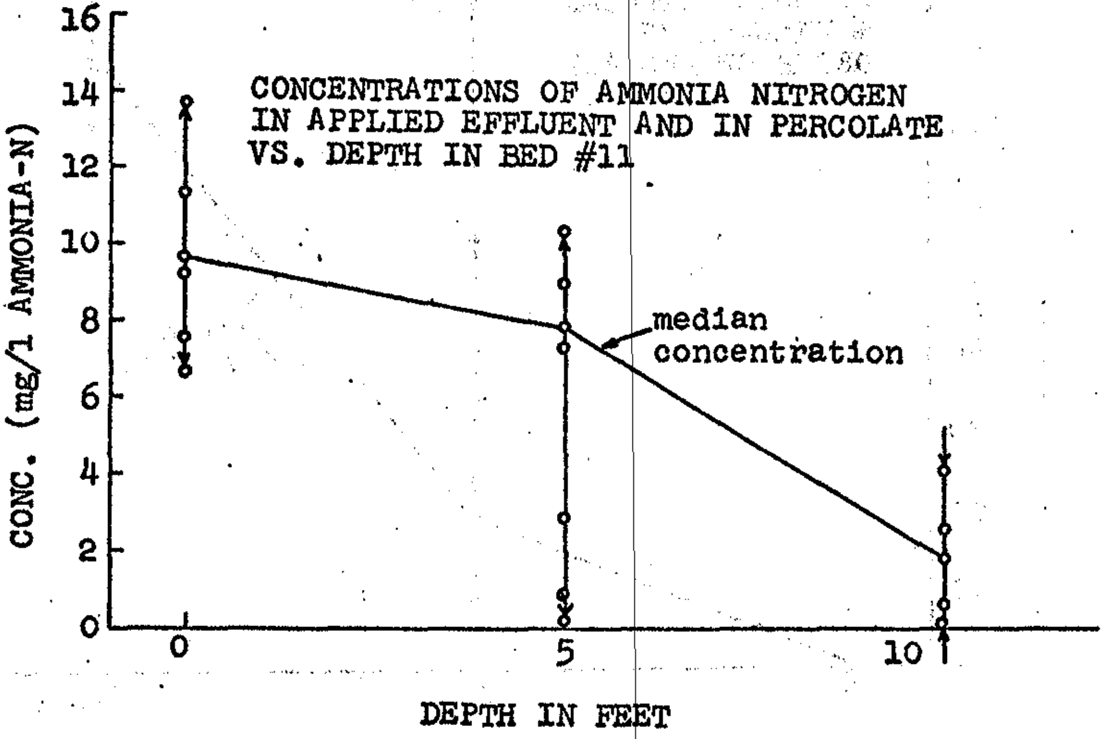

100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
median % removal
ORGANIC NITROGEN % REMOVAL
VS. DEPTH OF BED #11
0
5
10
DEPTH IN FEET
100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
ORGANIC NITROGEN % REMOVAL
VS DEPTH OF BED #13
median % removal
0
5
10
DEPTH IN FEET

TABLE V

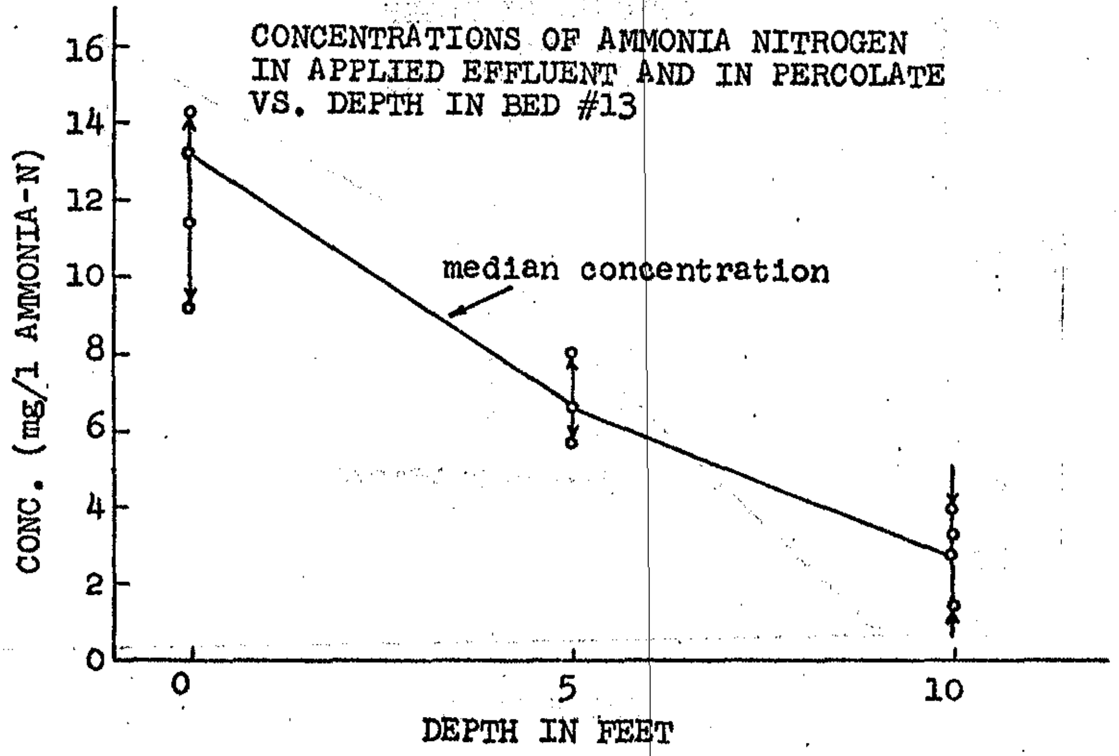
Ammonia Nitrogen Concentration (mg/l Ammonia-N) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	7.6	0.9	88.0	0.67	91.0
6/20	11	6.7	2.9	56.6	0.2	97.0
6/26	11	9.7	7.3	24.7	2.6	73.2
7/1	11	13.7	9.0	34.3	4.1	70.0
7/8	11	11.4	10.4	8.8	2.4	79.0
7/23	11	13.2	7.8	41.0	1.7	87.0
7/25	11	9.2	8.7	5.4	1.8	80.5
(Median)		9.7	7.8	19.5	1.8	81.7
7/8	13	11.4	8.0	29.8	3.8	66.6
7/15	13	14.2	6.6	53.5	3.3	76.8
7/19	13	13.2	5.7	57.0	2.8	79.0
7/23	13	13.2	7.5	43.0	1.7	87.0
7/25	13	9.2	5.7	38.0	1.5	83.6
(Median)		13.2	6.6	50.0	2.8	78.8

FIGURE 9

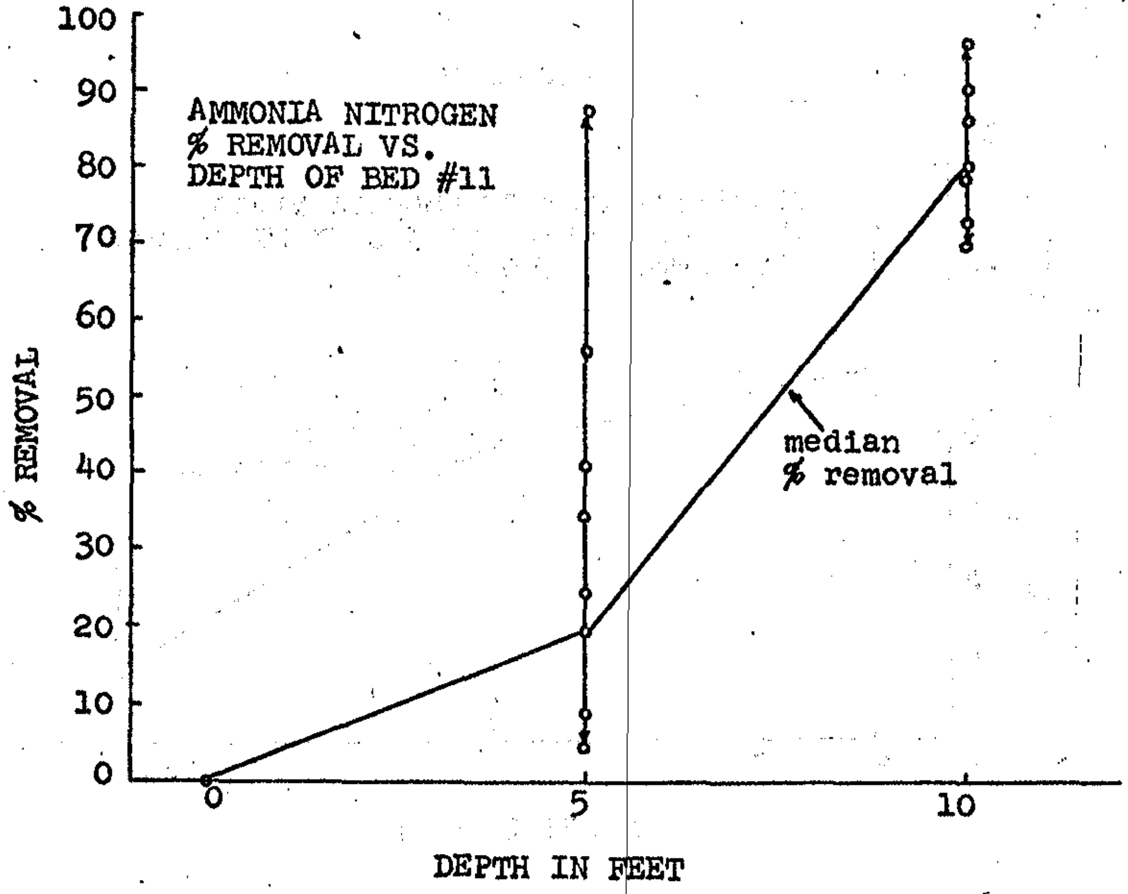


CONCENTRATIONS OF AMMONIA NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #11

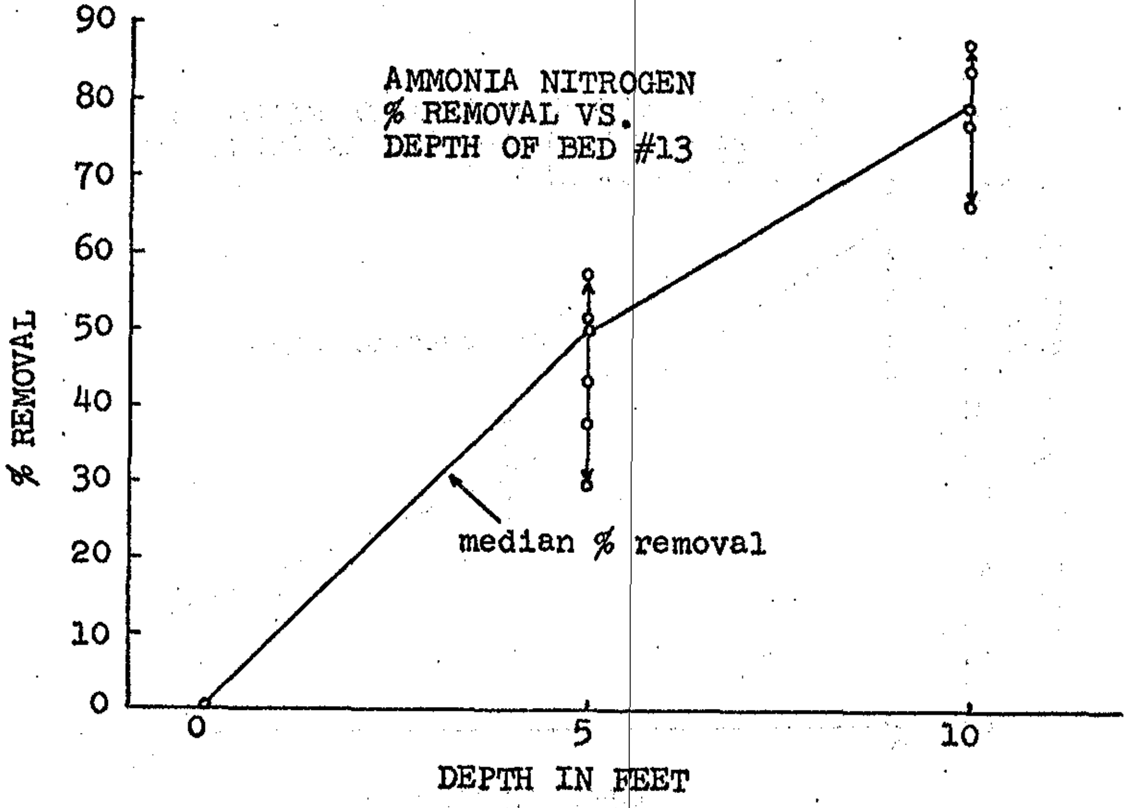


CONCENTRATIONS OF AMMONIA NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #13

FIGURE 10



100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
AMMONIA NITROGEN
% REMOVAL VS.
DEPTH OF BED #11
median
% removal
0
5
10
DEPTH IN FEET



90
80
70
60
50
40
30
20
10
0
% REMOVAL
AMMONIA NITROGEN
% REMOVAL VS.
DEPTH OF BED #13
median % removal
0
5
10
DEPTH IN FEET

TABLE VI

Nitrite Nitrogen Concentration (mg/l NO_2-N) and Percent Removal

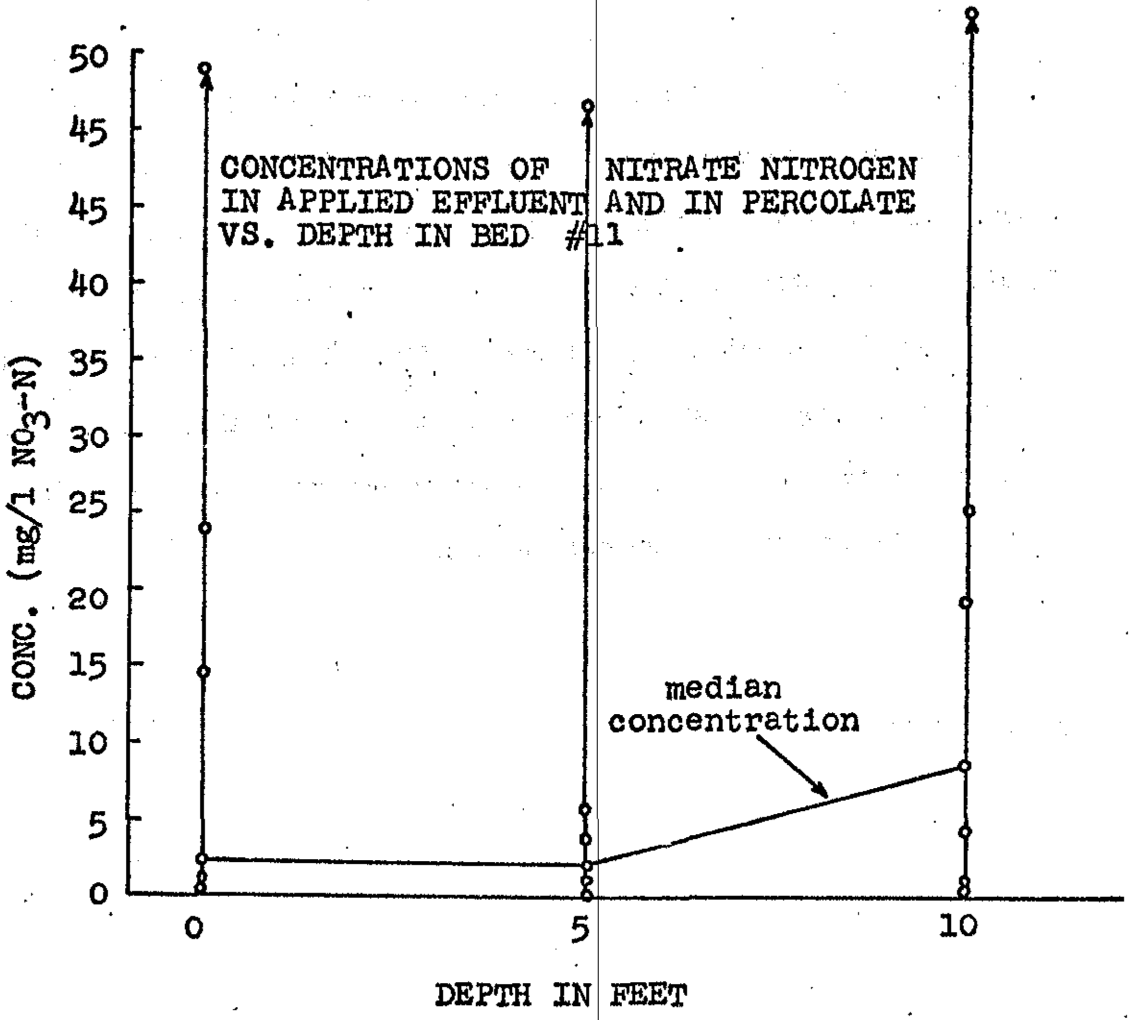
Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	0.39	0.14	64.0	0.04	89.7
6/20	11	1.10	0.11	90.0	0.09	92.0
6/26	11	0.63	0.02	96.7	0.01	98.5
7/1	11	0.02	0.12	-500.0	0.05	-150.0
7/8	11	0.39	0.01	97.5	0.01	97.5
7/23	11	0.01	0.01	0	0.04	-300.0
7/25	11	0.02	0.02	0	0.04	-100.0
(Median)		0.39	0.02	94.9	0.04	89.5
7/8	13	0.39	0.03	92.3	0.03	92.3
7/15	13	0.02	0.03	-50.0	0.06	-200.0
7/19	13	0.33	0.12	63.7	0.07	78.8
7/23	13	0.01	0.39	-3800.0	0.10	-900.0
7/25	13	0.02	0.05	-150.0	0.09	-350.0
(Median)		0.02	0.05	-150.0	0.07	-250.0

TABLE VII

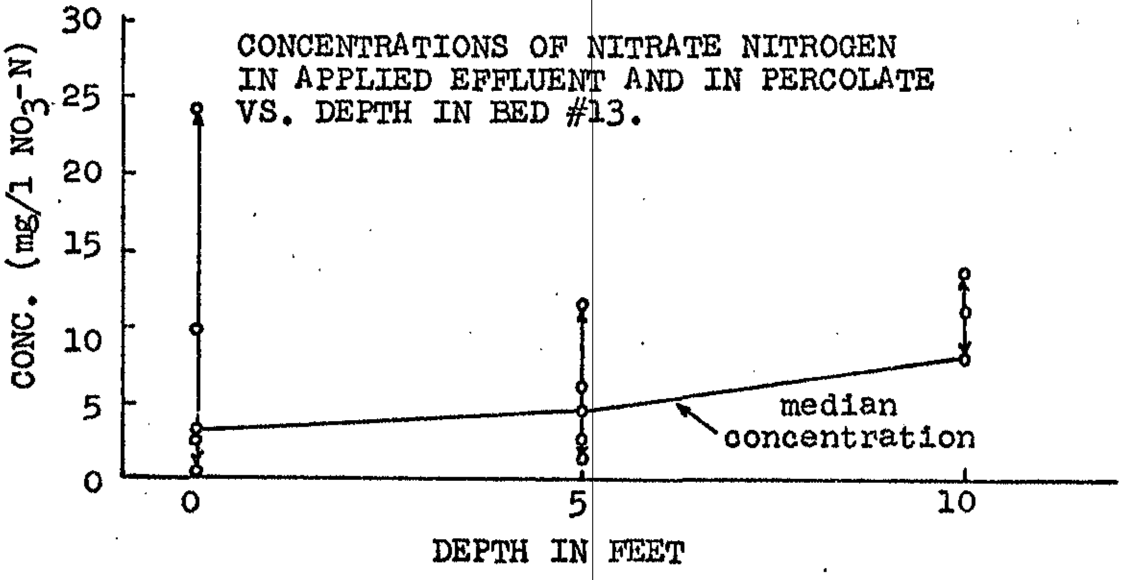
Nitrate Nitrogen Concentration (mg/l NO_3-N) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	0.14	0.04	71.5	0.11	21.4
6/20	11	54.0	52.0	3.7	58.0	- 7.4
6/26	11	14.4	3.9	73.0	4.5	68.7
7/1	11	1.2	2.4	-100.0	1.2	0
7/8	11	24.0	6.0	75.0	8.7	63.7
7/23	11	1.2	1.5	- 25.0	25.5	-2020.0
7/25	11	2.4	2.1	12.5	19.5	- 713.0
(Median)		2.4	2.4	0	8.7	- 263.0
7/8	13	24.0	11.4	52.5	13.5	43.7
7/15	13	9.8	1.5	84.7	7.8	20.4
7/19	13	3.27	6.18	- 89.0	8.03	- 146.0
7/23	13	1.2	2.7	-125.0	7.8	- 550.0
7/25	13	2.4	4.5	- 87.5	11.1	- 362.0
(Median)		3.27	4.5	- 37.5	8.03	- 146.0

FIGURE 11



CONCENTRATIONS OF NITRATE NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #11.



CONCENTRATIONS OF NITRATE NITROGEN IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #13.

Organic nitrogen can be converted to ammonia by the action of bacteria under either aerobic or anaerobic conditions.(5) Ammonia is oxidized to nitrite and nitrate by nitrifying bacteria, and other authors (11, 12, 7, 6, 9, 13, 5) have shown that soil does not have the ability to retain nitrates. Under anaerobic conditions, nitrates and nitrites are both reduced either to ammonia or nitrogen gas. Since there was no measurable increase in ammonia nitrogen, nitrification appears to be the dominant phenomenon in the overall reduction of organic and ammonia nitrogen.

E. Phosphorus Analyses

The results of the polyphosphate, orthophosphate and total phosphate analyses are tabulated in Tables VIII, IX, and X, respectively. The samples taken June 17, June 20, and June 26 were analyzed for total phosphate and polyphosphate in accordance with Standard Methods.(2) All subsequent samples were analyzed by the sulfuric-nitric acid digestion methods. (3)

Graphs showing the comparison of beds #11 and #13 with respect to the median concentration of poly, ortho, and total phosphate vs. depth of bed are shown in Figures 12, 13, and 14, respectively. Since over 85% of the influent total phosphate is composed of orthophosphates and since the ratio of ortho to total phosphate was fairly constant, comparison of beds #11 and #13 is made on the basis of total phosphate.

It is immediately apparent that the two beds differ greatly. Bed #11 which has been used regularly over the years shows a slight increase in the median total phosphate concentration from zero to 5 feet (25.4 to 33.4 mg/l PO The concentration then drops off to a value of 27.5 mg/l at 10 feet. On the other hand, bed #13 which has been used only sparingly shows 72% removal of total phosphate (25.8 to 7.2 mg/l PO_4) in the first 5 feet of sand. The concentration then increases slightly to a value of 10.0 mg/l in the next 5 feet so that the overall removal in 10 feet reduces to 61.1%.

At first glance it appears that the relatively unused sands of bed #13 have a high capacity for phosphorus removal in the initial 5 feet, while the same portion of bed #11 has lost its removal capacity (assuming it once had it However, why there is no further decrease in the total phosphate from 5 to 10 feet in bed #13 is difficult to explain.

The literature contains many varied and conflicting reports with respect to the behavior of phosphorus in soils and sand. Preul (14) conducted studie

TABLE VIII

Polyphosphate Concentration (mg/l PO4) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	0	0	--	0	--
6/20	11	10.9	0.8	92.5	0.1	99.0
6/26	11	4.2	5.0	- 19.0	5.0	-19.0
7/8	11	1.8	6.0	-233.0	3.4	-89.0
7/23	11	1.8	0.4	77.7	0.4	77.7
7/25	11	3.0	0.4	86.6	0.2	93.5
(Median)		3.0	0.8	73.2	0.4	86.5
7/8	13	1.8	1.7	5.6	1.7	5.6
7/15	13	0.6	1.2	-100.0	1.4	-133.0
7/19	13	2.6	2.2	15.4	3.4	- 30.8
7/23	13	1.8	0.8	55.6	0.4	77.7
7/25	13	3.0	0.6	80.0	0.6	80.0
(Median)		1.8	1.2	33.3	1.4	22.2

TABLE IX

Orthophosphate Concentration (mg/l PO_4) and Percent Removal

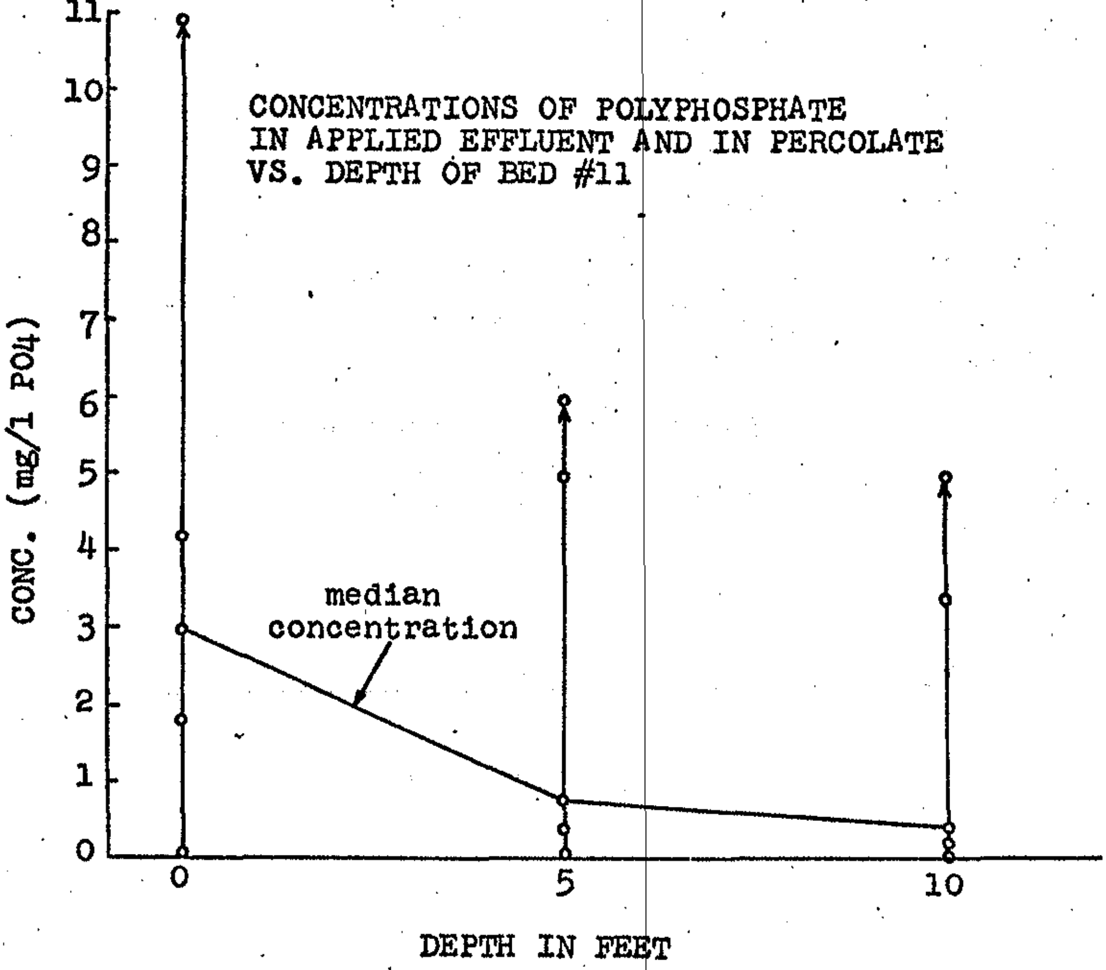
Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	21.1	23.9	- 13.3	19.7	6.6
6/20	11	11.9	25.0	-110.0	21.0	-76.5
6/26	11	20.8	27.6	- 32.7	24.2	-16.3
7/8	11	37.8	28.2	25.4	27.0	28.6
7/23	11	30.6	38.6	- 26.2	25.4	17.0
7/25	11	22.8	38.2	- 67.5	30.4	-33.4
(Median)		22.0	27.9	- 26.8	24.8	-12.7
7/8	13	37.8	6.9	82.0	16.5	56.3
7/15	13	21.4	6.4	70.0	8.6	60.0
7/19	13	18.4	5.0	72.7	7.2	60.8
7/23	13	30.6	6.4	79.0	7.6	75.0
7/25	13	22.8	6.4	72.0	7.6	66.6
(Median)		22.8	6.4	71.8	7.6	66.5

TABLE X

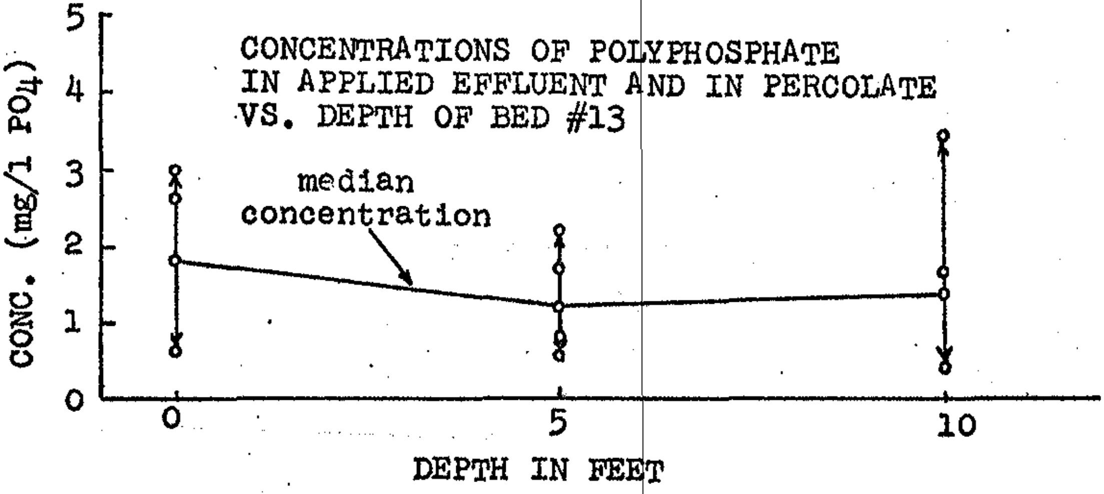
Total Phosphate Concentration (mg/l PO_4) and Percent Removal

Sample Date	Bed No.	Influent	5 ft. Depth	Percent Removal	10 ft. Depth	Total % Removal
6/17	11	21.1	23.9	-13.3	19.7	6.6
6/20	11	22.8	25.8	-13.2	21.1	7.5
6/26	11	25.0	32.6	-30.4	29.2	-14.4
7/8	11	39.6	34.2	13.6	30.4	23.2
7/23	11	32.4	39.0	-20.4	25.8	20.4
7/25	11	25.8	38.6	-49.6	30.6	-18.6
(Median)		25.4	33.4	-31.5	27.5	8.3
7/8	13	39.6	8.6	78.2	18.2	54.0
7/15	13	22.0	7.6	65.4	10.0	54.5
7/19	13	21.0	7.2	65.7	10.6	49.5
7/23	13	32.4	7.2	77.8	8.0	75.7
7/25	13	25.8	7.0	72.8	8.2	68.3
(Median)		25.8	7.2	72.0	10.0	61.1

FIGURE 12

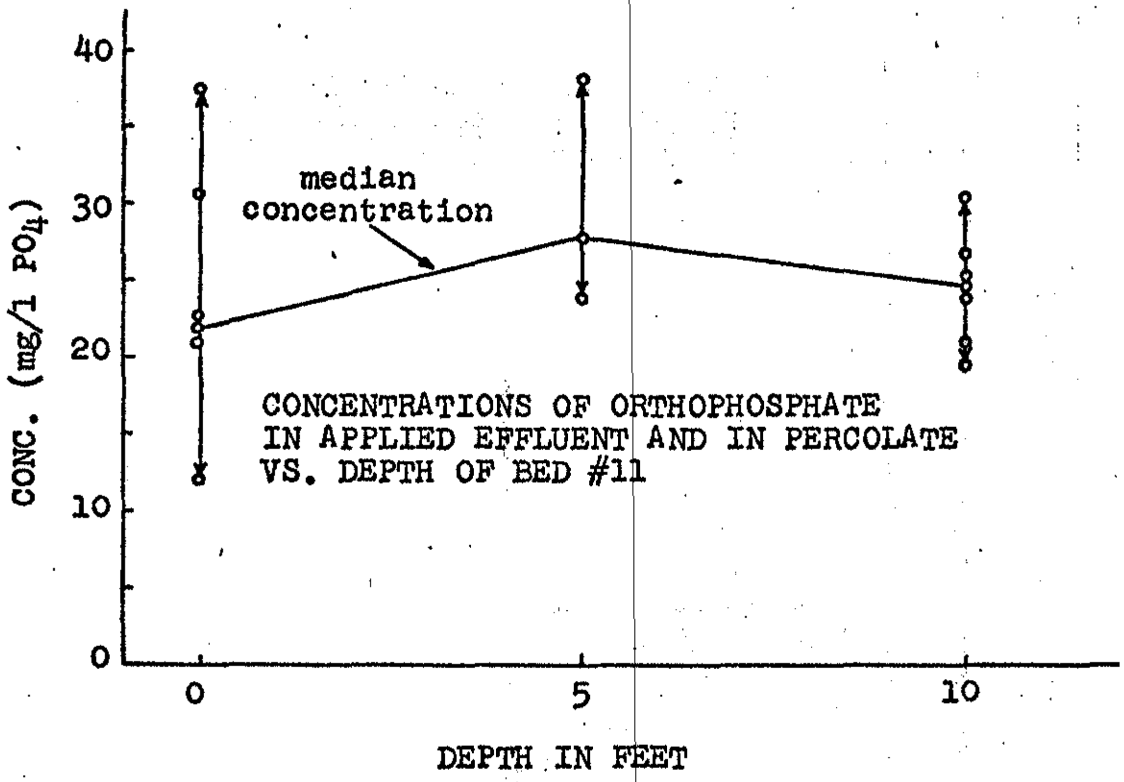


CONCENTRATIONS OF POLYPHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11



CONCENTRATIONS OF POLYPHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13

FIGURE 13


CONCENTRATIONS OF ORTHOPHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #11

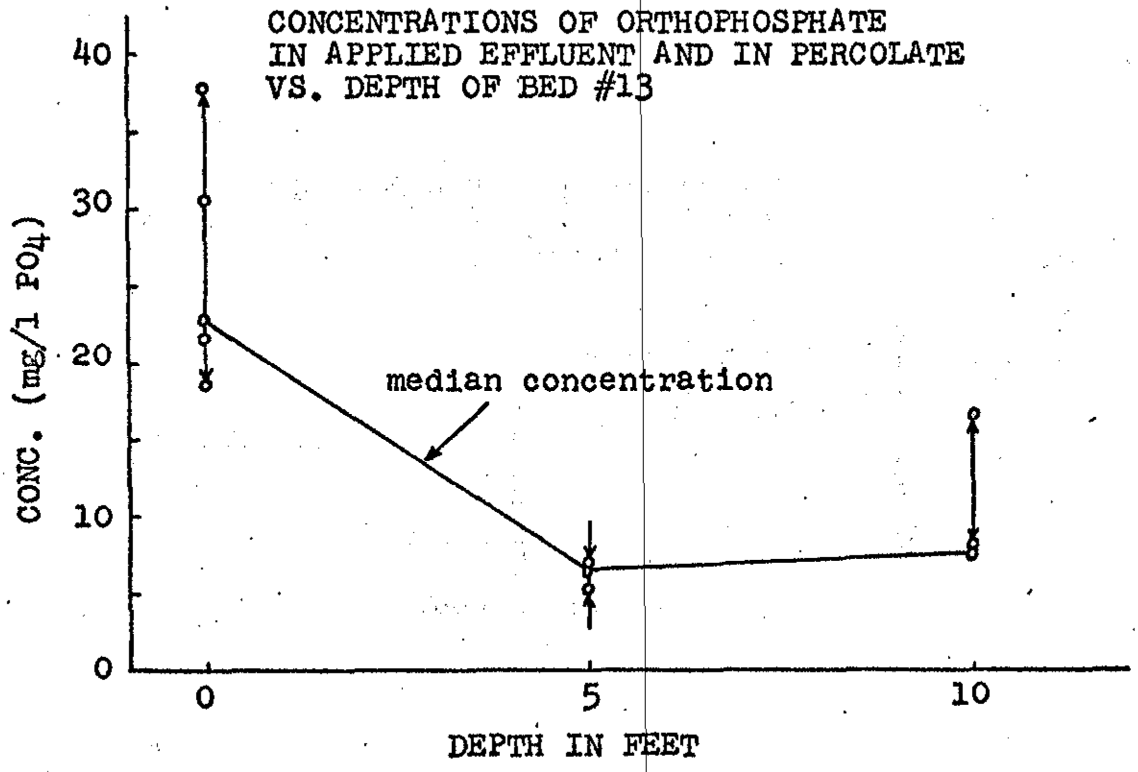
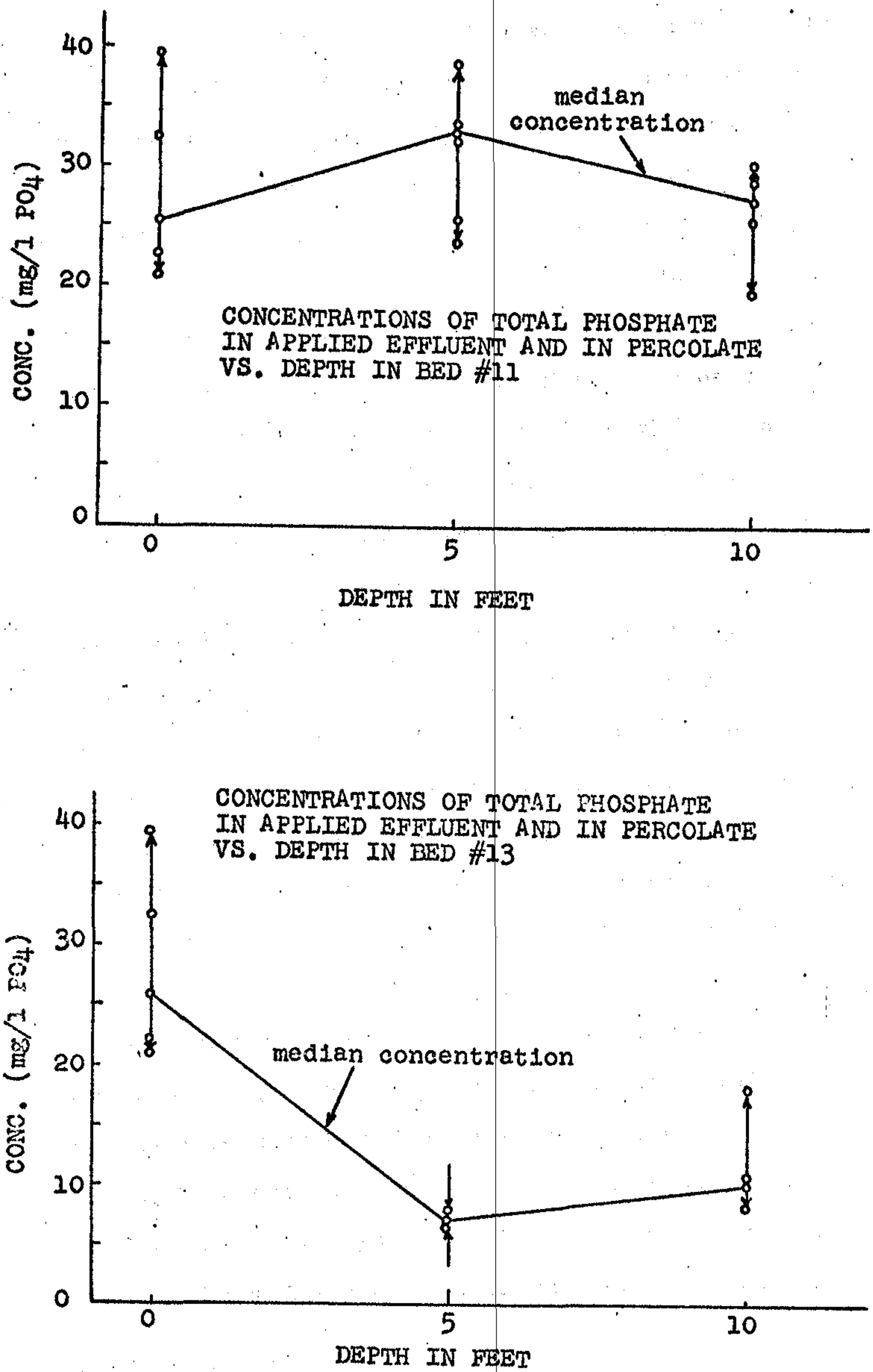

CONCENTRATIONS OF ORTHOPHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH OF BED #13

FIGURE 14


40
30
20
10
0
CONC. (mg/1 PO$_4$)
median concentration
CONCENTRATIONS OF TOTAL PHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #11
0
5
10
DEPTH IN FEET
CONCENTRATIONS OF TOTAL PHOSPHATE IN APPLIED EFFLUENT AND IN PERCOLATE VS. DEPTH IN BED #13
40
30
20
10
0
CONC. (mg/1 PO$_4$)
median concentration
0
5
10
DEPTH IN FEET

on the ground-water in the area of various waste stabilization ponds. Generally the soil near these ponds was sandy or silty. Ground-water samples were taken from observation wells (usually less than 20 feet deep) up to 200 feet from the edge of the ponds. Generally the phosphates were reduced to less than 1.0 mg/l within 30 feet of the ponds. Initial concentrations varied from 4.0 to 21.5 mg/l, with a mean of 9.2. However, Preul noted one case of substantial increase in phosphates near a well 100 feet from a pond. This he could not explain except that it was due possibly to some localized effect in the soil. Preul indicates that phosphate removal is probably due to the strong affinity of phosphates for soil particles.

Pennypacker, et al. (8) conducted a study of renovation of wastewater effluent by irrigation of forest land. They found that 98.8 to 99.4% of the phosphorus was removed in the upper 12 inches of the soil. Ground-water concentrations of phosphorus were reduced to less than 0.07 mg/l P from an initial average concentration of 8.5. They attributed removal to the fact that phosphorus is fixed readily by soil colloids. Greenberg and Thomas (12) in a study of sewage effluent disposal on sand loam basins (7.9% clay, 17.7% sand and 74.4% silt), found that phosphate ions disappeared during the first foot of travel. This they felt was due to a replacement of the hydroxyl ions on the clay lattices, or more likely, to uptake by the microorganisms developing in the soil.

On the opposite side of the ledger, studies conducted in California (9) on the percolating liquid from four sewage spreading basins, showed that phosphates disappeared during the first foot of vertical water travel in the period 1950-51, but in the period 1952 the concentration of phosphates increased, and even at a depth of 13 feet did not disappear. In another California study (6), a comparison was made between sewage disposed on soil at Whittier Narrows vs. Rio Hondo. At Whittier the soil consisted of two feet of highly organic soil, followed by thin discontinuous layers of silt and micaceous material. At Rio Hondo the soil was very homogeneous and composed mainly of a fine to medium sand (uniformity coefficient 2.36 and effective size of 0.139 mm). Phosphate removal varied greatly at the two sites. The concentrations of total phosphate (practically all in the ortho form) were fairly uniform in the surface waters at the two basins. At Whittier there was a decrease in phosphate concentration after two feet of percolation, a build-up at four feet, and finally almost complete removal in the percolate at eight feet. At Rio Hondo Basin (somewhat similar to the Lake George Beds) there was no significant change in phosphate concentration with depth.

Bailey (15) maintains that the pH of the soil is a dominating factor in phosphorus fixation and a minimum of phosphorus fixation occurs when the soil is "neutral", pH 6 to 7. In the present study analyses of influent to the bed, and 5 and 10 foot samples, all showed a pH range of 6 to 7. Assuming that the sand also is in this same range, this helps explain why there was little phosphate removal through the 10 feet of sand. However, comparing beds #11 and 13, it appears that the sand of bed #13 does have some capacity for phosphate removal, namely 61.1% in 10 feet. Bed #11 has lost its capacity over the years. No explanation can be found for the reason why in bed #13 the total phosphate decreased over 72% in the first 5 feet, het failed to decrease further in the next 5 feet.

F. Sand Analysis

In Table XI are shown the results of the sieve analyses performed on three sand samples. These samples were analyzed to get a general idea of the characteristics of the sands. The New York State Department of Health (15) recommends an effective grain size between 0.3 and 0.6 mm, and the uniformity coefficient should be 3.5 or less for open sand filters. The natural filter bed sand is somewhat smaller than the recommended size range. However, the recommendations are for constructed sand filters where optimum percolation is desired.

TABLE XI

Sieve Analyses - Bed #13

Sample Location	Effective Size	Uniformity Coefficient
Test boring hole #3 Approx. 30-33' depth	0.19 mm	2.6
Test boring hole #3 Approx. 10' depth	0.135 mm	3.4
Center of Bed 13" below surface*	0.25 mm	3.6

*Sample collected and analyzed by New York State Department of Health

CONCLUSIONS AND RECOMMENDATIONS

Based on the field and laboratory results, the following conclusions and recommendations are made:

1. Almost all coliform organisms are removed from the percolate in the vertical travel through 10 feet of sand. The applied effluent is not chlorinated which demonstrates that a sand bed removes coliforms very well. In all probability, coliforms are completely removed by deeper percolation.

2. Ten feet of sand proves to be highly efficient in reducing the BOD to minimum values. Further removal is expected in the lower depths of the beds.

3. The sand filters have no effect on chloride removal from the effluent.

4. Almost 100% of organic nitrogen removal is obtained in 10 feet of sand filtration.

5. Ammonia nitrogen decreases 80% as the effluent percolates through 10 feet of sand. This is due primarily to nitrification. Further nitrification is expected in deeper penetration of the percolate.

6. Nitrite nitrogen was insignificant in this study.

7. Nitrate nitrogen concentrations increase in the upper 10 feet of sand due to nitrification. The sand filters have no effect on the removal of nitrates from the percolate.

8. Total phosphate removal over 60% can be obtained from fresh sand. Removal efficiency decreases as the bed is used. Phosphate removal seems to be a function of the ion exchange capacity of the sand and not of biological activity, because the removal capacity becomes exhausted with time. A lysimetry study, utilizing unused sand vs. sand taken from one of the frequently used beds, should help to determine the optimum conditions for phosphate removal through sand filtration.

9. Some of the water from wells sampled in this study showed a tendency to foam when shaken vigorously. Apparently there is some concentration of ABS. Further study should be done to determine the efficiency of the beds in removing ABS.

10. The intermittent application of treated effluent does not cause clogging of the sand beds. The infiltration capacity and nutrient removal is improved after a period of rest. The reason for this was not investigated. It has been hypothesized (6) that biological growths within the sand beds force the sand to open somewhat and to remain open after periods of drying and aeration.

11. The difference in infiltration capacity from bed to bed can be attributed to the following factors:

a) Some beds are flooded continuously for longer periods of time. Therefore, the organic load or nutrients applied varies.

b) Rest periods in some beds are longer.

c) Sand characteristics vary from bed to bed. Finer sand beds would probably have better nutrient removal percentages.

d) The age of beds is different.

12. The sand beds should be operated intermittently on as short a cycle as may be operationally feasible.

13. The application of surface layers of sand is recommended to improve infiltration rates.

14. Future studies should include:

a) Observations of the percolation rate.

b) Analysis of the sand characteristics of all the beds.

c) Sampling at multiple depths in different beds.

d) A study of the biology of the sand in the beds.

e) Well drilling exploration to locate the ground-water table,

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