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Application of Plastic Media Trickling Filters for Biological Nitrification Systems

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APPLICATION OF PLASTIC MEDIA TRICKLING FILTERS FOR BIOLOGICAL NITRIFICATION SYSTEMS

by

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ABSTRACT

APPLICATION OF PLASTIC MEDIA TRICKLING FILTERS FOR BIOLOGICAL NITRIFICATION SYSTEMS

A detailed research program (EPA Contract No. 14-12-900), undertaken by Dow Chemical U.S.A. (Midland, Michigan) has demonstrated the feasibility of utilizing plastic media trickling filters in a stage treatment system to achieve biological nitrification. The study has defined the controlling parameters, operational characteristics, and basic design guidelines and economics of the process.

Unchlorinated clarified secondary effluent from the Midland, Michigan, Waste Treatment Plant was fed at controlled rates to a pilot plant trickling filter. This is a low BOD_5 stream (15-30 mg/l) with an ammonia nitrogen concentration in the range of 10-20 mg/l NH_3-N.

The system consistently maintained 80-90 percent oxidation of ammonia nitrogen. This was achieved at flow application rates up to 1.5 gpm/sq ft, with variable recycle ratios, and at wastewater temperatures from 40-70°F. There appears to be a practical limit of ammonia nitrogen in the effluent in the range of 1-1.5 mg/l. The system has shown consistent and stable performance throughout both summer and winter operation. Recovery to physically induced upset was rapid.

The visible slime growth was thin, tough, and resistant to drying. Net solids production by the nitrification tower was low. The tower effluent can be passed directly to a mixed media filter without intermediate clarification. The effectiveness of final chlorination appeared to be improved by the nitrification process. The influent BOD_5 and suspended solids to the nitrification tower were not significantly altered by the process. Subsequent anaerobic denitrification was achieved by controlled addition of methanol directly to a mixed media filter; significant changes were observed in its operation. Ninety-five percent denitrification (and 85 percent total nitrogen removal overall) was maintained simultaneously with effective suspended solids removal.

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CONCLUSIONS

1. Plastic media trickling filters are capable of achieving consistent, high level nitrification (>90 percent conversion) when operating on a low BOD_5 waste stream (15-30 mg/l) containing ammonia nitrogen concentrations in the range of 10-20 mg/l.

2. The system has shown consistent and stable performance throughout both summer and winter operation. High level nitrification can be achieved in summer at influent application rates in the range of 1.0-1.5 gpm/sq ft, and winter application rates in the range of 0.5 gpm/sq ft plus recycle.

3. Increased recycle provided improved flow stabilization but showed minimal effects on the overall degree of nitrification achieved.

4. There appears to be a final effluent limitation for ammonia nitrogen in the range of 1-2 mg/l.

5. The visible slime growth on the plastic media was thin, tough, and resistant to drying. Net solids production by the nitrification tower was low. Suspended solids and BOD_5 levels in the tower effluent (prior to clarification) were not significantly different from those of the tower influent. The tower effluent may pass directly to a mixed media filter without intermediate clarification.

6. Subsequent denitrification may be achieved by controlled addition of methanol directly to the mixed media filter. Ninety-five percent denitrification (and 85 percent total nitrogen removal overall) was maintained simultaneously with effective suspended solids removal. Significant changes were observed in the operation of the mixed media filter.

7. The nitrification system can effect reductions in ultimate fish toxicity, improve bacteriological disinfection efficiency, and result in realistic breakpoint chlorination economics.

II

INTRODUCTION

Nitrogenous oxygen demand recently has been receiving increased attention in evaluating the overall effects of treated sewage effluent on a receiving body of water. Major emphasis has been placed on removal of biological oxygen demand (BOD) and suspended solids from wastewater before discharge, with no distinction being made between the carbonaceous and nitrogenous forms of oxygen demand.

In general, most efficiently operated conventional biological treatment facilities are capable of high removals of carbonaceous material (>90 percent). These same facilities, however, have been shown to oxidize only 10 to 60 percent of the influent nitrogen (1,2). This wide range of efficiencies is indicative of the relative unpredictability of nitrification as experienced in most current treatment systems. The resultant nitrogen-laden effluents have been shown to play a significant role in the oxygen balance of receiving waters.

Work done by the Michigan Water Resources Commission indicated that the most important source of oxygen demand in the Grand River below Lansing, Michigan, was nitrogenous in origin (3). It accounted for as much as 75 percent of the total oxygen depletion within a 10 mile stretch below that City. Similarly, Wezernak and Gannon (4) concluded from studies on the Clinton River below Pontiac, Michigan, that the major deoxygenation components were in the form of nitrogenous compounds. These instances, among others (5,6), indicate the increased need and the likelihood for more stringent requirements on total oxygen demand (TOD). This will ultimately necessitate the development of effective nitrification incorporated into overall wastewater treatment at many locations.

The studies by Barth et al. (7) and Johnson and Schroepfer (2) indicate the effectiveness of the "stage" approach in obtaining predictable nitrification in laboratory units. This is generally agreed to be related to the relative difference in the rapid growth rate of the heterotrophic bacterial populations active in carbonaceous removal and the slower development of the autotrophic nitrifying bacteria.

This project was initiated to investigate the feasibility of utilizing a plastic media oxidation tower for a stage nitrification system. It was felt that a fixed film reactor with high surface area would develop the aged biological growth necessary for good nitrification and produce an effluent with a high degree of settleability. Plastic media oxidation towers having minimal and highly flexible space requirments can be readily adapted to most existing treatment plants, realizing savings in capital expenditure costs as shown by Germain (8).

PROJECT OBJECTIVES

The need for controllable and economical processes to achieve biological nitrification arises from the increased possibility of more stringent effluent standards on ammonia nitrogen (NH_3-N) in large volumes of municipal wastes. In the near future, many existing waste treatment facilities will have to be upgraded and a large number of new plants will have to be designed for NH_3-N control.

The main objective of this contract was to establish the feasibility of utilizing plastic media trickling filters for biological nitrification in a stage approach. The controlling parameters were to be identified and the necessary process design guidelines developed for field application of the nitrification process.

Major emphasis was placed on development of design considerations which could be utilized in practical and economical application of the results of the contract. Miminal effort was devoted to theoretical research considerations of the complex biological processes involved.

MATERIALS AND METHODS

STUDY LOCATION AND FACILITIES

The location of this research was the Midland, Michigan, Wastewater Treatment Plant. This is a well-operated secondary wastewater treatment plant treating predominantly domestic sewage. It incorporates primary sedimentation followed by two-stage rock media trickling filters with intermediate and final clarification. The organic and hydraulic loadings on these trickling filters are great enough that nitrification does not occur. The sludges are dewatered chemically and/or thermally without digestion and ultimately transported to a sanitary landfill. Typical performance data and effluent characteristics from the Midland location during the course of this contract are shown in Table 1.

The pilot plant nitrification work was conducted using unchlorinated final effluent from the Midland plant as a waste stream source. This influent feed was applied to a standard pilot plant oxidation tower located near the headworks of the Midland facility. This unit consisted of a 3-foot diameter column packed to a depth of 21.5 feet with SURFPAC® (registered trademark of The Dow Chemical Company) biological oxidation media. Plastic oxidation media is designed to promote film flow across a large uniform surface per unit volume, and to provide a high void ratio for adequate oxygen transfer and alleviation of plugging problems. The physical characteristics of the artificial media used in this contract are shown in Table 2 and a cross-sectional diagram of the pilot oxidation unit in Figure 1.

The clarified but unchlorinated final effluent from the Midland plant was directed to the oxidation tower throughout the study as needed. Provision was made to recycle the tower effluent, if desired, prior to suspended solids removal by pilot scale clarification and/or mixed media pressure filtration.

TABLE 1

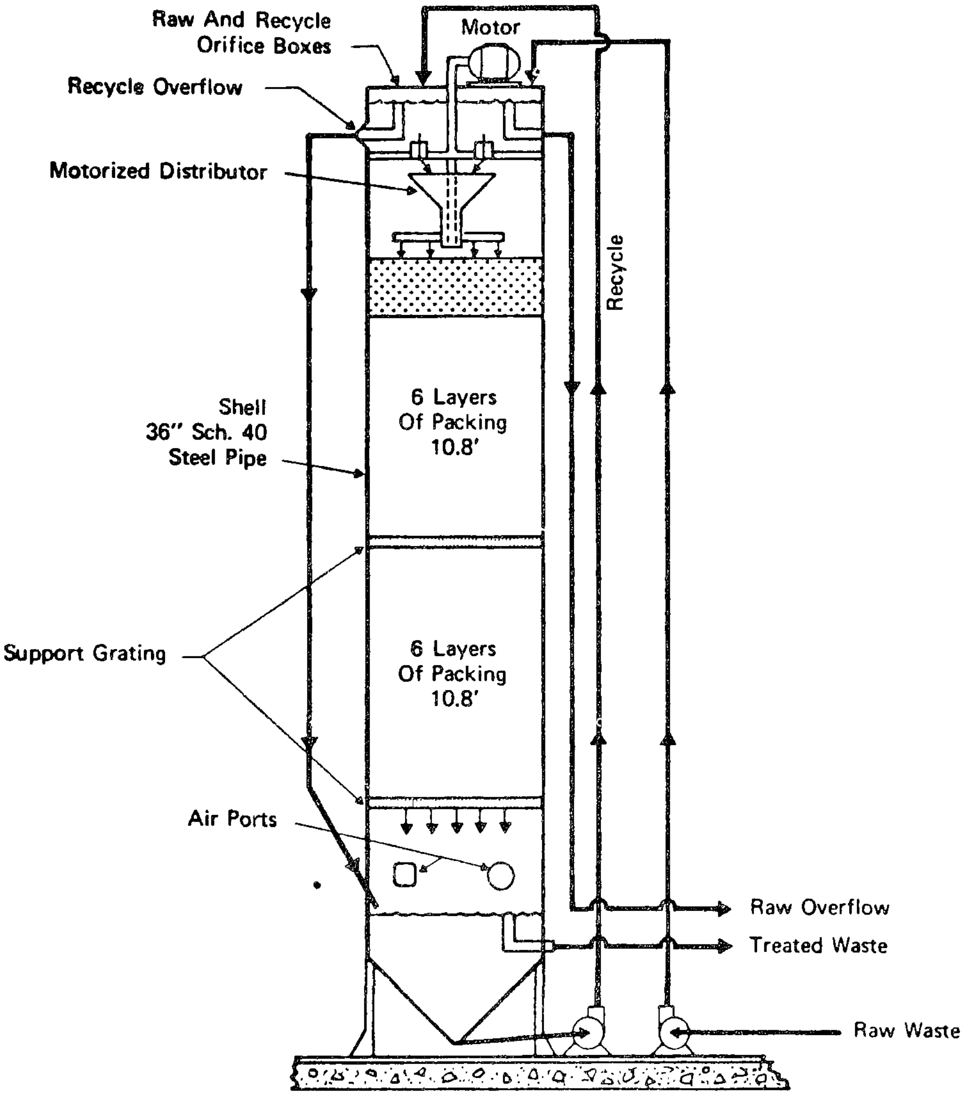
MIDLAND, MICHIGAN, WASTEWATER TREATMENT EFFLUENT CHARACTERISTICS

		Avg. Secondary Effluent (mg/l)
BOD_5		15 - 20
Suspended Solids		15 - 20
pH		7 - 8
NH_3-N		8 - 18
NO_3-N		0.3 - 0.5
Organic-N		1.5 - 4.0
Temperature:	Winter	44°F (7°C)
	Summer	68°F (20°C)

TABLE 2

PLASTIC MEDIA CHARACTERISTICS

Available Surface Area	27 sq ft/cu ft
Void Space	94%
Sheet Thickness	30 mil
Weight	2.6 lb/cu ft
Material	Polyvinyl Chloride



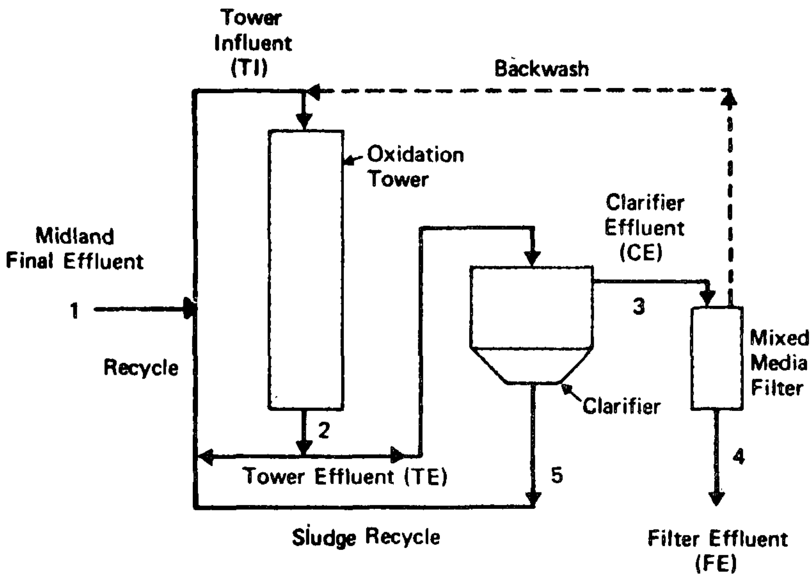
PILOT SCALE TRICKLING FILTER CROSS SECTION
FIGURE 1

ANALYTICAL PROGRAM

A flow schematic of the pilot plant installation is shown in Figure 2, along with designation of the five major sampling locations. Additional sampling was done at intermediate tower depths periodically during the study. Samples from four sampling points (Numbers 1, 2, 3, and 4) were taken with automatic compositing devices and refrigerated during collection. The operation of the oxidation tower was continuous. Sufficient time for acclimitization was allowed between the different periods of study.

Since daily changes in the controlling parameters were not expected to be great, the sampling schedule was limited to four 24-hour composite periods during each week of operation. The auto-samplers were started on Monday mornings and composited samples collected at 24-hour intervals on Tuesday, Wednesday, Thursday, and Friday morning. Except for special studies, the samplers were shut down after the Friday morning sample. Where appropriate the analyses were performed the same day the sample was collected.

Specific analyses for nitrite (NO_2-N) and nitrate (NO_3-N) nitrogen were accomplished using an automatic colorimetric analyzer (Technicon AutoAnalyzer) which was provided for this contract by the Environmental Protection Agency. Carbonaceous analyses were done on a combustion analyzer (Beckman). The following procedures specified in "Standard Methods for the Examination of Water and Wastewater," 13th Edition, were used: suspended solids, Part 224C; Kjeldahl nitrogen, Part 216; biochemical oxygen demand, Part 219; ammonia nitrogen, Part 212 (distillation; pH, Part 221; and temperature, Part 162. From time to time throughout the study, there was additional sampling and analytical work specific to supplementary investigations.



PILOT PLANT SCHEMATIC
FIGURE 2

V

RESULTS AND DISCUSSIONS

PILOT PLANT OPERATION

The first six months of the contract period were spent primarily in conceptual planning, engineering, site modification, construction, equipment procurement and installation, and establishing the analytical program. All materials and equipment were obtained and installed by late January 1971. The initial startup of the pilot facility took place in early February 1971.

As seen in Figure 1, the influent flow to the pilot oxidation tower is controlled by means of a fixed orifice operating from a constant hydraulic head box. The excess influent waste is returned to the sewer and the measured flow through the orifice directed into a mixing funnel and subsequent rotary distribution system. During periods of recycle, tower effluent is taken from the sump at the bottom of the tower and controlled flows are directed to the media in a similar manner. On the recirculation system, the overflow maintaining a constant head is directed back into the tower sump so that no treated waste is lost from the system.

No provisions were made during this study for variable pilot plant feed to correspond to normal diurnal fluctuations experienced in the waste volume of the full-scale treatment plant. All work was done at constant hydraulic application rates. These rates were measured as application rates to the oxidation tower in gpm/sq ft cross-section surface area. This measure is often used as a standard guideline for operation of trickling filters. When reference is made to the incoming waste application rate, it is as influent feed in gpm/sq ft; recirculation is referred to as recycle in gpm/sq ft; and, the combination of influent feed and recycle is referred to as the total hydraulic application rate in gpm/sq ft. The operating levels of the hydraulic application rate distinguish the different operating periods of the contract.

An operational summary of the pilot plant throughout the entire 18 months of experimental work is shown in Table 3. The controlling parameters for the periods indicated are subdivided into the individual operating sections regulated to study their relationship to nitrification. Further assembly of the experimental results and operational periods into distinct groups is done throughout the remainder of this report to support specific areas of discussion. Daily data summaries for each study period are included in the Appendix. Data summaries and analyses for each study period and groups of periods have been filed with the Official Project File at EPA Headquarters, Washington, D. C., and with the Project Officer at NERC, Cincinnati, Ohio.

STARTUP

It was evident from the initial operation of the pilot unit that little, if any, nitrification was occurring in the oxidation tower. This situation continued throughout the first four to six weeks of operation.

Attempts to accelerate the establishment of a nitrifying population included seeding the pilot plant with 15 gallons of activated sludge material from a known nitrifying source. This return sludge was obtained from the Pontiac, Michigan, sewage treatment plant and was added to the pilot facility on March 12, 1971. The seeding procedure was an effort to expose the pilot tower to bacterial solids of a nitrifying nature and to accelerate the development of a nitrifying growth on the plastic media.

TABLE 3

OPERATIONS SUMMARY

*TI = Tower Influent CE = Clarifier Effluent
TE = Tower Effluent FE = Filter Effluent

Period	Flow (gpm/sq ft) Influent	Flow (gpm/sq ft) Recycle	Sample Location*	Date	SS mg/l	Temp. (°F)	Inorg C mg/l	TOC mg/l	NH_3-N mg/l	Org N mg/l	NO_3-N mg/l	NO_2-N mg/l	Total N mg/l
1	0.5	0.0	TI	4/13 - 4/30/71	16	51	52	28	10.0	2.1	0.6	0.1	13.0
			TE		11	48	38	22	1.9	1.6	8.5	0.3	12.4
			CE		9		40	19	1.9	1.5	8.6	0.3	12.4
2	0.5	1.0	TI	5/4 - 5/14/71	12	54	55	41	11.3	1.5	0.7	0.1	13.7
			TE		6	51	36	30	1.3	1.4	10.7	0.1	13.8
			CE		8		35	31	1.2	1.4	10.7	0.1	13.5
3	1.0	0.0	TI	/18 - 6/11/71	12	57	50	23	12.0	1.5	0.8	0.1	14.3
			TE		13	54	28	16	1.7	1.1	10.3	0.5	13.8
			CE		9		28	19	1.8	1.0	10.1	0.8	13.8
4	2.0	0.0	TI	6/15 - 6/30/71	22	62	49	39	13.1	1.3	1.1	0.2	15.7
			TE		17	60	38	27	4.9	2.0	8.9	0.6	16.5
			FE		4		38	24	4.7	1.3	8.6	0.8	15.4
5	1.0	0.0	TI	7/15 - 8/6/71	10	67	38	20	13.3	1.3	1.2	0.3	16.3
			TE		18	61	22	20	2.5	2.7	10.7	1.1	17.0
			FE		2		22	20	2.6	2.4	8.4	0.9	14.4
6	1.5	0.57	TI	8/10 - 8/17/71	21	68	41	27	14.6	2.4	1.3	0.3	17.7
			TE		84	62	25	20	3.4	2.0	10.5	1.2	17.3
			FE		10		25	20	3.4	1.8	10.3	1.3	16.9
7	1.0	0.57	TI	8/18 - 8/27/71	24	68	42	22	15.8	3.5	0.5	0.3	20.2
			TE		28	64	22	18	3.4	3.1	10.1	1.1	18.7
			CE		13			18	3.1	3.5	10.2	1.6	18.5
			FE		4		23	16	3.8	1.4	10.1	0.9	16.2
8	0.5	1.0	TI	9/10 - 10/8/71	20	66	44	19	16.8	4.3	0.4	0.2	21.2
			TE		18	63	19	14	1.4	2.8	14.9	0.5	19.5
			FE		3		19	12	1.4	2.0	14.4	0.3	18.2
9A	1.0	0.0	TI	11/1 - 11/12/71	20	60	47	21	17.6	2.5	0.4	0.1	20.7
			TE		18	56	28	18	5.9	2.7	9.7	1.4	19.8
			FE		9		29	15	6.4	2.9	9.2	0.8	17.3
9B	0.5	1.0	TI	11/15 - 11/30/71	15	57	45	21	16.7	4.3	0.5	0.1	21.7
			TE		35	50	20	15	1.7	1.9	16.2	0.3	20.1
			FE		2		18	13	1.4	1.3	15.8	0.2	19.0
10	0.5	1.0	TI	12/1 - 12/30/71	15	53	47	22	12.3	3.6	0.7	0.2	17.8
			TE		12	46	31	17	3.0	1.5	9.4	1.0	15.3
			FE		3		31	15	2.3	1.6	10.6	0.4	14.9
11	0.5	1.0	TI	1/1 - 1/31/72	13	49		22	13.2	3.5	0.5	0.1	17.4
			TE		10	42		16	1.9	1.9	9.9	0.5	14.4
			FE		3			13	1.5	1.5	10.5	0.2	13.8
12	1.0	0.0	TI	2/8 - 2/18/72	16	48		20	15.5	4.2	0.5	0.1	20.4
			TE		9	44		16	6.1	1.6	8.8	0.7	17.3
			FE		5			15	5.7	1.4	8.8	0.2	16.0
13	1.0	0.5	TI	2/21 - 2/25/72	20	46		20	15.4	3.8	0.5	0.1	21.1
			TE		9	44		15	6.1	2.4	8.9	0.3	17.7
			FE		2			13	5.3	1.4	8.9	0.2	16.8
14	0.71	0.5	TI	2/29 - 3/17/72	18	46		19	15.0	2.9	0.5	0.1	18.3
			TE		12	42		13	2.6	2.0	11.8	0.2	16.6
			FE		7			13	2.1	1.9	11.8	0.1	15.4
15	0.71	0.0	TI	3/20 - 4/28/72	7	48		16	7.5	1.6	1.1	0.1	10.2
			TE		7	43		13	1.2	1.2	7.5	0.1	10.0
			FE		6	49		15	0.7	1.0	4.2	0.2	6.2
16	0.71	0.0	TI	5/1 - 5/26/72	11	53		16	8.1	0.9	0.5	0.1	9.6
			TE		13	49		14	1.1	0.6	8.5	0.2	10.5
			FE		4			16	0.7	0.5	0.3	0.1	1.3
17	0.71	0.0	TI	5/31 - 6/22/72	20	59		26	11.8	0.8	0.3	0.1	12.5
			TE		30	56		18	1.5	0.9	8.7	0.9	11.3
			FE		10	61		20	1.0	0.8	0.2	0.1	1.9
18	0.71	0.0	TI	6/23 - 7/19/72	11	62		22	13.4	0.8	0.4	0.1	14.3
			TE		30	58		19	2.0	0.8	9.5	0.9	13.3
			FE		2	64		18	1.7	0.8	1.1	0.3	3.6
19	0.71	0.5	TI	7/21 - 9/1/72	21	65		43	8.0	3.8	0.6	0.2	12.8
			TE		58	62		34	0.9	5.3	8.4	0.6	15.1
			CE		17			30	0.9	2.8	8.4	0.5	12.7
			FE		3			27	0.7	1.8	7.4	0.2	9.9

Shortly after the seeding procedure, there was evidence of a biological growth occurring on the surfaces within the pilot clarifier, the center column, side walls, and in the overflow weir box from the clarifier. This periphyton-like growth was also very evident in the open drain channel in the floor of the pilot facility. It was characterized by a very light fluffiness and settled poorly. Further, it did not adhere very tightly to surfaces and readily broke loose and washed out of the system with minimal disturbance. Based on these observations, the initial recycle over the oxidation tower was terminated to minimize the hydraulic shear on the oxidation media in an effort to establish this growth on the tower. A flow of 0.5 gallons per minute was then pumped from the bottom of the clarifier to the tower influent to return any settled solids.

The month of March was characterized by a very cool spring-time condition; the average influent temperature to the pilot plant was 47°F. In previous work (9), there have been indications that the development of a nitrifying population is somewhat dependent upon temperature and this could be a possible source for the problems experienced at this point in the study. There was an additional average drop in waste temperature across the pilot unit of approximately 4°F due to cooling effected by the packed tower.

There did not appear to be any other limiting characteristic of the waste which might have caused difficulties in establishment of a nitrifying population. The carbon concentration, nutrient levels, pH, and buffering capacity of the influent waste were typical of a normal secondary sewage effluent with nothing specifically limiting to nitrification.

Near the end of March 1971, the analytical monitoring indicated that there was a decrease in ammonia nitrogen occurring across the pilot plant unit. This corresponded with the appearance of a visible slime growth on the plastic media. The system was definitely achieving high level nitrification by the second week in April 1971. This performance was maintained throughout the subsequent 18 months of pilot operation and no further difficulties were encountered in establishing or maintaining an actively nitrifying system.

The establishment of a viable nitrifying population was probably enhanced by seeding the system with a known source of nitrifiers. It is difficult to conclude, however, that nitrification would not have developed without such a seeding procedure. Other work has indicated that there were similar time lags in developing a viable nitrification system (10).

It was unfortunate that the pilot plant startup took place when extreme winter temperatures were prevalent since this could have significantly retarded the establishment of a biological growth.

REPRESENTATIVE PERFORMANCE

The performance of each operating period is summarized in Table 3, showing mean values for key indicators. Detailed results from study Period VIII (9/10-10/29/71) are provided in Table 4. This six-week period during the fall of 1971 is representative of the general pilot plant performance throughout the entire study program.

TABLE 4

REPRESENTATIVE DATA - PERIOD VIII

Conditions: 9/10 to 10/29, 1971

Feed: 0.5 gpm/sq ft

Recycle: 1.0 gpm/sq ft

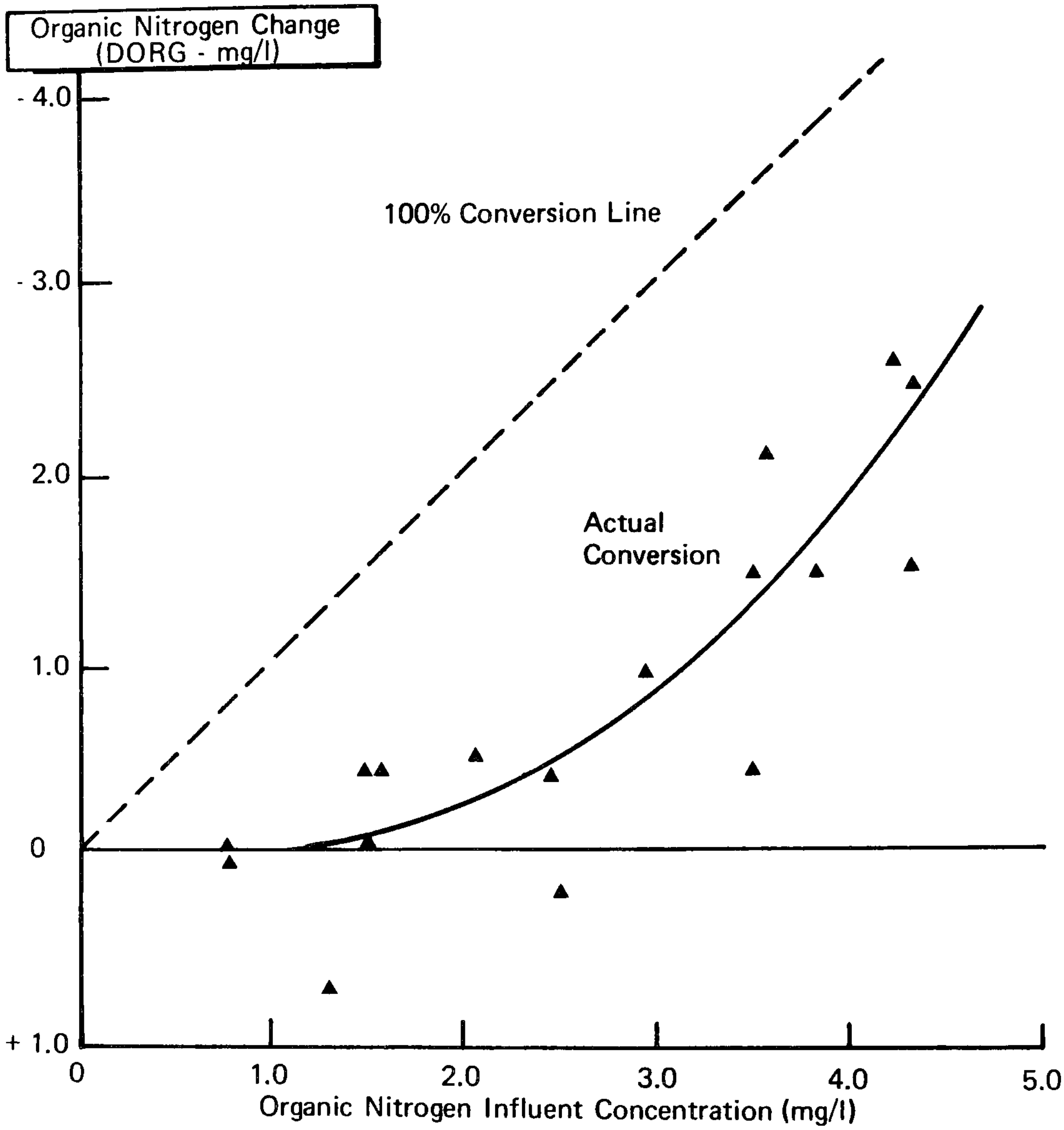
	Concentration, mg/l		
	Tower Influent	Tower Effluent	Filter Effluent
NH_3-N	16.8	1.4	1.4
NO_3-N	0.4	14.9	14.4
NO_2-N	0.2	0.5	0.3
Organic-N	4.3	2.7	2.0
Total Nitrogen	21.7	19.5	18.1
TOC	18.8	14.0	12.4
Inorganic Carbon	44.2	18.6	19.0
Suspended Solids	19.6	18.0	3.3
Temperature	65°F	61°F	

The system was in a state of active nitrification with greater than 90 percent conversion of influent ammonia nitrogen throughout this period. There was a corresponding increase in nitrate concentration across the oxidation tower with minimal levels of nitrite nitrogen throughout the system. There is very little nitrogen removal - rather a conversion of ammonia to nitrate; the total nitrogen concentration remains relatively constant across the tower. Some organic nitrogen disappears - probably hydrolyzed to NH_3-N prior to nitrification. Throughout the entire study there appears to be a residual concentration of organic nitrogen of approximately 1-2 mg/l. The change in organic nitrogen across the tower corresponding to the influent organic nitrogen concentration is shown in Figure 3. Data represent mean values from Periods I-XVIII. Additional work to achieve biological denitrification in the mixed media filter will be discussed in a later section.

The oxidation tower functioned strictly as a nitrifying system with little carbonaceous removal taking place. The carbonaceous load to the tower was generally in the range of 5-10 lbs BOD_5/1000 cu ft media/day. Throughout the entire study, there was little decrease across the tower in total organic carbon (TOC) or BOD_5, the latter being monitored only periodically. Coincident with this lack of carbonaceous activity was a very low solids yield from the nitrifying system. Throughout the entire program there was very little generation of suspended solids from the oxidation of ammonia nitrogen. The changes in inorganic carbon indicated in Table 4 are probably directly related to changes in the alkalinity and the buffering capacity of the waste due to nitrification.

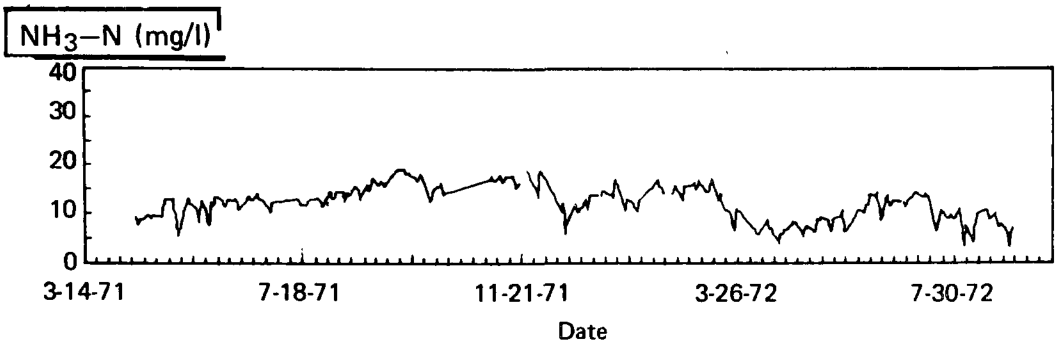
NITRIFICATION EFFICIENCY

Throughout the study periods there were some variations in the influent concentration of ammonia nitrogen. Based on mean values, this ranged from 7.0 mg/l up to 18.5 mg/l. The variations of the influent NH_3-N concentration over the entire study period is shown in Figure 4. These variations were directly related to groundwater infiltration into the sewer system. The lower concentrations occurred during late winter and springtime and the higher values during the dry weather conditions of late summer and early fall.



FATE OF ORGANIC NITROGEN IN A NITRIFYING TRICKLING FILTER

FIGURE 3



INFLUENT NH_3–N CONCENTRATION
FIGURE 4

Irrespective of the influent ammonia nitrogen level or the mode of tower operation, the lower limit of the ammonia nitrogen concentration in the effluent of the oxidation tower appears to be 1-2 mg/l. The data shown in Table 5 represent five different operating periods throughout a one year period. The mean values of the final effluent ammonia nitrogen concentration fall within the 1-2 mg/l range. There were numerous days, as shown in Figure 5, for which the effluent concentration was <1 mg/l of ammonia nitrogen; however, as in most biological processes, there were an equal number of days of values >1 mg/l. During operation at optimum hydraulic conditions, the average effluent values seemed to consistently fall between 1-2 mg/l ammonia nitrogen.

Substrate limitation seemed to be the limiting factor rather than a physical parameter such as nitrogenous loading, as can be seen when comparing results from similar periods. Despite considerable variation in influent ammonia nitrogen concentration for Periods II, VIII, and XV (11.3, 16.8, and 7.5 mg/l, respectively), the corresponding effluents contained 1.3, 1.4, and 1.2 mg/l NH_3-N. This information leads to the conclusion that at the hydraulic and nitrogen loadings encountered, the optimum average final effluent concentration will fall within the 1-2 mg/l range.

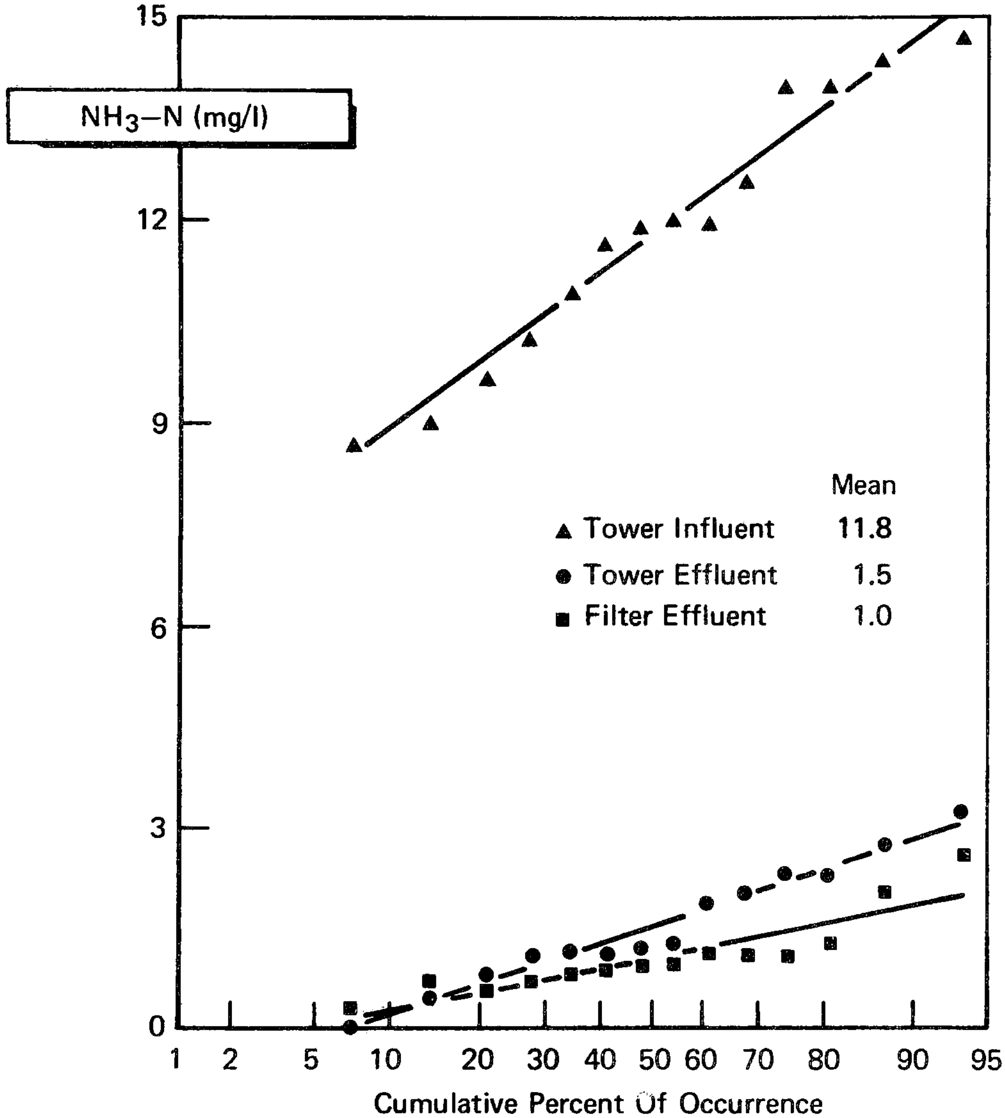
TABLE 5

AMMONIA NITROGEN EFFLUENT LIMITATION

Operating Period	Season	Flow (gpm/sq ft) Feed	Flow (gpm/sq ft) Recycle	NH_3-N (mg/l) Tower Influent	NH_3-N (mg/l) Tower Effluent
2	May	0.5	1.0	11.3	1.3
3	June	1.0	0	12.0	1.7
8	Oct.	0.5	1.0	16.8	1.4
11	Jan.	0.5	1.0	13.2	1.9
15	April	0.71	0	7.5	1.2

HYDRAULIC APPLICATION RATE

Two widely used design parameters for trickling filters are substrate loading (lbs/1000 cu ft media/day) and influent hydraulic application rate (gpm/sq ft surface application area). The pilot unit used in this study was constructed in such a manner that the hydraulic rate could be changed quickly and precisely whenever desired. Since chemical additions were not considered, the influent ammonia nitrogen concentration was limited to the limited range occurring in the treated domestic sewage. Therefore, the only method of significantly increasing the ammonia loading to the trickling filter was to increase the influent feed rate. Due to these limitations, the nitrification tower performance will be discussed in terms of hydraulic loadings with passing reference to substrate loadings.



CUMULATIVE PERCENT OF OCCURRENCE OF NH_3–N: PERIOD VIII

FIGURE 5

According to the data in Table 6, there is a definite relationship between hydraulic loading and nitrification performance. Figure 6 illustrates that effective (>80 percent) nitrification is not feasible at influent feed rates much greater than 1.0 gpm/sq ft. Performance drops off rapidly as the influent feed approaches 2.0 gpm/sq ft.

At the ammonia nitrogen concentrations encountered, 80 to 90 percent nitrification is achievable at influent feed rates under 1.0 gpm/sq ft. The inverse proportion relationship (increasing performance with decreasing influent feed rate) is characteristic of previous experience with carbonaceous oxidation in trickling filters. The effects of higher ammonia nitrogen influent concentration are not yet clearly defined. A critical consideration that was extensively evaluated is temperature. The effect of temperature on the hydraulic loading-nitrification performance is discussed in a later section.

TOWER DEPTH

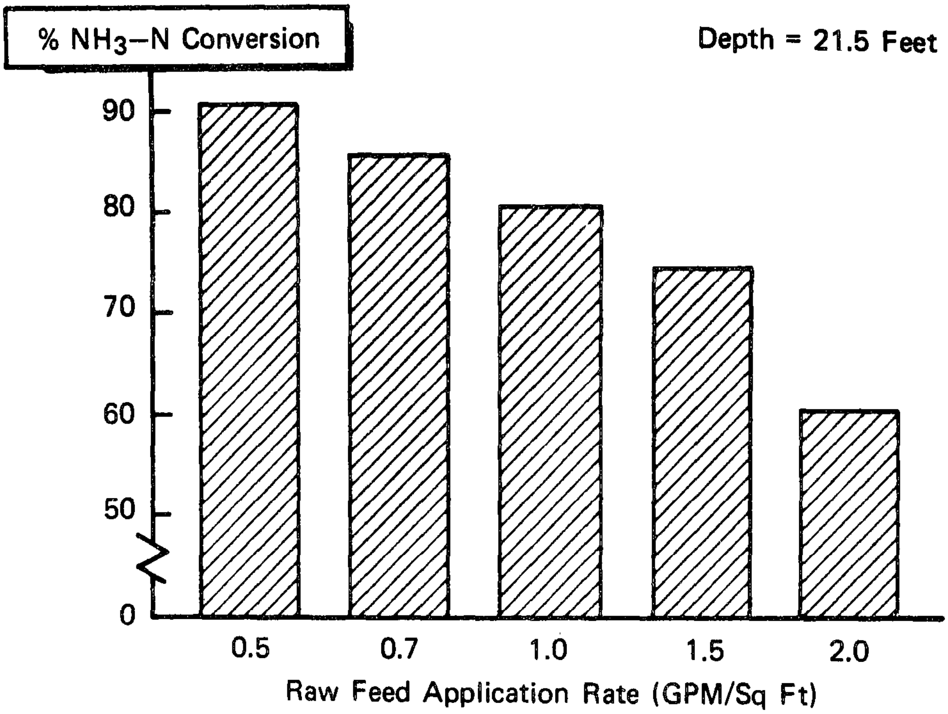
In an effort to locate the most active areas of the nitrifying tower, several profiles of nitrogen species were developed by collecting samples at intermediate tower depths. The ammonia nitrogen profile, when plotted from two different operating conditions as shown in Figures 7 and 8, indicates that the total media depth (21.5 feet) would be required to achieve an effluent ammonia nitrogen concentration of 1-2 mg/l.

The curves suggest that at these conditions, additional media depth would have little effect on the ammonia nitrogen concentration in the final effluent. Even fairly low influent

TABLE 6

SUMMARY OF PERIODS II, IV, VI, AND XV

Period	Date	Flow (gpm/sq ft) Inf.	Recycle	Sample Location	NH_3-N	NH_3-N Loading Lb/M cu ft/Day	% Efficiency
II	5/4 - 5/14/71	0.5	1.0	Influent	11.3	3.1	89
				Effluent	1.3		
XVIII	6/23 - 7/19/72	0.71	0	Influent	13.4	5.2	85
				Effluent	2.0		
V	7/15 - 8/6/71	1.0	0	Influent	13.3	7.3	82
				Effluent	2.5		
VI	8/10 - 8/17/71	1.5	0.5	Influent	14.6	12.1	77
				Effluent	3.4		
IV	6/15 - 6/30/71	2.0	0	Influent	13.1	14.5	63
				Effluent	4.9		



INFLUENT HYDRAULIC APPLICATION RATE vs NITRIFICATION PERFORMANCE

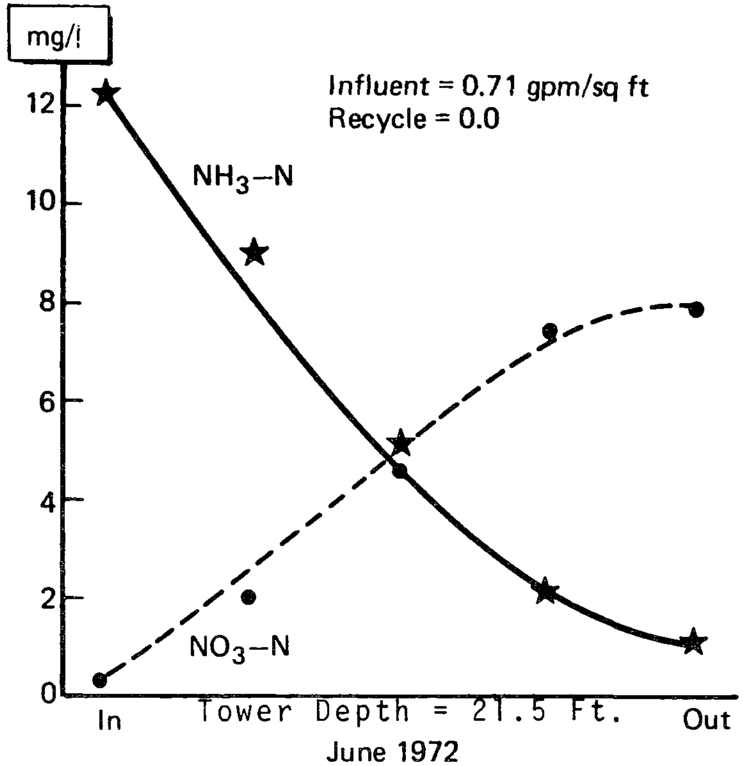
FIGURE 6

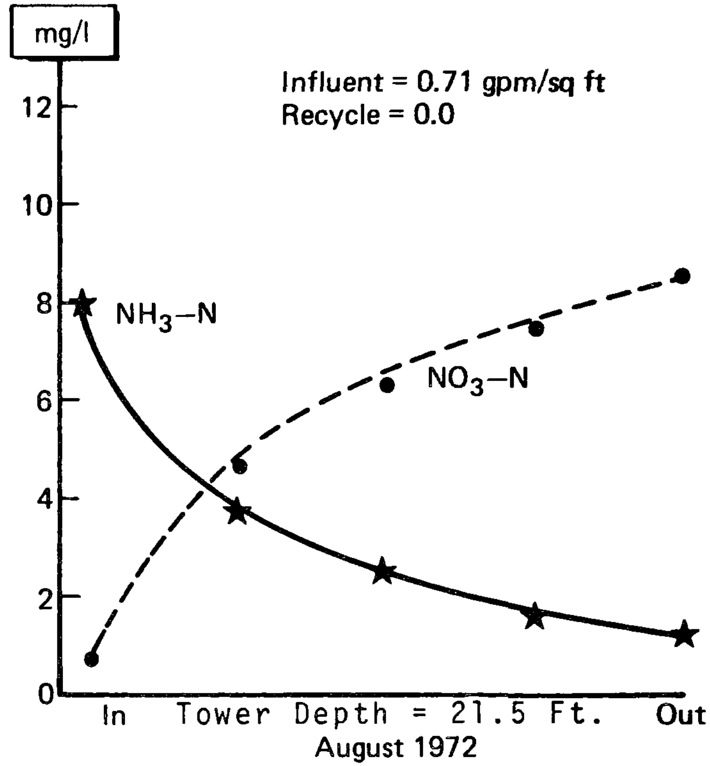
concentrations (which provide low nitrogenous loadings) did not enable the trickling filter to consistently achieve <1.0 mg/l ammonia nitrogen in the effluent.

Some thought was given to operating a second pilot tower in series with the existing installation, but this was not done because of limitations of time and funds.

RECYCLE

In an effort to achieve the maximum performance from the nitrification tower, considerable work was done on the effects of recirculation of the tower effluent. The results of several periods utilizing recycle (summarized in Table 7)





NITRIFYING TOWER NITROGEN SPECIES PROFILE

FIGURE 7

FIGURE 8

TABLE 7

SUMMARY OF RECIRCULATION EFFECTS

Period	Date	Flow (gpm/sq ft) Influent	Flow (gpm/sq ft) Recycle	Sample Location	NH_3-N	% NH_3 Conversion
I	April 71	0.5	0	Influent	10.0	81
				Effluent	1.9	
II	May 71	0.5	1.0	Influent	11.3	89
				Effluent	1.3	
XI	Jan. 72	0.5	1.0	Influent	13.2	86
				Effluent	1.9	
XIV	March 72	0.71	0.5	Influent	15.0	83
				Effluent	2.6	
XVIII	July 72	0.71	0	Influent	13.4	86
				Effluent	2.0	

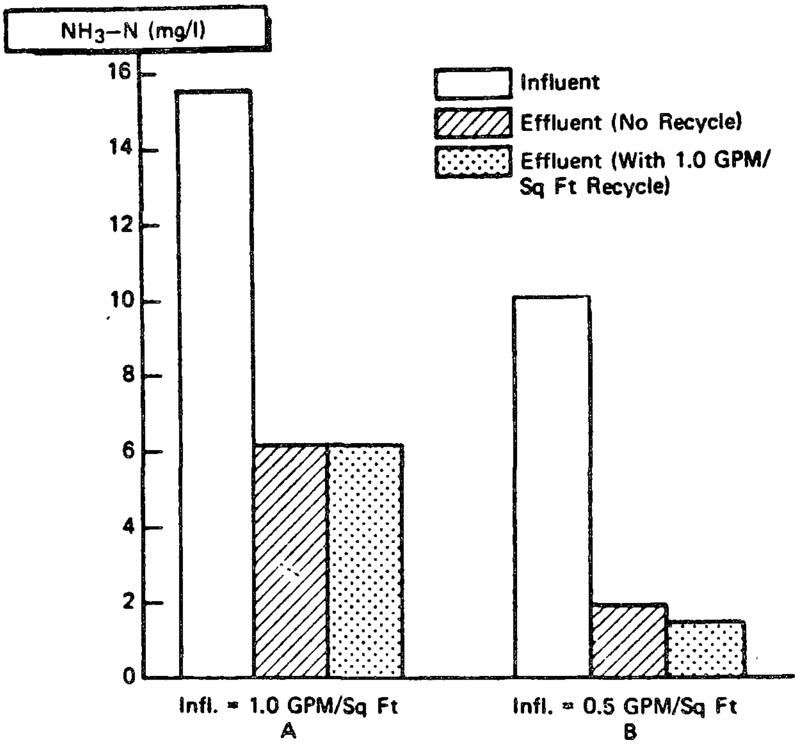
were rather inconclusive. In general, recycling the tower effluent did not significantly improve the overall nitrification performance of the system. Although several periods with recycle do exhibit slightly improved efficiency (see Figure 9), other periods of comparable operation show the effect of recycle to be negligible.

Considering all of the variables which influence the efficiency of nitrification, such as temperature, influent applications, etc., it is reasonably evident that adjustment of tower recycle is not alone sufficient to consistently provide low concentrations of ammonia nitrogen in the final effluent. The increased pumping costs associated with high recycle systems would probably negate any benefits of improved efficiency. However, since most waste treatment facilities have diurnal variations in flow volume, it is a general practice to design trickling filters with recycle capacity to maintain adequate and stabilized flow applications during low flow periods. The benefits of recycle are more a means of achieving consistent stabilized operation rather than high level performance.

TEMPERATURE (SEASONAL)

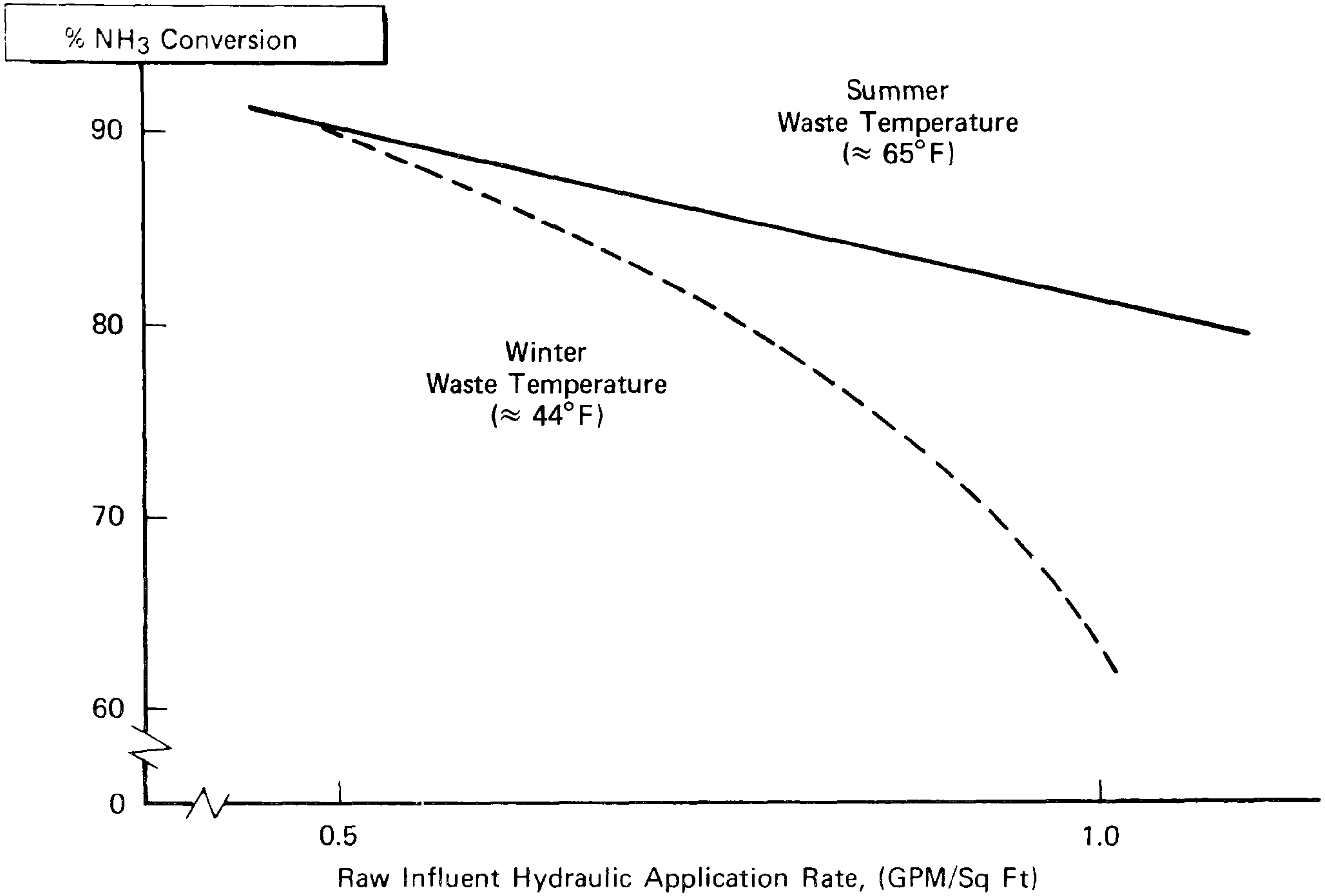
The pilot plant was operated continuously over an 18 month period to evaluate all seasonal conditions. It had been previously seen that nitrifying bacterial populations are extremely sensitive to low temperatures. It was imperative, therefore, to evaluate the nitrification performance during both summer and winter conditions.

Cumulative performance over a wide range of operating conditions from two distinct temperature conditions is shown in Figure 10. Clearly illustrated is the three-way



EFFECT OF RECYCLE ON NITRIFICATION PERFORMANCE

FIGURE 9



LOADING–TEMPERATURE–PERFORMANCE RELATIONSHIP OF A NITRIFYING TRICKLING FILTER

FIGURE 10

relationship between temperature, hydraulic loading, and percent nitrification. The effect of cold weather on nitrification performance, very evident at moderately high flow rates, is significantly reduced at lower hydraulic application rates.

One of the major reasons for the need for efficient nitrification is related to the total oxygen demand (TOD) contained within a municipal sewage effluent. Since ammonia nitrogen has a high oxygen demand, it is necessary to convert the ammonia to the most completely oxidized nitrate form prior to discharge to alleviate upset of the oxygen balance within the receiving body of water. A comparison of the performances during Periods III and XII (differing significantly only with respect to operating temperature) is summarized in Table 8. The performance was significantly reduced at the lower temperature.

It is important to note that high level nitrification efficiency was attained during the coldest winter months operating at influent waste temperatures as low as 37°F. This was accomplished by operating the system at a moderately low influent hydraulic application rate. Since the overall volume of media required to achieve a given effluent quality is directly related to the influent waste application rate, the effect of temperature could have a significant bearing on the total capital economics of a given installation. If a system was to be designed for high level performance throughout the year, i.e. producing an effluent of 1.5 mg/l of ammonia nitrogen at a treatment facility located in a northern climate, the system design would have to be based on a relatively low influent feed rate. Conversely, if winter

TABLE 8

EFFECT OF TEMPERATURE ON PERFORMANCE

Period	Date	Flow (gpm/sq ft) Influent	Flow (gpm/sq ft) Recycle	Sample Location	NH_3-N	Temperature (°F)
III	June 71	1.0	0	Influent	12.0	57
				Effluent	1.7	54
XII	Feb. 72	1.0	0	Influent	15.5	48
				Effluent	6.1	44

conditions were not going to be experienced, the same effluent requirements could be achieved at a greater application rate, reducing the required trickling filter volume and corresponding costs.

The biological nitrification tower exhibits good design flexibility. The system can be designed for seasonal variations in effluent quality. A system designed for economical operation to provide high level treatment for summer conditions would continue to provide nitrification at a lower conversion level during the winter months. Even if high level nitrification is required on a year-round basis, a properly designed biological oxidation tower is capable of providing nitrification in the range of 90 percent conversion with a final effluent concentration of 1-2 mg/l.

SUSPENDED SOLIDS RELATIONSHIP

Biological nitrification systems are known to be dependent upon the development of late-stage biological nitrifying populations. For this reason, the pilot plant was initially established with a clarifier to accept all of the discharge from the oxidation tower. It was felt that it would be necessary to recirculate the biological solids collected in this clarifier back to the oxidation tower to provide the aged growths necessary for active nitrification. Additional solids capture was provided by the final mixed media filter. The initial high solids backwash from the mixed media filter could be returned to the oxidation tower to assure the maintenance of late-stage nitrifying populations.

The pilot scale clarifier was used during the initial periods of operation. It soon became evident that very few, if any, suspended solids were sloughing from the nitrification tower and subsequently little sludge was accumulating in the clarifier return. The minimal net solids production of the nitrifying tower is illustrated by the information, from six different operating periods, included in Table 9. These data represent a variety of operating conditions in virtually all seasons of the year.

Previous work has shown that the nitrifying oxidation reaction is a relatively low solids yield process (11) - the low net solids production across the nitrifying tower would substantiate this. It is known that during the oxidation of carbonaceous material there is a definite increase in biological matter which ultimately purges itself from the biological reactor. In the case of nitrification, with very little solids generated and virtually no carbonaceous activity, the suspended solids quality of the tower effluent (prior to settling) was generally no worse than that of the system influent. It is important to note that the pilot trickling filter was operated at a constant hydraulic flow rate during each period. Whenever the system was changed to evaluate new hydraulic flow rates, significant solids sloughing was observed for 2-3 days while the biomass adjusted to the new hydraulic shear conditions.

The visible growth on the plastic media during the nitrification study was described as a tough, thin, grayish-brown slime which did not apparently follow the characteristic buildup and subsequent sloughing evident in filters operating in carbonaceous oxidation. It is evident that this nitrifying slime was essentially retained on the surfaces of the plastic media tower. After the first three periods of operation the effluent from the oxidation tower was pumped directly to the mixed media filter without intermediate clarification.

TABLE 9

SUSPENDED SOLIDS RELATIONSHIPS

Period	Date	Flow (gpm/sq ft)		Suspended Solids (mg/l)			
		Feed	Recycle	Tower Inf.	Tower Eff.	Clarifier Eff.	Filter Eff.
I	April 71	0.5	0	21	18	12	-
III	May 71	1.0	0	13	13	9	-
IV	June 71	2.0	0	22	17	-	7
VII	Aug. 71	1.0	0.5	24	28	-	4
VIII	Sept. 71	0.5	1.0	20	18	-	3
X	Dec. 71	0.5	1.0	15	12	-	3

The oxidation tower can achieve efficient nitrification without a net change in the suspended solids concentration of the waste. In cases where the existing suspended solids quality is acceptable, a strict nitrifying tower effluent may be discharged or sent to tertiary solids polishing facilities without conventional clarification. This is in contrast to suspended growth (activated sludge) biological nitrifying systems where due to the suspended nature of the bacterial population, a clarifier is required for efficient manipulation of the mixed liquor suspended solids and food-to-microorganism ratios. It has been shown that in sus-ended growth stage nitrification, the net solids produced across the nitrifying stage is also negligible but the clarifier is still needed for operation of the system (11).

SOLIDS RECYCLE

During Periods VI and VII, an attempt was made to recycle solids from the clarifier to the oxidation tower to maintain a high solids contact system. The original thinking was that this would be necessary for achieving the late-stage biological growth necessary for nitrification. Since it was found active nitrification was occurring without solids recycle, the major emphasis was then to recycle solids in an effort to achieve a higher level of performance.

Few solids were generated in the system so it was not possible to maintain a consistently high solids recycle. A gradual buildup of solids in the clarifier provided opportunity to recycle solids for one week in Period VI. During this time the suspended solids concentration in the tower effluent was maintained at roughly 85 mg/l. This was a four-fold increase over the influent suspended solids concentration.

Nitrification was relatively poor during this period, with an effluent concentration of 3.4 mg/l ammonia nitrogen. The subsequent Period VII during which the solids concentration was maintained at a level of approximately 30 mg/l showed an effluent concentration in the range of 4.5 mg/l ammonia nitrogen.

On the basis of this limited examination of solids recycle and the fact that the system was actively nitrifying without solids recycle, it was concluded that solids recycle was not needed to achieve nitrification and did not provide any improvement in overall performance. Recycling organic solids over the oxidation tower could actually prove detrimental. It is possible that solubilization of organic material could occur in the oxidation process and produce additional ammonia nitrogen and organic oxygen demand with detrimental effects on the final effluent quality. No further work was done with recirculation of settled solids during the current research program.

MIXED MEDIA FILTRATION

Many locations which will require nitrogen control might also be required to meet very low final effluent suspended solids standards. Therefore, the pilot plant system included a mixed media filter to study liquid-solids separation of the tower effluent. This would also assure complete solids capture from the pilot plant system should it be necessary to recirculate the suspended material to establish the late-stage growths needed for efficient nitrification. The mixed media filter was installed to accept flows either directly from the oxidation tower or from the clarifier.

The filter selected for this study was a tri-media pilot scale downflow pressure filter. It contained filter material of anthracite coal, silica sand, and garnet sand ranging from 1.2 mm down to 0.2 mm and specific gravities from 1.5 to 4.5. The filter is graded such that large particles of low density are at the top and small particles of high density are at the bottom. The general volumetric proportions of media were approximately 10 percent high density sand, 30 percent silica sand, and 60 percent anthracite coal. The 20-inch diameter, 5-foot side-shell-length filter was equipped with fixed distribution surface wash and a lateral pipe underdrain system. The average design flow rate was approximately 5 gpm/sq ft cross-section area.

At the time of sizing the pilot plant equipment, nominal operating conditions were estimated to be in the range of 10-15 gpm. As the study progressed, it was obvious that the operating range for the oxidation tower was something less than 10 gpm. As a result, the mixed media filter was operated at flows consistently below its full design rate. Virtually all of the performance data for the mixed media filter was obtained at flow rates of 3.0 gpm/sq ft or less. (For example, when the pilot oxidation tower is operated at 0.5 gpm/sq ft, the maximum flow to the mixed media filter would be only 1.6 gpm/sq ft.)

In view of these limited operating conditions, it is understandable that, as shown in Table 10, the mixed media filter achieved very efficient removal of suspended solids. The efficiency of the mixed media filter for solids removal, under a variety of conditions, is shown in Figure 11.

TABLE 10

MIXED MEDIA FILTER OPERATING CHARACTERISTICS

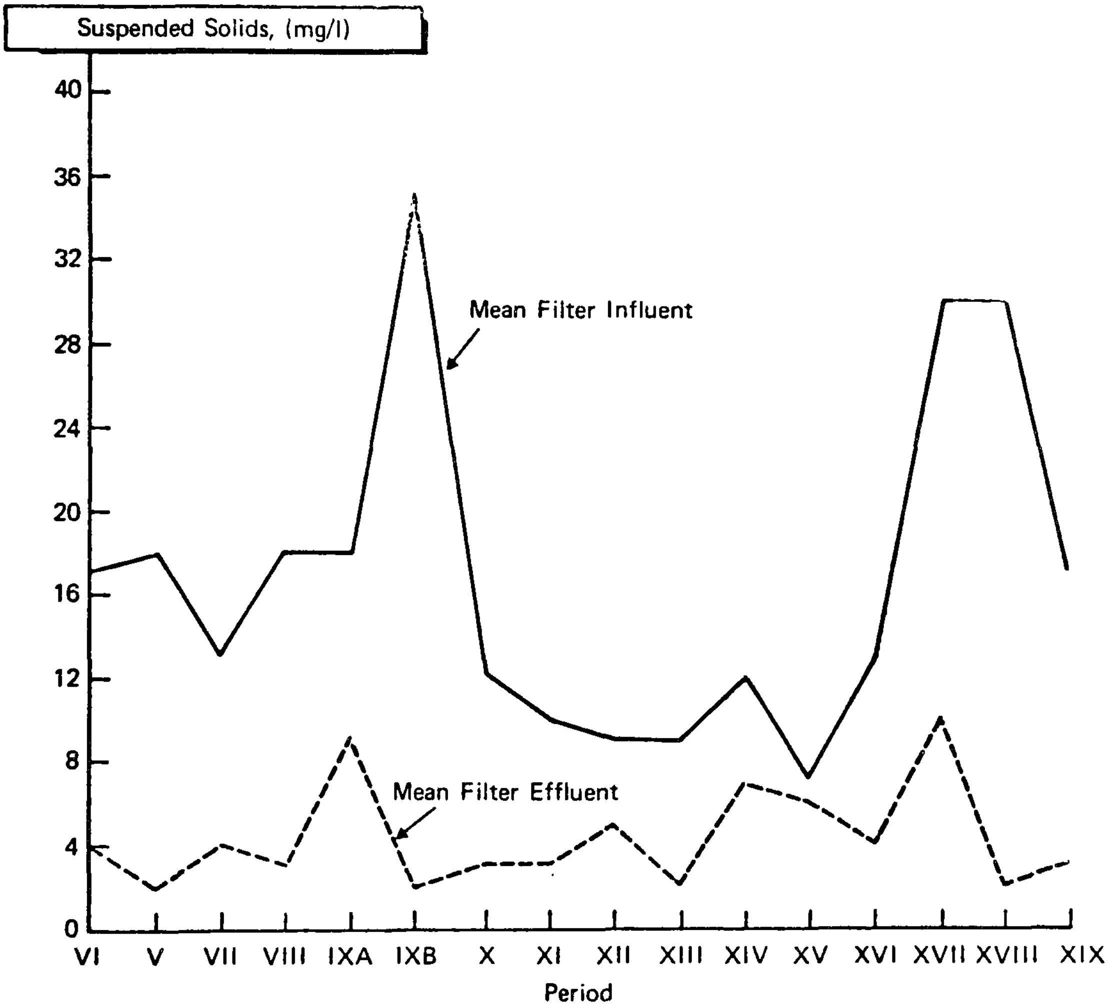
Characteristic		Approximate Value
Pressure: Post-Backwash		1.0 psi
Pressure: Pre-Backwash		6.0 psi
Backwash Frequency		Every 48 hours
Backwash Volume		375 gal. in 10 min (2.5% of flow volume)
Backwash Procedure	1.	2 min surface wash
	2.	8 min surface and backwash

The pressure filter was operated on a run cycle based on a 10-foot head loss. At the application rates used in this study of 3.0 gpm/sq ft or less, filter runs in excess of 48 hours were common, even when accepting flow directly from the nitrification tower.

Due to the physical limitations of the pilot plant equipment, the most significant finding of the mixed media filtration work was the fact that it was possible to accept unclarified oxidation tower effluent without detrimental effects on unit operation. This was largely due to the low net solids production of the nitrifying tower.

DENITRIFICATION STUDIES

Total nitrogen removal or combined nitrification and denitrification will be required in some locations. The trickling filter nitrification system alters the nitrogen species balance (converting NH_3-N to NO_3-N) but does not remove nitrogen from the waste stream. Several processes are available to remove the nitrate ion; these denitrification processes include biological denitrification reactions or various chemical-physical systems.



MIXED MEDIA FILTER SOLIDS REMOVAL PERFORMANCE

FIGURE 11

The mixed media filter used for solids separation provided a chamber essentially devoid of atmospheric oxygen. A study was incorporated into the existing research program to evaluate biological denitrification. Objectives of this study were evaluation of any deleterious effects on filter performance due to the establishment of a biological denitrifying growth in the filter chamber; determining if there was adequate residence time within the mixed media filter; and observing if filter backwashing would interfere with continuous denitrification. This work spanned a 3.5 month period during the summer of 1972, and was limited in scope. It did not investigate the effect of temperature on the denitrification process nor evaluate dissolved oxygen levels of the final denitrified effluent.

Previous work has established that methanol is a feasible carbon source to sustain a biological denitrification process (12). In this process the nitrate ion becomes a chemical oxygen supply for the anoxic oxidation of the carbonaceous material by facultative denitrifying bacteria. The resultant nitrogen gas discharges to the atmosphere.

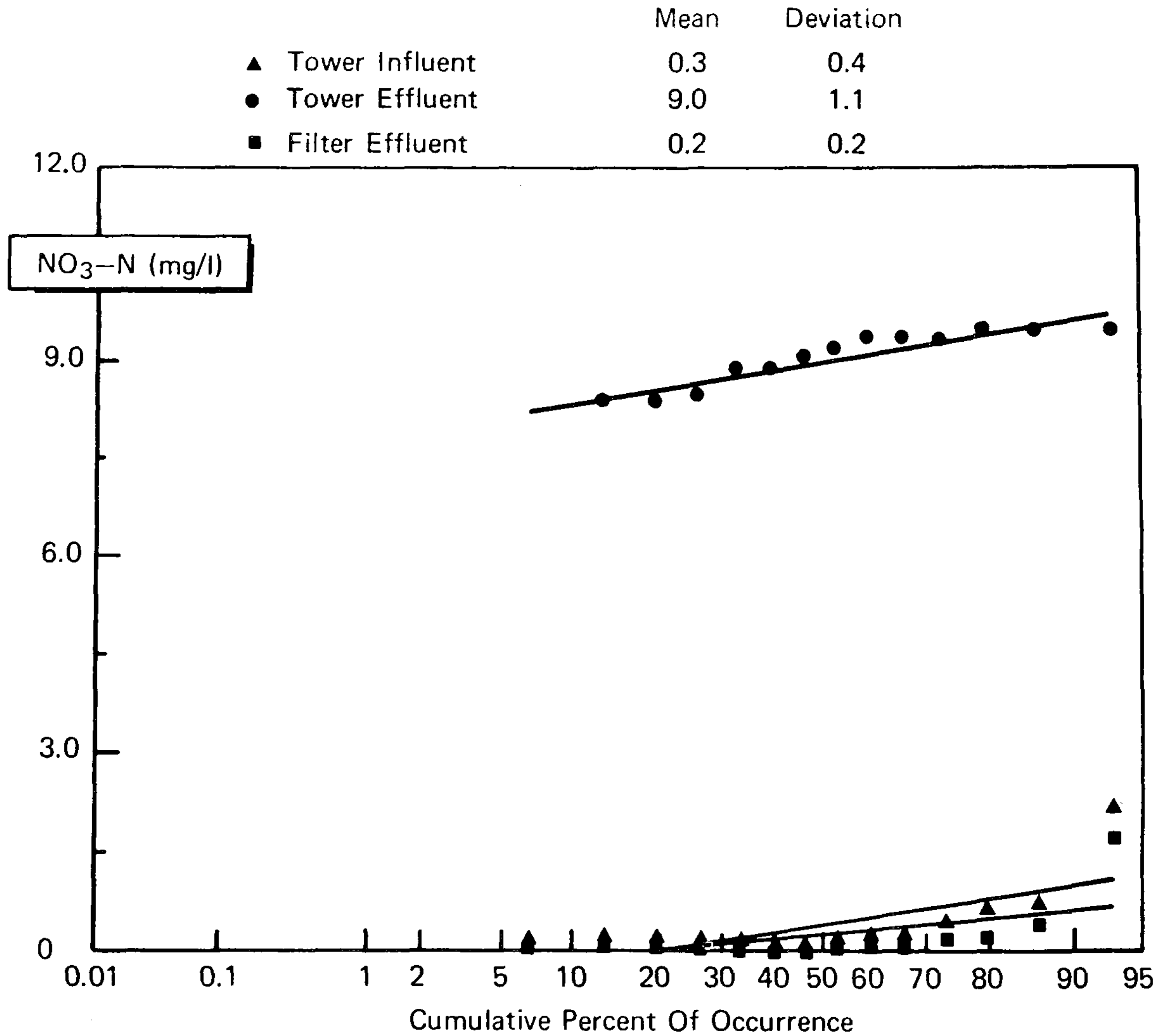
Based on work by McCarty (12), it was decided to supply 3.5 mg methanol/mg nitrate nitrogen for the reaction. The sophisticated equipment necessary to maintain this precise ratio was not immediately available. An average nitrate nitrogen concentration was assumed (15 mg/l) and a constant feed rate of 52.5 mg/l methanol was used. Since the actual nitrate nitrogen concentration into the mixed media filter averaged approximately 9 mg/l during this study period, the process was operating at 65-90 percent excess theoretical carbon.

The methanol addition to the mixed media filter was controlled incrementally to allow the system to acclimitize. Over a period of 3 days, the methanol feed to the mixed media filter was gradually increased from 0 to 52.5 mg/l. After an acclimitization period of 4 weeks, a high level of denitrification was being achieved in the mixed media filter and continued until termination of the methanol feed.

During May, June, and most of July 1972, the denitrification process averaged >95 percent nitrate nitrogen removal; the overall system operated at >85 percent total nitrogen removal. The final effluent contained an average 1-3 mg/l of total nitrogen. This was comprised primarily of residual ammonia and organic nitrogen fractions which were unaffected by the denitrification process.

The denitrification process, as illustrated by the nitrate nitrogen probability plot in Figure 12, was very stable. No biochemical upsets were observed. The process did react adversely to a brief shutdown of the methanol feed, as is apparent in the data from Period XVIII. Recovery to the former high level of performance, however, was rapid.

The final effluent suspended solids levels during the denitrifying periods were indicative of the capacity of the filter to simultaneously denitrify and remove suspended solids from the waste stream. The operating characteristics of the mixed media filter, however, were significantly altered with the establishment of denitrification. Major changes occurred in the filter run time, backwash volume, and operating head loss, but continuous and effective operation was maintained throughout the study.



NO_3–N CONCENTRATION PROBABILITY – PERIOD XVII
FIGURE 12

Several pertinent facts about the mixed media filter operation preceding and following the establishment of denitrification are provided in Table 11. The frequency of backwashing changed from 2-3 days prior to Period XV to only 24 hours. Then it became imperative (due to high head loss) that the filter be backwashed. Additionally, the backwash volume to "clear" the filter was doubled. The previous procedure of a two minute surface wash and eight minute surface wash-backwash cycle had to be performed twice in sequence for each backwash during denitrification. These conditions changed the backwash volume from the previous 2 percent of total flow to 10 percent of total flow.

The nature of the backwash changed also. In previous operations an initial short run produced very dark backwash, followed by increasing clarity until a rather clear backwash stream was obtained. During denitrification, no initial "slug" was noticed. Rather, there was a brown stream (with what appeared to be fine particles) that cleared very slowly, even after 20 minutes of backwash.

During a period of high level denitrification, an experiment was conducted to determine the nature of the atmosphere within the mixed media filter chamber. Just prior to backwashing the sewage flow was stopped. The filter was tapped and connected to a gas sample bomb; the pressure in the filter was sufficient to flush out the flask and collect a one liter gas sample. The analytical results from mass spectroscopy are presented in Table 12, and compared to a similar analysis conducted five weeks after termination of the denitrification process. The 6 mole percent oxygen

TABLE 11

EFFECTS OF DENITRIFICATION ON MIXED MEDIA FILTER OPERATING CHARACTERISTICS

		Approximate Value	
		Prior to Denitrification	During Denitrification
Post-Backwash Operating Pressure		1 psi	3 - 5 psi
Pre-Backwash Operating Pressure		5 - 6 psi	12 - 15 psi
Filter Run Time		48 - 72 hours	24 hours
Backwash Volume		375 gal./10 min (2.5% of flow volume)	750 gal./20 min (10% of flow volume)
Backwash Procedure	1.	2 min surface wash	2 min surface wash
	2.	8 min surface backwash	8 min surface backwash
	3.	-	2 min surface wash
	4.	-	8 min surface backwash

could partially be the result of air contamination. The 15 percent methane fraction strongly suggests the presence of a methanogenic bacteria. It has been observed that the denitrifying bacteria apparently adhere to the media and are not flushed out during backwashing. Such may well be the case for the methanogenic bacteria, providing the extended residence time necessary for such organisms to function effectively.

TABLE 12

MIXED MEDIA FILTER GAS SAMPLES

	Concentration, Mole Percent	
	During Denitrification 7/7/72	After Denitrification 8/28/72
Carbon Monoxide	-	0.36
Carbon Dioxide	0.40	1.10
Methane	15.50	0.27
Nitrogen	77.61	97.15
Oxygen	5.71	0.21
Argon	0.77	0.91

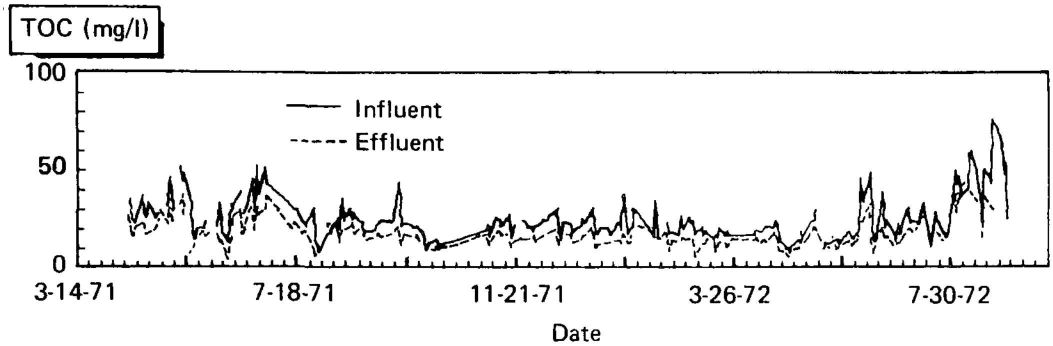
The denitrification process was terminated by eliminating the carbon source (the methanol feed was shut off). The operating characteristics of the mixed media filter, however, were sluggish in their return to former values. A residual of the biomass created by the methanol addition probably still remained in the filter chamber. This would contribute to the slow improvement in head loss and backwash characteristics noted. After several weeks, the filter returned to levels typical of its operation prior to denitrification.

In view of the physical limitations of the mixed media unit, it was not possible to make realistic quantitative evaluations of the operating characteristics of the combined mixed media/denitrification process. The main contribution of the denitrification study was the clearly evident result that biological denitrification can occur without interruption in a mixed media filter undergoing intermittent backwash. Backwashing does not wash out the denitrifying populations and efficient denitrification continues in a stable fashion. The two processes (trickling filter nitrification and mixed media filter denitrification) were shown to be compatible and produced the consistent, high quality effluent desired.

CARBONACEOUS LOADING

As previously indicated, the pilot plant nitrification tower was operated as a strict nitrifying stage subsequent to efficient carbonaceous BOD_5 removal in conventional secondary treatment. The influent feed during the contract period was consistently below 25 mg/l BOD_5 and total organic carbon values were below 25 mg/l. The total organic carbon concentration of the pilot plant influent throughout the study periods is shown in Figure 13.

It is evident that this system was operated at a very low carbonaceous loading. Even at maximum hydraulic application rates attained during the contract period, the carbonaceous BOD_5 loading was less than 15 lbs/1000 cu ft media/day. From the data in Figure 13, it can be seen that very little carbonaceous oxidation was occurring through the pilot plant system and that the unit was operating as a strict nitrifying stage. This was further confirmed by the minimal suspended solids generation discussed earlier.



TOTAL ORGANIC CARBON OCCURRENCE
FIGURE 13

Prior to termination of the pilot plant operation, some work was done with the carbonaceous loading to the oxidation tower. The loading was doubled by taking feed from an intermediate point in the municipal facility which contained BOD_5 concentrations in the range of 40-60 mg/l. During this operation, the pilot scale clarifier was reinserted into the system following the trickling filter to accept the expected increases in suspended solids from the tower. During limited evaluations at these conditions, the high level of nitrification (approximately 90 percent) did not deteriorate. An increase in suspended solids coming from the oxidation tower was evident as shown in Table 13.

TABLE 13

SUSPENDED SOLIDS CHARACTERISTICS DURING
SIMULTANEOUS CARBONACEOUS AND NITROGENOUS OXIDATION

Sample Location	Suspended Solids, mg/l
Tower Influent	28
Tower Effluent	58
Clarifier Effluent	19
Mixed Media Filter Effluent	4

The suspended solids concentration in the unsettled tower effluent during this period was significantly greater than that generally noted throughout the rest of the contract. The fact that suspended solids generation was higher (along with limited results showing increased carbonaceous BOD removals across the oxidation tower) suggests that simultaneous carbonaceous and nitrogenous oxidation was occurring.

This brief evaluation indicates that simultaneous carbonaceous and nitrogenous oxidation is compatible in the pilot scale trickling filter. It is likely that at some point, the degree of carbonaceous oxidation (due to increased BOD_5 loading) would be such that the related suspended solids generation and subsequent tower sloughing could create a washout of nitrifying bacteria and decreased nitrification effectiveness. Even under these conditions, the nitrification could possibly be maintained with adequate solids clarification and recirculation. These aspects were not clearly defined due to the limited scope of this study.

CHLORINATION OF NITRIFIED SEWAGE

During the course of the contract, there was considerable speculation on possible relationships between ammonia nitrogen concentration and the final chlorination process used by many wastewater treatment facilities. The efficiency of disinfection by chlorination is greatly diminished by the formation of chloramines; the biocidal activity of monochloramine may be 1/25 to 1/50 the activity of free chlorine (in the form of HOCl). Monochloramine is the major product formed in the reaction between chlorine and the ammonia present in most conventional sewage treatment plant effluents.

A study was designed to determine the stability, biocidal activity, and residual fish toxicity of chlorinated nitrified domestic sewage. This study included comparative chlorination of both nitrified and non-nitrified discharges (pilot plant influent vs. pilot plant effluent). Static 96-hour bioassays were conducted under typical sewage plant disinfection conditions. Chlorine residuals and bacteria counts were determined at appropriate intervals throughout the disinfection period.

Tests were conducted by adding varying amounts of chlorine to one liter aliquots of sewage (tower influent or effluent). After 15 minute contact time, the chlorine residuals were measured. Bioassays were then conducted in 1:10 dilutions of the waste with fresh Lake Huron water. The test organism was the common fathead minnow (*Pimephales promelas*).

Fish survivals were determined over a 96-hour period. Total bacteria and/or total coliforms were plated at 5 minute intervals over the initial 15 minute contact. Chlorine residuals were measured at identical times, and additionally after 24 hours.

Total available chlorine was determined by colorimetric and ampereometric methods. Excess sodium iodide (0.2 g/25 ml) was added in both methods to determine total available chlorine as liberated iodine. The ampereometric method used was described in *Standard Methods*. The colorimetric method is based on measurement of the tri-iodide species at a wavelength of 352 millimicrons using a Beckman Model DBG Spetrophotometer. The results from the two methods correlated closely. (No iodate interference could be observed below pH 10 using this large excess of iodide.)

Total bacteria counts were determined by dilution in sterile solutions of sodium hyposulfite, followed by direct plating on nutrient agar as described in _Standard Methods_. Similarly, total coliforms were determined using endo agar.

Lower fish toxicities and improved bacteriological disinfection were obtained for nitrified samples as opposed to non-nitrified samples as shown in Tables 14, 15, and 16. At the higher chlorine concentrations there was evidence of breakpoint chlorination, or nearly complete oxidation of ammonia, in the nitrified sample. Chlorine residuals and chlorine demands were affected markedly by the concentration of stable monochloramine. These results are likely the result of the nitrified tower effluent containing lower concentrations of ammonia nitrogen, producing a mixture of chloramine (NH_2Cl) and free chlorine (in the form of HOCl), whereas the tower influent had sufficient ammonia nitrogen to form predominantly chloramine.

The effects of chlorine residuals on fathead minnow survival are shown in Table 14. At chlorine concentrations above 5 mg/l, partial or complete fish kill was observed for tower influent samples. Tower effluent samples showed partial or total fish kill at 8 mg/l chlorine and above. In each case there was a direct correlation between 24-hour chlorine residual and percent fish kill. At 25 mg/l chlorine concentration (slightly beyond the breakpoint for this sample), no fish kill was observed with the nitrified effluent. The free chlorine residual (which is known to be highly toxic to fish) was apparently too short-lived to produce fish kills in these 48-hour static tests.

TABLE 14

EFFECT OF CHLORINE RESIDUALS ON FATHEAD MINNOW SURVIVALS

Chlorine Concentration (mg/l)	Tower Influent (mg/l)			Tower Effluent (mg/l)		
	Initial Residual	24 Hour Residual	% Fish Survival (48 Hour)	Initial Residual	24 Hour Residual	% Fish Survival (48 Hour)
4	0.28	0.02	70	0.2	0.03	100
5	0.33	0	100	0.1	0	100
6	0.40	0.04	60	-	-	-
8	0.74	0.13	10	0.47	0.10	70
10	0.72	0.18	0	0.38	0	50
15	1.1	0.31	0	1.0	0.23	0
					(Breakpoint)	
25	-	-	-	0.46	0.08	100

TABLE 15

EFFECT OF CHLORINE CONCENTRATIONS AND RESIDUALS ON TOTAL BACTERIA

	Tower Influent				Tower Effluent			
	Chlorine Residual	Percent Kill			Residual	Percent Kill		
Chlorine Concentration (mg/l)	15 Min (mg/l)	5 Mins	10 Mins	15 Mins	15 Min (mg/l)	5 Mins	10 Mins	15 Mins
0	-	7.5×10^5 Bacteria/ml			-	1.0×10^5 Bacteria/ml		
4	2.4	98.0	99.3	99.7	2.0	>99.9	>99.9	>99.9
6	3.6	98.0	>99.9	>99.9	-	-	-	-
8	5.4	98.0	>99.9	>99.9	4.4	>99.9	>99.9	>99.9
15	-	-	-	-	10.0	>99.9	>99.9	>99.9
25	-	-	-	-	4.6	>99.9	>99.9	>99.9

TABLE 16

EFFECT OF CHLORINE CONCENTRATIONS AND RESIDUALS ON TOTAL BACTERIA

Chlorine Concentration (mg/l)	Tower Influent				Tower Effluent			
	Chlorine Residual 15 Min (mg/l)	Percent Kill			Residual 15 Min (mg/l)	Percent Kill		
		5 Mins	10 Mins	15 Mins		5 Mins	10 Mins	15 Mins
0	-	4.5×10^6 Bacteria/ml			-	7.5×10^4 Bacteria/ml		
5	3.3	99.0	99.5	>99.9	1.4	>99.9	>99.9	>99.9
10	7.2	>99.9	>99.9	>99.9	3.8	>99.9	>99.9	>99.9
15	10.8	>99.9	>99.9	>99.9	1.8	>99.9	>99.9	>99.9
25	-	-	-	-	11.3	>99.9	>99.9	>99.9

The initial results of disinfecting non-nitrified tower influent and nitrified tower effluent are summarized in Tables 15 and 16, respectively. Prior to disinfection, nitrified tower effluent showed both lower total bacteria and lower total coliform counts than tower influent by nearly an order of magnitude. As shown in Table 16, 4 mg/l chlorine was more effective in reducing total bacteria counts in nitrified tower effluent than in tower influent. At 5 mg/l chlorine, total coliform counts were also more efficiently reduced in nitrified tower effluent, as shown in Table 16.

The data presented here are rather limited in scope; no attempt was made to draw further quantitative predictions from this work.

OPERATING STABILITY

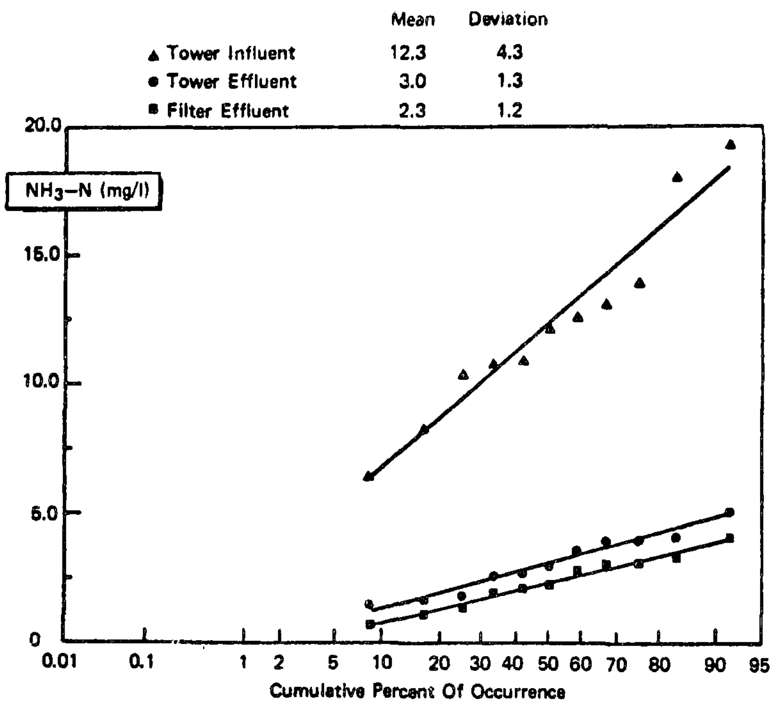
Biological nitrification in suspended growth (activated sludge) systems has been characterized by highly unstable performance. Considerable work has been done in evaluating the numerous interferences which have a dramatic effect on nitrifying systems (13). Virtually all dynamic conditions which influence operation of conventional carbonaceous oxidation systems have even more pronounced effects on nitrifying systems. This is one of the reasons why efficiently operated conventional plants still do not achieve any stable degree of nitrification.

Throughout the 18 months of pilot plant operation, the trickling filter nitrification tower proved to be a highly stable process. There were no noticeable biochemical upsets encountered in the study. All of the variations in nitrifying efficiency were related to physically induced operational modifications and efficiency variations due to temperature changes. On at least two occasions during the contract period, there were flow interruptions to the oxidation tower which caused additional physical upsets to the nitrifying system. One of these disruptions in early July 1971 lasted three days. The oxidation media was without hydraulic application and consequently experienced severe drying conditions. Contrary to the initial startup problems, the pilot plant system returned to efficient nitrification levels within a matter of days subsequent to the resumption of flow. Another feed malfunction in early January 1972 necessitated the operation of the tower on complete recycle for several days. One week after resumption of the influent feed the tower was again achieving 90 percent nitrification.

The data show that the overall performance of the oxidation tower nitrifying system is extremely stable when operating at optimum conditions. Even when the pilot tower is being operated at conditions other than optimum (see Figure 14), the system continued to nitrify in a stable manner albeit at a lower level. This is in contrast to other conventional biological nitrification systems (activated sludge) where a minor disruption in operation can create a dramatic loss of nitrifying capability until the correct controlling parameters are adjusted.

DESIGN GUIDELINES

Based on 18 months of continuous pilot plant operation under a wide variety of operating conditions, it is possible to establish nitrification design guidelines for plastic media trickling filters. The key design consideration which provides a practical basis for sizing full-scale



NITRIFICATION STABILITY AT 76% CONVERSION
(MEAN)

FIGURE 14

installations is the influent waste hydraulic application rate. Once the influent application rate has been established, a total media volume can be determined directly from the volume of flow to be treated for nitrification, assuming a set of conditions for other controlling factors such as waste temperature, tower depth, degree of treatment required, degree of prior carbonaceous removal, and absence of inhibiting toxic components. A summary of design considerations is shown in Table 17 for a combination of the actual operating conditions experienced in this research program. These considerations are also provided in Figure 15.

It has been established that scale-up to full-scale facilities is realistic and valid (14). This is based on considerable prior experience involving the utilization of this plastic media in similar pilot plant installations operated for carbonaceous BOD removal. Full-scale installations generally will perform as well as or better than controlled pilot plant investigations.

ECONOMICS

The cost of a full-scale plastic media oxidation tower is directly related to the volume (in cubic feet) of plastic media. Installations are generally based on an installed price per unit volume of fabricated media. Although the unit price for plastic media varies, a reasonable estimation on the order of $2.00/cu ft delivered and installed. Representative costs for plastic media at various media volumes are shown in Figure 16.

In 1967, a study was made of the construction cost for towers utilizing SURFPAC® biological oxidation media. This was accomplished by taking various sized units from 6000 to 700,000 cu ft of media and selecting typical supporting

TABLE 17

DESIGN GUIDELINES

Basis:

A. Waste stream contains no significant nitrification inhibitors.

B. Influent NH_3-N concentration <25 mg/l.

C. Carbonaceous loading <15 lbs BOD_5/1000 cu ft media/day

D. Media depth = 21.5 feet

E. Relatively constant total hydraulic flow.

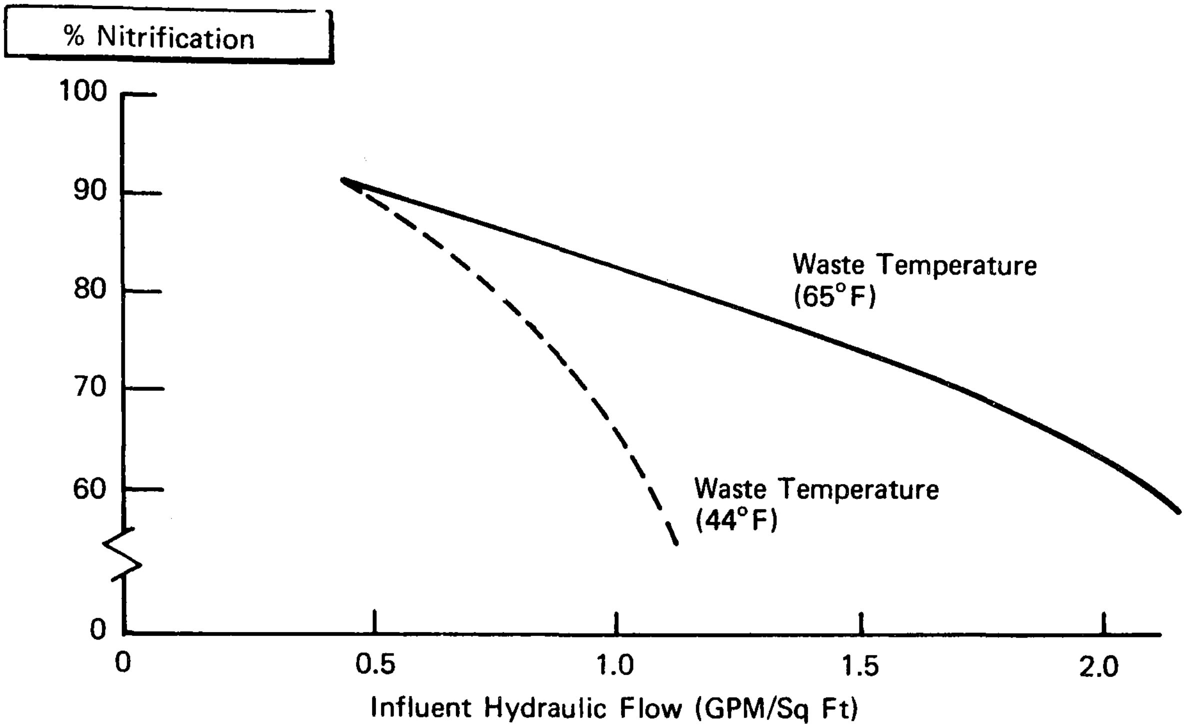
F.

Influent Feed Rate (gpm/sq ft)	Nitrification Performance (%)
0.5	90
0.75	85
1.0	80
1.5	75

G. These values are valid for wastewater temperatures >60°F. Figure 15 illustrates the effect of wastewater temperature on these guidelines.

H. Media: 27 sq ft/cu ft

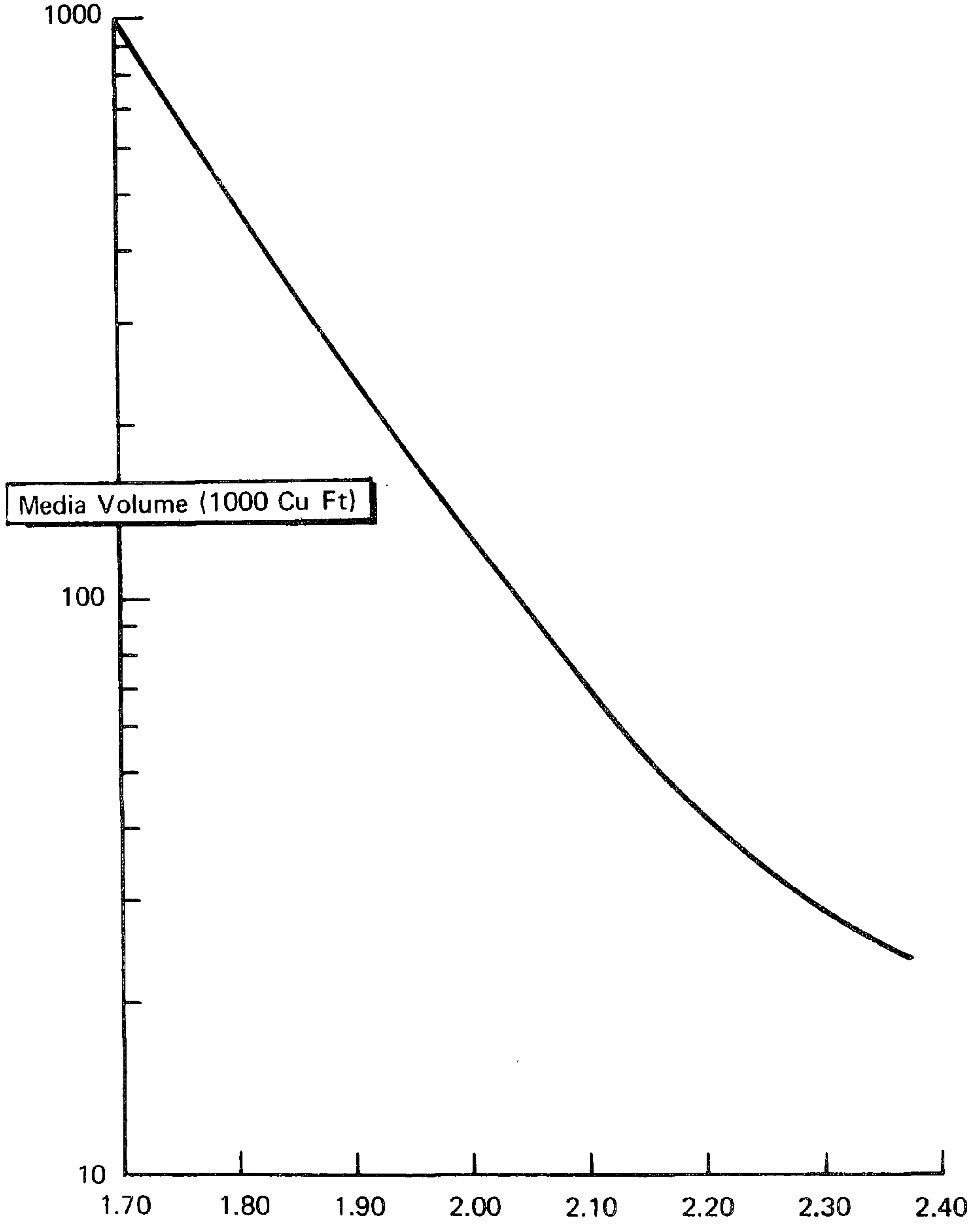
94% void volume



TRICKLING FILTER DESIGN GUIDELINES

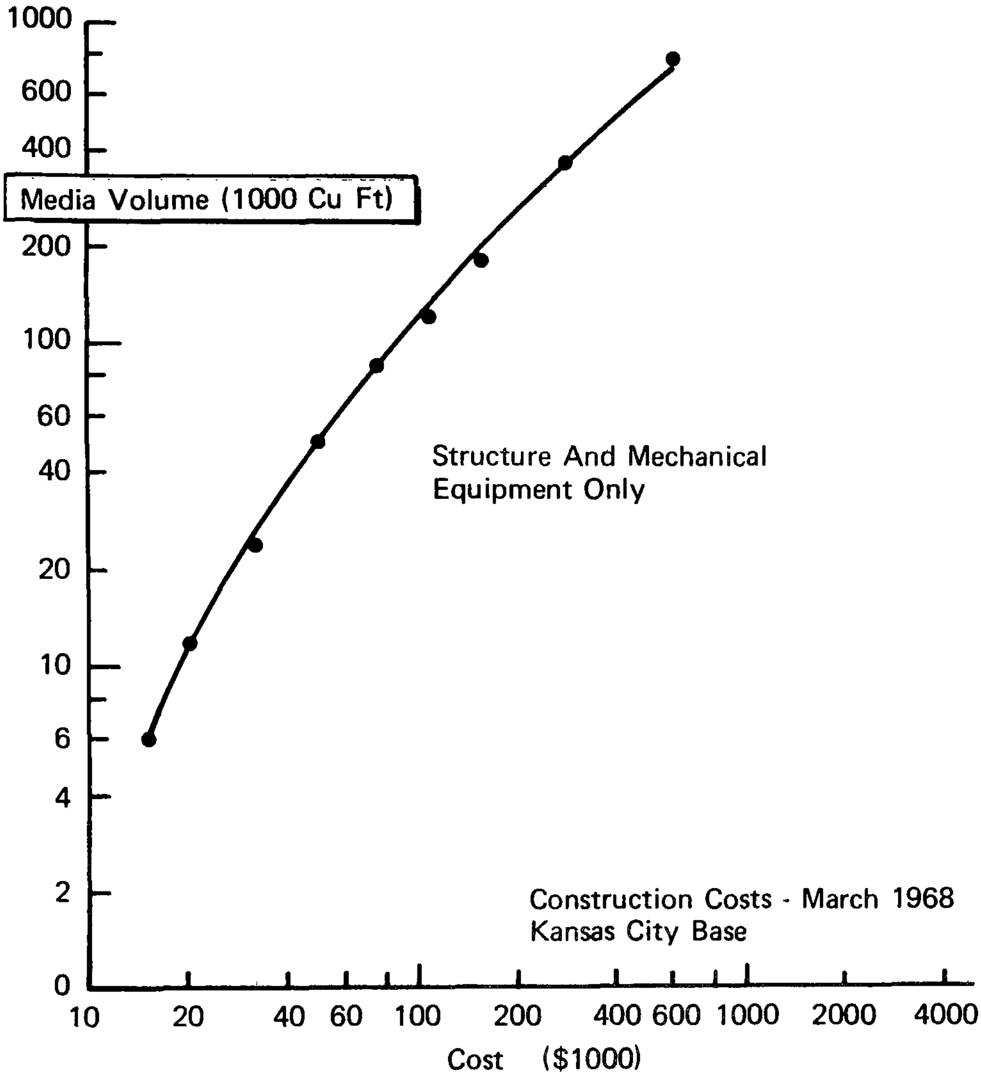
FIGURE 15

and containing structures that would be required. Estimates were made of the quantities of construction materials, mechanical equipment, excavation, etc. Construction costs were applied to derive total costs for the structures. Major equipment costs were obtained from manufacturers. The cost curve shown in Figure 17 was prepared from this information for a tower with a media depth of 21.5 feet. It is indicative of the estimated costs for structural and mechanical equipment required for variable volumes of media exclusive of the media cost itself.



APPROXIMATE UNIT COSTS OF PLASTIC BIOLOGICAL OXIDATION MEDIA (INSTALLED)

FIGURE 16



CONSTRUCTION COST vs MEDIA VOLUME FOR 21.5 FT DEPTH

FIGURE 17

This general graph for structural and mechanical equipment was assumed to be in earth, and no allowance was included for rock excavation. No allowance was made for unusually wet excavation conditions where dewatering would be required. If piling must be used or special foundation conditions exist, the additional cost must be added to the figure obtained from the cost curve.

The wall structure utilized for these estimates was based on a fiberglass corrugated panel and steel framework. The media support system was based on aluminum grating. The cost of the center column and appropriate rotary distributor is included but no allowance was made for a pumping station. The estimate includes contractors overhead and profit but does not include any engineering and legal fees.

A cost estimate obtained from this curve must be updated using one of the generally accepted cost indices. These costs were based on construction costs in the Kansas City, Missouri, area in March 1968. Experience has shown that updating of these costs can be accomplished by utilizing the Engineering News Record construction cost index published weekly and at mid-month by Engineering News Record. The ENR index for March 1968, at Kansas City, Missouri, was 1064.

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Mr. Edwin F. Barth served as Project Officer for the Office of Research and Monitoring, Environmental Protection Agency.

REFERENCES

1. Barth, E. F., Mulbarger, M., Salotto, B. U., and Ettinger, M. B., Removal of Nitrogen by Municipal Wastewater Treatment Plants, J. Water Pollution Control Federation 38, 1208-19 (1966).

2. Johnson, W. K., and Schroepfer, G. L., Nitrogen Removal by Nitrification and Denitrification, J. Water Pollution Control Federation 36, 1015-1036 (1964).

3. Courchaine, R. J., Significance of Nitrification in Stream Analysis - Effects on the Oxygen Balance, J. Water Pollution Control Federation 40, 835-47 (1968).

4. Wezernak, C. T., and Gannon, J. J., Evaluation of Nitrification in Streams, J. of Sanitary Engineering Division, ASCE, 94 (SA5) 883-895 (1968).

5. O'Connel, R. L., and Thomas, N. A., Effect of Benthic Algae on Stream Dissolved Oxygen, J. of Sanitary Engineering Division, ASCE, 91 (SA3) 1-16 (1965).

6. Gameson, A.L.H., Some aspects of the Carbon, Nitrogen, and Sulphur Cycles in the Thames Estuary. II. Influences on the Oxygen Balance, Symposia of the Institute of Biology, No. 8, The Effect of Pollution on Living Material, Institute of Biol., London, England, p 51ff (1959).

7. Barth, E. F., Brenner, R. C., and Lewis, R. F., Chemical-Biological Control of Nitrogen and Phosphorus in Wastewater Effluent, J. Water Pollution Control Federation 40, 2040-54 (1968).

8. Germain, J. E., Economic Treatment of Domestic Waste by Plastic-Medium Trickling Filter, J. Water Pollution Control Federation 38, 192-203 (1966).

9. Jenkins, S. H., Nitrification, Water Pollution Control 6, 610-618 (1969).

10. Mechalas, B. J., Allen, III, P. M., and Matyskiela, W. W., A Study of Nitrification and Denitrification, Federal Water Quality Administration, Water Pollution Control Research Series, No. 17010DR07/70, July 1970, p 9.

11. Mulbarger, M. C., Nitrification and Denitrification in Activated Sludge Systems, J. Water Pollution Control Federation 43, 2059-70 (1971).

12. McCarty, P. L., Beck, L., and St. Amant, P., Biological Denitrification of Wastewaters by Addition of Organic Materials, Proc. 24th Ind. Waste Conf., Purdue Univ., Eng. Ext. Series 135, 1271-85 (1969).

13. Wild, Jr., H. E., Sawyer, C. N., and McMahon, T. C., Factors Affecting Nitrification Kinetics, J. Water Pollution Control Federation 43, 1845-54 (1971).

14. Gerlich, J. W., Better Than the Pilot Model, The American City, Buttenheim Publishing Corp., New York, New York (October 1967).

15. American Public Health Association, Standard Methods for the Examination of Water, Sewage and Industrial Wastes. 12th Edition, New York, 1965.

VIII

PUBLICATION AND PATENT DISCLOSURE

Submitted to the Journal Water Pollution Control Federation for publication: "Application of Plastic Media Trickling Filters for Biological Nitrification," Duddles, G. A., Richardson, S. E., and Barth, E. F.

Invention disclosure filed: Communication by Sidney J. Walker, The Dow Chemical Company, to Benjamin H. Bochenek, Environmental Protection Agency, on October 4, 1972, titled: "Synthetic Media Trickling Filter Biological Nitrification Process," Duddles, G. A., and Richardson, S. E., Dow Invention Disclosure D-24250.

IX

APPENDIX - PERIOD ANALYSES

Group 1 - Period I - Days 4/13/71 - 4/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)	(TOC, MG/L			)	(SOC, MG/L			)	(TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
103	25.	7.	8.	****	35.	28.	****	****	****	****	****	****	49.	46.	****
104	17.	14.	11.	****	24.	17.	18.	****	****	****	****	****	50.	46.	****
105	9.	6.	4.	****	23.	17.	16.	****	****	****	****	****	51.	49.	****
106	17.	11.	12.	****	22.	22.	13.	****	****	****	****	****	51.	48.	****
110	****	****	****	****	37.	24.	22.	****	****	****	****	****	52.	50.	****
111	30.	29.	15.	****	27.	22.	19.	****	****	****	****	****	51.	47.	****
112	24.	****	****	****	25.	18.	17.	****	****	****	****	****	51.	47.	****
113	22.	6.	5.	****	33.	****	16.	****	****	****	****	****	51.	46.	****
117	16.	12.	9.	****	27.	20.	20.	****	****	****	****	****	51.	48.	****
118	9.	8.	7.	****	25.	21.	20.	****	****	****	****	****	51.	49.	****
119	8.	9.	6.	****	27.	24.	24.	****	****	****	****	****	51.	46.	****
120	****	10.	9.	****	****	30.	24.	****	****	****	****	****	51.	49.	****
...	16.	11.	9.	****	28.	23.	19.	****	****	****	****	****	51.	48.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 1 - Period I - Days 4/13/71 - 4/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 3.50 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	TE	CE	FE	ORG-N, MG/L TI	TE	CE	FE	NO3-N, MG/L TI	TE	CE	FE	NO2-N, MG/L TI	TE	CE	FE	TOT-N, MG/L TI	TE	CE	FE
103	9.7	1.6	1.8	****	2.6	1.1	1.2	****	0.8	7.7	8.3	****	0.2	0.3	0.4	****	13.3	10.7	11.7	****
104	8.0	1.7	1.8	****	0.6	0.5	0.7	****	0.8	7.5	6.0	****	0.2	0.3	0.3	****	9.6	10.0	8.8	****
105	9.1	1.9	1.6	****	1.9	0.5	1.6	****	0.9	6.9	6.9	****	0.1	0.3	0.3	****	12.0	9.6	10.4	****
106	9.0	1.7	1.5	****	1.2	2.1	2.0	****	0.6	8.2	8.1	****	0.1	0.1	0.4	****	10.9	12.1	12.0	****
110	10.2	2.1	2.2	****	4.4	2.4	1.6	****	0.9	8.4	9.6	****	0.1	0.4	0.4	****	15.6	13.3	13.8	****
111	10.1	1.8	2.4	****	1.1	1.3	1.7	****	0.5	8.5	8.4	****	0.1	0.3	0.4	****	11.8	11.9	12.9	****
112	9.3	1.8	2.0	****	3.5	2.2	1.2	****	0.6	8.5	8.5	****	0.1	0.3	0.3	****	13.5	12.8	13.0	****
113	10.1	1.6	2.0	****	2.2	2.2	1.7	****	0.9	9.7	9.5	****	0.1	0.3	0.5	****	13.3	13.8	13.7	****
117	9.5	1.7	1.6	****	4.4	3.1	****	****	1.1	9.7	9.7	****	0.1	0.3	0.3	****	15.1	14.8	14.9	****
118	9.7	1.7	1.8	****	1.2	1.4	1.7	****	0.5	8.8	9.3	****	0.1	0.4	0.4	****	11.5	12.3	13.2	****
119	12.8	2.5	2.6	****	0.7	1.0	1.1	****	0.4	9.3	8.2	****	0.1	0.4	0.5	****	14.0	13.2	14.4	****
120	13.5	2.7	1.5	****	2.1	2.0	2.1	****	0.3	9.5	9.3	****	0.1	0.5	0.3	****	16.0	14.7	13.2	****
...	10.0	1.9	1.9	****	2.1	1.6	1.5	****	0.6	8.5	8.4	****	0.1	0.3	0.3	****	13.0	12.4	12.4	****

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
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... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period II - Days 5/4/71 - 5/14/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L				TOC, MG/L				SOC, MG/L				TEMP, F		
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
124	18.	5.	8.	****	31.	24.	28.	****	****	****	****	****	53.	49.	****
125	19.	9.	6.	****	35.	23.	26.	****	****	****	****	****	53.	50.	****
126	4.	5.	5.	****	46.	37.	31.	****	****	****	****	****	54.	51.	****
127	15.	5.	3.	****	29.	25.	24.	****	****	****	****	****	54.	52.	****
131	11.	1.	4.	****	****	****	****	****	****	****	****	****	56.	54.	****
132	7.	7.	6.	****	51.	33.	37.	****	****	****	****	****	55.	53.	****
133	5.	4.	2.	****	44.	38.	39.	****	****	****	****	****	54.	49.	****
134	21.	14.	30.	****	48.	28.	32.	****	****	****	****	****	55.	51.	****
...	12.	6.	8.	****	41.	30.	31.	****	****	****	****	****	54.	51.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period II - Days 5/4/71 - 5/14/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)(	ORG-N, MG/L			)(	NO3-N, MG/L			)(	NO2-N, MG/L			)(	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
.24	13.6	1.4	1.2	****	1.6	2.4	1.2	****	1.6	10.7	10.7	****	0.1	0.3	0.3	****	16.9	14.8	13.4	****
.25	11.1	1.2	1.2	****	0.5	1.9	1.9	****	0.3	10.8	10.7	****	0.1	0.2	0.3	****	12.0	14.1	14.1	****
.26	10.6	1.9	1.6	****	1.1	0.6	1.8	****	0.2	10.7	10.7	****	0.1	0.1	0.1	****	12.0	13.3	14.2	****
.27	5.8	0.4	0.3	****	4.5	1.6	1.0	****	1.9	11.7	11.7	****	0.3	0.1	0.1	****	12.5	13.8	13.1	****
.31	11.1	0.3	0.2	****	1.3	1.5	1.4	****	0.5	11.6	11.6	****	0.1	0.2	0.2	****	13.0	13.6	13.4	****
.32	12.2	0.4	0.2	****	0.6	0.9	1.1	****	0.3	10.9	10.9	****	0.1	0.1	0.1	****	13.2	12.3	12.3	****
.33	13.8	4.9	4.8	****	1.4	1.1	1.0	****	0.4	9.0	8.7	****	0.1	0.1	0.1	****	15.7	15.1	14.6	****
.34	12.6	0.6	0.6	****	1.4	1.9	1.9	****	0.6	10.8	10.7	****	0.1	0.2	0.3	****	14.3	13.5	13.5	****
...	11.3	1.3	1.2	****	1.5	1.4	1.4	****	0.7	10.7	10.7	****	0.1	0.1	0.1	****	13.7	13.8	13.5	****

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period III - Days 5/18/71 - 6/11/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	TE	CE	FE	TOC, MG/L TI	TE	CE	FE	SOC, MG/L TI	TE	CE	FE	TEMP, F TI	TE	FI
138	30.	8.	2.	****	32.	****	34.	****	****	****	****	****	58.	55.	****
139	20.	40.	15.	****	16.	9.	13.	****	****	****	****	****	59.	57.	****
140	10.	7.	18.	****	14.	13.	13.	****	****	****	****	****	57.	54.	****
141	15.	20.	14.	****	19.	16.	17.	****	****	****	****	****	55.	52.	****
145	8.	5.	5.	****	19.	20.	16.	****	****	****	****	****	55.	53.	****
146	11.	6.	6.	****	23.	17.	17.	****	****	****	****	****	54.	51.	****
147	7.	7.	11.	****	****	18.	16.	****	****	****	****	****	54.	51.	****
153	12.	9.	10.	****	21.	18.	16.	****	****	****	****	****	****	****	****
154	10.	7.	8.	****	33.	14.	14.	****	****	****	****	****	56.	54.	****
155	7.	24.	10.	****	18.	15.	17.	****	****	****	****	****	57.	55.	****
159	35.	38.	16.	****	13.	5.	18.	****	****	****	****	****	58.	56.	****
160	3.	1.	****	****	32.	12.	20.	****	****	****	****	****	59.	57.	****
161	4.	2.	1.	****	29.	24.	23.	****	****	****	****	****	58.	55.	****
162	3.	2.	3.	****	33.	27.	29.	****	****	****	****	****	58.	55.	****
...	12.	13.	9.	****	23.	16.	19.	****	****	****	****	****	59.	57.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period III - Days 5/18/71 - 6/11/71

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TOWER FLOW  =   1.00 GAL/MIN/FT2
RECYCLE     =   0.00 GAL/MIN/FT2
RATIO       =   0.00
FILTER FLOW =   5.00 GAL/MIN
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NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)(	ORG-N, MG/L			)(	NO3-N, MG/L			)(	NO2-N, MG/L			)(	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
138	10.9	1.2	1.9	****	2.9	1.1	0.4	****	0.2	9.3	9.0	****	0.1	0.5	1.0	****	14.1	12.1	12.3	****
139	8.5	1.3	1.8	****	3.1	0.7	0.5	****	0.1	9.4	9.3	****	0.1	0.6	0.8	****	11.8	12.0	12.4	****
140	11.6	1.3	1.2	****	0.7	1.2	1.0	****	0.2	9.3	9.3	****	0.1	0.7	0.7	****	12.6	12.5	12.2	****
141	13.2	0.8	1.2	****	2.0	1.0	1.3	****	0.2	9.2	10.0	****	0.1	0.8	1.0	****	15.5	11.8	13.5	****
145	8.3	2.0	1.1	****	1.0	1.0	1.2	****	0.6	9.6	9.3	****	0.1	0.6	0.8	****	10.0	13.2	12.4	****
146	13.0	1.9	2.0	****	1.5	1.1	1.3	****	0.6	9.6	9.3	****	0.1	0.6	0.7	****	15.2	13.2	13.3	****
147	12.1	2.0	2.3	****	1.9	1.3	0.5	****	0.3	9.4	9.4	****	0.1	0.6	0.6	****	14.4	13.3	12.8	****
153	13.8	2.0	1.9	****	2.4	1.1	1.4	****	0.6	10.8	10.3	****	0.1	0.7	0.7	****	16.9	14.6	14.3	****
154	13.0	1.8	1.8	****	1.6	1.2	0.5	****	2.0	11.5	11.5	****	0.1	0.5	0.5	****	16.7	15.0	14.3	****
155	12.0	0.9	1.2	****	0.7	1.3	0.8	****	1.1	12.9	13.2	****	0.2	0.3	0.6	****	14.0	15.4	15.8	****
159	13.1	1.2	1.2	****	0.1	1.0	1.4	****	1.2	13.4	12.8	****	0.2	0.4	0.4	****	14.6	16.0	15.8	****
160	13.2	2.0	2.0	****	1.2	1.3	1.4	****	0.9	10.3	8.7	****	0.1	0.6	1.7	****	15.4	14.2	13.8	****
161	13.5	2.0	1.9	****	1.6	1.6	1.1	****	0.4	9.8	9.4	****	0.1	0.7	1.4	****	15.6	14.1	13.8	****
162	13.1	3.1	3.2	****	0.1	1.4	1.1	****	0.9	10.5	9.8	****	0.1	0.5	1.0	****	14.1	15.5	15.1	****
...	11.1	2.3	2.3	****	1.0	1.2	1.4	****	1.9	10.2	10.3	****	0.1	0.6	1.2	****	13.1	14.3	15.2	****

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NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI    = TOWER INFLUENT
TE    = TOWER EFFLUENT
CE    = CLARIFIER EFFLUENT
FI    = FILTER INFLUENT
FE    = FILTER EFFLUENT

...   = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES
        DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT
        QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM
        MEAN ANALYSES.
***   = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY   = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)
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Group 8 - Period IV - Days 6/15/71 - 6/30/71

TOWER FLOW = 2.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	SS, MG/L TE	SS, MG/L CE	SS, MG/L FE	TOC, MG/L TI	TOC, MG/L TE	TOC, MG/L CE	TOC, MG/L FE	SOC, MG/L TI	SOC, MG/L TE	SOC, MG/L CE	SOC, MG/L FE	TEMP, F TI	TEMP, F TE	TEMP, F FI
166	11.	2.	****	1.	39.	31.	****	26.	****	****	****	****	60.	58.	****
167	11.	9.	****	3.	****	17.	****	17.	****	****	****	****	61.	58.	****
168	8.	9.	****	4.	27.	18.	****	19.	****	****	****	****	****	****	****
169	****	41.	****	****	29.	23.	****	19.	****	****	****	****	61.	59.	****
173	7.	34.	****	3.	45.	35.	****	36.	****	****	****	****	61.	59.	****
174	****	****	****	****	28.	20.	****	21.	****	****	****	****	62.	59.	****
175	****	****	****	****	52.	34.	****	31.	****	****	****	****	62.	60.	****
176	15.	17.	****	7.	36.	27.	****	24.	****	****	****	****	62.	60.	****
180	11.	21.	****	8.	51.	30.	****	31.	****	****	****	****	65.	63.	****
181	2.	3.	****	1.	43.	38.	****	11.	****	****	****	****	64.	62.	****
...	22.	17.	****	4.	39.	27.	****	24.	****	****	****	****	62.	60.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 8 - Period IV - Days 6/15/71 - 6/30/71

TOWER FLOW = 2.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)(	ORG-N, MG/L			)(	NO3-N, MG/L			)(	NO2-N, MG/L			)(	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
166	12.8	6.1	****	6.0	2.4	1.3	****	1.2	0.2	7.1	****	6.2	0.2	0.6	****	0.9	15.6	15.1	****	14.3
167	13.4	5.1	****	4.6	0.2	1.3	****	1.2	0.3	7.3	****	7.0	0.2	0.7	****	1.1	14.1	14.4	****	13.9
168	13.9	6.7	****	6.1	1.6	0.4	****	0.1	0.2	7.4	****	7.6	0.2	0.7	****	1.0	15.9	15.2	****	14.7
169	13.2	5.5	****	5.3	0.8	1.1	****	0.1	0.1	8.4	****	7.8	0.2	0.6	****	1.0	14.3	15.6	****	14.1
173	14.5	5.2	****	5.3	0.9	3.7	****	1.3	1.5	9.8	****	9.4	0.3	0.7	****	0.6	17.2	19.4	****	16.6
174	13.1	3.5	****	4.1	1.6	3.9	****	1.6	1.7	10.3	****	10.1	0.3	0.7	****	0.9	16.7	18.4	****	16.7
175	13.4	4.9	****	4.4	1.5	2.5	****	1.5	1.6	9.4	****	10.3	0.2	0.6	****	0.7	16.7	17.4	****	16.9
176	13.4	4.2	****	4.5	1.2	2.0	****	0.9	1.6	10.4	****	10.2	0.2	0.6	****	0.8	16.4	17.2	****	16.4
180	10.7	5.5	****	4.7	1.6	2.4	****	1.5	1.5	8.8	****	8.9	0.5	0.2	****	0.6	14.4	17.9	****	15.7
181	12.7	3.0	****	2.7	1.5	1.7	****	1.9	3.1	10.3	****	9.1	0.3	0.7	****	1.1	17.6	15.7	****	14.8
...	13.1	4.9	****	4.7	1.3	2.0	****	1.3	1.1	8.9	****	8.6	0.2	0.6	****	0.8	15.7	16.5	****	15.4

NH3-N = AMMONIA NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period V - Days 7/15/71 - 8/6/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	TE	CE	FE	TOC, MG/L TI	TE	CE	FE	SOC, MG/L TI	TE	CE	FE	TEMP, F TI	TE	FI
196	7.	41.	****	4.	30.	20.	****	20.	****	****	****	****	68.	60.	****
197	10.	28.	****	3.	30.	24.	****	20.	****	****	****	****	67.	60.	****
202	1.	1.	****	2.	23.	18.	****	21.	****	****	****	****	66.	62.	****
203	1.	3.	****	1.	22.	20.	****	20.	****	****	****	****	67.	62.	****
208	6.	10.	****	****	31.	11.	****	****	****	****	****	****	68.	62.	****
209	7.	5.	****	****	13.	7.	****	****	****	****	****	****	66.	61.	****
210	2.	6.	****	****	11.	11.	****	****	****	****	****	****	65.	61.	****
211	4.	26.	****	****	8.	10.	****	****	****	****	****	****	66.	60.	****
215	22.	24.	****	****	16.	16.	****	****	****	****	****	****	67.	61.	****
216	9.	16.	****	****	17.	****	****	****	****	****	****	****	66.	60.	****
217	22.	34.	****	****	17.	20.	****	****	****	****	****	****	67.	61.	****
218	13.	22.	****	****	20.	23.	****	****	****	****	****	****	67.	62.	****
...	10.	14.	****	2.	20.	20.	****	20.	****	****	****	****	68.	63.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
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Group 5 - Period V - Days 7/15/71 - 8/6/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	TE	CE	FE	ORG-N, MG/L TI	TE	CE	FE	NO3-N, MG/L TI	TE	CE	FE	NO2-N, MG/L TI	TE	CE	FE	TOT-N, MG/L TI	TE	CE	FE
196	13.6	1.1	****	0.9	1.2	4.3	****	5.4	0.7	11.5	****	11.0	0.3	0.7	****	0.4	15.8	17.6	****	17.7
197	12.4	2.7	****	2.7	2.3	5.5	****	3.0	0.2	10.0	****	6.0	0.2	0.1	****	0.6	15.2	17.7	****	12.3
202	12.2	3.4	****	2.9	2.1	1.6	****	1.6	1.3	7.8	****	8.3	0.6	1.6	****	1.0	16.2	14.4	****	13.8
203	13.1	4.2	****	4.4	1.2	1.3	****	0.6	1.1	7.9	****	8.1	0.4	1.7	****	1.4	15.8	15.1	****	14.5
208	13.3	2.4	****	7.4	0.9	2.1	****	1.7	1.2	8.4	****	8.9	0.4	1.6	****	1.1	15.8	14.9	****	14.1
209	13.5	3.0	****	****	2.0	1.8	****	****	1.5	10.7	****	****	0.4	1.1	****	****	17.4	16.6	****	****
210	13.4	2.6	****	****	0.4	2.2	****	****	1.4	12.5	****	****	0.5	1.5	****	****	15.7	18.8	****	****
211	12.0	1.9	****	****	1.1	2.5	****	****	0.9	12.5	****	****	0.4	1.0	****	****	14.4	18.3	****	****
215	12.5	1.6	****	****	1.9	1.7	****	****	1.5	12.5	****	****	0.4	1.0	****	****	16.3	16.8	****	****
216	14.9	****	****	****	1.4	****	****	****	2.1	****	****	****	0.5	****	****	****	18.9	****	****	****
217	13.6	3.2	****	****	1.3	3.1	****	****	1.6	11.0	****	****	0.3	0.9	****	****	16.8	18.2	****	****
218	13.7	1.7	****	****	1.2	3.0	****	****	1.8	11.5	****	****	0.3	1.1	****	****	17.0	17.3	****	****
...	15.0	2.5	****	****	0.7	3.2	****	****	1.0	13.0	****	****	0.3	0.5	****	****	17.0	19.2	****	****

NH3-N = AMMONIA NITROGEN
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NO3-N = NITRATE NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 7 - Period VI - Days 8/10/71 - 8/17/71

TOWER FLOW = 1.50 GAL/MIN/FT2
RECYCLE = 0.57 GAL/MIN/FT2
RATIO = 0.37
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L				TOC, MG/L				SOC, MG/L				TEMP, F		
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
222	46.	132.	18.	****	25.	22.	22.	****	****	****	****	****	68.	63.	****
223	11.	117.	14.	****	20.	14.	10.	****	****	****	****	****	67.	61.	****
224	12.	53.	2.	****	35.	20.	29.	****	****	****	****	****	67.	62.	****
225	15.	35.	8.	****	24.	20.	19.	****	****	****	****	****	67.	62.	****
229	****	****	****	****	30.	22.	22.	****	****	****	****	****	69.	64.	****
...	21.	84.	10.	****	27.	20.	20.	****	****	****	****	****	68.	62.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 7 - Period VI - Days 8/10/71 - 8/17/71

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TOWER FLOW   =   1.50 GAL/MIN/FT2
RECYCLE      =   0.57 GAL/MIN/FT2
RATIO        =   0.37
FILTER FLOW  =   5.00 GAL/MIN
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NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	TE	CE	FE	ORG-N, MG/L TI	TE	CE	FE	NO3-N, MG/L TI	TE	CE	FE	NO2-N, MG/L TI	TE	CE	FE	TOT-N, MG/L TI	TE	CE	FE
222	15.0	3.8	3.6	****	0.2	1.7	1.5	****	2.0	11.0	11.0	****	0.3	1.1	1.1	****	17.5	17.6	17.2	****
223	13.0	2.6	2.9	****	0.1	1.8	1.8	****	1.1	11.0	11.0	****	0.3	1.1	1.1	****	14.4	16.5	16.8	****
224	14.8	3.4	3.6	****	0.1	1.6	1.3	****	1.1	****	9.6	****	0.4	****	1.4	****	16.3	****	15.9	****
225	14.2	2.9	3.4	****	3.2	2.4	2.4	****	1.6	10.8	10.7	****	0.3	1.2	1.3	****	19.3	17.3	17.8	****
229	15.2	4.3	3.7	****	3.9	2.7	2.2	****	0.9	9.5	9.4	****	0.4	1.5	1.6	****	21.3	18.0	16.9	****
...	14.6	3.4	3.4	****	2.4	2.0	1.8	****	1.3	10.5	10.3	****	0.3	1.2	1.3	****	17.7	17.3	16.9	****

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NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI    = TOWER INFLUENT
TE    = TOWER EFFLUENT
CE    = CLARIFIER EFFLUENT
FI    = FILTER INFLUENT
FE    = FILTER EFFLUENT

...   = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES
        DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT
        QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM
        MEAN ANALYSES.
***   = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY   = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)
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Group 6 - Period VII - Days 8/18/71 - 9/3/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.57 GAL/MIN/FT2
RATIO = 0.57
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)(	TOC, MG/L			)(	SOC, MG/L			)(	TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
230	23.	31.	17.	10.	25.	24.	20.	24.	****	****	****	****	69.	64.	****
231	23.	31.	17.	10.	28.	18.	21.	18.	****	****	****	****	69.	66.	****
232	40.	10.	9.	1.	26.	19.	21.	21.	****	****	****	****	69.	64.	****
236	32.	19.	17.	2.	23.	21.	19.	16.	****	****	****	****	68.	64.	****
237	4.	16.	6.	2.	17.	16.	15.	15.	****	****	****	****	69.	64.	****
238	****	****	15.	8.	18.	15.	13.	12.	****	****	****	****	68.	64.	****
239	17.	46.	24.	1.	18.	16.	18.	14.	****	****	****	****	68.	63.	****
243	11.	13.	****	2.	19.	15.	****	14.	****	****	****	****	67.	64.	****
244	23.	17.	****	1.	22.	17.	****	16.	****	****	****	****	67.	64.	****
245	11.	8.	****	2.	23.	18.	****	17.	****	****	****	****	67.	65.	****
246	25.	1.	****	1.	24.	16.	****	14.	****	****	****	****	68.	66.	****
...	24.	28.	13.	4.	22.	18.	18.	16.	****	****	****	****	68.	64.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 6 - Period VII - Days 8/18/71 - 9/3/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.57 GAL/MIN/FT2
RATIO = 0.57
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L				ORG-N, MG/L				NO3-N, MG/L				NO2-N, MG/L				TOT-N, MG/L			
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
230	14.8	3.1	3.2	3.0	1.4	2.7	2.7	2.2	0.6	9.7	8.5	9.2	0.3	1.3	1.5	0.8	17.1	16.8	15.9	15.2
231	14.9	2.7	2.8	2.6	4.6	2.5	1.6	1.6	0.3	9.5	9.3	8.4	0.4	1.5	1.7	1.6	20.2	16.2	15.4	14.2
232	13.2	3.1	2.5	3.2	5.1	4.2	3.0	1.7	0.9	10.5	10.3	9.2	0.7	1.8	1.8	1.3	19.9	19.6	17.6	15.4
236	16.4	****	4.2	4.1	****	1.1	5.9	2.1	0.9	10.9	10.6	10.0	0.3	0.3	1.4	1.0	30.2	18.0	22.1	17.2
237	15.2	3.9	4.1	3.9	2.2	5.4	5.3	1.1	0.6	10.4	10.0	10.0	0.4	1.6	2.0	1.0	18.4	21.3	21.4	16.0
238	16.1	2.2	2.4	2.8	4.0	3.1	2.9	1.5	0.3	10.5	10.5	10.0	0.3	1.5	1.5	0.9	20.7	17.3	17.3	15.2
239	17.7	3.2	2.5	2.4	1.4	3.9	3.2	1.5	0.4	12.4	12.4	12.6	0.3	1.6	1.6	0.7	19.8	21.1	19.7	17.2
243	16.3	4.6	****	5.0	5.8	3.4	****	1.2	0.6	13.0	****	13.0	0.1	****	****	****	23.0	21.0	****	19.2
244	17.0	5.2	****	6.4	5.6	1.6	****	0.5	1.0	13.0	****	9.6	0.2	0.1	****	0.4	23.8	19.9	****	16.9
245	16.7	3.4	****	4.3	3.2	2.6	****	1.5	0.9	12.7	****	9.9	0.2	0.3	****	1.2	21.0	19.0	****	16.9
246	16.1	3.0	****	4.1	1.9	4.4	****	0.6	0.1	8.5	****	10.0	0.1	****	****	1.1	18.2	15.9	****	15.8
...	15.8	3.4	3.1	3.8	3.5	3.1	3.5	1.4	0.5	10.1	10.2	10.1	0.3	1.1	1.6	0.9	20.2	18.7	18.5	16.2

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period VIII - Days 9/10/71 - 10/15/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L				TOC, MG/L				SOC, MG/L				TEMP, F		
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
253	****	****	****	****	23.	18.	****	16.	****	****	****	****	68.	65.	****
257	42.	26.	****	8.	44.	22.	****	23.	****	****	****	****	****	****	****
258	12.	18.	****	1.	21.	12.	****	10.	****	****	****	****	69.	67.	****
259	11.	3.	****	1.	22.	14.	****	17.	****	****	****	****	68.	66.	****
260	11.	29.	****	3.	22.	18.	****	14.	****	****	****	****	68.	65.	****
265	22.	21.	****	1.	21.	16.	****	12.	****	****	****	****	66.	61.	****
266	20.	20.	****	1.	20.	16.	****	13.	****	****	****	****	66.	62.	****
267	17.	18.	****	1.	21.	18.	****	15.	****	****	****	****	66.	60.	****
271	38.	23.	****	1.	17.	12.	****	12.	****	****	****	****	66.	63.	****
272	10.	10.	****	1.	12.	12.	****	11.	****	****	****	****	66.	65.	****
273	2.	9.	****	1.	9.	11.	****	10.	****	****	****	****	66.	64.	****
274	9.	4.	****	1.	12.	10.	****	9.	****	****	****	****	67.	64.	****
278	22.	30.	****	9.	14.	9.	****	8.	****	****	****	****	65.	61.	****
279	49.	25.	****	8.	13.	13.	****	7.	****	****	****	****	65.	61.	****
280	9.	17.	****	5.	11.	10.	****	9.	****	****	****	****	63.	58.	****
...	20.	18.	****	3.	19.	14.	****	12.	****	****	****	****	66.	63.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
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... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period VIII - Days 9/10/71 - 10/15/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)(	ORG-N, MG/L			)(	NO3-N, MG/L			)(	NO2-N, MG/L			)(	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
253	19.6	2.0	****	1.8	3.3	3.7	****	2.6	0.3	14.5	****	13.6	0.2	0.5	****	0.5	23.4	20.7	****	18.5
257	19.6	2.0	****	1.8	3.3	3.7	****	2.6	0.3	14.5	****	13.6	0.2	0.5	****	0.5	23.4	20.7	****	18.5
258	18.5	1.6	****	1.3	4.3	4.C	****	1.7	0.4	15.0	****	14.3	0.2	0.3	****	0.4	23.4	20.9	****	17.4
259	18.5	1.1	****	1.0	7.9	2.7	****	3.1	0.4	15.8	****	14.8	0.2	0.4	****	0.4	17.0	20.0	****	19.3
260	18.8	1.1	****	1.1	4.5	2.3	****	2.2	0.5	17.5	****	17.1	0.2	0.5	****	0.2	24.0	21.4	****	20.6
265	17.2	1.1	****	1.4	7.4	2.6	****	1.5	1.0	16.0	****	15.3	0.3	0.4	****	0.2	25.9	20.1	****	18.4
266	18.0	1.0	****	1.3	3.3	3.4	****	1.9	0.5	16.2	****	15.8	0.2	0.6	****	0.3	22.0	21.2	****	19.3
267	18.4	2.1	****	1.6	2.7	1.6	****	1.7	0.5	17.0	****	16.0	0.2	0.8	****	0.4	21.8	20.5	****	19.7
271	14.5	1.6	****	1.4	3.6	2.6	****	1.8	0.3	16.4	****	16.2	0.1	0.7	****	0.3	18.5	21.3	****	19.7
272	13.1	1.3	****	1.0	4.5	1.5	****	1.8	0.5	12.0	****	11.3	0.2	0.3	****	0.1	18.3	15.1	****	14.2
273	14.2	1.0	****	1.2	5.7	2.C	****	2.5	0.7	14.8	****	14.0	0.3	0.2	****	0.1	20.9	18.0	****	17.8
274	15.2	1.2	****	1.7	8.0	3.8	****	1.7	0.4	15.2	****	14.5	0.2	0.4	****	0.1	23.8	20.6	****	18.0
278	16.5	1.6	****	1.6	2.9	3.3	****	2.5	0.5	13.4	****	13.9	0.2	0.6	****	0.1	20.1	18.9	****	18.1
279	16.6	1.6	****	1.7	2.4	2.6	****	1.6	0.5	13.0	****	13.4	0.2	1.0	****	0.6	19.7	18.2	****	17.3
280	14.3	1.1	****	1.4	1.7	1.7	****	1.9	0.6	12.7	****	13.1	0.2	0.8	****	0.4	16.8	16.3	****	16.8
...	16.8	1.4	****	1.4	4.3	2.8	****	2.0	0.4	14.9	****	14.4	0.2	0.5	****	0.3	21.2	19.5	****	18.2

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period IXA - Days 11/1/71 - 11/12/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	TE	CE	FE	TOC, MG/L TI	TE	CE	FE	SOC, MG/L TI	TE	CE	FE	TEMP, F TI	TE	FI
306	9.	5.	****	3.	19.	18.	****	15.	****	****	****	****	61.	56.	****
307	40.	32.	****	19.	19.	17.	****	14.	****	****	****	****	60.	55.	****
308	7.	6.	****	1.	22.	19.	****	18.	****	****	****	****	61.	57.	****
309	23.	14.	****	6.	16.	12.	****	11.	****	****	****	****	60.	54.	****
313	24.	30.	****	1.	25.	19.	****	18.	****	****	****	****	59.	55.	****
314	31.	12.	****	4.	24.	20.	****	15.	****	****	****	****	60.	56.	****
315	2.	16.	****	3.	24.	19.	****	15.	****	****	****	****	60.	56.	****
316	26.	28.	****	15.	21.	17.	****	16.	****	****	****	****	60.	55.	****
...	20.	18.	****	9.	21.	18.	****	15.	****	****	****	****	60.	56.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period IXA - Days - 11/1/71 - 11/12/71

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			) (	ORG-N, MG/L			) (	NO3-N, MG/L			) (	NO2-N, MG/L			) (	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
306	17.6	6.1	****	6.8	1.0	2.0	****	1.4	0.5	9.0	****	9.9	0.2	1.6	****	0.7	19.3	18.7	****	18.8
307	18.0	6.1	****	6.6	1.6	2.6	****	0.9	0.3	8.8	****	8.2	0.2	2.2	****	1.2	20.1	19.7	****	16.9
308	17.3	6.9	****	7.0	2.5	2.1	****	0.7	0.5	9.6	****	10.0	0.2	1.8	****	0.6	20.5	20.3	****	18.3
309	17.2	4.5	****	5.9	3.6	3.9	****	1.5	0.5	12.4	****	10.2	0.2	0.4	****	1.4	21.5	21.2	****	19.0
313	18.2	5.9	****	6.4	2.7	2.4	****	1.5	0.3	11.2	****	11.8	0.2	1.6	****	0.2	21.4	21.1	****	19.9
314	16.9	5.3	****	5.3	2.2	2.9	****	0.9	1.1	12.4	****	10.8	0.2	1.4	****	1.2	20.4	22.0	****	18.2
315	17.7	6.7	****	6.7	2.7	1.8	****	0.1	0.2	7.0	****	5.8	0.2	1.4	****	1.0	20.8	16.9	****	13.6
316	18.0	5.9	****	6.9	3.7	3.9	****	0.9	0.4	7.6	****	7.4	0.1	1.4	****	0.4	22.2	18.8	****	15.6
...	17.6	5.9	****	6.4	2.5	2.7	****	2.9	0.4	9.7	****	9.2	0.1	1.4	****	0.8	20.7	19.8	****	17.5

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period IXB - Days 11/15/71 - 11/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	SS, MG/L TE	SS, MG/L CE	SS, MG/L FE	TOC, MG/L TI	TOC, MG/L TE	TOC, MG/L CE	TOC, MG/L FE	SOC, MG/L TI	SOC, MG/L TE	SOC, MG/L CE	SOC, MG/L FE	TEMP, F TI	TEMP, F TE	TEMP, F FI
321	36.	50.	****	1.	27.	18.	****	16.	****	****	****	****	60.	56.	****
322	2.	47.	****	1.	15.	11.	****	11.	****	****	****	****	60.	55.	****
323	1.	43.	****	1.	21.	14.	****	11.	****	****	****	****	56.	47.	****
327	****	12.	****	1.	****	16.	****	14.	****	****	****	****	58.	50.	****
328	17.	12.	****	2.	24.	15.	****	15.	****	****	****	****	55.	48.	****
334	17.	48.	****	1.	19.	15.	****	13.	****	****	****	****	55.	46.	****
...	15.	35.	****	2.	21.	15.	****	13.	****	****	****	****	57.	50.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period IXB - Days 11/15/71 - 11/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIC = 2.00
FILTER FLOW = 3.50 GAL/MIN

NITRCGEN ANALYSES

DAY	NH3-N, MG/L				ORG-N, MG/L				NO3-N, MG/L				NO2-N, MG/L				TOT-N, MG/L			
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
321	18.2	1.5	****	1.8	5.3	4.4	****	1.7	0.3	18.2	****	17.8	0.2	0.2	****	0.2	24.0	24.3	****	21.5
322	15.8	0.3	****	0.3	3.0	1.4	****	1.7	0.1	16.2	****	****	0.3	0.2	****	****	19.2	18.1	****	****
323	16.5	0.7	****	0.3	2.6	1.1	****	1.6	0.8	17.8	****	16.3	0.2	0.2	****	0.2	20.1	19.8	****	18.4
327	****	3.2	****	2.5	****	1.7	****	0.8	****	15.8	****	15.9	****	0.6	****	0.1	****	21.3	****	19.3
328	19.1	2.5	****	2.0	3.5	1.2	****	0.8	0.8	15.0	****	14.8	0.1	0.2	****	0.4	23.5	18.9	****	18.0
334	14.0	2.1	****	1.5	7.2	1.7	****	1.6	0.7	14.4	****	14.6	0.1	0.4	****	0.2	22.0	18.6	****	17.9
...	16.7	1.7	****	1.4	4.3	1.9	****	1.3	0.5	16.2	****	15.8	0.1	0.3	****	0.2	21.7	20.1	****	19.0

NH3-N = AMMCNIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period X - Days 12/1/71 - 12/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L				TOC, MG/L				SOC, MG/L				TEMP, F		
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
335	20.	29.	****	1.	21.	18.	****	15.	****	****	****	****	55.	46.	****
336	3.	10.	****	1.	21.	14.	****	12.	****	****	****	****	55.	47.	****
348	17.	10.	****	3.	30.	21.	****	18.	****	****	****	****	54.	47.	****
349	17.	11.	****	1.	23.	18.	****	16.	****	****	****	****	51.	45.	****
350	8.	9.	****	1.	15.	13.	****	11.	****	****	****	****	53.	46.	****
351	1.	3.	****	1.	23.	18.	****	17.	****	****	****	****	****	****	****
356	10.	6.	****	4.	22.	18.	****	13.	****	****	****	****	52.	47.	****
357	12.	1.	****	1.	18.	14.	****	10.	****	****	****	****	****	****	****
362	27.	22.	****	5.	22.	15.	****	16.	****	****	****	****	50.	42.	****
363	22.	17.	****	6.	24.	17.	****	16.	****	****	****	****	52.	46.	****
364	10.	3.	****	1.	23.	17.	****	16.	****	****	****	****	****	****	****
...	15.	12.	****	3.	22.	17.	****	15.	****	****	****	****	53.	46.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period X - Days 12/1/71 - 12/30/71

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)	(ORG-N, MG/L			)	(NO3-N, MG/L			)	(NO2-N, MG/L			)	(TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
335	18.0	1.8	****	1.9	1.8	1.2	****	0.5	0.6	16.2	****	16.8	0.1	0.8	****	0.2	20.5	20.0	****	19.4
336	19.3	2.6	****	2.2	4.4	1.6	****	0.5	0.9	17.8	****	19.0	0.1	0.6	****	0.2	24.7	22.6	****	21.9
348	10.4	1.6	****	0.7	5.4	0.8	****	1.8	0.8	10.8	****	11.0	0.3	0.2	****	0.1	16.9	13.4	****	13.6
349	12.6	4.0	****	3.3	2.7	1.9	****	2.2	0.7	9.8	****	10.2	0.3	0.6	****	0.2	16.3	16.3	****	15.9
350	6.4	1.5	****	1.1	2.4	1.0	0.0	0.5	1.5	6.4	****	7.4	0.5	0.8	****	0.2	10.8	9.7	****	9.2
351	8.3	2.7	****	1.4	2.0	0.3	****	0.7	1.2	7.4	****	7.8	0.5	0.6	****	0.2	12.0	11.0	****	10.1
356	12.1	5.1	****	4.1	4.1	2.4	****	2.3	0.8	7.0	****	8.0	0.2	1.2	****	0.2	17.2	15.7	****	14.6
357	10.8	4.1	****	3.1	4.8	2.2	****	2.0	0.1	8.2	****	8.2	0.1	0.6	****	0.2	15.8	15.1	****	13.5
362	13.1	4.0	****	3.1	3.5	1.5	****	2.0	0.5	6.8	****	9.6	0.2	****	****	0.6	17.3	15.7	****	15.3
363	10.9	3.0	****	2.1	5.6	1.6	****	2.7	0.4	6.4	****	9.0	0.2	****	****	0.8	17.1	13.8	****	14.6
364	13.9	3.6	****	2.8	2.6	2.3	****	2.0	0.4	6.6	****	10.0	0.2	0.2	****	1.6	17.1	15.7	****	16.4
...	12.3	3.0	****	2.3	3.6	1.5	****	1.6	0.7	9.4	****	10.6	0.2	1.0	****	0.4	17.8	15.3	****	14.9

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period XI - Days 1/1/72 - 1/31/72

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)	(TOC, MG/L			)	(SOC, MG/L			)	(TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
369	5.	3.	****	1.	30.	23.	****	19.	****	****	****	****	51.	46.	****
370	10.	5.	****	3.	18.	11.	****	10.	****	****	****	****	50.	43.	****
371	6.	13.	****	1.	18.	12.	****	8.	****	****	****	****	48.	37.	****
372	15.	53.	****	3.	19.	13.	****	12.	****	****	****	****	50.	43.	****
378	43.	24.	****	1.	20.	14.	****	13.	****	****	****	****	51.	44.	****
379	12.	10.	****	1.	16.	14.	****	9.	****	****	****	****	50.	43.	****
383	17.	2.	****	1.	23.	15.	****	13.	****	****	****	****	50.	42.	****
384	16.	6.	****	1.	23.	15.	****	23.	****	****	****	****	50.	44.	****
385	8.	1.	****	1.	19.	13.	****	10.	****	****	****	****	50.	44.	****
386	8.	1.	****	1.	38.	19.	****	17.	****	****	****	****	50.	45.	****
389	22.	5.	****	7.	17.	13.	****	13.	****	****	****	****	48.	40.	****
391	3.	3.	****	1.	20.	14.	****	11.	****	****	****	****	46.	36.	****
392	3.	1.	****	1.	21.	31.	****	15.	****	****	****	****	48.	40.	****
393	16.	7.	****	1.	30.	22.	****	13.	****	****	****	****	49.	42.	****
...	13.	10.	****	3.	22.	16.	****	13.	****	****	****	****	49.	42.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 2 - Period XI - Days 1/1/72 - 1/31/72

TOWER FLOW = 0.50 GAL/MIN/FT2
RECYCLE = 1.00 GAL/MIN/FT2
RATIO = 2.00
FILTER FLOW = 3.50 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	NH3-N TE	NH3-N CE	NH3-N FE	ORG-N, MG/L TI	ORG-N TE	ORG-N CE	ORG-N FE	NO3-N, MG/L TI	NO3-N TE	NO3-N CE	NO3-N FE	NO2-N, MG/L TI	NO2-N TE	NO2-N CE	NO2-N FE	TOT-N, MG/L TI	TOT-N TE	TOT-N CE	TOT-N FE
369	14.0	2.6	****	1.8	4.0	4.1	****	2.7	0.4	9.4	****	11.4	0.2	1.6	****	0.2	18.6	17.7	****	16.1
370	****	****	****	2.3	****	****	****	2.8	****	****	****	10.4	****	****	****	0.2	****	****	****	15.7
371	14.0	4.3	****	3.9	5.3	4.1	****	3.2	0.1	6.6	****	7.8	0.1	0.8	****	0.2	19.5	15.4	****	15.1
372	15.1	6.0	****	5.2	2.4	4.0	****	2.4	0.3	8.4	****	8.4	0.1	0.8	****	0.6	17.9	19.2	****	16.6
378	13.7	2.2	****	1.7	3.8	3.6	****	2.4	0.8	13.2	****	13.4	0.2	0.8	****	0.2	18.5	19.8	****	17.7
379	17.5	1.1	****	0.5	0.9	0.7	****	1.2	0.9	12.2	****	12.8	0.2	0.6	****	0.2	19.5	14.6	****	14.7
383	13.3	1.5	****	1.2	4.3	1.4	****	0.8	0.6	11.2	****	12.0	0.1	0.4	****	0.2	18.3	14.5	****	14.2
384	12.2	1.1	****	0.6	4.0	0.6	****	0.7	0.5	9.2	****	8.8	0.1	0.4	****	0.2	16.8	11.3	****	10.3
385	11.2	1.3	****	0.9	2.7	0.7	****	0.7	0.5	9.4	****	9.8	0.2	0.2	****	0.2	14.6	11.6	****	11.6
386	13.4	1.4	****	0.9	3.1	1.1	****	0.9	0.5	9.0	****	10.2	0.2	0.2	****	0.2	17.2	11.7	****	12.2
389	12.6	1.2	****	1.0	4.9	1.2	****	0.6	0.6	10.2	****	10.0	0.1	0.2	****	0.2	18.2	12.8	****	11.8
391	11.5	0.8	****	0.6	3.9	1.1	****	1.2	0.6	8.6	****	9.8	0.1	0.2	****	0.2	16.1	10.7	****	11.8
392	11.2	0.7	****	0.4	2.7	1.2	****	1.3	0.7	11.7	****	12.0	0.2	0.3	****	0.1	14.8	13.9	****	13.7
393	12.9	0.9	****	0.9	3.6	2.1	****	0.8	0.5	10.7	****	10.9	0.1	0.3	****	0.1	17.1	14.0	****	12.7
...	13.2	1.9	****	1.5	3.5	1.9	****	1.5	0.5	9.9	****	10.5	0.1	0.5	****	0.2	17.4	14.4	****	13.8

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period XII - Days 2/8/72 - 2/18/72

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			) (TOC, MG/L				) (SOC, MG/L				) (TEMP; F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
404	23.	9.	****	1.	16.	21.	****	14.	16.	10.	****	14.	48.	43.	****
405	13.	7.	****	4.	34.	18.	****	16.	29.	15.	****	16.	48.	44.	****
406	17.	9.	****	7.	15.	16.	****	12.	13.	16.	****	15.	49.	45.	****
407	14.	1.	****	1.	15.	15.	****	14.	12.	14.	****	13.	49.	44.	****
411	****	16.	****	11.	****	19.	****	18.	****	17.	****	16.	****	****	****
412	23.	13.	****	8.	23.	18.	****	18.	16.	15.	****	18.	****	****	****
413	12.	11.	****	3.	17.	10.	****	12.	19.	13.	****	12.	48.	45.	****
414	12.	6.	****	2.	18.	15.	****	15.	19.	17.	****	17.	48.	45.	****
...	16.	9.	****	5.	20.	16.	****	15.	18.	15.	****	15.	48.	44.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 5 - Period XII - Days 2/8/72 - 2/18/72

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	TE	CE	FE	ORG-N, MG/L TI	TE	CE	FE	NO3-N, MG/L TI	TE	CE	FE	NO2-N, MG/L TI	TE	CE	FE	TOT-N, MG/L TI	TE	CE	FE
404	17.3	7.3	****	7.4	1.7	0.5	****	0.1	0.7	8.5	****	8.7	0.1	0.4	****	0.2	19.8	16.7	****	16.3
405	16.0	7.5	****	6.7	3.2	1.2	****	1.0	0.6	8.0	****	7.7	0.1	0.4	****	0.2	19.9	17.1	****	15.6
406	15.7	7.0	****	6.5	3.5	1.4	****	0.6	0.7	9.0	****	8.3	0.1	0.4	****	0.3	20.0	17.8	****	15.7
407	14.6	6.0	****	5.9	5.4	2.5	****	2.3	0.9	10.2	****	9.8	0.1	0.4	****	0.1	21.0	19.1	****	18.1
411	****	5.1	****	5.0	****	1.8	****	1.6	****	8.6	****	9.0	****	0.4	****	0.2	****	15.9	****	15.8
412	14.3	5.0	****	4.3	7.5	2.0	****	1.9	0.5	9.1	****	8.6	0.1	1.1	****	0.2	22.4	17.2	****	15.0
413	15.0	5.5	****	5.1	5.6	2.3	****	1.5	0.1	7.5	****	9.3	0.1	2.3	****	0.2	20.8	17.6	****	16.1
414	16.2	5.7	****	4.8	2.5	1.7	****	1.2	0.4	9.5	****	9.7	0.1	0.2	****	0.2	19.2	17.1	****	15.9
...	15.5	6.1	****	5.7	4.2	1.6	****	1.4	0.5	8.8	****	8.8	0.1	0.7	****	0.2	20.4	17.3	****	16.0

NH3-N = AMMONIA NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 6 - Period XIII - Days 2/21/72 - 2/25/72

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.50
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)(	TOC, MG/L			)(	SOC, MG/L			)(	TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
418	25.	17.	****	4.	17.	14.	****	14.	13.	12.	****	13.	46.	44.	****
419	19.	1.	****	3.	17.	14.	****	13.	17.	13.	****	11.	46.	43.	****
420	30.	9.	****	1.	27.	16.	****	14.	23.	15.	****	14.	47.	44.	****
421	8.	10.	****	1.	19.	15.	****	12.	15.	15.	****	15.	47.	44.	****
...	20.	9.	****	2.	20.	15.	****	13.	17.	14.	****	13.	46.	44.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 6 - Period XIII - Days 2/21/72 - 2/25/72

TOWER FLOW = 1.00 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.50
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)	(ORG-N, MG/L			)	(NO3-N, MG/L			)	(NO2-N, MG/L			)	(TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
418	13.4	4.8	****	3.8	****	3.8	****	****	0.6	8.0	****	8.4	0.1	0.3	****	0.1	23.4	16.9	****	17.4
419	15.9	6.4	****	5.6	4.7	2.1	****	1.6	0.5	9.1	****	8.8	0.1	0.3	****	0.2	21.2	17.9	****	16.2
420	16.1	6.6	****	5.9	3.5	3.2	****	1.7	0.4	9.1	****	9.0	0.1	0.3	****	0.2	20.1	19.2	****	17.8
421	16.0	6.5	****	5.7	3.2	0.6	****	0.9	0.5	9.5	****	9.2	0.1	0.3	****	0.2	19.8	16.9	****	16.0
...	15.4	6.1	****	5.2	3.8	2.4	****	1.4	0.5	8.9	****	8.9	0.1	0.3	****	0.2	21.1	17.7	****	16.8

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
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... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 4 - Period XIV - Days 2/29/72 - 3/17/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.70
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)(	TOC, MG/L			)(	SOC, MG/L			)(	TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
425	12.	9.	****	1.	26.	16.	****	15.	20.	15.	****	14.	48.	45.	****
426	26.	25.	****	11.	23.	15.	****	15.	21.	16.	****	16.	47.	43.	****
427	22.	12.	****	8.	24.	16.	****	14.	22.	18.	****	15.	45.	40.	****
428	6.	3.	****	2.	17.	5.	****	1.	****	****	****	****	46.	41.	****
432	27.	****	****	****	20.	13.	****	11.	17.	15.	****	13.	****	****	****
433	41.	9.	****	2.	16.	12.	****	13.	16.	14.	****	14.	****	****	****
434	8.	8.	****	1.	19.	14.	****	13.	14.	12.	****	11.	44.	39.	****
435	9.	3.	****	1.	17.	16.	****	13.	15.	15.	****	12.	46.	42.	****
439	3.	1.	****	1.	14.	16.	****	11.	17.	15.	****	14.	44.	38.	****
440	15.	17.	****	18.	16.	9.	****	11.	24.	24.	****	18.	47.	44.	****
441	****	22.	****	18.	15.	11.	****	13.	23.	17.	****	17.	46.	44.	****
442	25.	20.	****	16.	20.	14.	****	17.	24.	20.	****	15.	46.	44.	****
...	18.	12.	****	7.	19.	13.	****	13.	21.	16.	****	14.	46.	42.	****

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 4 - Period XIV - Days 2/29/72 - 3/17/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.70
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)	(ORG-N, MG/L			)	(NO3-N, MG/L			)	(NO2-N, MG/L			)	(TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
425	16.7	3.2	****	2.1	1.7	1.3	****	2.1	0.6	12.3	****	12.8	0.1	0.5	****	0.1	19.1	17.3	****	17.1
426	15.4	1.8	****	1.3	2.2	2.0	****	2.2	0.6	12.3	****	12.9	0.1	0.4	****	0.1	18.3	16.5	****	16.5
427	16.4	2.1	****	2.0	3.0	1.6	****	1.4	0.1	13.5	****	12.2	0.3	0.3	****	0.2	19.8	17.5	****	15.8
428	17.4	2.9	****	2.4	0.1	1.5	****	1.6	0.6	14.2	****	14.8	0.1	0.1	****	0.1	18.2	18.7	****	18.9
432	14.8	2.1	****	2.9	4.4	2.5	****	3.0	0.3	15.3	****	10.4	0.1	0.3	****	0.1	19.6	20.2	****	16.4
433	14.5	2.5	****	1.8	3.5	2.1	****	1.3	1.4	12.3	****	12.9	0.1	0.1	****	0.1	19.5	17.0	****	16.1
434	15.5	3.3	****	2.5	1.7	1.4	****	1.5	0.6	10.4	****	10.8	0.1	0.1	****	0.1	17.9	15.2	****	14.9
435	17.8	3.4	****	2.7	0.1	0.1	****	2.1	0.5	12.3	****	10.6	0.1	0.5	****	0.2	18.4	16.2	****	15.6
439	13.0	2.2	****	1.6	4.4	3.0	****	3.5	0.6	10.0	****	10.3	0.1	0.2	****	0.1	18.1	15.4	****	15.5
440	14.5	3.1	****	2.5	3.9	1.9	****	1.6	0.5	10.4	****	10.1	0.1	0.3	****	0.2	19.0	15.7	****	14.4
441	13.0	2.0	****	1.9	2.3	2.8	****	0.7	0.5	9.7	****	9.5	0.1	0.2	****	0.1	15.9	14.7	****	12.2
442	11.3	3.4	****	1.8	5.1	2.5	****	1.8	0.3	9.2	****	8.8	0.1	0.2	****	0.1	16.8	15.3	****	12.5
...	15.0	2.6	****	2.1	2.9	2.0	****	1.9	0.5	11.8	****	11.3	0.1	0.2	****	0.1	18.3	16.6	****	15.4

NH3-N = AMMONIA NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 3 - Period XV - Days 3/20/72 - 4/28/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L TI	TE	CE	FE	ORG-N, MG/L TI	TE	CE	FE	NO3-N, MG/L TI	TE	CE	FE	NO2-N, MG/L TI	TE	CE	FE	TOT-N, MG/L TI	TE	CE	FE
446	10.5	2.4	****	2.0	5.3	2.5	****	2.7	0.6	7.7	****	7.6	0.1	0.2	****	0.2	16.5	12.8	****	12.5
447	8.1	1.6	****	1.3	5.9	2.9	****	2.9	0.9	6.4	****	6.8	0.1	0.2	****	0.2	15.0	11.1	****	11.2
448	7.2	1.4	****	1.1	3.9	3.1	****	2.5	1.5	7.0	****	6.9	0.1	0.2	****	0.1	12.7	11.7	****	10.6
449	11.6	4.8	****	****	4.1	2.8	****	****	1.2	6.4	****	****	0.1	0.2	****	****	12.9	11.4	****	****
461	6.4	1.4	****	0.9	0.2	0.2	****	0.2	1.6	7.2	****	7.1	0.2	0.1	****	0.1	8.4	8.9	****	8.3
462	6.2	1.2	****	1.1	0.3	0.4	****	0.2	2.0	7.9	****	5.2	0.2	0.1	****	0.1	8.7	9.6	****	6.6
463	6.5	0.9	****	1.5	0.3	1.0	****	0.3	3.9	8.6	****	4.7	0.1	0.1	****	0.1	10.8	10.6	****	6.6
467	9.1	1.9	****	1.1	0.1	0.3	****	0.5	1.0	8.4	****	6.2	0.1	0.1	****	0.2	10.2	10.7	****	8.0
468	7.4	1.4	****	0.7	1.1	0.6	****	0.9	0.8	8.0	****	6.2	0.1	0.1	****	0.1	9.4	10.1	****	7.9
469	7.1	1.2	****	0.9	0.9	0.4	****	0.8	0.7	7.5	****	5.9	0.1	0.5	****	0.1	9.0	9.6	****	7.7
470	6.6	1.2	****	0.3	1.1	0.4	****	0.3	0.7	7.2	****	5.8	0.1	0.2	****	0.1	8.5	9.0	****	6.5
474	4.4	0.3	****	0.1	0.8	0.6	****	0.5	1.1	7.1	****	2.7	0.2	0.1	****	1.3	6.5	8.1	****	4.6
475	6.1	0.3	****	0.1	1.7	1.3	****	0.8	1.2	6.9	****	3.1	0.2	0.1	****	0.7	9.2	8.6	****	4.7
476	5.1	1.1	****	1.1	2.3	1.1	****	1.1	2.2	6.9	****	2.0	0.3	0.2	****	0.7	10.9	9.3	****	4.9
477	6.8	0.4	****	0.3	0.7	1.3	****	1.2	1.1	7.9	****	2.4	0.2	0.1	****	0.7	8.8	9.7	****	4.6
481	7.9	0.6	****	0.3	0.1	0.3	****	0.2	0.3	8.3	****	2.1	0.1	0.1	****	0.2	8.3	9.3	****	2.8
482	8.6	0.4	****	0.3	0.4	1.6	****	1.5	0.5	8.4	****	0.8	0.1	0.2	****	0.2	9.6	10.6	****	2.8
483	8.5	0.5	****	0.3	0.1	1.1	****	1.1	0.6	8.1	****	0.1	0.1	0.2	****	0.1	9.3	9.9	****	1.6
484	8.3	0.7	****	0.6	0.6	1.1	****	0.5	0.5	8.0	****	0.2	0.1	0.2	****	0.1	9.5	10.0	****	1.4
...	7.5	1.2	****	0.7	1.6	1.2	****	1.0	1.1	7.5	****	4.2	0.1	0.1	****	0.2	10.2	10.0	****	6.2

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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 3 - Period XV - Days 3/20/72 - 4/28/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	SS, MG/L TE	SS, MG/L CE	SS, MG/L FE	TOC, MG/L TI	TOC, MG/L TE	TOC, MG/L CE	TOC, MG/L FE	SOC, MG/L TI	SOC, MG/L TE	SOC, MG/L CE	SOC, MG/L FE	TEMP, F TI	TEMP, F TE	TEMP, F FI
446	1.	1.	****	1.	16.	13.	****	12.	17.	15.	****	14.	46.	44.	****
447	32.	4.	****	1.	18.	11.	****	10.	19.	10.	****	10.	46.	43.	****
448	4.	1.	****	2.	16.	13.	****	13.	15.	12.	****	12.	44.	40.	****
449	7.	2.	****	****	16.	15.	****	****	18.	14.	****	****	****	****	****
461	4.	2.	****	1.	16.	15.	****	13.	16.	15.	****	14.	45.	40.	****
462	2.	10.	****	1.	16.	15.	****	19.	16.	18.	****	16.	45.	39.	****
463	12.	4.	****	4.	19.	16.	****	25.	17.	16.	****	24.	****	****	****
467	8.	3.	****	1.	18.	13.	****	19.	31.	24.	****	26.	49.	44.	****
468	8.	7.	****	8.	19.	15.	****	16.	25.	33.	****	26.	48.	44.	****
469	6.	3.	****	2.	21.	14.	****	16.	28.	23.	****	27.	48.	44.	****
470	4.	2.	****	3.	21.	13.	****	17.	26.	25.	****	20.	47.	42.	****
474	7.	5.	****	3.	20.	19.	****	20.	15.	18.	****	18.	50.	46.	50.
475	9.	26.	****	9.	24.	18.	****	15.	29.	18.	****	19.	****	****	52.
476	4.	3.	****	1.	22.	17.	****	19.	20.	17.	****	18.	48.	43.	47.
477	3.	4.	****	1.	15.	9.	****	11.	14.	10.	****	11.	49.	42.	47.
481	1.	10.	****	12.	10.	9.	****	8.	8.	9.	****	8.	49.	42.	48.
482	2.	15.	****	3.	10.	7.	****	8.	11.	7.	****	8.	49.	43.	48.
483	14.	16.	****	25.	8.	7.	****	13.	8.	8.	****	14.	49.	44.	50.
484	6.	2.	****	4.	10.	9.	****	12.	11.	8.	****	9.	49.	45.	51.
...	7.	7.	****	6.	16.	13.	****	15.	18.	16.	****	16.	48.	43.	49.

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
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Group 3 - Period XVI - Days 5/1/72 - 5/26/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			)(	TOC, MG/L			)(	SOC, MG/L			)(	TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
488	28.	13.	****	9.	14.	11.	****	13.	14.	10.	****	11.	52.	49.	56.
489	31.	11.	****	5.	12.	10.	****	12.	15.	11.	****	13.	50.	46.	57.
490	13.	13.	****	6.	14.	19.	****	18.	13.	11.	****	19.	49.	45.	53.
491	9.	10.	****	5.	16.	13.	****	13.	14.	9.	****	11.	51.	46.	56.
495	10.	7.	****	4.	23.	18.	****	20.	24.	21.	****	23.	51.	45.	52.
496	11.	5.	****	5.	23.	19.	****	20.	26.	20.	****	24.	51.	46.	57.
497	9.	6.	****	2.	24.	21.	****	27.	24.	19.	****	26.	53.	47.	54.
498	27.	11.	****	5.	29.	22.	****	31.	29.	21.	****	28.	53.	48.	56.
502	****	26.	****	1.	****	13.	****	12.	****	10.	****	12.	53.	50.	57.
503	3.	3.	****	2.	10.	12.	****	10.	10.	10.	****	10.	53.	50.	56.
504	3.	3.	****	1.	12.	12.	****	12.	12.	10.	****	11.	****	****	58.
505	1.	7.	****	1.	12.	11.	****	12.	11.	10.	****	11.	54.	52.	57.
509	5.	42.	****	4.	14.	15.	****	15.	13.	13.	****	13.	56.	52.	57.
510	4.	12.	****	1.	14.	11.	****	12.	12.	11.	****	12.	56.	52.	59.
512	3.	26.	****	3.	12.	12.	****	12.	12.	11.	****	12.	57.	53.	60.
...	11.	13.	****	4.	16.	14.	****	16.	16.	13.	****	16.	53.	49.	57.

SS = SUSPENDED SOLIDS
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Group 3 - Period XVI - Days 5/1/72 - 5/26/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)	(ORG-N, MG/L			)	(NO3-N, MG/L			)	(NO2-N, MG/L			)	(TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
488	5.8	0.4	****	0.3	0.8	0.7	****	0.6	0.8	9.8	****	0.1	0.1	0.2	****	0.1	7.5	11.1	****	0.9
489	7.2	0.3	****	0.3	0.4	0.5	****	0.5	0.6	8.5	****	0.1	0.1	0.1	****	0.1	8.3	9.4	****	0.8
490	7.8	0.7	****	0.5	0.3	0.3	****	0.3	0.6	8.4	****	0.1	0.1	0.2	****	0.2	8.8	9.6	****	1.0
491	7.3	0.4	****	0.1	1.0	0.3	****	0.5	0.5	7.7	****	0.1	0.1	0.2	****	0.1	8.9	8.6	****	0.7
495	6.3	0.7	****	0.3	0.1	0.9	****	0.1	0.5	8.8	****	1.3	0.1	0.2	****	0.1	7.0	10.6	****	1.8
496	9.3	1.5	****	0.9	1.6	0.1	****	0.3	0.4	9.9	****	0.1	0.1	0.3	****	0.1	9.8	11.7	****	1.4
497	8.9	1.4	****	0.8	1.6	0.4	****	0.1	0.4	6.5	****	0.1	0.1	0.3	****	0.1	11.0	8.6	****	0.9
498	9.8	0.8	****	0.2	0.1	1.5	****	0.8	0.3	6.4	****	0.1	0.2	0.4	****	0.1	10.4	9.1	****	1.0
502	8.7	1.0	****	1.1	0.5	0.9	****	1.3	1.0	7.9	****	2.4	0.2	0.1	****	****	10.4	9.9	****	****
503	7.5	1.4	****	1.3	1.0	0.3	****	0.1	0.5	8.5	****	0.2	0.1	0.2	****	0.1	9.1	10.4	****	1.6
504	6.5	2.5	****	1.2	2.2	0.1	****	1.1	0.7	8.2	****	0.1	0.1	0.2	****	0.1	9.5	11.0	****	2.3
505	9.2	1.7	****	1.3	0.4	0.2	****	0.1	0.4	7.9	****	0.3	0.1	0.2	****	0.1	11.1	10.0	****	1.8
509	9.6	0.3	****	0.3	0.2	2.7	****	0.6	0.9	10.0	****	0.3	0.1	0.2	****	0.2	10.8	13.2	****	1.4
510	10.9	1.7	****	1.7	0.1	0.1	****	0.1	0.4	9.8	****	0.1	0.1	0.2	****	0.1	11.4	11.7	****	1.7
512	6.8	2.5	****	1.0	3.3	0.1	****	0.3	0.2	9.8	****	0.1	0.1	0.4	****	0.1	10.4	12.8	****	1.3
...	8.1	1.1	****	0.7	0.9	0.6	****	0.5	0.5	8.5	****	0.3	0.1	0.2	****	0.1	9.6	10.5	****	1.3

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
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*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 3 - Period XVII - Days 5/31/72 - 6/22/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L TI	SS, MG/L TE	SS, MG/L CE	SS, MG/L FE	TOC, MG/L TI	TOC, MG/L TE	TOC, MG/L CE	TOC, MG/L FE	SOC, MG/L TI	SOC, MG/L TE	SOC, MG/L CE	SOC, MG/L FE	TEMP, F TI	TEMP, F TE	TEMP, F FI
517	21.	****	****	5.	18.	14.	****	13.	14.	12.	****	11.	55.	50.	57.
518	11.	46.	****	4.	17.	15.	****	16.	14.	13.	****	15.	55.	50.	56.
519	5.	17.	****	2.	14.	12.	****	13.	12.	11.	****	12.	57.	54.	59.
523	18.	41.	****	18.	18.	15.	****	18.	15.	14.	****	15.	58.	55.	61.
524	13.	****	****	14.	46.	24.	****	25.	39.	21.	****	16.	59.	55.	61.
525	21.	20.	****	3.	36.	24.	****	21.	18.	15.	****	16.	59.	56.	62.
526	4.	15.	****	3.	34.	25.	****	28.	25.	19.	****	20.	60.	58.	63.
530	40.	37.	****	5.	49.	34.	****	38.	35.	25.	****	28.	58.	55.	60.
531	8.	2.	****	2.	19.	13.	****	18.	17.	13.	****	16.	60.	58.	62.
532	7.	13.	****	10.	13.	9.	****	12.	9.	9.	****	10.	62.	60.	****
533	15.	28.	****	6.	14.	14.	****	12.	18.	14.	****	12.	60.	57.	63.
537	39.	46.	****	17.	39.	22.	****	34.	31.	21.	****	33.	61.	59.	64.
538	26.	52.	****	28.	21.	16.	****	19.	24.	18.	****	20.	60.	57.	65.
539	47.	44.	****	31.	****	****	****	****	****	****	****	****	59.	54.	61.
...	20.	30.	****	10.	26.	18.	****	20.	21.	16.	****	17.	59.	56.	61.

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
SOC = SOLUBLE ORGANIC CARBON
TEMP = TEMPERATURE
TI = TOWER INFLUENT
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 3 - Period XVII - Days 5/31/72 - 6/22/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	(NH3-N, MG/L			)(	ORG-N, MG/L			)(	NO3-N, MG/L			)(	NO2-N, MG/L			)(	TOT-N, MG/L			)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
517	8.7	2.0	****	1.1	0.1	1.3	****	0.7	****	8.9	****	0.4	0.1	0.6	****	0.1	11.0	12.8	****	2.3
518	9.7	0.8	****	0.7	0.1	0.8	****	0.4	0.2	9.1	****	0.1	0.1	0.6	****	0.1	10.1	11.3	****	1.3
519	10.9	1.1	****	1.1	0.1	0.4	****	0.7	0.6	9.5	****	0.1	0.1	0.6	****	0.1	11.6	11.6	****	2.0
523	10.3	3.2	****	1.3	0.1	0.1	****	0.1	0.4	9.2	****	0.1	0.1	0.5	****	0.1	10.8	12.9	****	1.6
524	12.0	0.1	****	0.3	0.1	0.2	****	0.1	0.1	8.9	****	0.1	0.1	1.0	****	0.1	12.2	10.2	****	0.6
525	12.0	1.3	****	1.1	0.1	0.7	****	0.7	0.2	9.4	****	0.1	0.1	0.6	****	0.1	12.4	12.0	****	1.9
526	14.4	0.5	****	0.8	****	1.9	****	2.6	0.2	9.4	****	0.2	0.1	0.6	****	0.2	11.4	12.4	****	3.8
530	14.0	1.2	****	0.7	2.5	1.0	****	1.2	0.7	9.5	****	****	0.1	0.5	****	0.4	17.3	12.2	****	4.0
531	14.7	1.1	****	1.0	3.1	1.5	****	2.0	0.1	9.5	****	0.1	0.1	0.5	****	0.1	18.0	12.6	****	3.2
532	11.9	1.9	****	0.9	0.8	0.9	****	0.6	0.1	9.4	****	0.2	0.2	0.6	****	0.1	12.2	11.9	****	1.2
533	9.0	1.1	****	0.7	1.0	0.9	****	0.4	0.1	****	****	0.1	0.1	0.2	****	0.1	9.2	****	****	0.9
537	14.0	2.3	****	2.0	1.9	1.4	****	1.4	0.1	8.4	****	0.1	0.1	0.6	****	0.2	14.2	11.3	****	2.3
538	11.7	2.3	****	1.0	0.7	1.1	****	0.7	0.1	8.5	****	0.1	0.1	0.2	****	0.1	11.9	11.0	****	1.2
539	12.6	2.8	****	2.6	0.7	1.1	****	0.4	0.1	8.4	****	0.1	0.1	0.8	****	0.1	12.8	12.0	****	1.6
...	11.8	1.5	****	1.0	0.8	0.9	****	0.8	0.3	8.7	****	0.2	0.1	0.5	****	0.1	12.5	11.3	****	1.9

NH3-N = AMMONIA NITROGEN
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Group 3 - Period XVIII - Days 6/23/72 - 7/19/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	SS, MG/L				TOC, MG/L				SOC, MG/L				TEMP, F		
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
540	47.	52.	****	3.	24.	17.	****	17.	30.	21.	****	19.	59.	53.	****
544	****	83.	****	1.	16.	12.	****	13.	13.	10.	****	10.	61.	57.	61.
545	8.	59.	****	1.	14.	13.	****	12.	9.	14.	****	9.	62.	59.	64.
546	1.	55.	****	1.	22.	13.	****	14.	13.	12.	****	17.	62.	59.	65.
547	21.	71.	****	3.	17.	13.	****	16.	19.	13.	****	12.	****	****	64.
552	14.	25.	****	2.	31.	20.	****	20.	24.	17.	****	19.	60.	55.	61.
553	10.	19.	****	2.	23.	19.	****	20.	20.	15.	****	21.	61.	56.	61.
554	14.	21.	****	3.	24.	18.	****	19.	16.	13.	****	16.	62.	57.	62.
558	3.	18.	****	1.	22.	23.	****	19.	21.	16.	****	22.	62.	60.	66.
559	4.	31.	****	1.	24.	29.	****	24.	26.	29.	****	23.	63.	62.	67.
560	15.	15.	****	1.	32.	26.	****	29.	27.	29.	****	23.	63.	61.	67.
561	29.	36.	****	2.	33.	29.	****	20.	26.	19.	****	19.	63.	60.	****
565	6.	11.	****	3.	11.	13.	****	9.	13.	13.	****	9.	63.	61.	67.
566	9.	15.	****	3.	17.	24.	****	17.	18.	17.	****	17.	63.	61.	67.
...	11.	30.	****	2.	22.	19.	****	18.	20.	17.	****	17.	62.	58.	64.

SS = SUSPENDED SOLIDS
TOC = TOTAL ORGANIC CARBON
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TEMP = TEMPERATURE
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Group 3 - Period XVIII - Days 6/23/72 - 7/19/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.00 GAL/MIN/FT2
RATIO = 0.00
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L				ORG-N, MG/L				NO3-N, MG/L				NO2-N, MG/L				TOT-N, MG/L			
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
540	12.9	1.8	****	2.2	0.9	1.2	****	0.8	0.1	7.5	****	6.1	0.1	0.5	****	0.1	14.0	11.0	****	9.2
544	12.6	2.1	****	1.4	0.7	1.2	****	0.2	1.1	10.5	****	10.5	0.1	0.5	****	0.5	14.5	14.3	****	12.6
545	****	****	****	****	****	****	****	****	0.1	9.5	****	2.3	0.1	0.5	****	0.3	****	****	****	****
546	12.5	2.5	****	1.9	1.3	0.6	****	0.6	0.1	10.1	****	10.4	0.1	0.5	****	0.2	14.0	13.7	****	13.1
547	11.9	1.9	****	1.4	0.8	0.8	****	0.8	0.1	10.6	****	1.0	0.1	0.3	****	0.2	12.9	13.6	****	3.4
552	14.4	4.4	****	3.2	1.2	0.7	****	1.1	0.6	9.4	****	0.9	0.1	0.6	****	0.7	16.3	15.1	****	5.9
553	14.0	3.6	****	3.3	0.3	0.2	****	0.5	0.1	8.5	****	0.1	0.1	0.6	****	0.2	15.1	12.9	****	4.0
554	14.1	2.8	****	2.2	1.1	0.6	****	1.0	0.4	9.6	****	0.1	0.1	0.7	****	0.1	15.7	13.7	****	3.4
558	13.5	0.8	****	-0.8	0.9	1.3	****	1.1	0.7	10.8	****	0.2	0.1	1.0	****	0.5	15.2	13.9	****	2.6
559	14.4	2.6	****	2.3	0.6	0.6	****	0.6	0.2	9.1	****	0.1	0.1	1.4	****	0.6	15.3	13.7	****	3.6
560	13.9	2.5	****	2.3	0.6	0.9	****	0.6	0.1	9.7	****	0.1	0.1	0.8	****	0.2	14.7	13.9	****	3.2
561	13.2	1.3	****	1.2	1.0	1.5	****	1.5	0.6	9.7	****	0.5	0.1	0.8	****	0.5	14.9	13.3	****	3.7
565	6.7	0.8	****	0.5	2.2	1.0	****	0.8	1.3	8.9	****	0.9	0.2	0.5	****	0.3	10.4	11.2	****	2.5
566	8.2	0.1	****	0.1	2.9	2.5	****	2.2	0.7	9.4	****	1.1	0.1	0.6	****	0.3	12.9	12.6	****	3.7
...	13.4	2.0	****	1.7	0.8	0.8	****	0.8	0.4	9.5	****	1.1	0.1	0.5	****	0.3	14.3	13.3	****	3.6

NH3-N = AMMONIA NITROGEN
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Group 9 - Period XIX - Days 7/21/72 - 9/1/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.70
FILTER FLOW = 5.00 GAL/MIN

OTHER ANALYSES

DAY	(SS, MG/L			) (	TOC, MG/L			) (	SOC, MG/L			) (	TEMP, F		)
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	FI
568	****	33.	18.	3.	29.	19.	18.	15.	34.	18.	19.	15.	****	****	****
572	27.	36.	17.	10.	18.	15.	15.	13.	17.	15.	15.	12.	65.	63.	****
574	26.	36.	10.	9.	15.	17.	15.	11.	15.	14.	15.	11.	62.	58.	****
575	35.	48.	15.	7.	15.	17.	16.	14.	15.	18.	18.	14.	63.	58.	****
579	14.	64.	20.	1.	50.	41.	36.	25.	30.	22.	27.	18.	64.	62.	****
580	13.	29.	32.	1.	43.	29.	30.	25.	24.	22.	18.	21.	65.	64.	****
581	6.	67.	7.	1.	47.	40.	31.	25.	22.	23.	24.	18.	64.	62.	****
582	20.	22.	20.	2.	36.	40.	34.	35.	23.	28.	26.	21.	64.	60.	****
586	4.	34.	8.	9.	40.	46.	40.	50.	23.	32.	28.	31.	63.	59.	****
587	11.	82.	20.	1.	59.	41.	40.	32.	32.	29.	29.	29.	63.	59.	****
588	26.	10.	19.	1.	57.	40.	40.	29.	34.	27.	32.	25.	63.	59.	****
589	28.	23.	25.	1.	60.	39.	38.	32.	43.	28.	27.	23.	64.	59.	****
594	31.	50.	33.	1.	31.	33.	29.	16.	18.	28.	26.	15.	****	****	****
595	5.	17.	2.	1.	21.	16.	16.	16.	16.	12.	15.	11.	64.	61.	****
596	32.	89.	30.	1.	51.	38.	24.	17.	37.	21.	23.	17.	****	****	****
600	40.	****	****	6.	43.	32.	30.	22.	30.	29.	25.	17.	66.	62.	****
601	****	44.	15.	****	76.	32.	27.	30.	41.	24.	25.	25.	67.	66.	****
603	26.	85.	33.	5.	73.	****	60.	60.	25.	****	22.	23.	66.	64.	****
607	40.	99.	11.	2.	63.	56.	40.	42.	43.	35.	34.	37.	66.	64.	****
608	17.	65.	10.	1.	49.	42.	35.	42.	43.	35.	28.	37.	66.	63.	****
609	14.	87.	5.	1.	53.	43.	37.	28.	42.	27.	30.	27.	66.	64.	****
610	3.	64.	10.	3.	25.	41.	20.	13.	16.	14.	13.	12.	66.	64.	****
...	21.	58.	17.	3.	43.	34.	30.	27.	28.	24.	24.	21.	65.	62.	****

SS = SUSPENDED SOLIDS
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DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

Gropu 9 - Period XIX - Days 7/21/72 - 9/1/72

TOWER FLOW = 0.71 GAL/MIN/FT2
RECYCLE = 0.50 GAL/MIN/FT2
RATIO = 0.70
FILTER FLOW = 5.00 GAL/MIN

NITROGEN ANALYSES

DAY	NH3-N, MG/L				ORG-N, MG/L				NO3-N, MG/L				NO2-N, MG/L				TOT-N, MG/L			
	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE	TI	TE	CE	FE
568	10.9	0.1	1.0	1.2	5.3	3.8	3.3	2.1	0.1	7.7	7.8	5.5	0.1	0.7	0.9	0.2	16.4	12.3	13.0	9.0
572	9.2	1.1	1.3	1.5	2.2	****	1.8	2.6	2.2	7.8	7.5	8.2	0.1	0.9	0.9	0.1	13.7	****	11.5	12.4
574	9.9	1.6	1.8	1.5	3.6	3.0	0.5	****	0.1	8.7	8.8	9.6	0.1	1.3	1.2	0.4	13.7	14.6	12.3	****
575	8.9	0.1	1.0	0.8	2.6	3.4	3.8	****	****	8.7	8.7	9.5	0.1	1.3	1.3	0.5	****	13.5	14.8	****
579	11.4	1.1	1.2	1.3	5.1	6.9	3.2	1.3	0.4	8.2	8.4	8.1	0.2	1.8	1.6	0.7	17.1	18.0	14.4	11.4
580	6.5	1.4	0.7	1.2	4.3	0.7	0.7	1.2	0.2	6.6	6.9	6.4	0.2	1.0	1.3	0.4	11.2	9.7	9.6	9.2
531	4.0	0.6	0.5	0.2	4.1	****	0.6	0.7	0.1	7.0	6.7	6.4	0.1	0.3	0.6	0.1	8.3	7.9	8.4	7.4
582	7.9	0.8	0.3	1.1	3.4	7.3	7.4	1.4	0.2	7.3	6.9	7.8	0.2	0.4	1.0	0.2	11.7	15.8	15.6	10.5
586	4.4	0.9	0.8	0.2	2.1	3.7	1.1	2.9	2.5	7.0	6.4	6.8	0.2	0.4	0.4	0.2	9.2	12.0	8.7	10.1
587	4.8	0.4	0.2	0.2	3.0	3.2	2.1	1.1	0.3	7.6	7.5	6.0	0.1	0.5	0.5	0.1	8.2	11.7	10.3	7.3
588	8.3	0.7	0.2	0.3	3.1	4.0	1.9	2.7	0.1	9.0	8.7	8.1	0.5	0.5	0.3	0.9	12.0	14.2	11.1	12.0
589	10.4	1.0	1.6	2.1	4.8	5.0	2.1	2.8	0.1	9.4	9.8	10.0	0.2	0.6	0.2	0.1	15.5	16.0	13.7	15.0
594	11.2	1.8	0.8	0.8	4.4	1.6	5.0	2.2	0.1	10.0	11.8	9.7	0.8	1.0	0.2	0.1	16.5	14.4	17.8	12.8
595	10.4	0.5	0.4	0.5	4.0	5.5	2.9	2.2	0.1	9.9	9.8	8.8	0.6	0.6	0.2	0.1	15.1	16.5	13.3	11.6
596	9.0	0.8	0.6	0.3	3.9	7.8	3.3	2.2	0.1	10.4	10.3	8.0	0.5	0.6	0.2	0.1	13.5	19.6	14.4	10.6
600	10.3	1.3	1.1	0.5	3.7	****	3.4	1.8	3.5	10.7	10.3	8.0	0.6	0.8	0.2	0.1	18.1	26.1	15.0	10.4
601	7.3	1.4	0.7	0.5	4.9	5.7	3.0	1.6	0.3	8.5	8.3	3.8	0.3	0.5	0.2	0.1	12.8	16.1	12.2	6.0
603	8.1	0.9	0.9	0.6	3.0	6.2	6.0	2.2	0.2	8.4	9.0	5.7	0.6	0.5	0.4	0.1	11.9	16.0	16.3	8.6
607	6.5	2.6	2.2	1.4	7.0	7.1	2.2	1.3	0.2	6.7	6.3	6.3	0.1	0.1	0.1	0.1	13.8	16.5	10.8	9.1
608	3.4	1.1	0.8	0.5	6.8	8.9	3.0	1.6	1.0	7.5	8.1	6.5	0.4	0.4	0.3	0.1	11.6	17.9	12.2	8.7
609	7.3	0.8	1.6	0.2	3.1	6.5	1.4	1.7	0.1	8.7	8.7	5.9	0.2	0.3	0.2	0.1	10.7	16.3	11.9	7.9
610	6.7	0.7	0.3	0.1	0.9	3.5	4.1	0.8	1.2	9.1	9.1	7.9	0.2	0.3	0.3	0.1	9.0	13.6	13.8	8.9
...	8.0	0.9	0.9	0.7	3.8	5.3	2.8	1.8	0.6	8.4	8.4	7.4	0.2	0.6	0.5	0.2	12.8	15.1	12.7	9.9

NH3-N = AMMONIA NITROGEN
ORG-N = ORGANIC NITROGEN
NO3-N = NITRATE NITROGEN
NO2-N = NITRITE NITROGEN
TOT-N = TOTAL NITROGEN
TI = TOWER INFLUENT
TE = TOWER EFFLUENT
CE = CLARIFIER EFFLUENT
FI = FILTER INFLUENT
FE = FILTER EFFLUENT

... = MEAN VALUES FOR NITROGEN ANALYSES AND OTHER ANALYSES DETERMINED FROM PROBABILITY PLOTS. MEAN VALUES FOR EFFLUENT QUALITY INDICATORS AND SYSTEM PERFORMANCE INDICATORS CALCULATED FROM MEAN ANALYSES.
*** = MISSING, UNDEFINED, AND/OR UNRELIABLE DATA
DAY = CALENDAR DAY (JANUARY 1, 1971 = DAY 1)

*U.S. GOVERNMENT PRINTING OFFICE:1973 546-308/5 1-3

SELECTED WATER
RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

W

APPLICATION OF PLASTIC MEDIA TRICKLING FILTERS FOR BIOLOGICAL NITRIFICATION SYSTEMS

Duddles, G. A., and Richardson, S. E.

Dow Chemical Company
Midland, Michigan 48640

17010 FSJ

Contract

Environmental Protection Agency, Office of Research and Monitoring

June 1970 - Feb. 1973

Environmental Protection Agency report number, EPA-R2-73-199, June 1973.

This study demonstrated the feasibility of using plastic media in a stage system to achieve biological nitrification of municipal effluents. The secondary effluent from the Midland, Michigan, wastewater treatment plant was dosed to a pilot scale trickling filter containing plastic media with a specific surface area of 27 ft^2/ft^3. This effluent contained 15-30 mg/l of BOD_5 and 10-20 mg/l of ammonia nitrogen. When dosed to the filter at application rates of 0.5 gpm/ft^2 consistent nitrification was obtained under both summer and winter conditions. Net cell growth was minimal, and the filter effluent could be directly filtered by tri-media filtration. The tri-media filter also served as a denitrification system when methanol was added to the nitrified effluent ahead of filtration. Significant changes were noted in the operational characteristics of the tri-media filter.

*Biological treatment, *Nitrification, *Denitrification, *Trickling filters, Municipal wastewater, Filtration

*Temperature effects, *Ammonia nitrogen, *Nitrate nitrogen, *Process efficiency, Frequency distribution

05D

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