WASTEWATER STABILIZATION PONDS AND PL 92-500 CASE STUDIES AND UPGRADING

by

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INTRODUCTION

Prior to enactment of the Federal Water Pollution Control Act of 1972 (PL 92-500), a minimum of secondary treatment was required for all municipal wastewater treatment facilities receiving a construction grant. The definition of secondary treatment was 85 percent removal of five-day biochemical oxygen demand (BOD_5) and suspended solids (SS) with effluent disinfection. However, this pre PL 92-500 definition was more oriented toward requiring the upgrading of raw and primary discharges for protection of public health and was generally implemented by requiring the installation of a "secondary treatment process" which over a year's period might be expected to provide approximately 85 percent removal of BOD_5 and suspended solids. Wastewater stabilization ponds, trickling filters, and activated sludge were the three primary processes which were generally accepted as providing secondary treatment.

The enactment of PL 92-500 required the EPA to formally define secondary treatment. The regulations defining secondary treatment (1) were published in final form in April, 1973. They require that as a minimum all facilities treating domestic wastewater provide an effluent with a quality as shown in Table 1.

TABLE 1. SECONDARY TREATMENT CRITERIA UNDER PL 92-500

PARAMETER	WEEKLY AVERAGE	MONTHLY AVERAGE
BOD_5	45 mg/l	30 mg/l
SS	45 mg/l	30 mg/l
Fecal coliform	400/100 ml	200/100 ml
pH	Range of 6-9	
Other	85% removal of BOD & suspended solids	

These criteria mean that any wastewater treatment plant whose weekly or monthly average effluent quality is less than the values given in Table 1 even once during a given year would be in violation of the secondary treatment criteria. Secondary treatment is the minimum level of treatment and can be used on effluent limited streams. Of equal importance are stream segments where treatment requirements greater than secondary are required. Region IV has estimated that of existing ponds, 290 must meet secondary treatment criteria while 642 would have to produce an effluent quality better than this. The estimated cost for replacement with activated sludge plants, of the same capacity, is $775 million.

This paper will report on the ability of the wastewater stabilization pond process to meet the secondary treatment criteria. In addition, case studies of upgrading various wastewater stabilization ponds to meet the secondary treatment criteria will be presented.

This information should be of value to those who seek a familiarity with the ability of stabilization ponds to meet the secondary treatment requirements of PL 92-500 and the expected effects of various processes to upgrade stabilization pond treatment. In addition, those involved in the design of systems to upgrade stabilization ponds may be able to draw parallels between the information presented here and their actual situation to arrive at the design of an efficient-low cost system.

WASTEWATER STABILIZATION PONDS AND SECONDARY TREATMENT

Foree and McCarty (2) give an excellent description of the physical and microbiological processes that occur simultaneously in a wastewater stabilization pond and Figure 1 illustrates these processes. In the aerobic zone, in the presence of wind and solar energy, bacterial oxidation stabilizes the waste organics and produces carbon dioxide which is utilized for algal photosynthesis. Algal photosynthesis then produces a large part of the oxygen which is utilized for waste stabilization. In the anaerobic zone, the solids which have settled undergo decomposition with methane as the primary end product.

Wastewater stabilization ponds were widely accepted as capable of providing effluent quality at least equivalent to accepted secondary treatment. This degree of treatment would protect public health. Barsom (3) reports that in the semi-arid Great Plains states, stabilization ponds produced effluent qualities equivalent to secondary treatment for most of the year. However, differences in climate, soil type, population density, and other problems have prevented such success for other portions of the country. In a survey of state engineers, Barsom found that

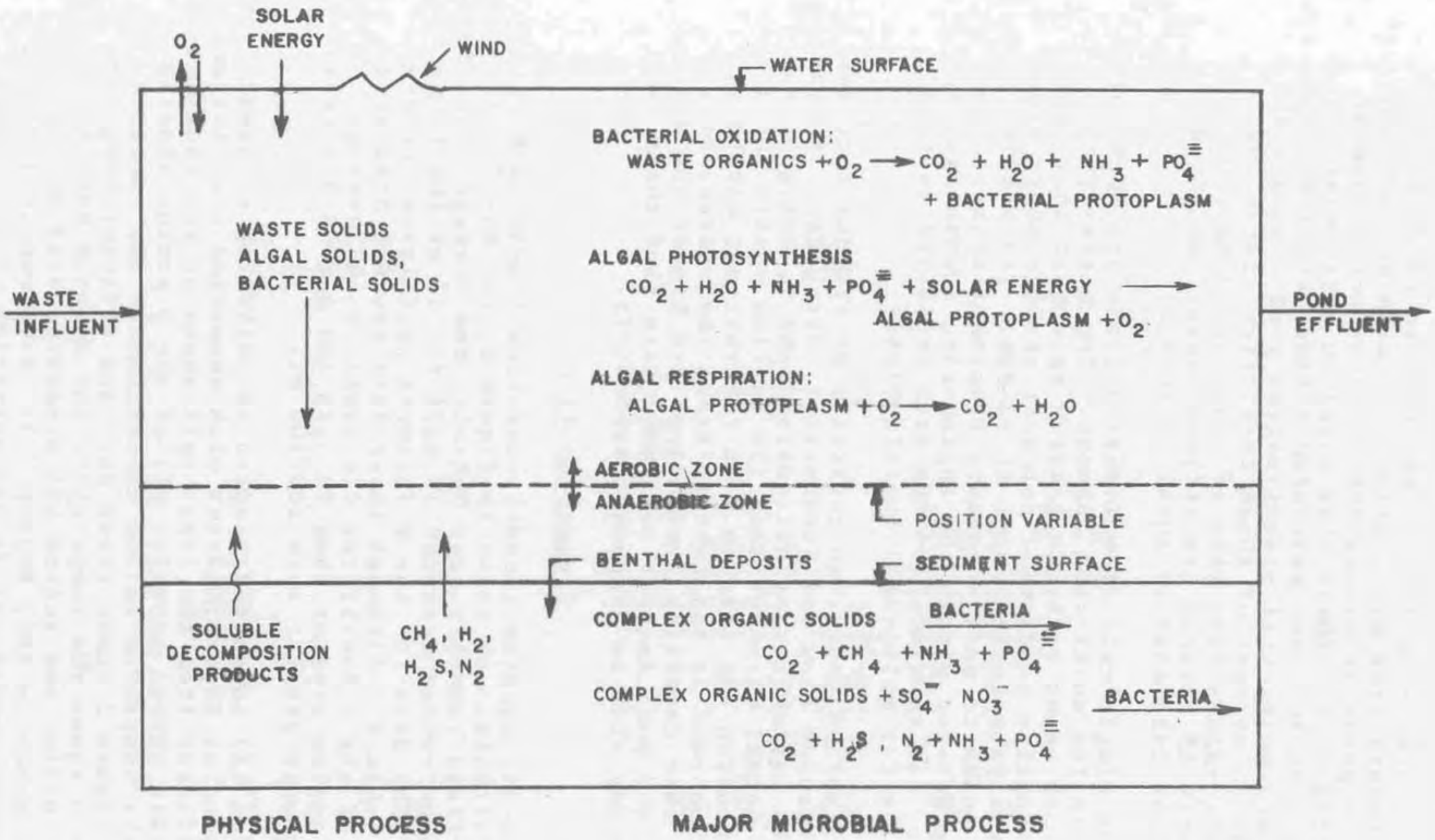

Figure. 1. Schematic Diagram Illustrating Major Processes Occurring in a Typical Waste Stabilization Pond. (from (2))

twenty-four states considered stabilization ponds as equivalent to secondary treatment, eighteen states did not consider stabilization ponds as equivalent to secondary treatment, and eight conditioned their view based on particular situations. Based on BOD_5 and suspended solids data from over 100 single and multi-cell stabilization ponds tabulated by Barsom, only 35 percent of those facilities listed had effluent BOD_5 values less than or equal to 30 mg/l. In addition, only 15 percent had effluent suspended solids concentrations less than or equal to 30 mg/l.

Data on single cell stabilization ponds are much more abundant than for multi-cell lagoons. The engineering profession now seems to be in general agreement that single cell stabilization ponds will not meet the secondary treatment criteria promulgated under PL 92-500. The ability of multi-cell ponds to meet secondary treatment criteria is still being debated within the engineering community. For this reason, the remainder of the data presented in this paper will be for multi-cell installations.

Stabilization ponds can generally be divided into two types, continuous flow and intermittent discharge. A continuous flow wastewater stabilization pond is designed such that under normal circumstances the outflow equals the inflow minus evaporation and seepage. An intermittent discharge stabilization pond is designed to store the wastewater and release it when receiving streamflows are higher and water quality in the pond is near optimum. Data from these two types of ponds will be discussed separately.

Continuous Flow

Pierce (4) studied 1 continuous flow lagoon in Michigan and 9 in Illinois. As shown in Figure 2, for the 3 cell pond at Chesterfield Township near Detroit, the average suspended solids concentration exceeded 30 mg/l for 12 of the 17 months reported. The data for the 9 Illinois facilities are presented in Table 2. Although these data are not presented by month, of the 9 facilities discussed, 5 had average suspended solids greater than 30 mg/l and 4 of 9 had fecal coliform counts greater than 200/100 ml.

O'Brien (5) conducted studies on polishing effluent from a 3 cell pond at Endora, Kansas with submerged rock filters. For the effluent from the final cell ahead of the rock filter, the data showed that for all of the 6 months studied to date, the suspended solids concentration has exceeded 30 mg/l. Figure 3 shows these data and effluent BOD_5 data and Figure 4 shows the temperature and ammonia data in the effluent. Walter and Bugbee (6) presented data on 37, 2 and 3 cell ponds in EPA, Region VII. As shown in Table 3, the average suspended solids concentration of the 3 and 2

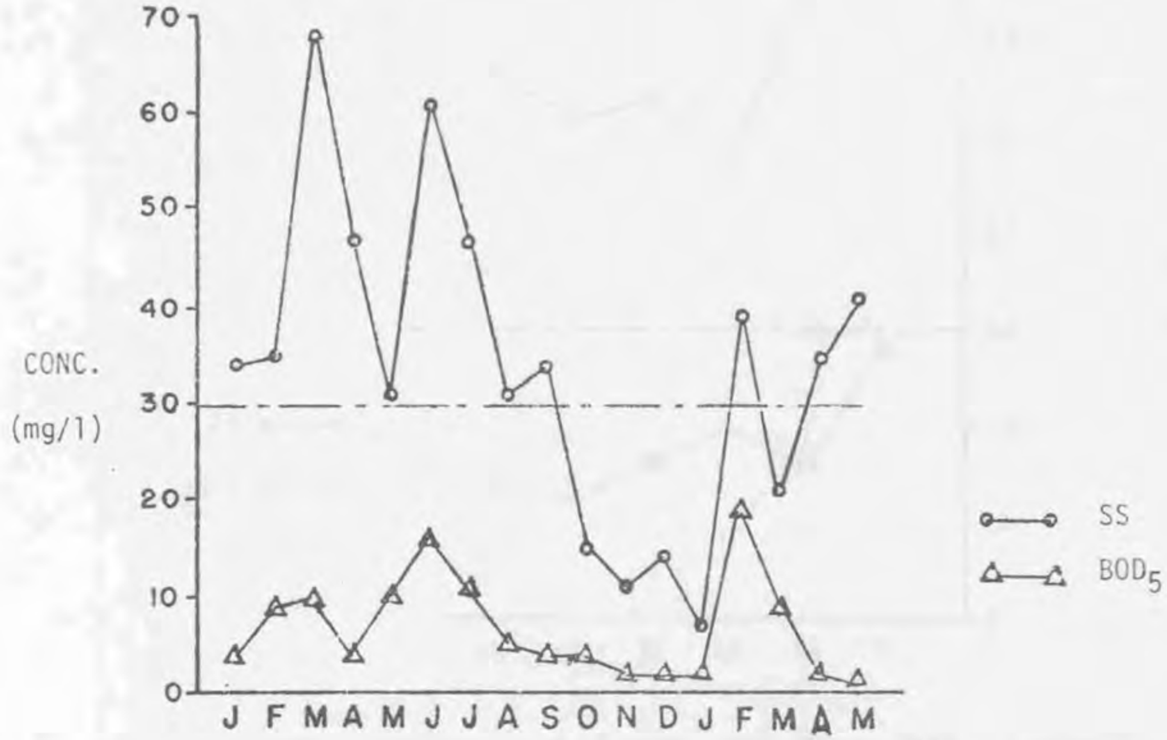

Figure 2. Effluent Quality from Chesterfield Township, Mich. System (from (4))

TABLE 2. SUMMARY BY ILLINOIS EPA ANALYSIS OF RESULTS FROM NINE MUNICIPAL WASTE STABILIZATION LAGOONS WITH CHLORINATED EFFLUENTS. (from (4))

Facility No.	No. Samples	BOD_5 Range	(mg/1) Avg.	Susp. Sol. Range	(mg/1) Avg.	NH_3-N Range	(mg/1) Avg.	NO_3-N Range	(mg/1) Avg.	Fecal Col. (MPN) Range	Geom. Mean
1	7	1-37	8	4-74	26	0.7-7.0	2.1	0-0.3	0.1	100-600	184
2	8	4-27	19	6-80	45	0.2-1.2	0.5	0-0.8	0.2	100-1700	237
3	2	13-27	21	11-35	26	0.4-1.8	1.1	0.1-0.7	0.4	0-100	10
4	6	18-50	35	70-160	105	0.3-3.1	1.0	0-0.5	0.2	100-3400	546
5	9	1-38	9	1-19	8	0.1-5.9	1.0	0-0.6	0.1	10-30000	272
6	7	15-45	25	13-88	60	0.2-8.3	2.7	0-1.0	0.3	10-1000	116
7	3	0-25	12	1-58	25	0.2-7.1	2.5	0.2-0.3	0.2	50-100	62
8	9	12-46	23	3-66	38	0.2-3.0	0.9	--	--	0-1300	19
9	3	9-33	21	22-92	54	0.3-2.5	1.0	0-1.9	0.6	0-140	5

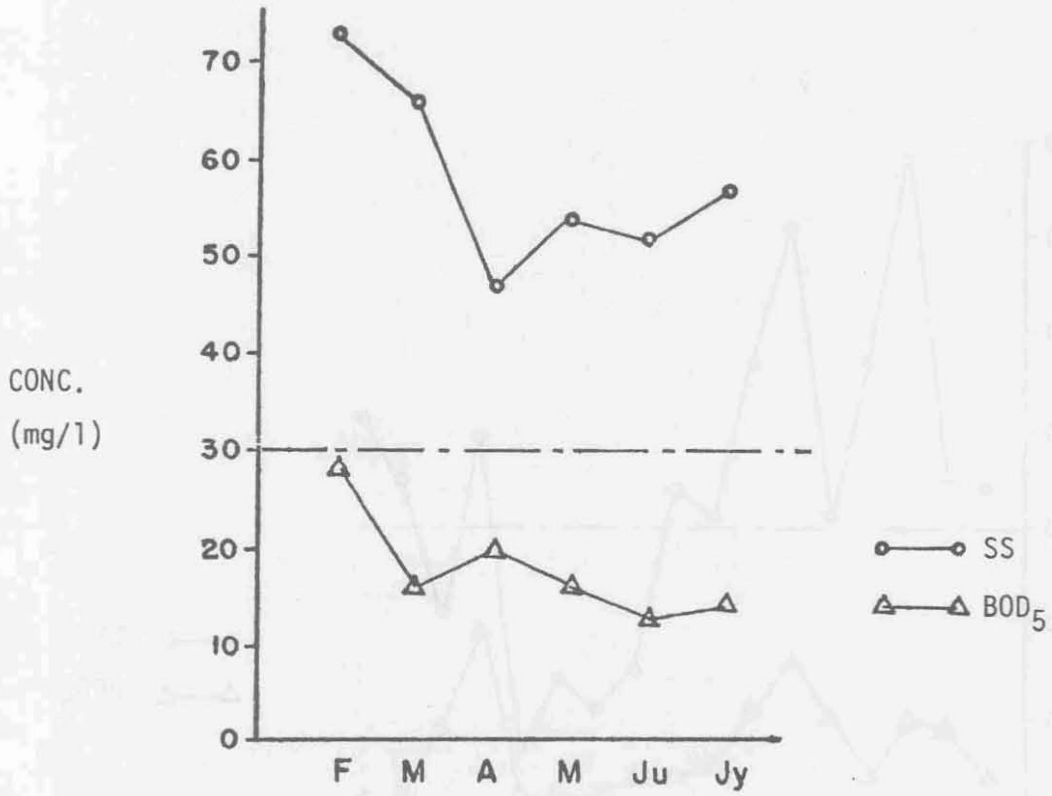

Figure 3. Effluent Quality from Endora Facility (from (5))

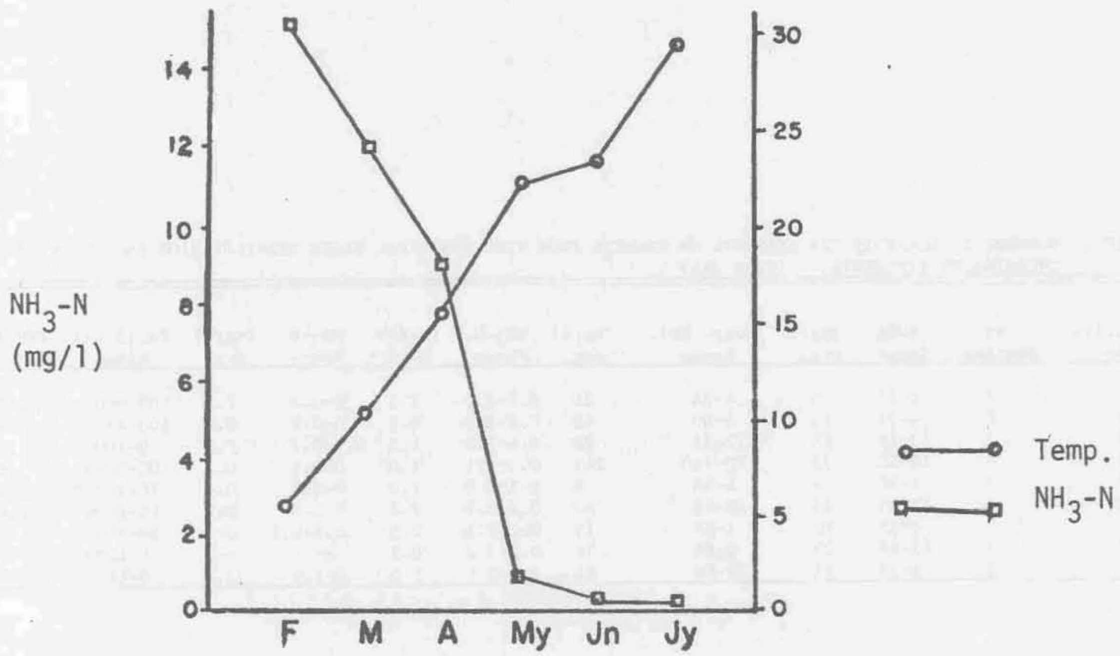

Figure 4. Effluent Quality from Endora Facility (from (5))

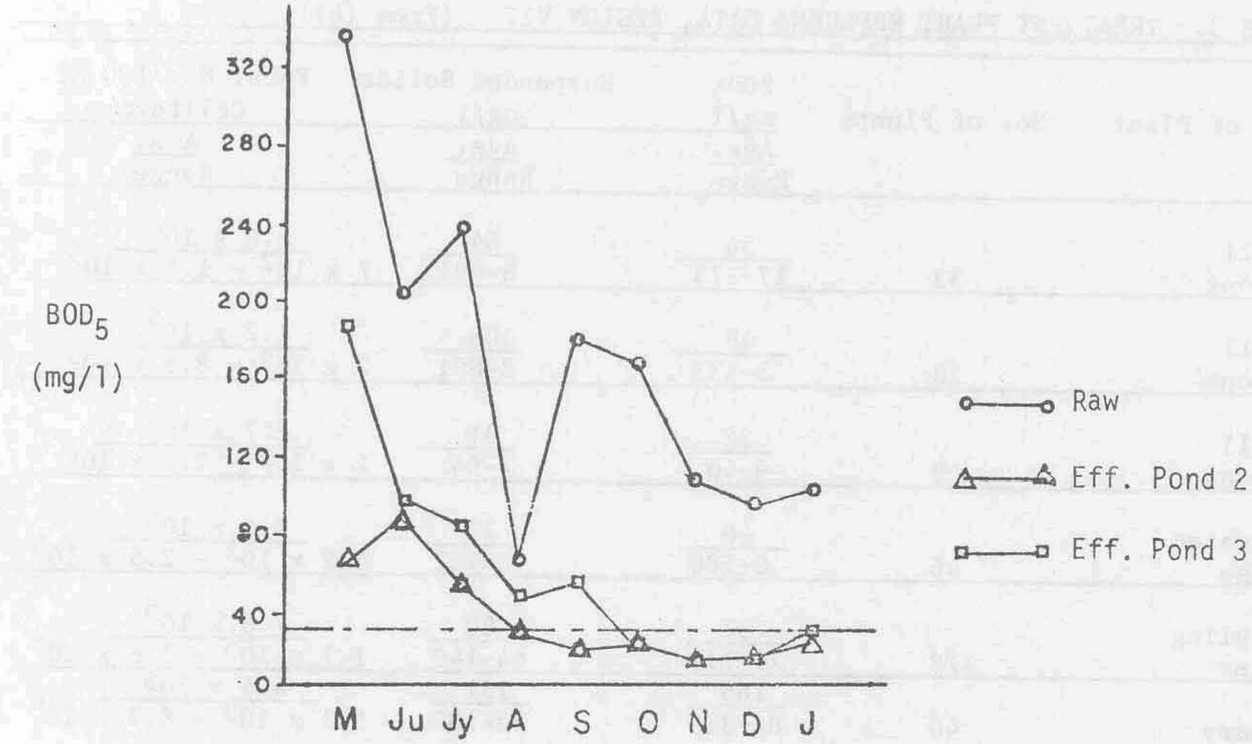

Figure 5. BOD_5 for Jackson, Miss. System (from (7))

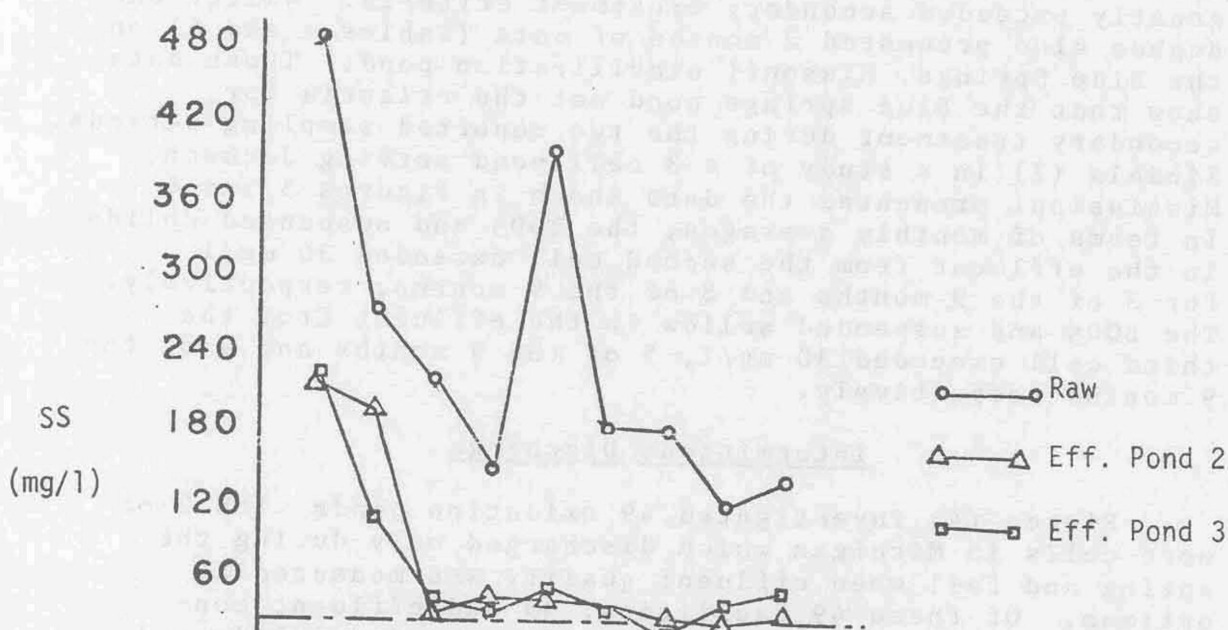

Figure 6. Suspended Solids for Jackson, Miss. System (from (7))

TABLE 3. TREATMENT PLANT EFFLUENT DATA, REGION VII (From (6))

Type of Plant	No. of Plants	BOD_5 mg/l Ave.	BOD_5 mg/l Range	Suspended Solids mg/l Ave.	Suspended Solids mg/l Range	Fecal Coliform No./100 ml Ave.	Fecal Coliform No./100 ml Range
1 Cell Lagoons	33	54	17-273	64	8-891	2.6×10^4	$7 \times 10^2 - 1.5 \times 10^5$
2 Cell Lagoons	28	48	3-133	105	8-891	1.2×10^5	$2 \times 10^2 - 8.5 \times 10^5$
3 Cell Lagoons	9	22	9-40	31	7-54	2.7×10^4	$2 \times 10^2 - 2.7 \times 10^4$
Activated Sludge	46	40	8-180	72	5-162	2.2×10^5	$5.2 \times 10^3 - 2.8 \times 10^5$
Trickling Filter	178	37	20-71	80	44-149	7.6×10^5	$1.7 \times 10^5 - 1.6 \times 10^6$
Primary	40	165	84-315	131	32-182	4.4×10^6	$5.1 \times 10^3 - 8.7 \times 10^6$

cell ponds was 22 mg/l and 48 mg/l, respectively. Average fecal coliform counts for both the 2 and 3 cell ponds greatly exceeded secondary treatment criteria. Walter and Bugbee also presented 2 months of data (Tables 4 and 5) on the Blue Springs, Missouri stabilization pond. These data show that the Blue Springs pond met the criteria for secondary treatment during the two reported sampling periods. Sindala (7) in a study of a 3 cell pond serving Jackson, Mississippi presented the data shown in Figures 5 and 6. In terms of monthly averages, the BOD5 and suspended solids in the effluent from the second cell exceeded 30 mg/l for 3 of the 9 months and 8 of the 9 months, respectively. The BOD_5 and suspended solids in the effluent from the third cell exceeded 30 mg/l, 5 of the 9 months and 9 of the 9 months, respectively.

Intermittent Discharge

Pierce (4) investigated 49 oxidation ponds with 2 or more cells in Michigan which discharged only during the spring and fall when effluent quality was measured at optimum. Of these 49 facilities, 35 had effluent concentrations greater than 30 mg/l of suspended solids and 8 had effluent concentrations exceeding 45 mg/l of BOD5. Ten of the 49 also exceeded secondary treatment fecal coliform criteria. If

TABLE 4. SUMMARY OF OPERATING DATA, BLUE SPRINGS LAGOON SYSTEM, AVERAGE VALUES, JANUARY 22 TO FEBRUARY 20, 1974. (from (6))

Sampling Station	Flow mgd	Temp ^oC	pH	BOD_5 mg/1	COD mg/1	NFS mg/1	Tot P mg/1	NH_3-N mg/1	NO_2-NO_3-N mg/1	TKN mg/1	ToT N mg/1	Fecal Coliform Organ/ 100 ml
Influent[3] Wet Well 1/22-2/2/74	3.0	12.7	7.57	42.5	171	63	3.95	3.53	1.71	6.91	8.62	420×10^3
Influent Wet Well 2/3-2/20/74	1.48	11.6	6.35	176	900	307	8.75	10.67	0.12	15.94	16.06	475×10^3
Effluent Cell 1		4.5	7.39	28.1	119	17	6.66	10.25	0.10	12.63	12.73	69.7×10^3
Effluent Cell 2		4.1	7.34	27.9	89	13	6.58	10.63	0.10	12.57	12.67	29.9×10^3
Effluent Cell 3	2.46	3.7	7.27	26.8	81	13	6.93	11.05	0.10	12.86	12.96	22×10^3

[3] Automatic compositor changed on 2/02/74 from ISCO 1391 to QCEC CVE. ISCO operation is by peristaltic pump, CVE by vacuum. Experience to date shows vacuum operation collects more solids.

TABLE 5. SUMMARY OF OPERATING DATA, BLUE SPRINGS LAGOON SYSTEM, AVERAGE VALUES, APRIL 22 TO MAY 24, 1974. (from (6)).

Sampling Station	Flow mgd	Temp ^oC	pH	BOD_5 mg/1	COD mg/1	NFS mg/1	Tot P mg/1	NH_3-N mg/1	NO_2-NO_3-N mg/1	TKN mg/1	ToT N mg/1	Fecal Coliform Organ/100 ml
Influent Wet Well	1.76	13.3	7.14	196	621	557	8.93	11.03	0.41	19.25	19.66	534×10^3
Effluent Cell 1		18.2	7.51	61.2	208	106	8.44	6.78	0.07	16.77	16.84	14.1×10^3
Effluent Cell 2		18.7	7.55	30.9	124	43	8.59	7.30	0.06	13.00	13.06	7.5×10^3
Effluent Cell 3	1.83	20.1	7.62	23.2	94	26	8.70	8.23	0.05	12.45	12.50	3.8×10^3

discharge periods were less than 1 week, the case might be built for utilizing the weekly average rather than the monthly average criteria. For Pierce's data, more than half (102 out of 186) of the discharge periods were longer than 10 days thus monthly average criteria seems more applicable. Overall, this data showed that suspended solids criteria were met only 50 percent of the time. Pierce also studied 49 stabilization ponds in Minnesota. For the spring discharge from these facilities, 3 of the 49 exceeded 30 mg/l of BOD_5 with the high value being 39 mg/l. In addition, 16 exceeded 30 mg/l of suspended solids and 10 exceeded 45 mg/l of suspended solids with the high value being 129 mg/l. Three of the 49 also exceeded 200 mg/l of fecal coliforms. A summary of this information is shown in Table 6.

TABLE 6. INTERMITTENT LAGOONS WITH QUALITY LESS THAN SECONDARY TREATMENT CRITERIA

	Number Exceeding Criteria for		
Number Investigated	BOD_5	SS	Fecal Coliform
49 (Michigan)	8	35	10
49 (Minnesota)*	3	16	3

*Spring discharge
Source of Data: Pierce (4)

The above data were presented to show that wastewater stabilization ponds, both continuous and intermittent flow, generally cannot meet secondary treatment criteria when designed by the methods commonly in practice today. In plant operational problems and the qualifications of operating personnel could have a significant impact on these data and analysis; however, the large number of plants considered should tend to minimize the possibilities of drawing incorrect conclusions based upon a small data sample.

UPGRADING WASTEWATER STABILIZATION PONDS

Rock Filters

Since only a relatively short time has elapsed since the enactment of PL 92-500, very few ponds have been upgraded and almost no data exists on upgraded ponds except those funded as research installations. One such installation is at Endora, Kansas (sewered population 2200) where O'Brien (5) is currently studying upgrading of lagoon effluent utilizing rock filters with the gradation shown in Table 7.

The physical layout of the overall system is shown in Figure 7 and the layout of the filter field test facility is shown in Figure 8. The physical dimensions of the filter system are shown in Table 8 and the loading and detention characteristics are shown in Table 9. Three grab samples

TABLE 7. SIZE GRADATION OF THE ROCK USED IN THE TWO EXPERIMENTAL FILTERS (from (5))

Sieve Opening	% Weight Retained	
cm	Large Rock	Small Rock
5.08	7.4	
3.81	28.8	
2.54	52.0	13.4
1.91	10.4	33.1
1.27	1.3	39.0
0.95	0.1	10.4
0.67		3.2
0.47		0.9
Porosity	0.44	0.44

TABLE 8. PHYSICAL DIMENSIONS OF THE EXPERIMENTAL FILTER SYSTEM WHEN THE WATER DEPTH IS 1.22 METERS. (from (5))

	Large Rock	Small Rock
Volume of Influent Pond m^3	126.5	119.4
Surface Area of Influent Pond m2	165.7	157.6
Volume of Submerged Rock m^3	126.6	142.1
Volume of Effluent Pond m^3	84.3	86.1
Surface Area of Effluent Pond m^2	137.1	125.0

TABLE 9. HYDRAULIC LOADING AND DETENTION TIMES WITHIN THE EXPERIMENTAL LAGOON SYSTEM (from (5))

		Filter			
	Influent Pond Detention	Hydraulic Loading		Detention	Effluent Pond Detention
Mo.	Time, Days	$1/day/m^3$	$gal/day/ft^3$	Time, Hrs.	Time, Days
		Large Rock			
Feb.	2.7	367.4	2.7	28.7	1.8
March	6.0	165.4	1.2	63.9	4.0
April	2.4	418.9	3.1	25.2	1.6
May	2.0	492.9	3.7	21.4	1.4
June	1.3	743.9	5.6	14.2	0.9
July	3.9	257.2	1.9	41.1	2.6
		Small Rock			
Feb.	2.7	307.8	2.3	34.3	2.0
March	6.7	124.7	0.9	84.7	4.9
April	2.5	339.5	2.5	31.1	1.8
May	2.1	397.6	3.0	26.6	1.5
June	1.4	604.3	4.5	17.5	1.0
July	4.0	210.6	1.6	50.1	2.9

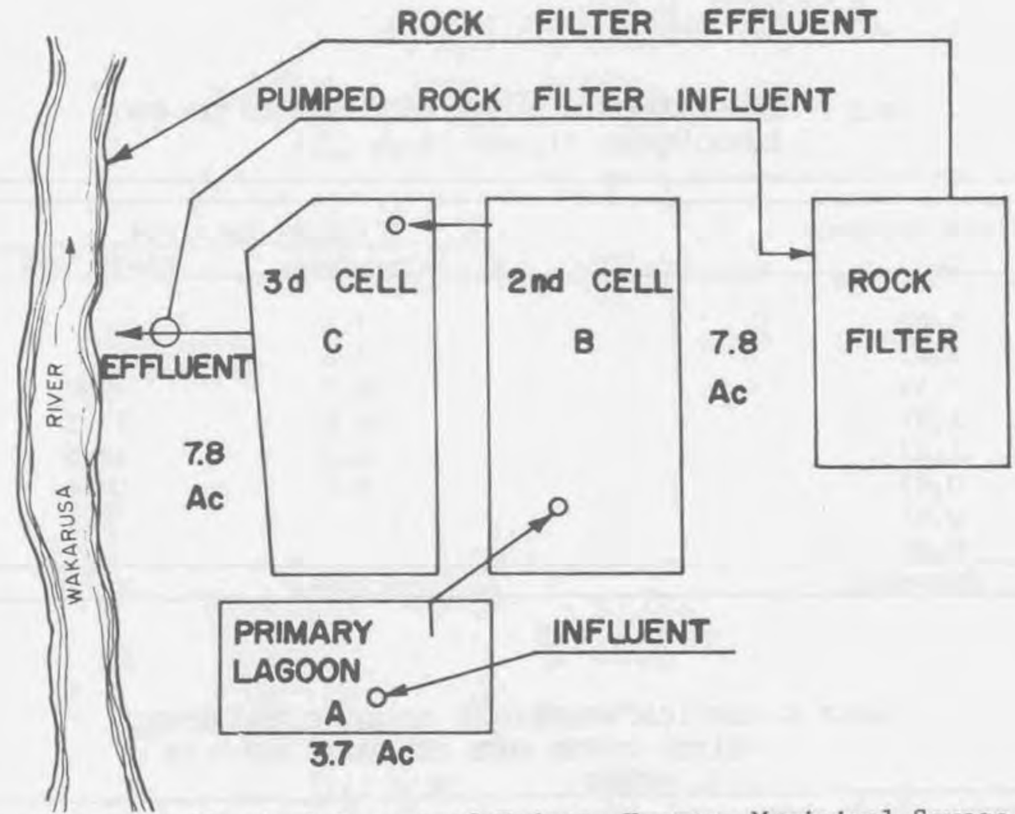

Figure 7. Physical Layout of Eudora, Kansas, Municipal Sewage Oxidation Pond System (from (5))

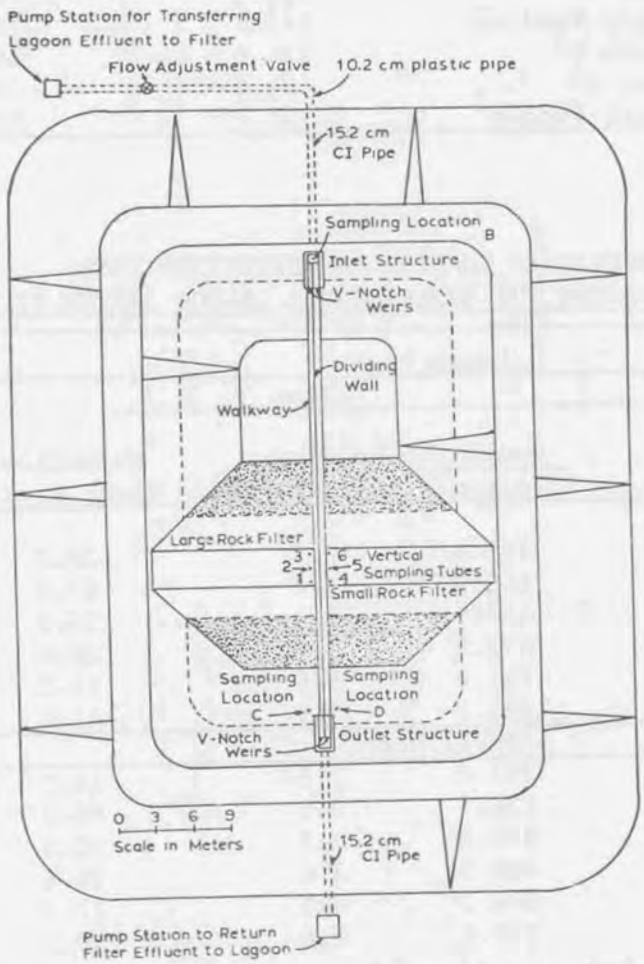

Figure 8. Plan of Experimental Rock Filter Field Test Facility. (from (5))

taken between 7:00 a.m. and 12:00 noon have been collected per week from the effluent of the final cell of the Endora lagoon system, the influent to the experimental filter and the effluent leaving the final filter pond. The results of the sampling are shown in Figures 9, 10, 11 and 12. These data can be subdivided into 3 periods. The first was January through March during which the filters were acting as sedimentation basins and a slime layer was in the process of being established. The increase in the ammonia concentration during December, January, and the first half of February was due to ice covering the lagoons. The second time interval was during April in which the water temperature increased and the biological slime layer became fully developed. During this period, the ammonia nitrogen concentration was large enough to support a significant amount of algal regrowth in the ponds behind the filters. Regrowth of algae continued throughout May, June and July, but the magnitude decreased as the ammonia in the lagoon effluent decreased.

The third time period started in May and continued through the early fall. It was characterized by decreasing effluent suspended solids concentration and onset of anaerobic conditions within the filter. As the filter went anaerobic, a bright green scum layer formed on the surface of the ponds behind the filter apparently from the ammonia released due to anaerobic decomposition within the filters. This has had little effect on the effluent quality because the effluent is drawn from approximately the mid-depth. The original purpose of the ponds behind the filters was to increase the dissolved oxygen and decrease the ammonia nitrogen concentration in the effluent. However, as evidenced from the above data, they have actually caused a deterioration in net suspended solids removal. Elimination of this final pond and aerating the effluent in a separate basin would seem to give this upgrading process good potential. A filter with elimination of the final pond has been designed by an engineering firm and installed by city employees to upgrade a 3 cell lagoon at California, Missouri (design population 3600) at a total construction cost of approximately $55,000. Figure 13 shows the plan of this facility.

Sand Filters

Middlebrooks and Marshall (8, 9) studied the ability of laboratory and pilot scale field intermittent sand filters to remove BOD_5 and suspended solids under various hydraulic loadings and filter media grain sizes using effluent from the Logan, Utah waste stabilization pond. A schematic of this sytem is shown in Figure 14. Results were

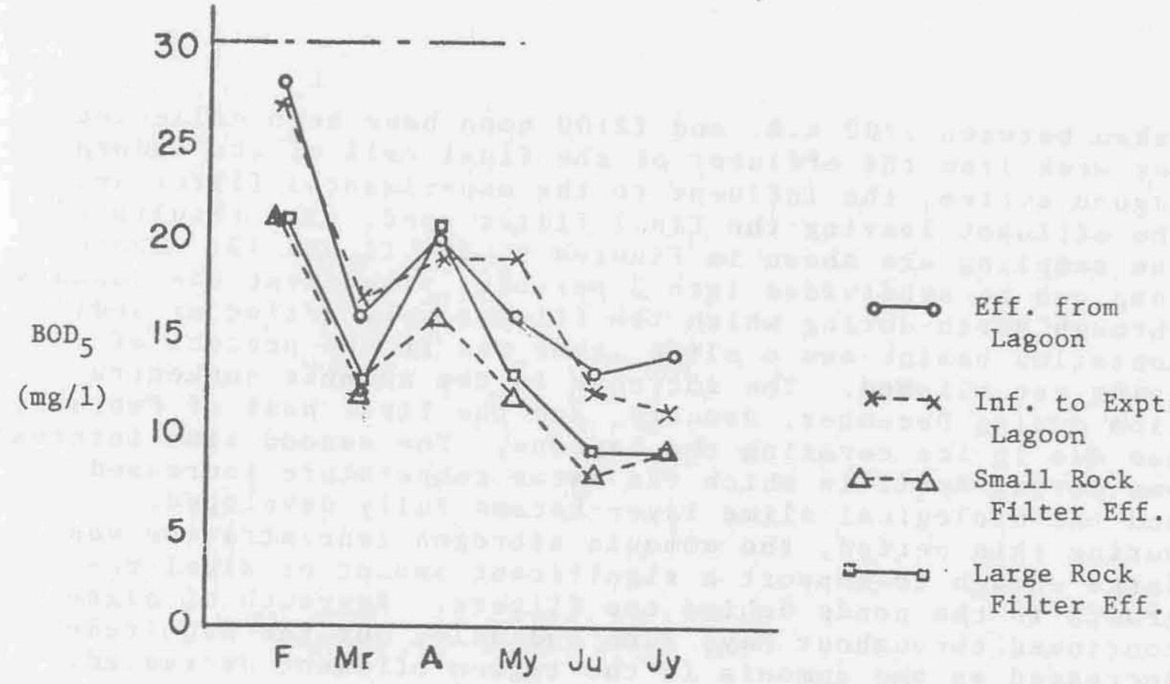

Figure 9. BOD_5 from Endora Facility (from (5))

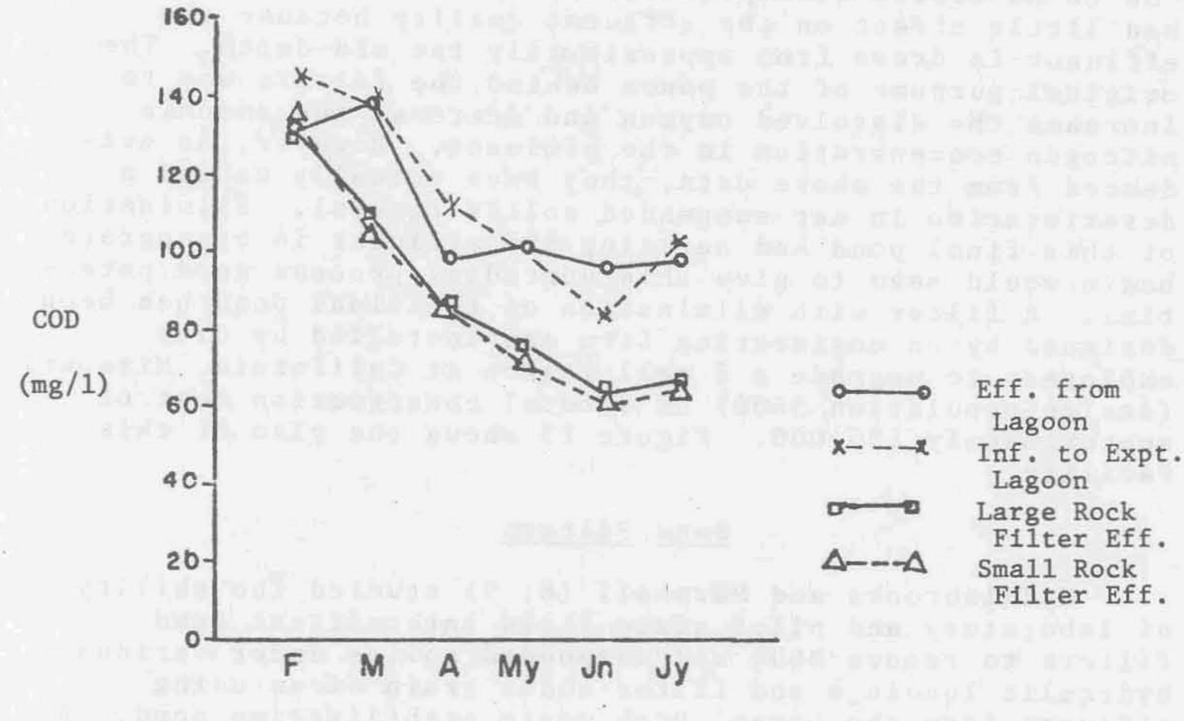

Figure 10. Effluent Quality from Endora Facility (from (5))

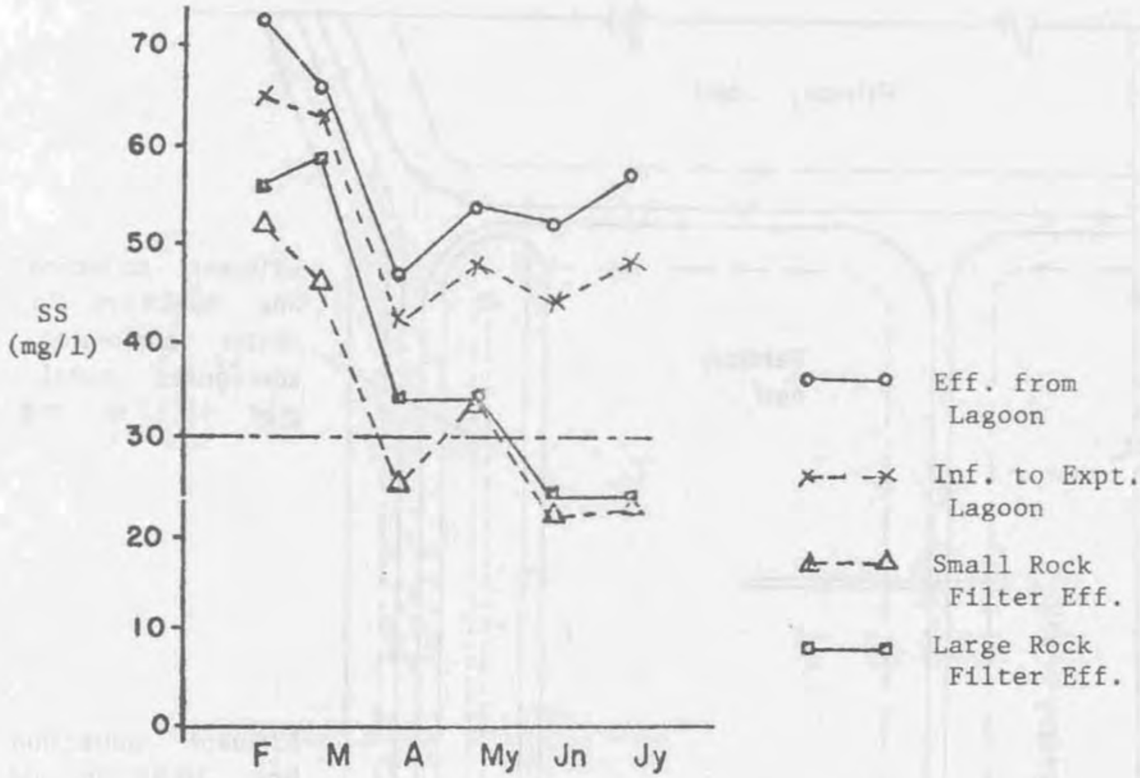

Figure 11. Suspended Solids from Endora Facility (from (5))

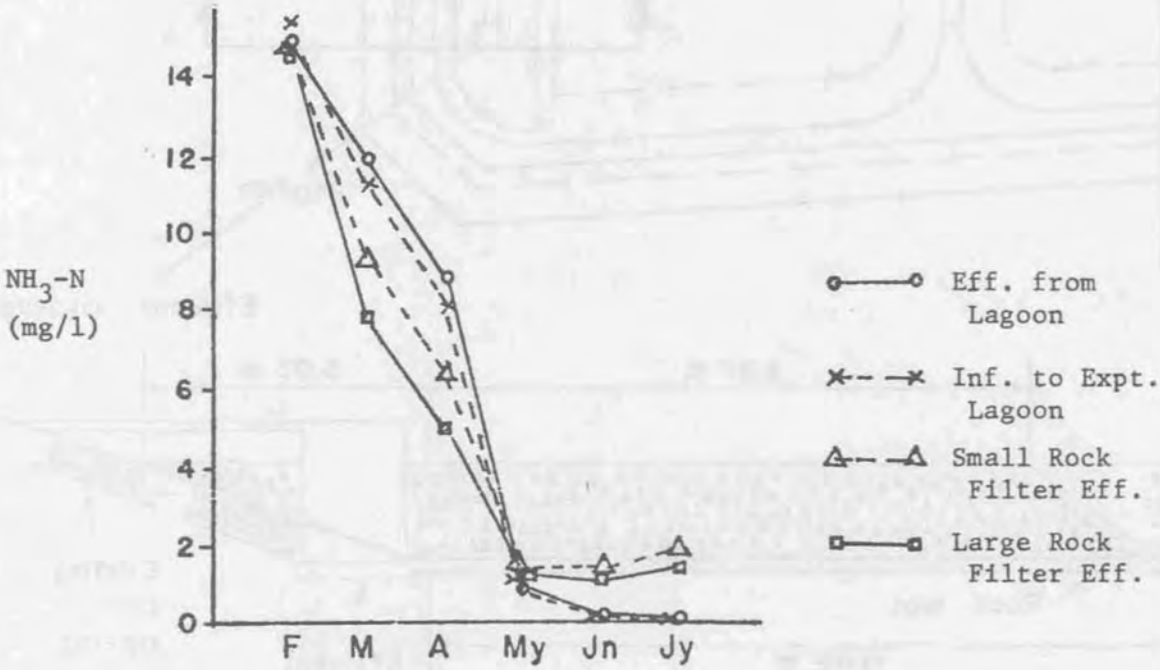

Figure 12. Ammonia Nitrogen from Endora Facility (from (5))

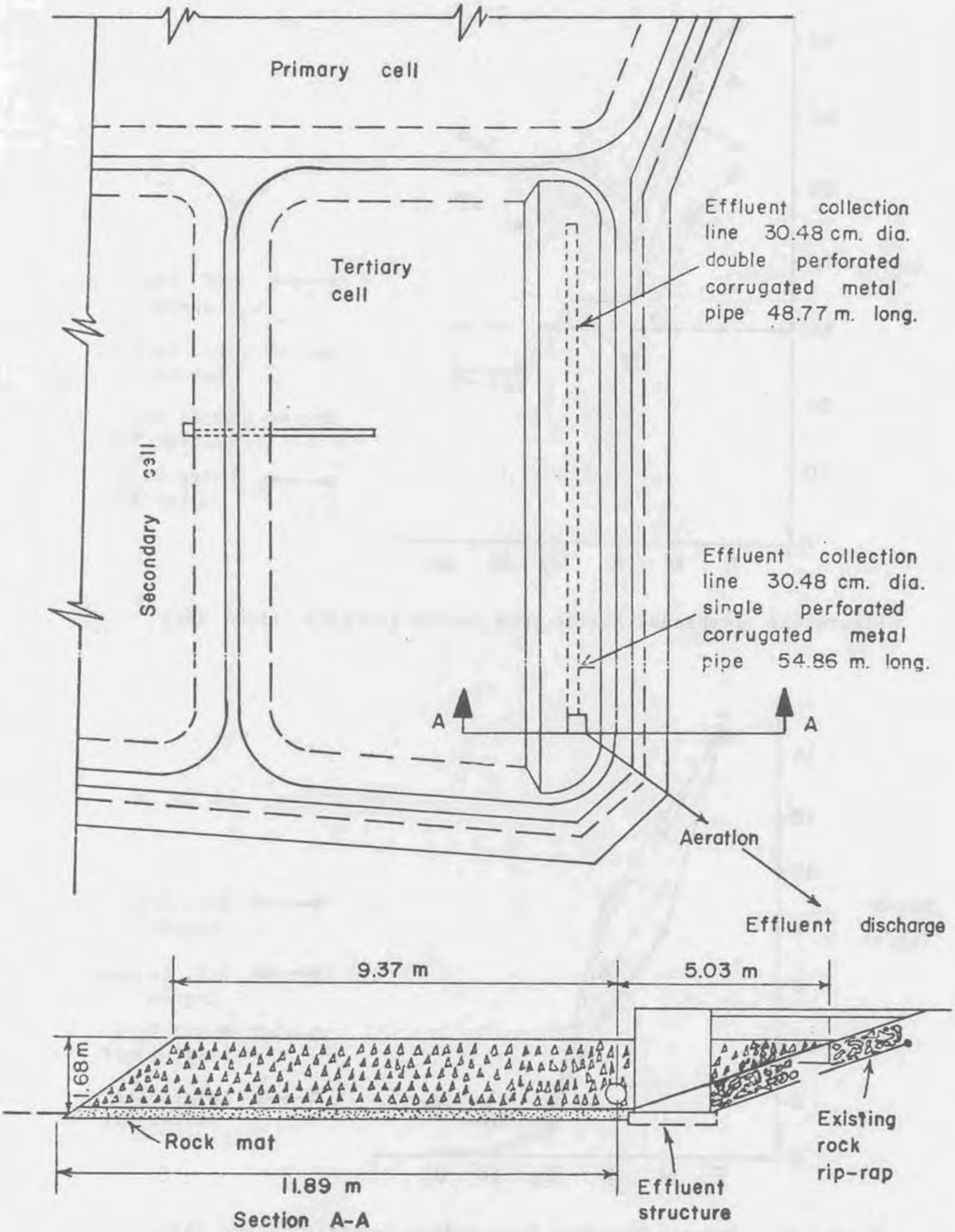

Figure 13. Plan of submerged rock filter constructed at California, Mo. (from (5))

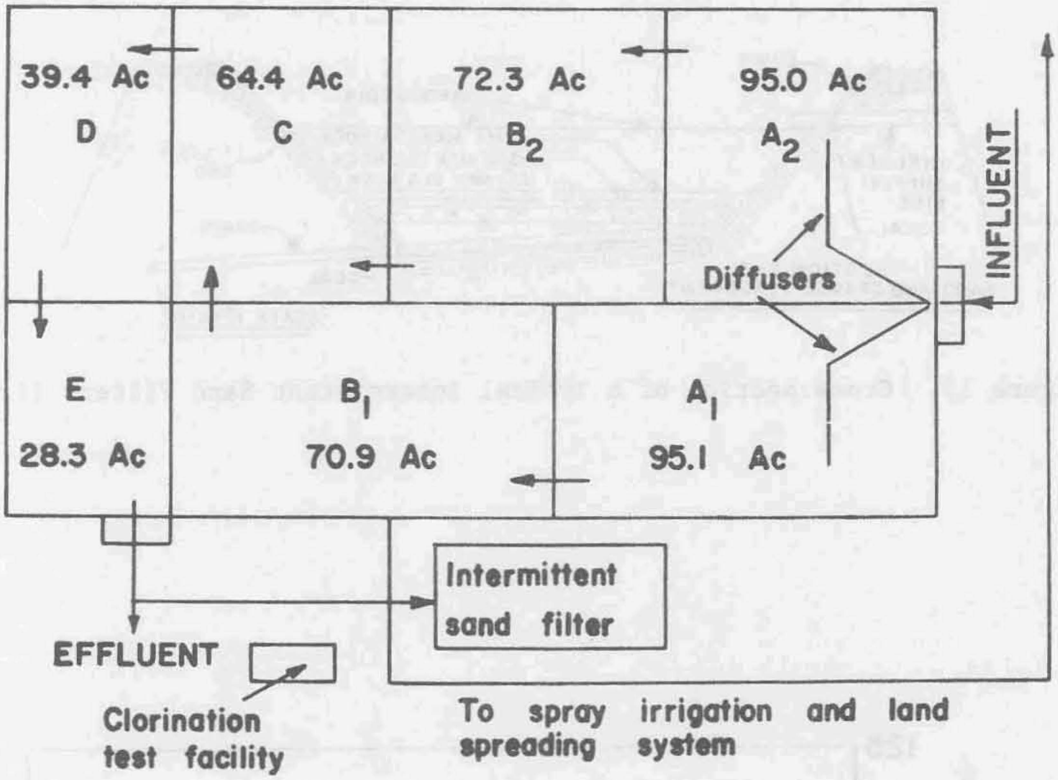

Figure 14. Flow diagram of Logan, Utah, lagoon treatment system. (from (10))

similar with both the lab and field filter units. This study indicated that hydraulic loading rates had little effect on the removal of BOD_5 and ammonia. BOD_5 and ammonia removal increased with decreasing effective size of the sand. Filters containing 0.17 mm effective sand size operated about 30 days with loadings of 0.7 and 0.8 MGAD at 42 mg/l of suspended solids before plugging. Field filters containing 0.72 mm effective size sand operated 137 consectuive days with loadings of 0.4, 0.5 and 0.6 MGAD with suspended solids concentration of 25 mg/l before plugging. Smaller sand size and lower hydraulic loadings produced better suspended solids removal.

Based on the laboratory and pilot scale studies of Middlebrooks and Marshall (8, 9), Reynolds, et al (10) evaluated the performance of 6, 25 feet by 36 feet (900 square feet surface area) intermittent sand filters located at the Logan, Utah sewage lagoons. A typical cross section of one of these filters is shown in Figure 15. The hydraulic loading of each filter was accomplished in less than 30 minutes and when the total amount of effluent applied did not drain in 24 hours, the filter was assumed to be plugged. Data were collected from July 12, 1974 to August 22, 1974 and were averaged to arrive at the results in Table 10. Reynolds, et al also studied the length of filter runs before plugging. They found that

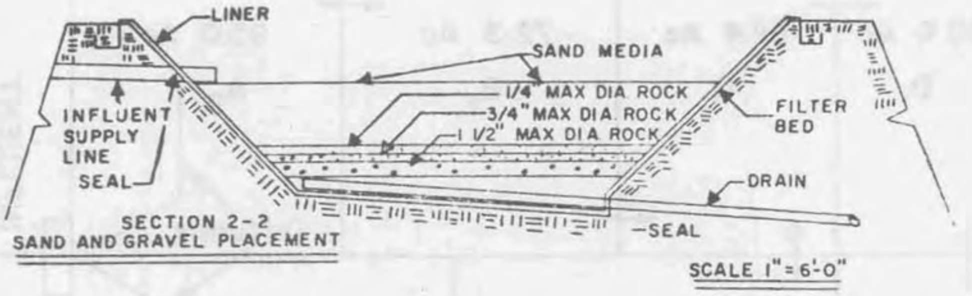

Figure 15. Cross Section of a Typical Intermittent Sand Filter (from (8))

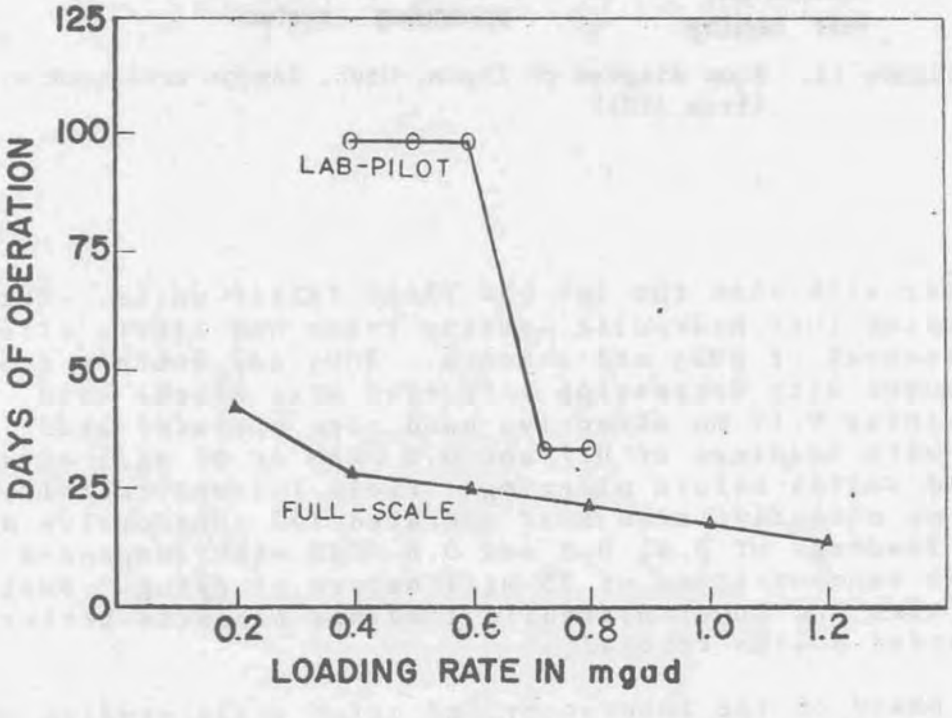

Figure 16. Days of Operation before Plugging 0.17 mm Sand (from (10))

TABLE 10. AVERAGE OF ALL SAMPLES COLLECTED DURING THE EXPERIMENTAL PERIOD.

Loading Rate in mgad	BOD_5 mg/1	COD mg/1	Suspended Solids mg/1	Volatile Suspended Solids mg/1	Total Phosphorus mg/1	Ortho-Phosphate mg/1	NH_3-N mg/1	NO_2-N mg/1	NO_3-N mg/1	pH	Temp °C	Dissolved Oxygen mg/1	Algal Mass Removed Kg
Influent	8.1	69.7	26.1	16.9	2.082	1.754	2.469	0.025	0.100	8.8	23.2	4.2	a
0.2	2.4	42.1	6.8	0.9	1.756	1.695	0.166	0.083	4.670	8.0	23.6	6.2	21.988
0.4	1.7	27.8	3.7	1.0	1.595	1.458	0.197	0.025	4.936	8.1	24.4	6.1	21.538
0.6	2.3	27.5	5.5	1.4	1.767	1.644	0.293	0.055	4.985	8.0	23.7	5.9	26.108
0.8	3.5	40.6	7.2	0.7	1.863	1.683	0.322	0.090	4.372	7.9	25.0	5.7	18.783
1.0	2.8	39.8	7.1	1.0	1.980	1.717	0.486	0.160	3.664	8.1	25.1	5.0	19.008
1.2	4.3	49.7	4.8	0.8	1.776	1.657	0.541	0.154	3.383	8.1	24.0	4.8	12.336

[a]Not applicable.

the length of a filter run varied from 14 days at a hydraulic loading of 1.2 MGAD to 42 days with a hydraulic loading of 0.2 MGAD. This was significantly less than that found by Middlebrooks and Marshall for the laboratory and pilot scale facilities. A comparison is shown in Figure 16. The shorter runs were attributed to higher average suspended solids concentrations. The lab and pilot investigations had an average influent suspended solids concentration of 20 mg/1 whereas the full scale study had an average influent concentration of 26 mg/1 with a range of 10 mg/1 to 72 mg/1. In addition, the lower filter runs could be caused by the significant growth of algae and thus higher corresponding suspended solids concentration which were observed to occur in the liquid as it awaited percolation through the filter. Figure 17 shows the magnitude with which this growth occurred. To alleviate this problem would require dosing at night or covering the filters to inhibit photosynthesis. The data of Reynolds, et al were analyzed to roughly determine the loading rate at which the largest amount of algal mass was removed and the result is shown in Figure 18. The average effluent suspended solids concentration found for each hydraulic loading rate is shown in Figure 19. The average effluent BOD_5 and COD concentrations for each hydraulic loading are plotted in Figures 20 and 21. The average effluent ammonia nitrate and nitrite nitrogen are shown in Figures 22, 23 and 24.

Reynolds, et al (11) report that a study is currently under way at Utah State University to evaluate intermittent sand filters of various effective size sands in series. They report that preliminary results indicate a high quality

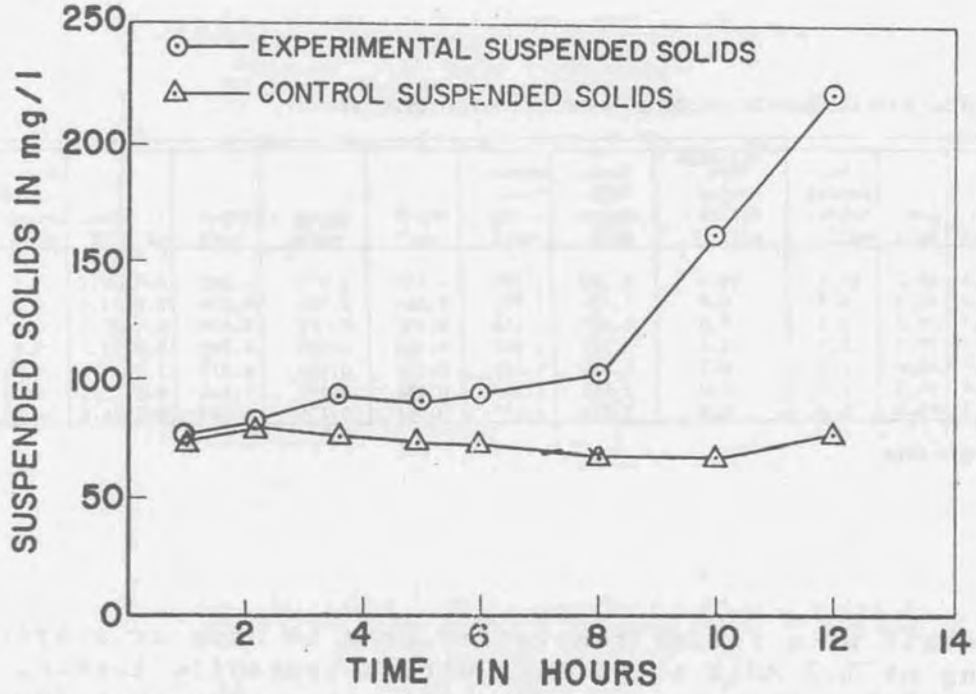

Figure 17. Algal Growth on Filters with Time. (from (10))

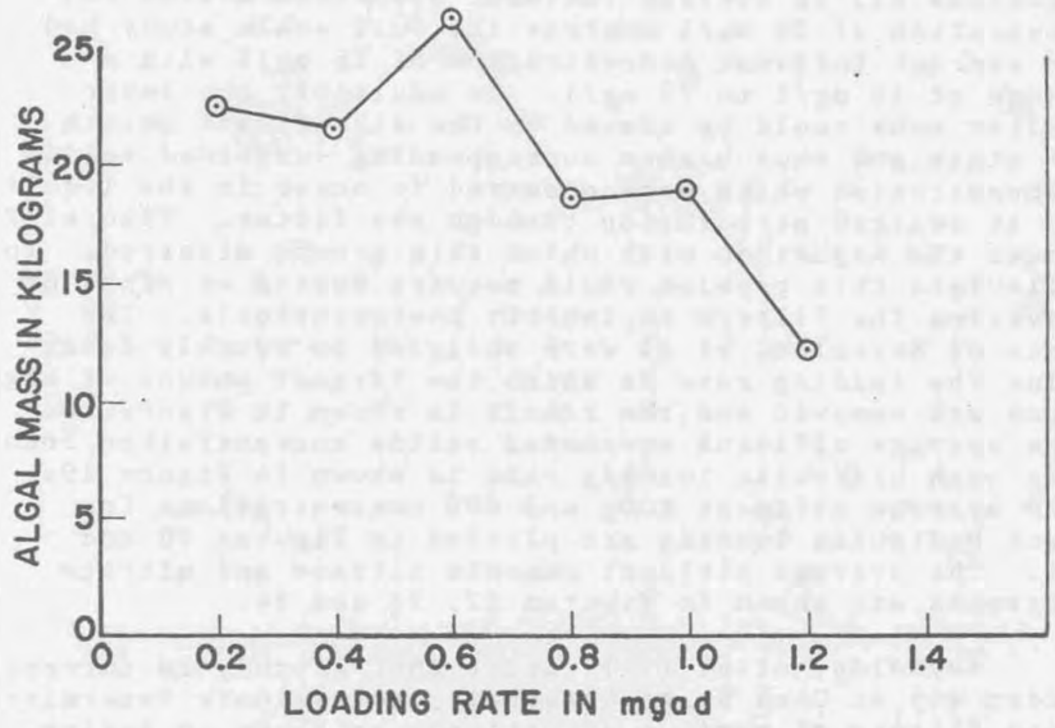

Figure 18. Total Mass Removed by Each Filter before Plugging. (from (10))

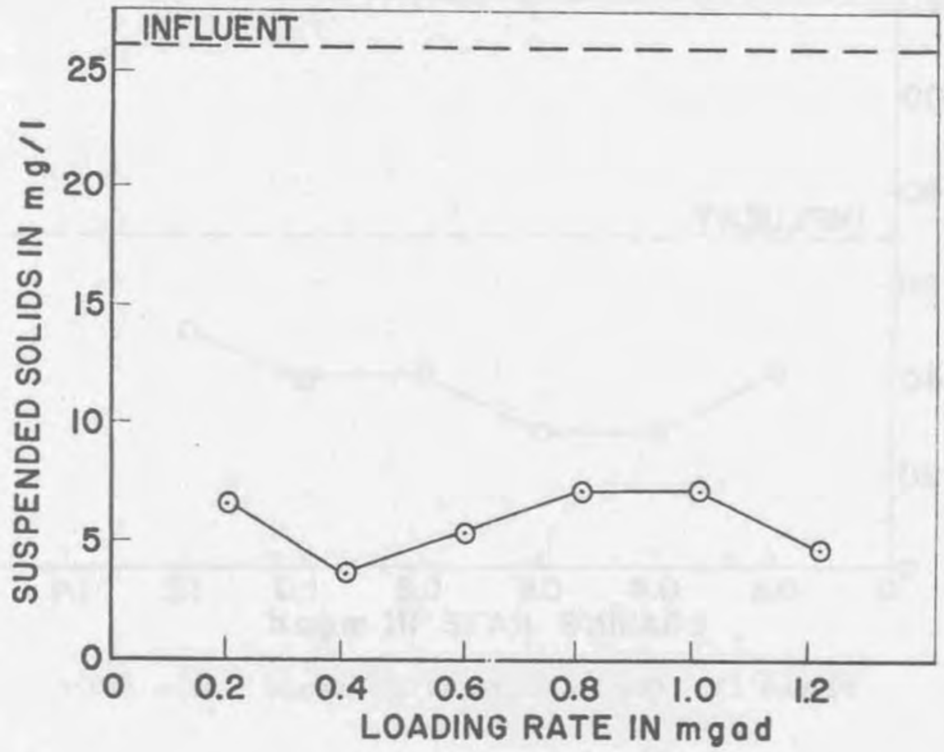

Figure 19. Suspended Solids in Filtered Effluent. (from (10))

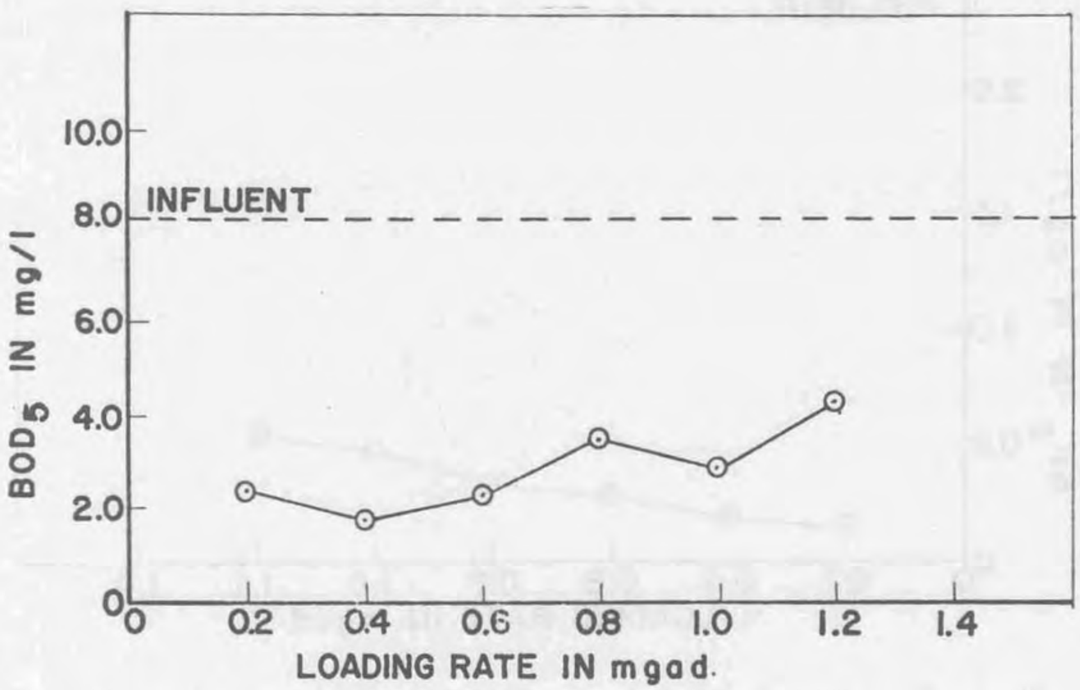

Figure 20. BOD_5 in Filtered Effluent. (from (10))

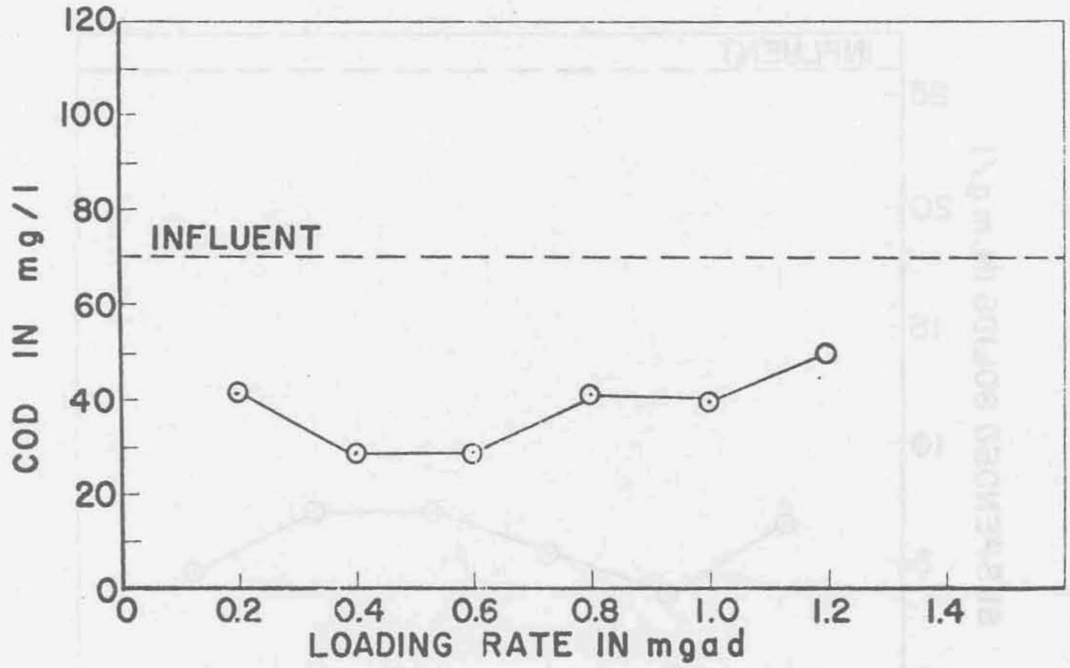

Figure 21. COD in Filtered Effluent. (from (10))

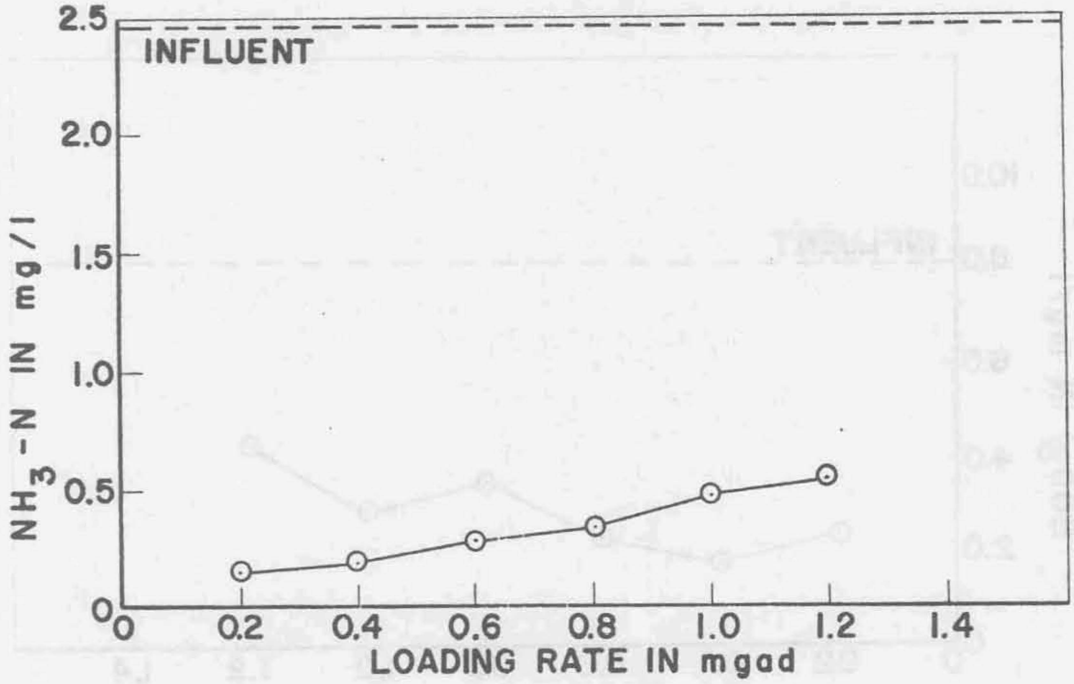

Figure 22. Ammonia Nitrogen in Filtered Effluent. (from (10))

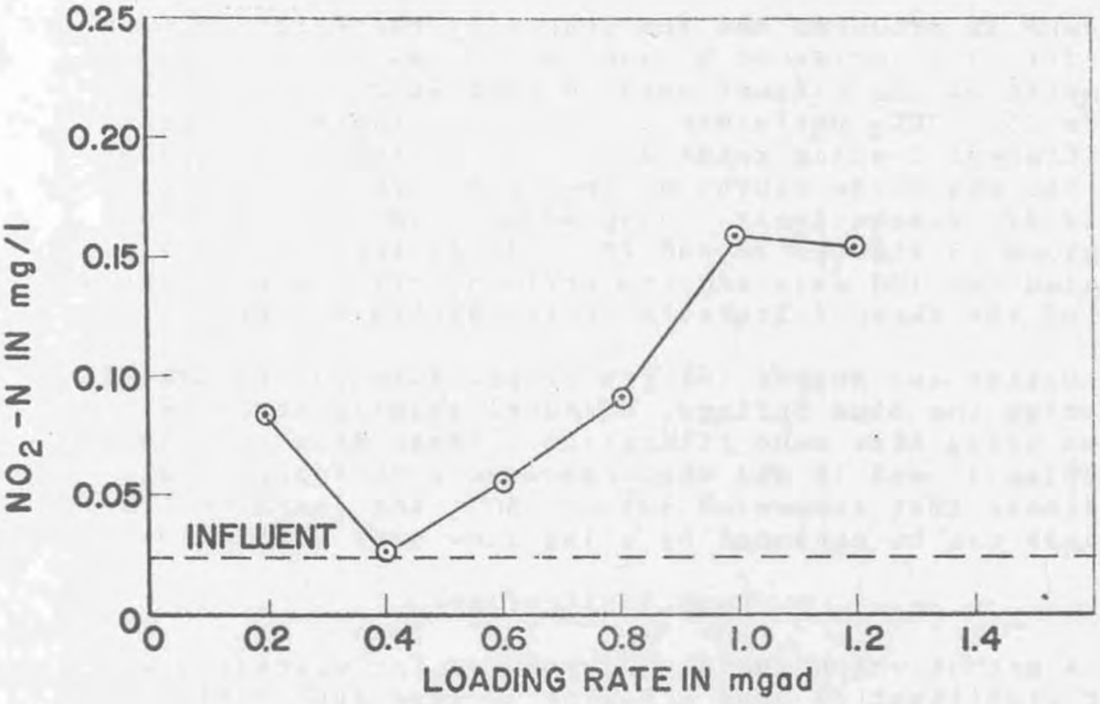

Figure 23. Nitrite Nitrogen in Filtered Effluent. (from (10))

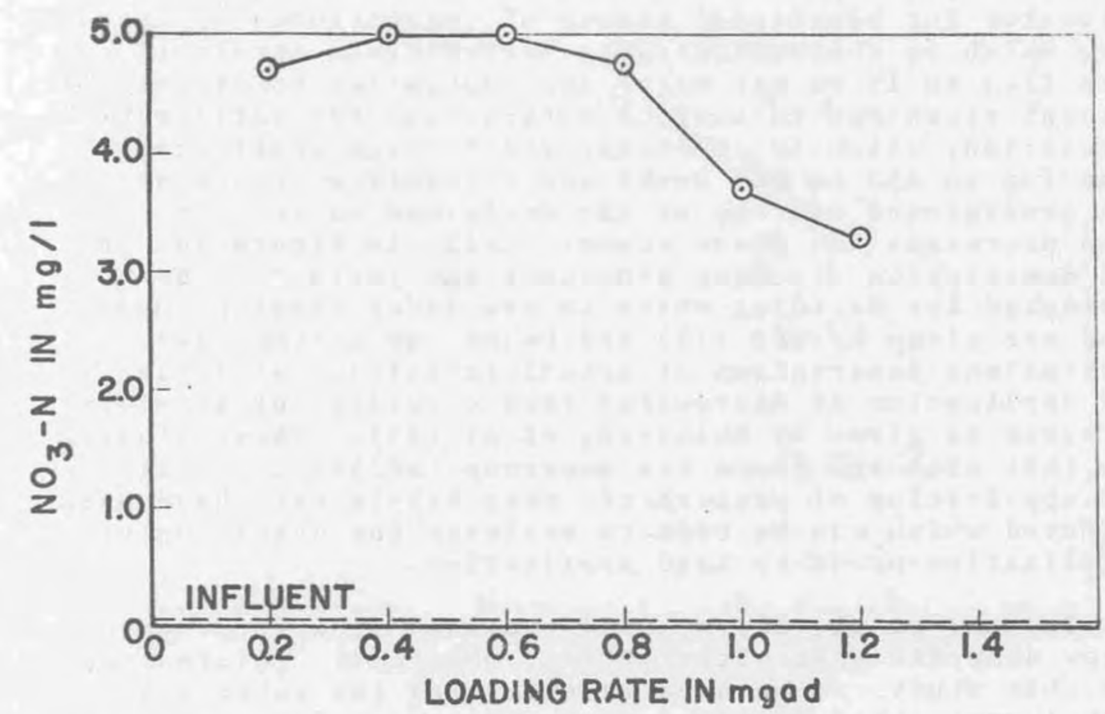

Figure 24. Nitrate Nitrogen in Filtered Effluent. (from (10))

effluent is produced and the length of the filter run is substantially increased because of series operation. A schematic of the filters used in this study is shown in Figure 25. BOD_5 performances for the filters in series at different loading rates and at a loading rate of 1.5 MGAD for the three months of the study are given in Figures 26 and 27, respectively. Suspended solids performances are given in Figures 28 and 29. All filters had been operated for 100 days and the effluent still passed through each of the three filters in series within 4 hours.

Walter and Bugbee (6) report preliminary results of upgrading the Blue Springs, Missouri stabilization pond system using slow sand filtration. These data are shown in Tables 11 and 12 and when compared with Tables 4 and 5 indicate that suspended solids, BOD_5 and fecal coliform removals can be enhanced by using slow sand filtration.

Land Application

A method which shows good promise for upgrading wastewater stabilization pond effluent is land application. The terminology commonly used in the land application field has been presented by Thomas (12) who divides land application approaches, as follows: (a) crop irrigation, which is characterized by relatively low application rates (less than 10 cm per week) and emphasizes the reuse of wastewater for beneficial growth of vegetation; (b) overland flow, which is characterized by intermediate application rates (7.5 to 15 cm per week) and emphasizes treatment with effluent discharge to surface waters; and (c) infiltration-percolation, which is characterized by high application rates (up to 150 cm per week) and emphasizes treatment with underground storage of the reclaimed wastewater. These three processes are shown schematically in Figure 30. A good description of these processes and factors to be considered for deciding which to use under varying conditions are given by EPA (13) and Pound and Crites (14). An excellent description of actual facilities utilizing land application of wastewater from a variety of treatment processes is given by Sullivan, et al (15). These studies show that although there are numerous facilities utilizing land application of wastewater, very little data have been collected which can be used to evaluate the upgrading of stabilization ponds by land application.

Thomas, et al (16) studied overland flow for treatment of raw domestic wastewater at Ada, Oklahoma. Information from this study can be used in assessing the potential effectiveness that overland flow could have for upgrading stabilization pond effluents or for use as a low cost substitute for stabilization pond treatment of municipal

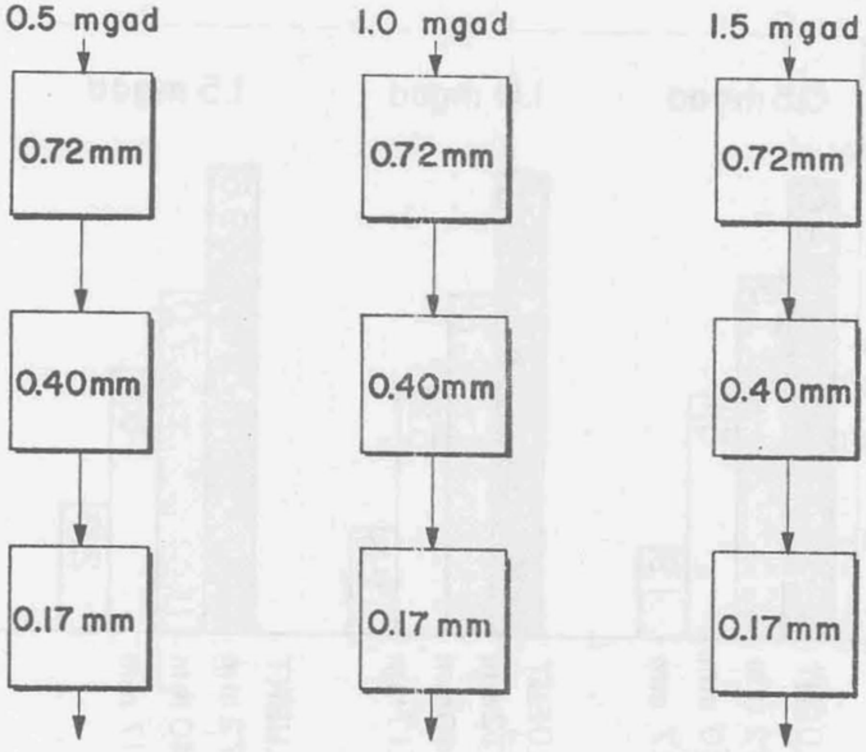

Figure 25. Series Intermittent Sand Filtration Operation. (from (11))

wastewater. The study utilized nozzles with different orifices to obtain average areal loadings of 7.4, 8.6 and 9.8 cm per week with the actual rates adjusted seasonally so that the 3 month duration winter rate was 85 percent of the average rate, the 3 month duration summer rate was 115 percent of the average rate, and the spring and fall rates were equal to the average rates. Wastewater was applied to plots measuring 11 meters by 36 meters which had been smoothed to a uniform slope of 2-4 percent. In the spring and fall, effluent was applied for 8 hours a day for 6 days a week, in the winter for 8 hours a day for 5 days per week, and in the summer for 9 hours a day for 6 days a week. The schematic of the wastewater handling system is shown in Figure 31. Operation of the system once it was functioning properly required about 1 hour per day. The study was conducted for 18 months and the results are presented for 3 periods. The first was the initial shakedown period when the system was undergoing rapid changes in treatment efficiency due to adaptation of microbial organisms, establishment of vegetation, and other environmental alterations commonly lumped under the aggregate term of aging. The second period was from November, 1971 through April, 1972 and would be typical of winter operation for a well matured system. The third period was May through

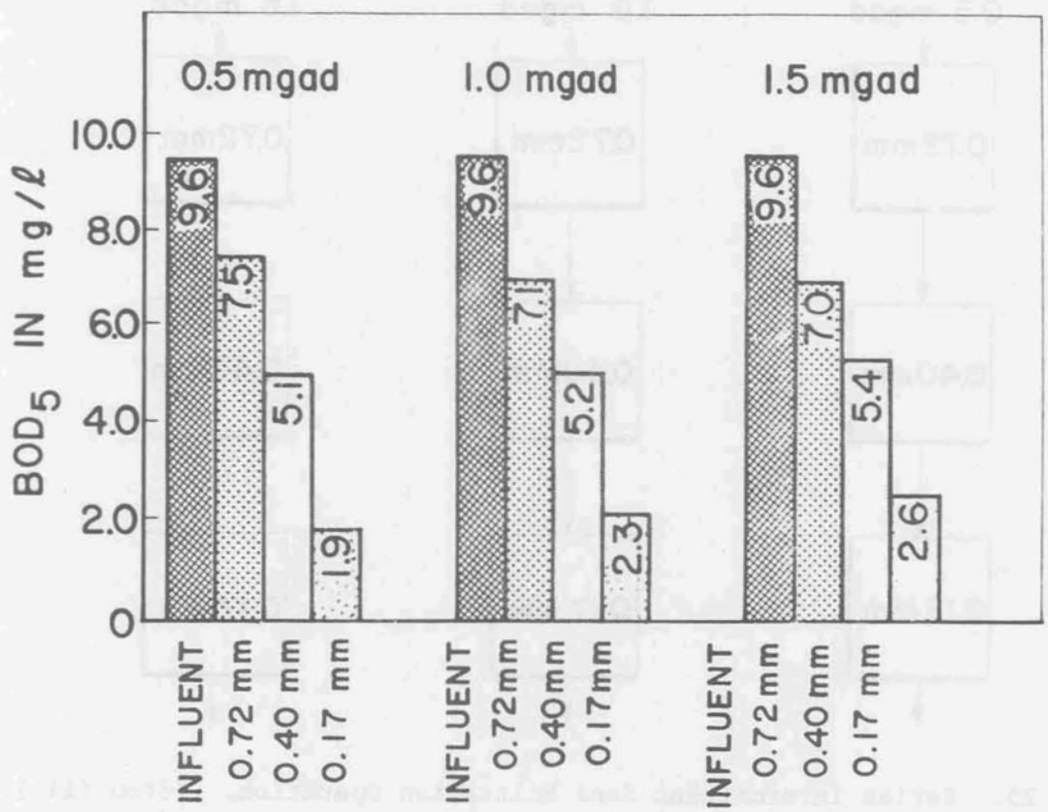

Figure 26. Series Filtration BOD_5 Performance. (from (11))

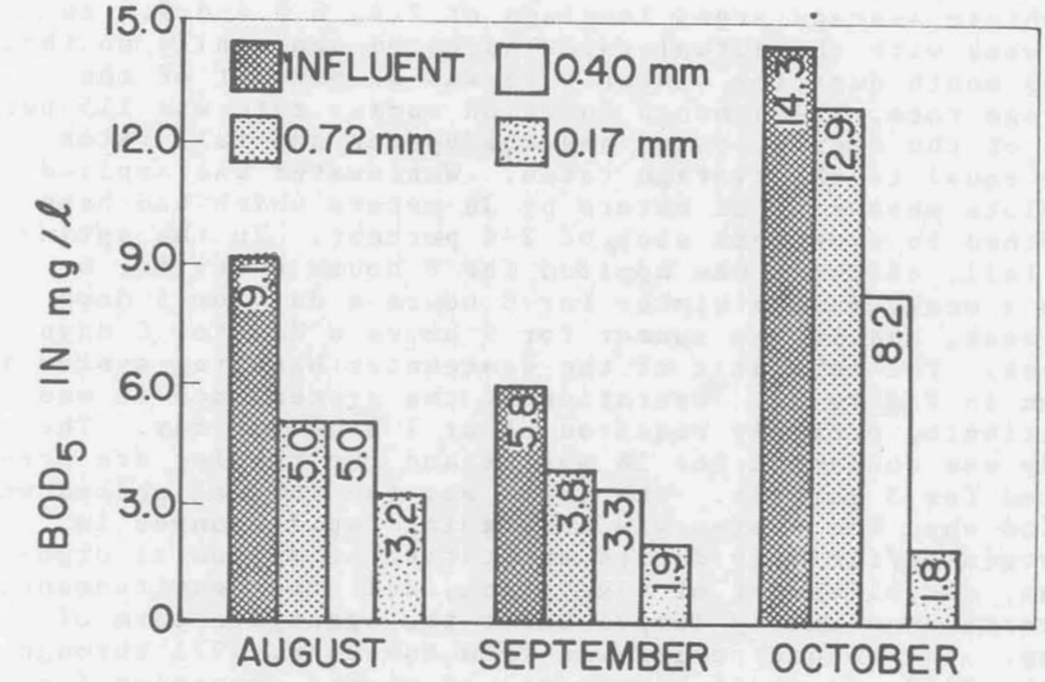

Figure 27. Series Filtration BOD_5 Performance at 1.5 mgad. (from (11))

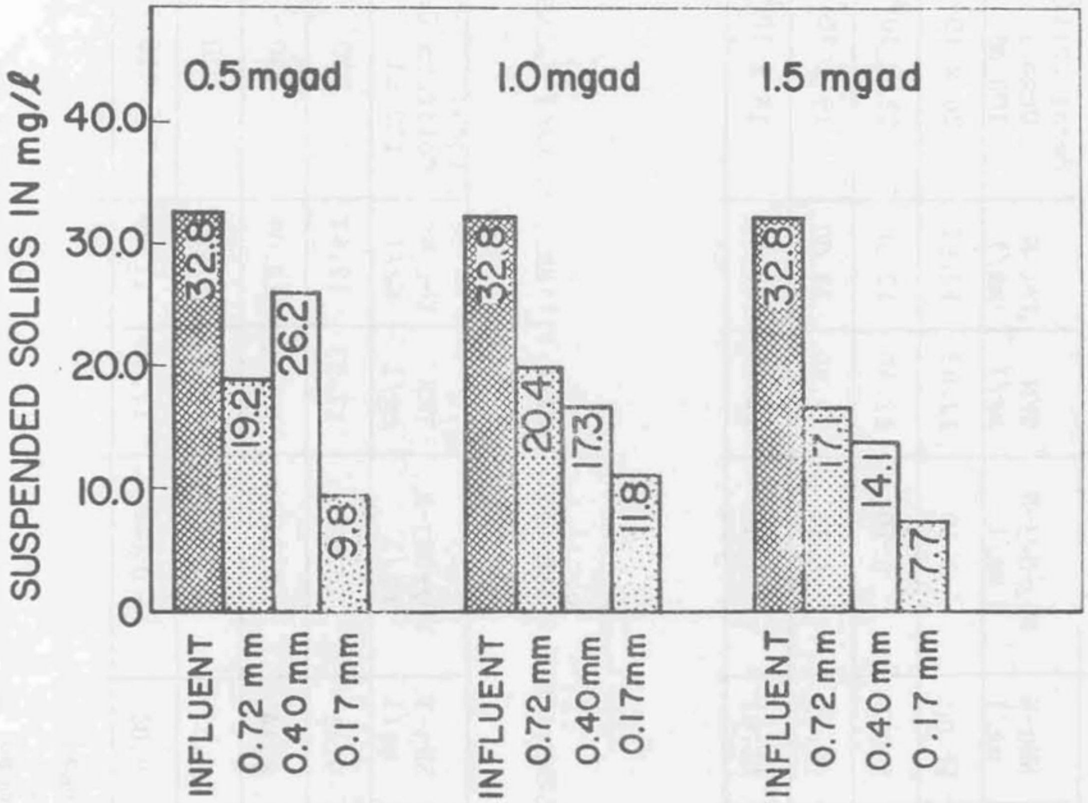

Figure 28. Series Filtration Suspended Solids Performance. (from (11))

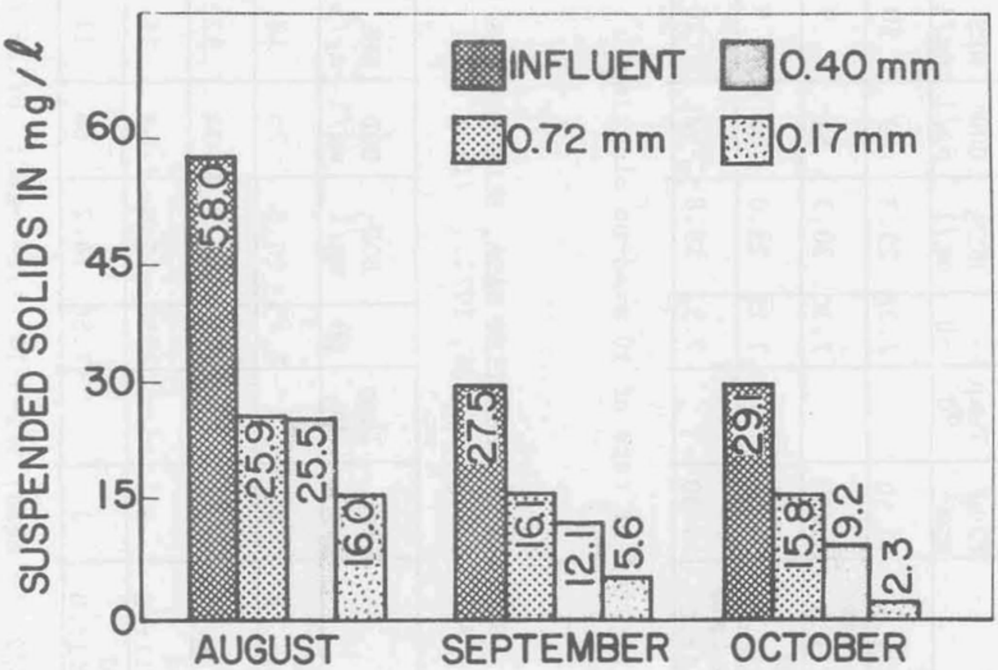

Figure 29. Series Filtration Suspended Solids Performance at 1.5 mgad. (from (11))

TABLE 11. SUMMARY OF OPERATING DATA, BLUE SPRINGS LAGOON SYSTEM. CELL 2 AND CELL 3 SAND FILTERS, AVERAGE VALUES, JANUARY 22 TO FEBRUARY 20, 1974. (From (6))

Sampling Station	Flow gpm^3	Temp ^oC	pH	BOD_5 mg/1	COD mg/1	NFS mg/1	Tot P mg/1	NH_3-N mg/1	NO_2-NO_3-N mg/1	TKN mg/1	Tot N mg/1	Fecal Coliform Organ/ 100 ml
Prep.Sand Cell 2.Filt.A	0.50		7.26	23.2	69	10	6.49	11.00	0.10	12.82	12.92	26×10^3
River-run Sand Cell 2.Filt.B	0.50		7.30	20.3	61	9	6.50	10.76	0.10	12.40	12.50	21×10^3
Prep. Sand Cell 3 Filt.C	0.50		7.29	25.0	82	9	6.69	11.05	0.10	12.90	13.00	19×10^3
River-run Sand Cell 3,Filt.D	0.50		7.32	19.8	62	10	6.67	11.01	0.10	12.73	12.83	15×10^3

[a]Flow applied at rate of 10 mgad-no plugging

TABLE 12. SUMMARY OF OPERATING DATA, BLUE SPRINGS LAGOON SYSTEM, CELL 2 AND CELL 3 SAND FILTERS, AVERAGE VALUES, APRIL 22 TO MAY 24, 1974. (from (6))

Sampling Station	Flow gpm^3	Temp ^oC	pH	BOD_5 mg/1	COD mg/1	NFS mg/1	Tot P mg/1	NH_3-N mg/1	NO_2-NO_3-N mg/1	TKN mg/1	Tot N mg/1	Fecal Coliform Organ/ 100 ml
Prep. Sand Cell 2,Filt. A	a		7.45	20.8	75	13	8.38	9.41	0.09	12.53	12.62	670
Prep.Sand Cell 2,Filt.B	b		7.47	18.5	74	12	8.14	8.14	0.04	12.05	12.09	680
Prep. Sand Cell 3, Filt.C	c		7.50	15.0	66	11	8.82	9.57	0.05	12.46	12.51	220
Prep. Sand Cell 3, Filt.D	d		7.56	14.2	66	11	8.28	9.01	0.04	11.86	11.90	210

[a]4/21-5/2 10 mgad; 5/2-5/14 1.25 mgad; 5/15-5/24 1.25 mgad
[b]4/21-5/4 5 mgad; 5/5-5/14 2.5 mgad; 5/15-5/24 2.5 mgad
[c]4/21-4/24 10 mgad; 4/24-4/29 10 mgad; 4/30-5/24 1.25 mgad
[d]4/21-4/28 5 mgad; 4/29-5/12 5 mgad; 5/13-5/24 2.5 mgad

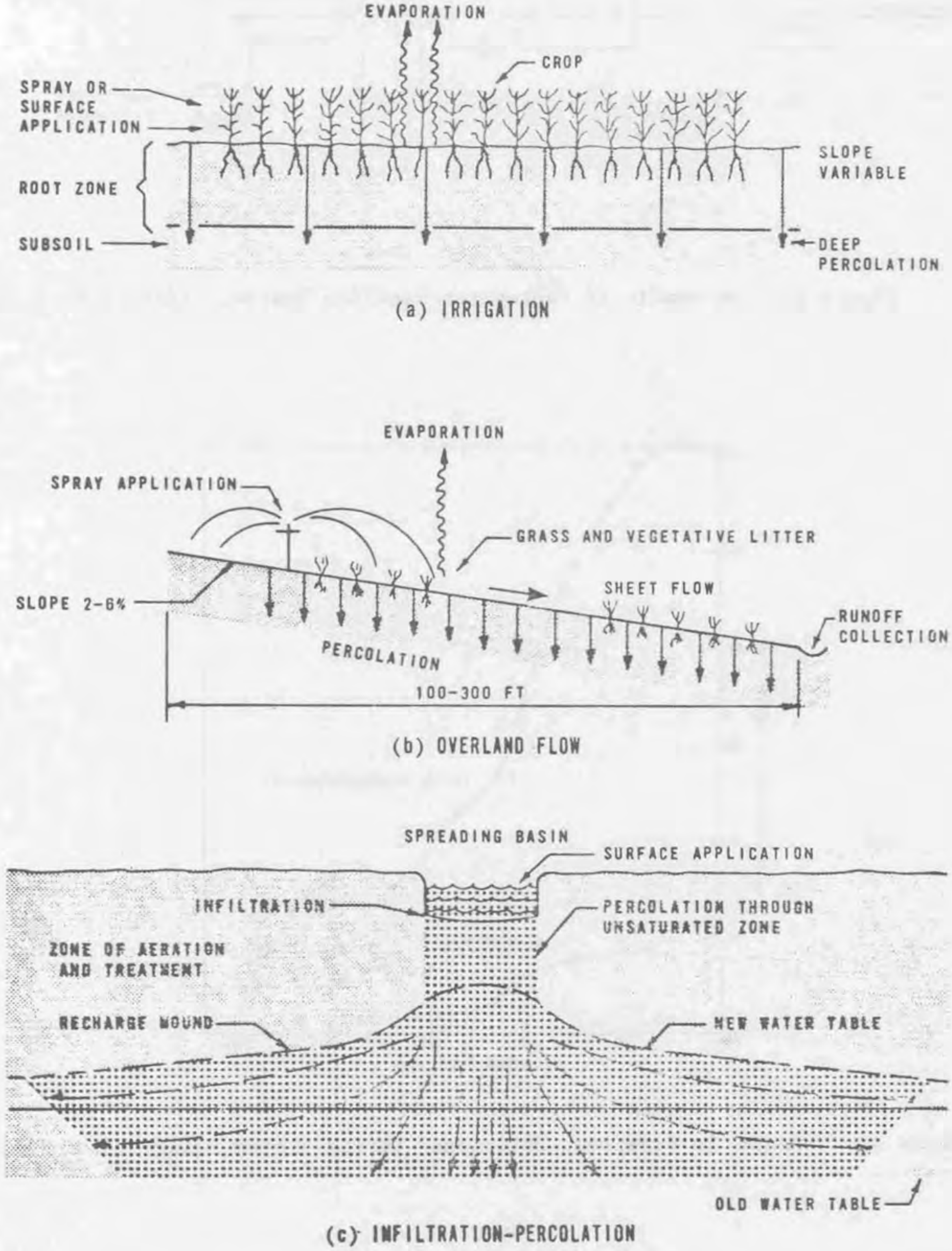

Figure 30. Land Application Approaches. (from (14))

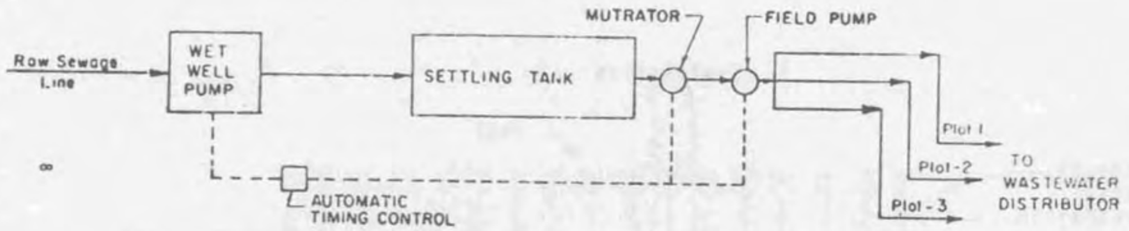

Figure 31. Schematic of Wastewater Handling System. (from (16))

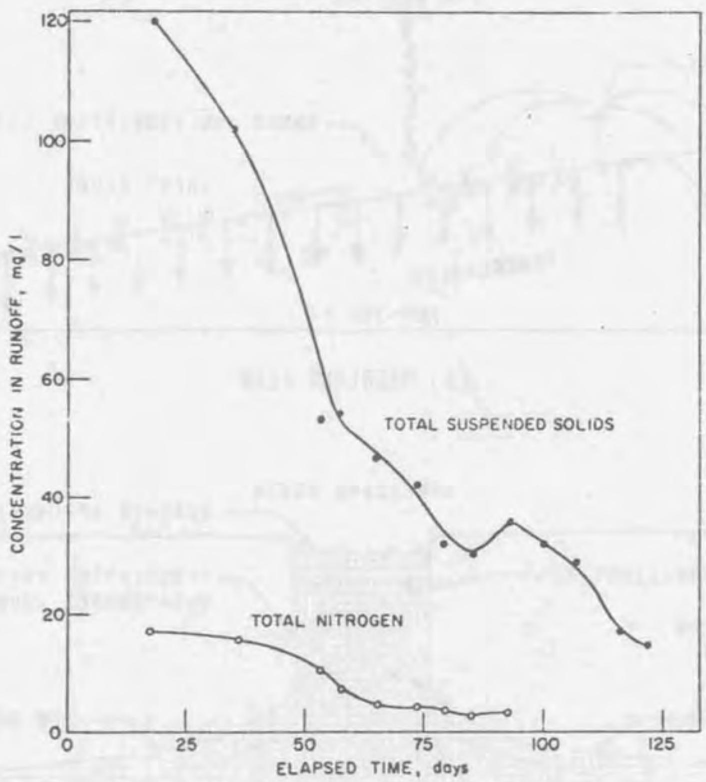

Figure 32. Changes in Treatment Efficiency during System Aging. (from (16))

September, 1972 and would be typical of summer operation. Table 13 gives the chemical quality of the raw wastewater. Typical changes in treatment efficiency by the land application system during aging are shown in Figure 32. Chemical quality for all parameters measured during the winter part of the study are shown in Table 14. Effluent concentrations of BOD and suspended solids and effluent concentrations of nitrogen and phosphorus for winter operation are also shown in Figures 33 and 34, respectively. Chemical quality of the runoff for the summer part of the study is shown in Table 15 and indicates, as expected, that summer removals are generally better than those during winter operation.

Conclusions which were drawn from Thomas's study are that overland flow offers a simple and economical method for treatment of wastewater in rural areas where land is available. A well operated system when loaded at an average loading of 10 cm/week in an area of comparable climate should produce an effluent with BOD and suspended solids less than 10 mg/l. A well operated overland flow system can achieve approximately 90 percent nitrogen removal in the summer and approximately 50 percent phosphorus removal year-round.

UPGRADING STABILIZATION PONDS IN THE SOUTHEAST

Middlebrooks, et al (17, 18) have reviewed various techniques for removing algae from stabilization pond effluents and conclude that the most promising techniques appear to be microstraining, land application, and granular media and intermittent sand filtration. Another effective technique is coagulation-flocculation which could have application if a technique can be developed to minimize operational problems and sludge removal problems. As described earlier, studies have been conducted (8, 9, 10) and another is proposed (19) which are applicable to upgrading stabilization pond effluents in the west; others (4, 5, 6, 16) are either underway or completed in the midwest. Another geographical area which has had relatively little study where a large number of stabilization ponds exist is the Southeast. Realizing the need to study techniques applicable to upgrading stabilization pond in the Southeast, the U. S. Environmental Protection Agency, in conjunction with the Mississippi Air and Water Pollution Control Commission, hopes to fund a proposal by Mississippi State University (20). The primary objective of the proposed project will be to demonstrate the feasibility of 4 alternative methods for removal of algae from wastewater stabilization pond effluents; (a) physical chemical treatment, (b) microstraining, (c) sand filtration, and (d) overland treatment.

Table 13. CHEMICAL CHARACTERISTICS OF RAW WASTEWATER FOR 18-MONTH STUDY PERIOD (from (16))

Parameter	Concentration, mg/1		
	Mean	Maximum	Minimum
Total Solids	1014	1660	650
Total Volatile Solids	300	525	149
Total Suspended Solids	160	420	52
Total Volatile Suspended Solids	123	306	40
Total Dissolved Solids	854	1504	525
Biochemical Oxygen Demand	150	273	84
Chemical Oxygen Demand	314	620	130
Total Organic Carbon	89	198	21
Total Nitrogen	23.6	36.8	10.7
Kjeldahl Nitrogen	22.8	36.8	8.3
Ammonia Nitrogen	17.0	29.0	6.9
Nitrate Plus Nitrite Nitrogen	0.8	-	-
Total Phosphorus	10.0	15.0	4.8

Three systems in Mississippi will be used to study physical chemical treatment, microstraining, and overland treatment and a system in Alabama will be used to study sand filtration. Figure 35 shows the proposed physical chemical treatment flow scheme and Figure 36 shows the proposed microstraining flow scheme. The proposed slow sand filtration flow scheme and the overland flow treatment scheme are shown in Figures 37 and 38, respectively. The study, when funded, will evaluate the technical and economic feasibility of each of the described methods of upgrading as related to small community capabilities and will elucidate the advantages and disadvantages of utilizing each method for upgrading stabilization ponds in the Southeast.

SUMMARY

The enactment of PL 92-500 and the definition of secondary treatment promulgated pursuant to the act have placed minimum regulatory effluent limitations on municipal wastewater treatment facilities which are generally not attainable through treatment by the wastewater stabilization pond process. Data have been presented which show that generally the suspended solids (mainly algae) con-

Table 14. CHEMICAL QUALITY OF PLOT RUNOFF FOR WINTER OPERATION FROM NOVEMBER 1971 THROUGH APRIL 1972 (from (16))

Parameter	Mean concentration, mg/l		
	7.4 cm/wk plot	8.6 cm/wk plot	9.8 cm/wk. plot
Total Solids	702	722	727
Total Volatile Solids	174	174	169
Total Suspended Solids	12	8	9
Total Volatile Suspended Solids	7	5	5
Total Dissolved Solids	690	714	718
Biochemical Oxygen Demand	12	11	8
Chemical Oxygen Demand	53	48	46
Total Organic Carbon	22	14	15
Total Nitrogen	5.4	7.2	6.8
Kjeldahl Nitrogen	2.4	3.6	2.9
Ammonia Nitrogen	0.5	2.0	1.3
Nitrate Nitrogen	2.8	3.4	3.7
Total Phosphorus	4.4	5.4	5.1

Table 15. CHEMICAL QUALITY OF PLOT RUNOFF FOR SUMMER OPERATION FROM MAY 1972 THROUGH SEPTEMBER 1972 (from (16))

Parameter	Mean concentration, mg/l		
	7.4 cm/wk plot	8.6 cm/wk plot	9.8 cm/wk plot
Total Solids	814	848	817
Total Volatile Solids	142	143	140
Total Suspended Solids	8	6	8
Total Volatile Suspended Solids	5	4	4
Total Dissolved Solids	806	842	809
Biochemical Oxygen Demand	11	7	8
Chemical Oxygen Demand	73	59	58
Total Organic Carbon	23	18	19
Total Nitrogen	2.6	2.2	2.2
Kjeldahl Nitrogen	1.8	1.7	1.7
Ammonia Nitrogen	1.0	0.7	0.6
Nitrate Nitrogen	0.4	0.5	0.4
Total Phosphorus	4.0	4.3	4.3

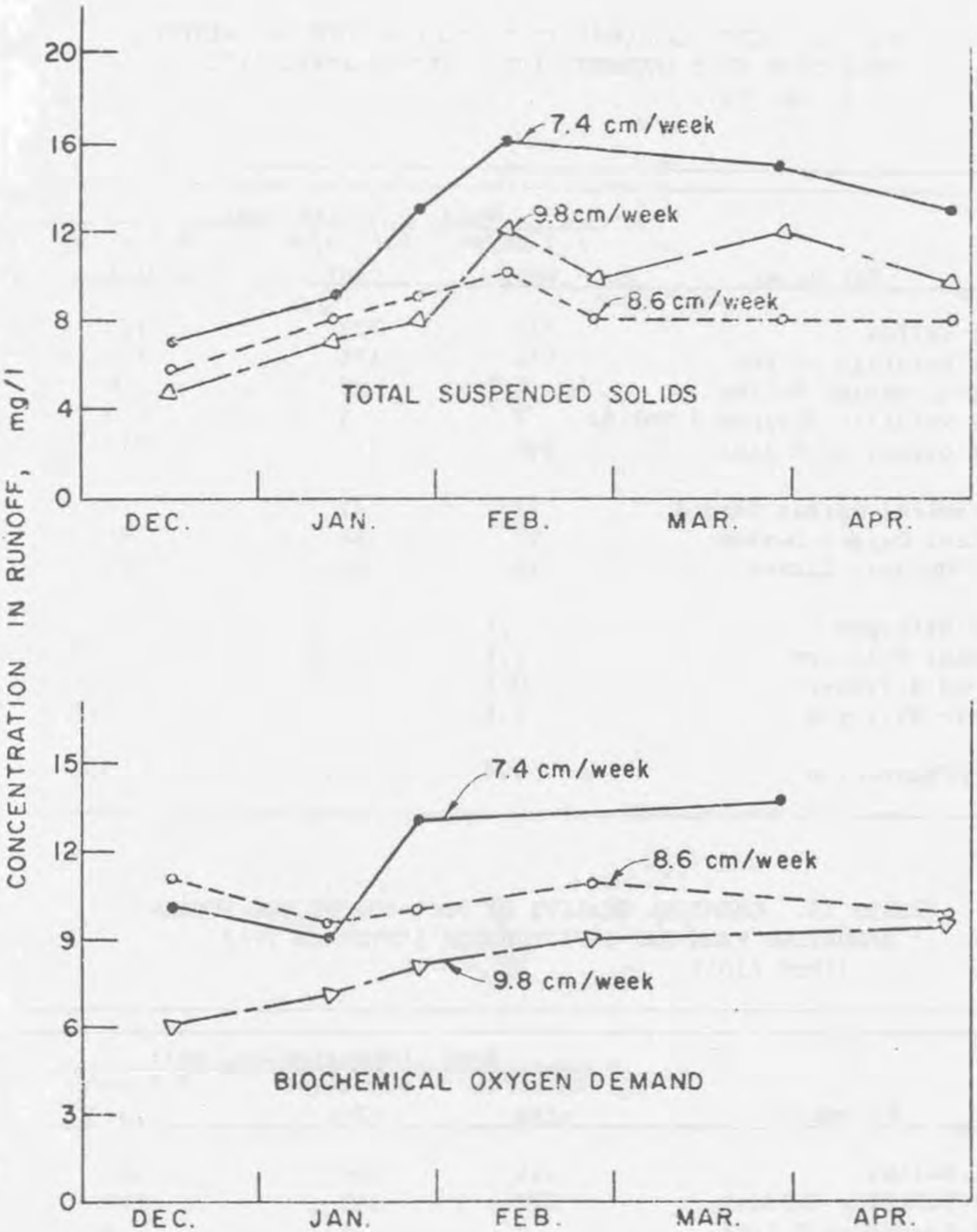

Figure 33. Removal of Suspended Solids and Biochemical Oxygen Demand in Winter. (From (16))

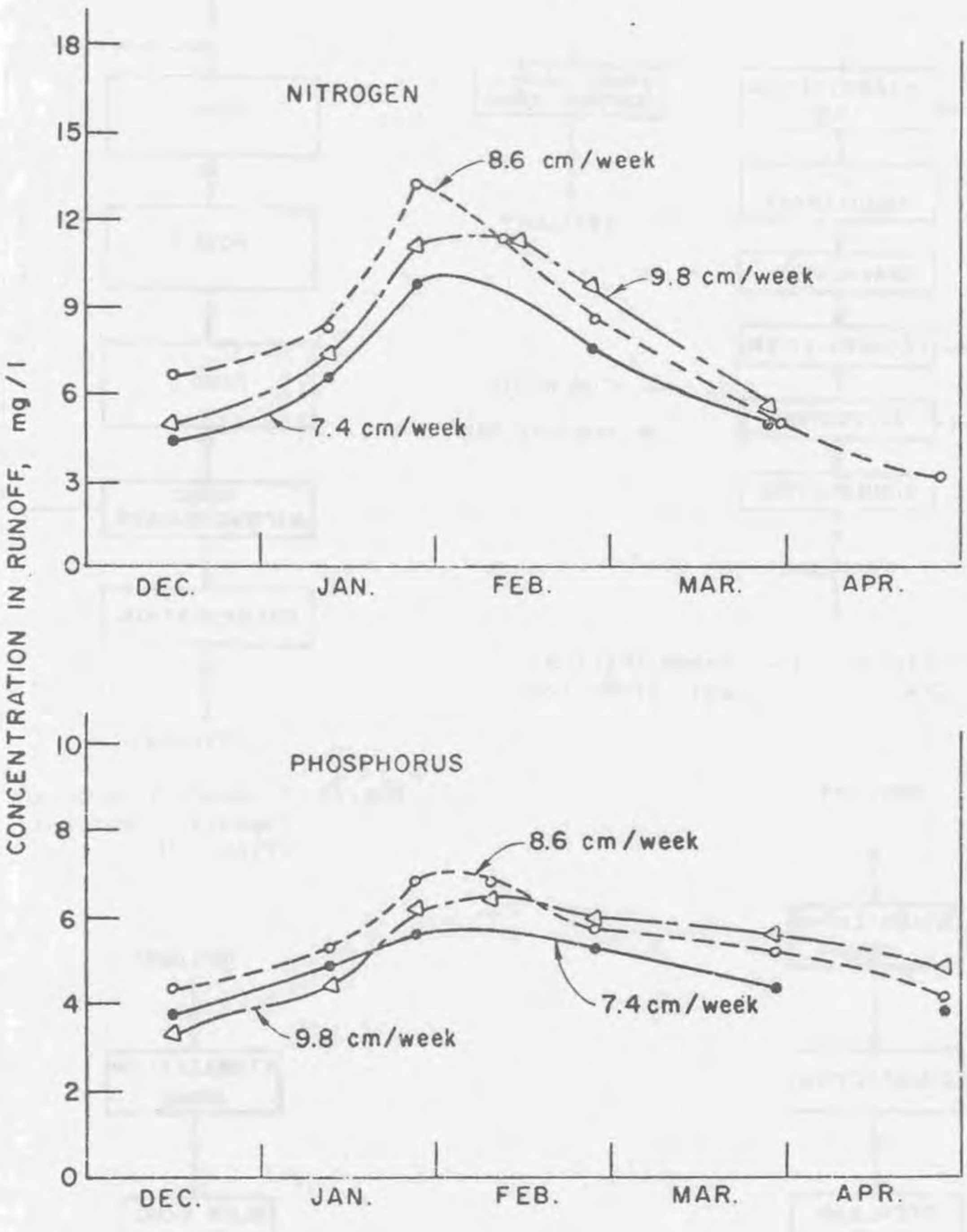

Figure 34. Nutrient Removal during Winter Operation. (from (16))

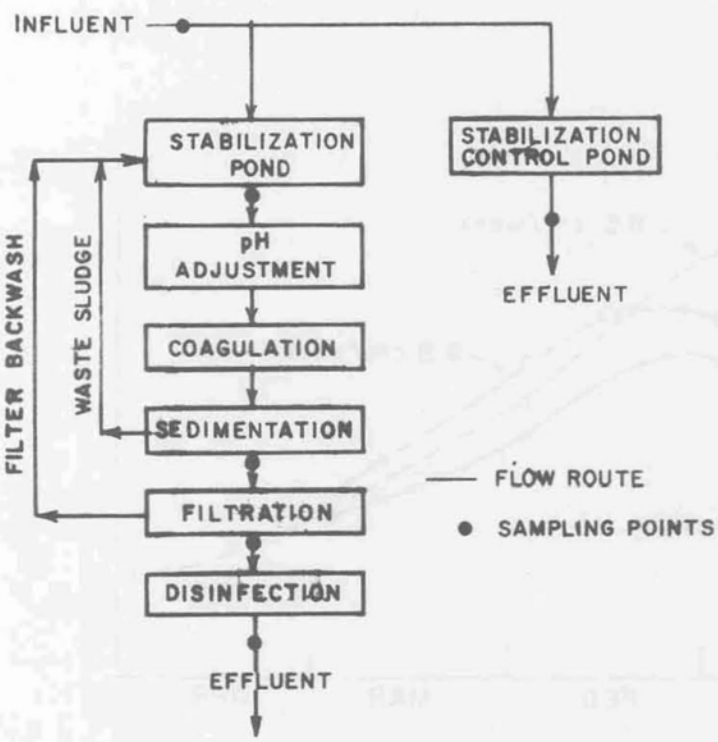

Fig.35. Proposed Flow Scheme, Physical-Chemical Treatment. (from (20))

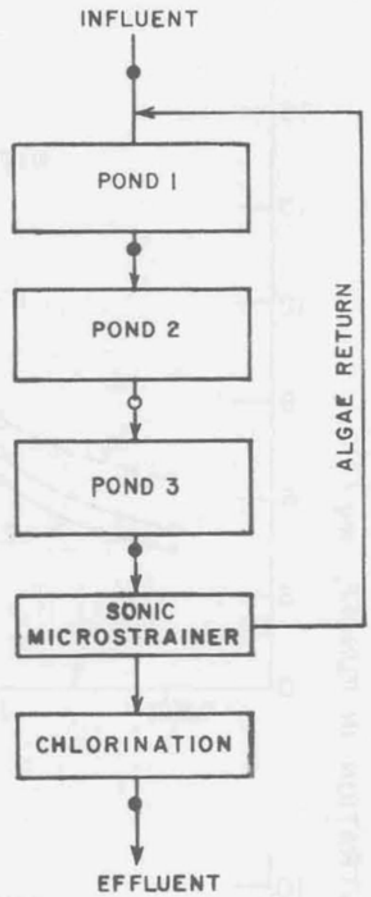

Fig.36. Proposed Flow Scheme, Physical Treatment (from (20))

Fig.37. Proposed Flow Scheme for Overland Treatment. (from (20))

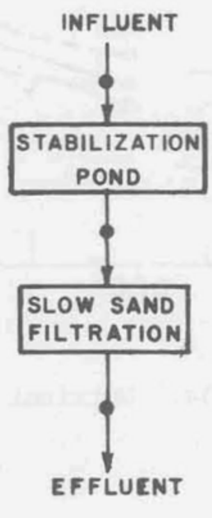

Fig. 38. Proposed Flow Scheme for Slow Sand Filtration. (from (20))

centration in the effluent from multi-cell stabilization ponds exceeds secondary treatment criteria. In addition, BOD_5 and fecal coliform levels are extremely variable when considered on a monthly average basis and may exceed secondary treatment criteria.

A case study using rock filters was described which showed that with modification of the study facility to prevent algae regrowth, this process shows great promise because of its economical construction and ease of operation and maintenance. Other studies were described which showed that sand filters are effective for removal of algae from stabilization pond effluents. A study by Thomas was described which utilized land application for treatment of raw domestic wastewater. Results of this study indicate that excellent removals of BOD, suspended solids, and nutrients can probably be obtained economically when land application is used to upgrade wastewater stabilization ponds. A proposed study to demonstrate the effectiveness of physical chemical treatment, microstraining, sand filtration, and overland flow for upgrading stabilization pond effluents was described. The results of all studies to date indicate strongly that the technology exists to economically upgrade wastewater stabilization ponds to meet secondary treatment criteria promulgated under PL 92-500 and the results of proposed studies should prove the point conclusively.

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