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Evaluation Of The Bio-Disc Treatment Process For Summer Camp Application

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EVALUATION OF THE BIO-DISC TREATMENT PROCESS FOR SUMMER CAMP APPLICATION

by

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ABSTRACT

The bio-disc wastewater treatment process was evaluated during operation for one summer at a recreational camp. The bio-disc section consisted of four stages, each of 22 polystyrene discs 1.98 m (6.5 ft) in diameter, and was preceeded by a septic tank that served to handle both the primary and the biological sludge produced.

Evaluation of the plant included time required for start-up, organic removal efficiency, response to flow variations, nutrient removals, aesthetic impact, and required maintenance and operation attention.

Overall organic removals reached essentially full efficiency by the end of the first week of operation. However, removals across the bio-disc section continued to increase somewhat till about the fifth or sixth week of operation. Average bio-disc unit percent removals were BOD - 84.5, COD - 71, TOC - 71, and suspended solids - 75. Average overall plant percent removals were 87.5, 79, 75, and 97.5 respectively.

Total nitrogen removal through the plant averaged 40.3 percent. Ammonia nitrogen removal in the disc section was only 25.2 percent. Overall total phosphorus removal was 15 percent. Maintenance and operational requirements for the plant were minimal requiring an average of 1.3 hours per week during the summer.

This report was submitted in fulfillment of Project #S-800707, under the sponsorship of the Environmental Protection Agency by the West Virginia State University.

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FIGURES

FIGURES
(continued)

TABLES

SECTION I

CONCLUSIONS

1. The bio-disc wastewater treatment process (also known as the Rotating Biological Contactor) appeared to be relatively well suited to a summer camp application where sewage flow was low and fluctuated considerably.

2. Start-up of this plant required a minimum amount of time. Only one week was needed to provide adequate treatment.

3. Average bio-disc unit percent removals were BOD - 84.5, COD - 71, TOC - 71, and suspended solids - 75. Average overall plant percent removals were 87.5, 79, 75, and 97.5 respectively.

4. Because of the low flows encountered, the performance of the plant was not greatly affected by either organic or hydraulic loading.

5. The effluent from the septic tank was stronger during the second half of the summer due to incomplete anaerobic decomposition of the settled solids. This resulted in somewhat poorer and more erratic removals during this period.

6. Overall total nitrogen removal averaged 40.3 percent. Ammonia nitrogen through the disc section fell from 41.3 to 30.9 mg/l giving 25.2 percent removal. The low nitrification was probably due to the relatively high BOD in the plant effluent of 32 mg/l. Phosphorus removal through the plant averaged 15 percent.

7. Sludge handling problems were minimal with this plant during its three months of operation. An annual cleaning of accumulated sludge by a tank truck is more than adequate.

8. Maintenance requirements for this plant were quite small. This study revealed that only 14 hours of maintenance were required during nearly 11 weeks of continuous operation, or 1.3 hours per week.

9. The plant did not produce objectionable odors nor detract from the natural environment of the camp.

SECTION II

RECOMMENDATIONS

In order to make efficient use of the organic removal capacity of the bio-disc stages, pretreatment of raw waste should be as efficient as possible. Although use of a septic tank is well suited to a "package plant" application, it should be capable of better organic removals than found in this study. It is recommended that well digested sludge from a properly functioning digester be pumped into the septic tank at the start of each season to encourage good digestion from the outset and allow efficient operation of the septic tank and bio-disc.

Recycle of sewage from the final clarifier during periods of low flow should be made an automatic function in order to keep the bio-mass in an optimum condition. At Camp Horseshoe, low flow usually occurred on weekends when the operator was away from the camp and therefore no recirculation was carried out.

SECTION III

INTRODUCTION

Treatment of wastewater flows from summer recreational camps presents a difficult problem. The volume of such flows fluctuates considerably depending upon the activity and number of campers throughout the summer. Other difficulties facing designers in providing wastewater treatment processes for such an application include a frequent lack of trained operators, preservation of the aesthetic qualities associated with these areas, and seasonal operation.

This study was performed in order to evaluate the effectiveness of the rotating biological disc wastewater treatment process in treating wastes from a summer camp. The evaluation consisted of monitoring start-up, determination of removal efficiency, microscopic observations, recording of required maintenance, and evaluation of aesthetic acceptability. The bio-disc process (also called Rotating Biological Contactor or RBC) is a secondary biological treatment scheme which utilizes a fixed microbial slime to metabolize wastewater organics. The slime is attached to a series of circular discs which remain approximately one-half submerged while rotating through the wastewater. As the discs rotate, the wastewater trickles down the face of the discs, providing the required reaction time for aeration and metabolism of the waste. The rotation of the discs serves to keep sloughed biological solids and solids carried over from primary treatment in suspension until they can be separated in a final clarifier.

The bio-disc unit studied is located at Camp Horseshoe, in Tucker County, West Virginia. The camp is owned by the U. S. Forest Service and rented to the Y.M.C.A. It is utilized by many different groups with most of the campers being of school age.

SECTION IV

LITERATURE REVIEW

Though relatively new in this country, the bio-disc process has already been used in a number of applications. Synthetic sewage consisting of dairy solids, dipotassium orthophosphate, and diammonium orthophosphate was treated by a bio-disc unit consisting of two stages of one hundred 0.91 m (3 ft) diameter aluminum discs per stage (1). The two stages were separated by an intermediate settler and followed by a final clarifier. COD removals of up to 80 percent were obtained, depending upon hydraulic loading, organic loading, disc rpm, mixed liquor D.O., and temperature.

Birks and Hynek (2) reported on a bio-disc system used to treat cheese processing wastes. The system consisted of a septic pre-treatment and flow equalization unit, followed by a four stage bio-disc unit with an integral clarifier. There were twenty-two 3.05 m (10 ft) diameter molded polystyrene discs per stage. At flows of 11.37 to 18.96 cu m/day (3000 to 5000 gpd) and a COD influent of up to 3000 mg/l, 85 to 86 percent COD reduction was obtained by the unit. For BOD influents ranging from 705 mg/l to 1700 mg/l, removals of 95 percent or better were achieved.

Application of the bio-disc treatment system to treatment of municipal wastewater was studied for a year utilizing a unit consisting of ninety-one 1.75 m (5.74 ft) diameter discs made of expanded polystyrene beads (3). The disc section was divided into two stages and received primary treated wastewater from a small municipal plant. The unit also included a final clarifier. At a hydraulic loading of 61 cu m/day/10^3 sq m (1.5 gpd/ft^2) of disc area and 3.2 to 5 rpm, BOD removals of 90 percent were attained. Under these same conditions, suspended solids removal was 80 percent while COD removal efficiency ranged from 80 to 85 percent. Another significant accomplishment of this unit was high ammonia and Kjeldahl nitrogen removal, which ranged from 85 to 95 percent. High nitrification rates were noted. Three stages of fifty 1.22 m (4 ft) diameter plastic discs were used in conjunction with a final clarifier in a study by Borchardt (4) treating municipal waste. During three years of operation, BOD removals of 89 to 94 percent were consistently achieved.

The effects of various operational parameters on the bio-disc process were studied by several workers (1,3,5). These parameters included hydraulic loading, rotational disc speed, sludge recycle, temperature, and staging. The conclusions reached were that organic removal efficiencies increased with increased disc rpm, staging and temperature. It was also found that organic removal efficiencies increased with decreased hydraulic loading and that sludge recycle had very little effect on the process. These three studies also identified organisms present in the disc biomass. The organisms found included <u>Geotrichum candidum</u> and <u>Bacillus cereus</u>, which because of their filamentous nature, functioned as support media;

Zoogloea filipendula, *Pseudomonas denitrificans*, *Aerobacter aerogenes*, *Escherichia coli*, and *Sphaerotilus*. A progression of fauna through successive stages of the bio-disc system was also noted (5). The fauna consisted of free swimming and stalked protozoa, rotifers, and nematodes.

SECTION V

DESCRIPTION OF THE BIO-DISC PLANT AND PROCEDURES

The treatment plant at Camp Horseshoe is shown schematically in Figure 1. The "package" bio-disc section and clarifier before installation are shown in Figure 2 with the clarifier and chlorine contact chamber at the far left. Figure 3 shows the front end of the plant as installed in the building and Figure 4 is a view of the building itself. Waste enters the plant by gravity into a below-ground rectangular septic tank which has a capacity of 33.73 cu m (8900 gallons). The clarified waste then overflows into a 14.02 cu m (3700 gallon) buffer tank. Two 0.152 cu m/min (40 gpm) float-controlled pumps raise the waste from the buffer tank to the bio-disc section of the plant which is located directly above the septic and buffer tanks. From the buffer tank, the waste is first pumped into a feed tank at the head end of the bio-disc unit. An overflow line is provided to permit flows in excess of design flow to return from the feed tank to the buffer tank. Four bucket feeders attached to the main shaft of the disc section collect the waste from the feed tank and feed it to the first bio-disc stage. The bucket feeders are not shown in Figure 1 for sake of clarity but may be seen in Figures 2 and 3. When the feed tank is full or overflowing, the buckets feeders supply a constant maximum rate of sewage to the discs of 33.73 cu m per day (8900 gpd).

The bio-disc unit which was designed to rotate at 2 rpm, has four stages in series with each stage separated by a bulkhead. Each stage contains 22 molded polystyrene discs 1.98 m (6.5 ft) in diameter, 1.27 cm (0.5 inches) thick, and spaced on 2.54 cm (1.0 inch) centers. Waste flows from stage to stage through openings in the bulkheads and then into a final clarifier. Recycle of clarified effluent from the final clarifier to the septic tank is possible through a valved gravity overflow line. Sludge which has settled out is removed by a rotating scraper with hollow connecting arms through which the sludge flows by gravity to the septic tank. Effluent normally passes from the final clarifier to a chlorine contact chamber for disinfection, and then is discharged from the plant.

As mentioned above, the volume of the septic tank is 33.73 cu m (8900 gallons) and that of a buffer tank is 14.02 cu m (3700 gallons). These volumes were based on a design flow of 33.73 cu m/day (8900 gpd) to provide a detention time of one day in the septic tank. However, it will be shown later that the design flow was not achieved during this project and therefore detention times exceeded normal ranges. Table 1 summarizes plant design specifications.

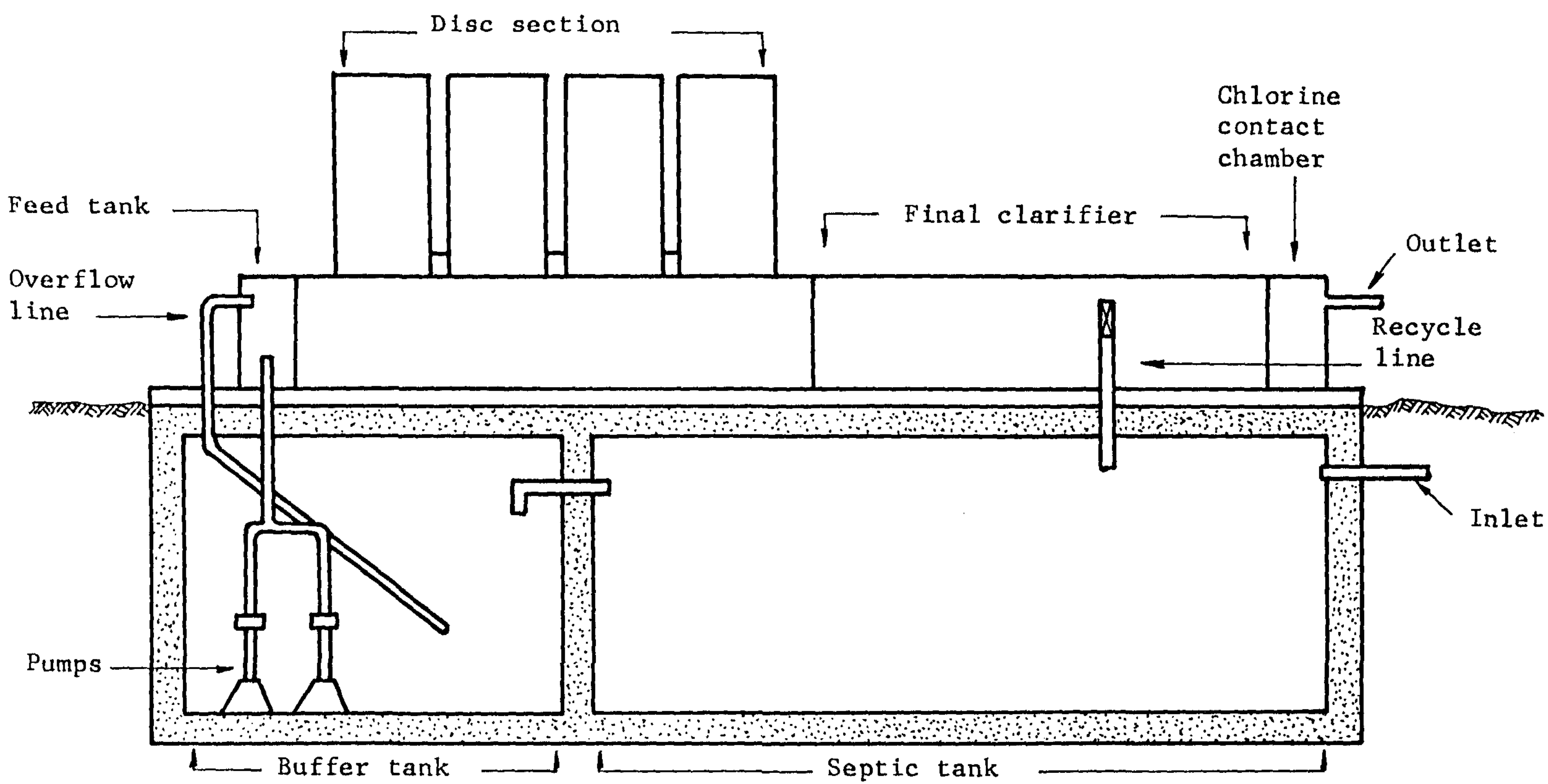

Figure 1. Schematic Diagram Camp Horseshoe Bio-Disc Plant

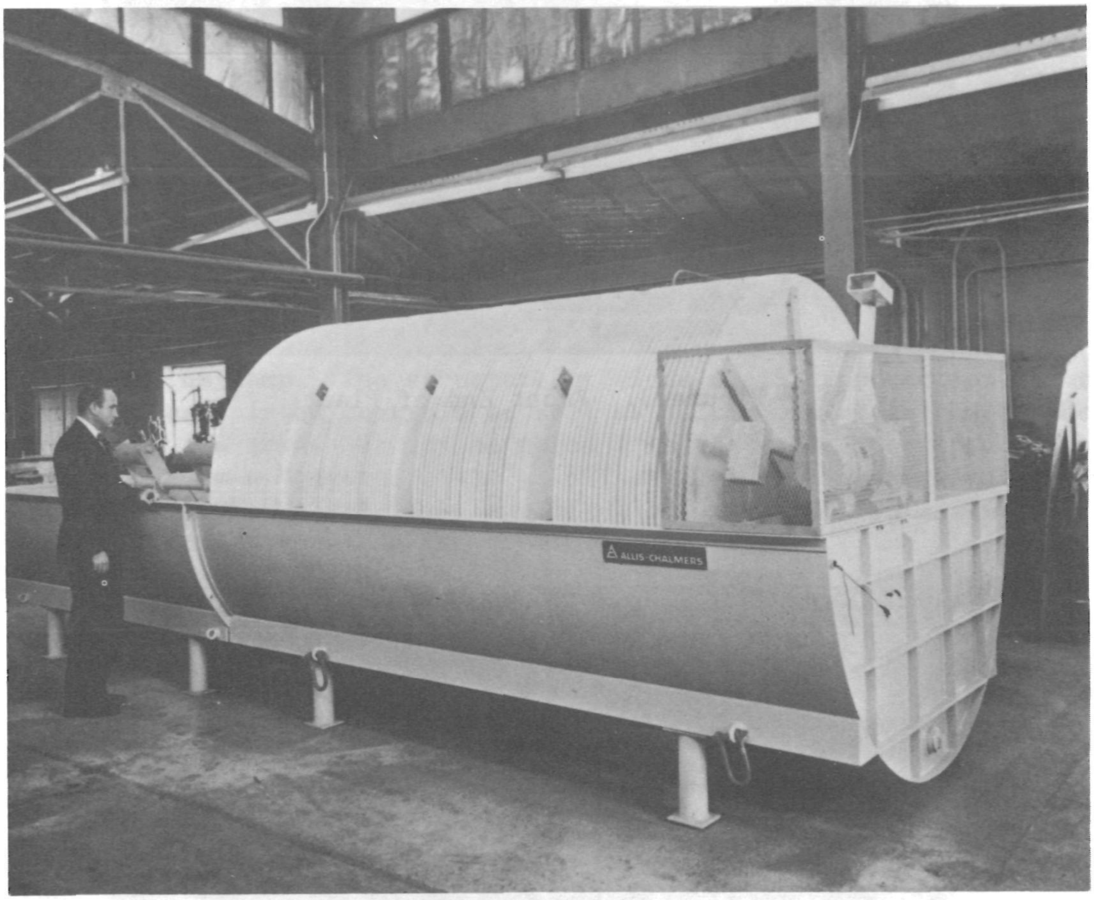

Figure 2. Bio-Disc Section Before Installation

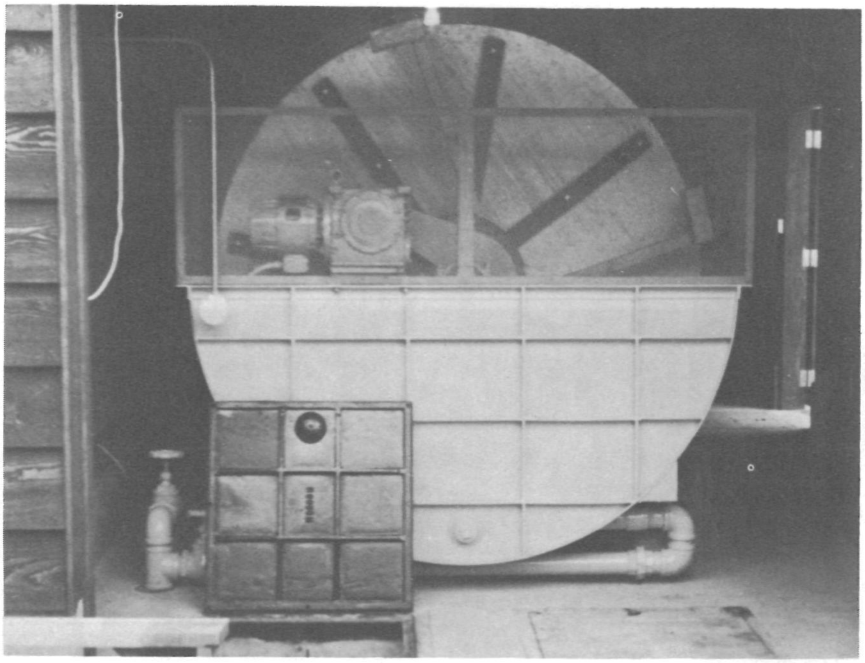

Figure 3. Front End of Plant

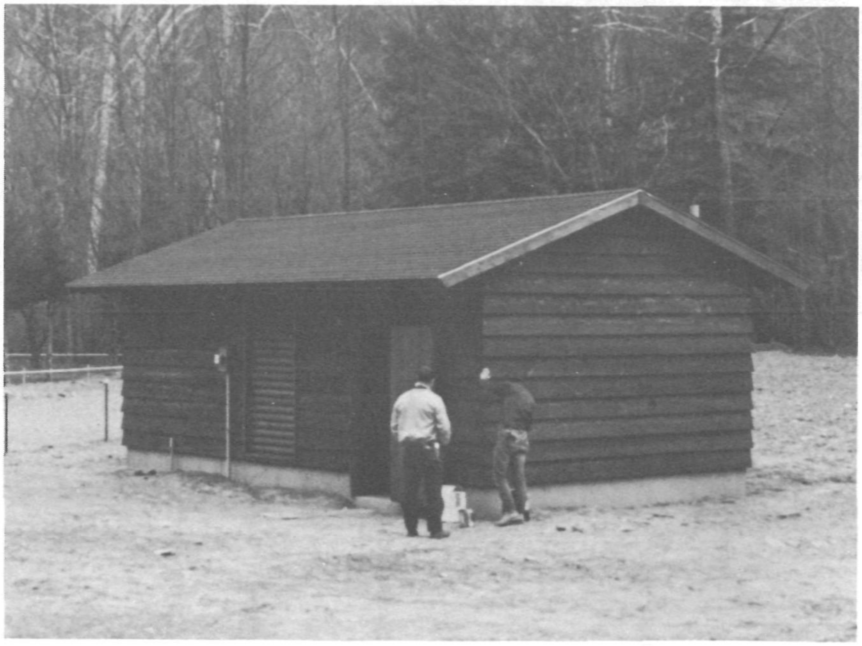

Figure 4. Plant Exterior

TABLE 1

Plant Specifications

1.	Septic Tank Volume	-	33.73 cu m (8900 gallons)
2.	Buffer Tank Volume	-	14.02 cu m (3700 gallons)
3.	Feed Tank Volume	-	0.61 cu m (160 gallons)
4.	Disc Section Volume, Gross	-	4.93 cu m (1300 gallons)
5.	Disc Section Volume, Net*	-	2.16 cu m (570 gallons)
6.	Submerged Volume of Discs	-	2.77 cu m (730 gallons)
7.	Total Effective Disc Area	-	539.80 sq m (5800 ft^2)
8.	Final Clarifier Volume	-	4.62 cu m (1220 gallons)
9.	Final Clarifier Surface Area	-	5.40 sq m (58 ft^2)
10.	Disc Velocity	-	2 rpm
11.	Disc Diameter	-	1.98 m (6.5 feet)
12.	Number of Stages	-	4
13.	Number of Discs per Stage	-	22

*As measured with no biomass growth

The entire above-ground portion of the plant is enclosed by a garage-like structure with an exterior which conforms to the other buildings in the camp. The structure provides weather protection for the unit and its associated controls as well as helping maintain the aesthetic appearance of the area. As may be noted from the above description, the facility is truly a "package plant". All unit operations are performed by the septic tank, buffer tank, and bio-disc unit itself. While the bio-disc section provides secondary biological treatment and final clarification, the septic and buffer tanks provide primary sedimentation, concentration and digestion of raw and biological sludge, solids, storage, flow equalization, and mixture and seeding of the raw waste with the recycled bio-disc sludge.

The sewerage system at the camp serves two toilet and shower buildings, the camp kitchen, and the camp infirmary. There are also three outdoor privies which receive considerable usage and thus reduce the waste load on the plant. The sewer line from the camp area to the plant is 366 m (1200 feet). This relatively short run prevented significant breakup of the sewage solids while flowing to the plant.

Except for a few instances, samples were collected daily throughout the 1972 camping season which ran from June 11 to August 25, or for a total of 11 weeks. Sampling points were as follows:

1.	Raw Sewage	- Manhole directly above plant 15.3 m (50 feet) plant
2.	Settled Sewage	- Buffer Tank
3.	Effluent	- Final Clarifier
4.	Chlorinated Effluent	- Chlorine Contact Chamber

Samples were collected four times daily for compositing at 8:00 A.M., 1:00 P.M., 6:00 P.M., and 10:00 P.M. Grab samples were collected as required for coliform analysis, pH, D.O., and determination of TOC removals across the stages. All samples were manually collected except during the initial week when raw sewage was collected using an automatic sampling device. This procedure was abandoned when it was realized that the sewage was not mascerated well enough for the sampler to function without frequent blockage. It was also found that the sampler did not always lift a representive sample of the entrapped solids to the storage bottle.

The collected samples were stored in an on-site refrigerator. Every other day these samples were composited with respect to flow, placed in an ice chest, and returned to the laboratory for analysis. Transit time to the laboratory was 90 minutes. The analyses performed and frequency of analysis are shown in Table 2. The analyses were performed in a staggered manner with respect to days of the week.

TABLE 2

Analyses Performed and Frequency of Analysis

	Frequency			
Analysis	Raw	Settled	Effluent	Chlorinated Effluent
BOD-5	*2/W	2/W	2/W	2/W
COD	* D	D	D	D
TOC	*4/W	4/W	4/W	
Suspended Solids	4/W	4/W	4/W	
Total Solids	-	-	W	
PO_4-P	* W	W	W	
NO_2-N	W	W	W	
NO_3-N	W	W	W	
NH_3-N	W	W	W	
TKN	W	W	W	
Total Coliform	W	W	W	3/W
Temperature	4/W		4/W	
Dissolved Oxygen	2/W	2/W	2/W	
pH	2/W	2/W	2/W	
Microscopic Observations	Bi-weekly on all stages			
Flow	Recorded continuously			

* D - Daily
* W - Weekly
* 2/W - Two samples per week
* 4/W - Four samples per week

The nature of several of the analyses required that they be performed on site. These included total coliform, temperature, dissolved oxygen, pH, microscopic observation of biomass, and flow. All other analyses were performed in the laboratory. Procedures utilized were in accordance with "Standard Methods for the Examination of Water and Wastewater", Thirteenth Edition, 1971 as shown below.

ANALYSIS	METHOD
BOD-5	Method 219 using the azide modification for the dissolved oxygen measurement
COD	Method 220 - Standard dichromate reflux method
TOC	Method 138A - Tentative combustion - infrared method
Suspended Solids	Method 224C using Gooch crucibles and glass-fiber filter discs
Total Solids	Method 224A
PO_4-P	Digestion by Method 223C-III, 1b, and phosphorus determination by Method 223E, stannous chloride reagent
NO_2-N	Method 134
NO_3-N	Method 213C
organic-N	Method 135-4b
NH_3-N	Method 135-4b with titration of ammonia in the distillate
TKN	Found by addition of organic-N and NH_3-N values
Total Coliform	Method 408A using the single step direct technique with M-Endo liquid medium
Dissolved Oxygen	Method 218F
pH	Method 221

Daily flow was determined by a mass balance around the buffer tank. The specific procedure used is described in Appendix A.

SECTION VI

RESULTS AND DISCUSSION

The treatment facility was constructed and put into operation midway through the 1971 camping season. Hence this study, which was made during the 1972 season, covers the first full summer of plant operation.

WASTEWATER CHARACTERISTICS AND FLOW

Average wastewater characteristics are presented in Table 3. It may be seen that the waste stream encountered, with a raw BOD of 250 mg/l and COD of 563 mg/l, was somewhat stronger than normal municipal wastes. The plant sewerage system serves only rest rooms, showers, and the camp kitchen as previously noted. This, in effect, makes it a separate sanitary sewer system. Also, the camper's activities included frequent use of paints and dyes which added to the waste strength. Extensive use of organic cleansing agents by staff personnel also caused an increase in overall waste strength. Finally, it appeared that very little ground water infiltration entered the plant system except during very heavy rains.

Flow measurements were not obtained until the first of July, about three weeks after the camp went into operation, since flow measuring equipment was not available until that time. Figure 5 shows that the flow of sewage to the treatment plant ranged from zero to 23.95 cu m/day (6320 gpd). Daily flow values are presented in Table 7 of Appendix B. The average flow throughout the summer (less weekends) was 16.88 cu m/day (4455 gpd). The average flow including weekends when no campers were present was 14.63 cu m/day (3860 gpd). These values were considerably below the design capacity of 33.73 cu m/day (8900 gpd). The minimum flows normally occurred on Friday, Saturday, or Sunday, depending upon when the previous week's campers had left. During the weekend of June 15 to 17, three commodes ran continuously, accounting for the absence of the normal minimum.

Figure 6 illustrates the average daily flow pattern. The time increments shown are those used in the sampling schedule. Table 4 relates the average flow of each time period to average daily flow and camp activity. Figure 7 shows a typical hourly flow pattern.

During the summer, the number of people in camp varied from 95 to 221 with an average of 143. The average per capita flow of sewage when campers were present was 0.12 cu m/cap/day (31 gpcd), with a range of 0.09 to 0.15 cu m/cap/day (25 to 39 gpcd). These flow rates were dependent upon the nature and size of the particular group utilizing the camp and, of course, do not reflect use of the privies. The average per capita flow for the entire period (weekends included was 0.10 cu m/cap/day (27 gpcd). Although waste strength was high, low flows offset this to result in only 27.2 gms (0.06 lbs) BOD per capita per day being produced.

TABLE 3

Average Wastewater Characteristics

	Raw	Settled	Effluent	Chlorinated Effluent
BOD-5 (mg/l)	250	210	32	* 50
COD (mg/l)	563	415	120	* 172
TOC (mg/l)	119	103	30	
Suspended Solids (mg/l)	315	31	8	
Total Solids (mg/l)	-	-	355	
PO_4-P (mg/l)	11.3	9.2	9.6	
NO_2-N (mg/l)	T	0.04	3.96	
NO_3-N (mg/l)	0.24	0.37	5.67	
NH_3-N (mg/l)	39.0	41.3	30.9	
TKN (mg/l)	72.5	57.0	35.6	
Total-N (mg/l)	75.8	57.4	45.2	
Total Coliform (per 100 ml)	495×10^6	206×10^6	49×10^6	0.8
Temperature (°F)	66.9	-	67.5	
pH	6.9	6.8	7.0	
Dissolved Oxygen (mg/l)	1.5	2.2	1.8	
Flow (cu m/day)	Daily Average - 16.88 (4455 gpd) excluding weekends Daily Average - 14.63 (3860 gpd) including weekends			

Daily values for the above parameters are contained in Tables 6 and 7 of Appendix B.

*See Appendix C for discussion of these values.

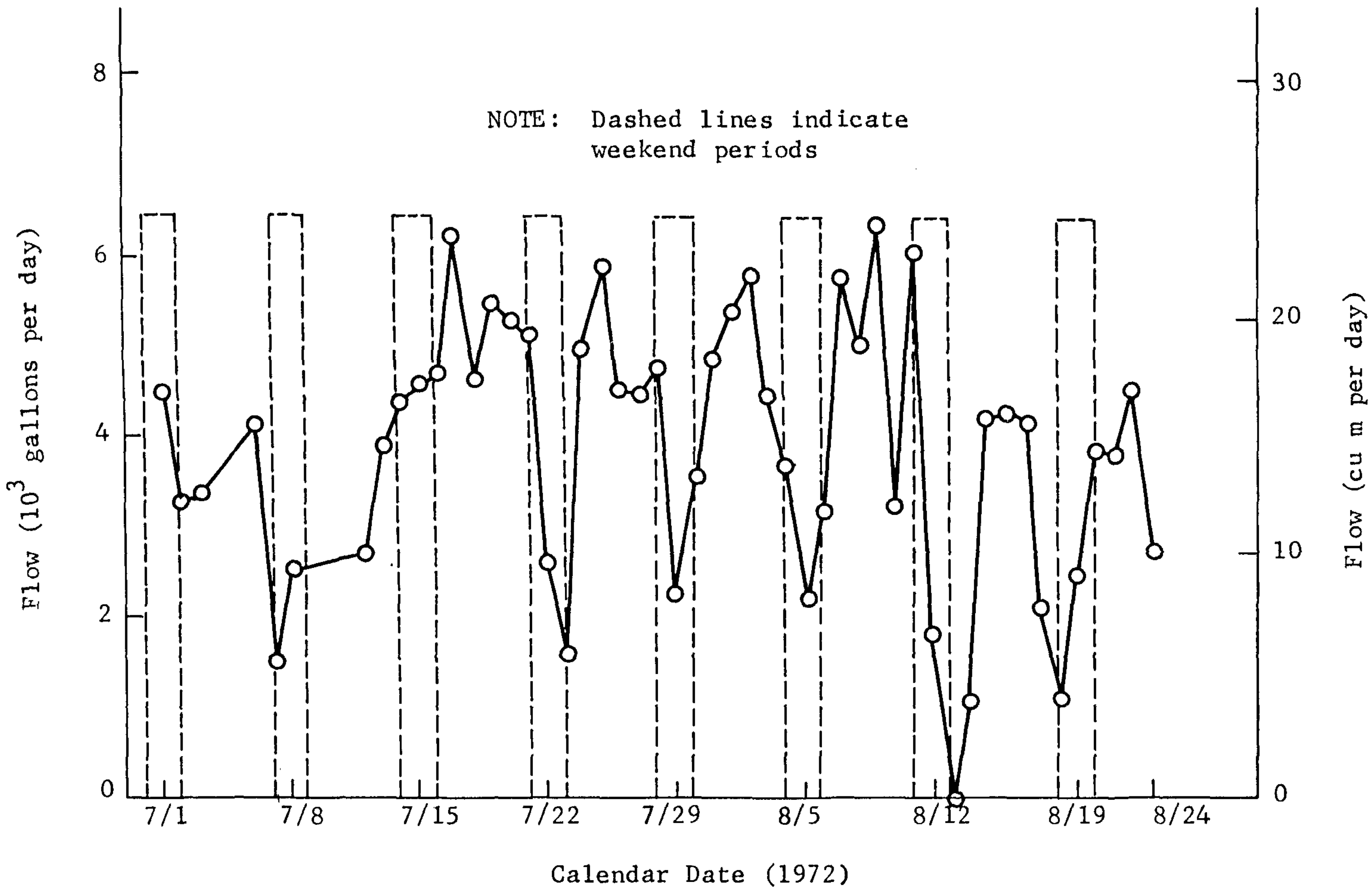

Figure 5. Daily Sewage Flow

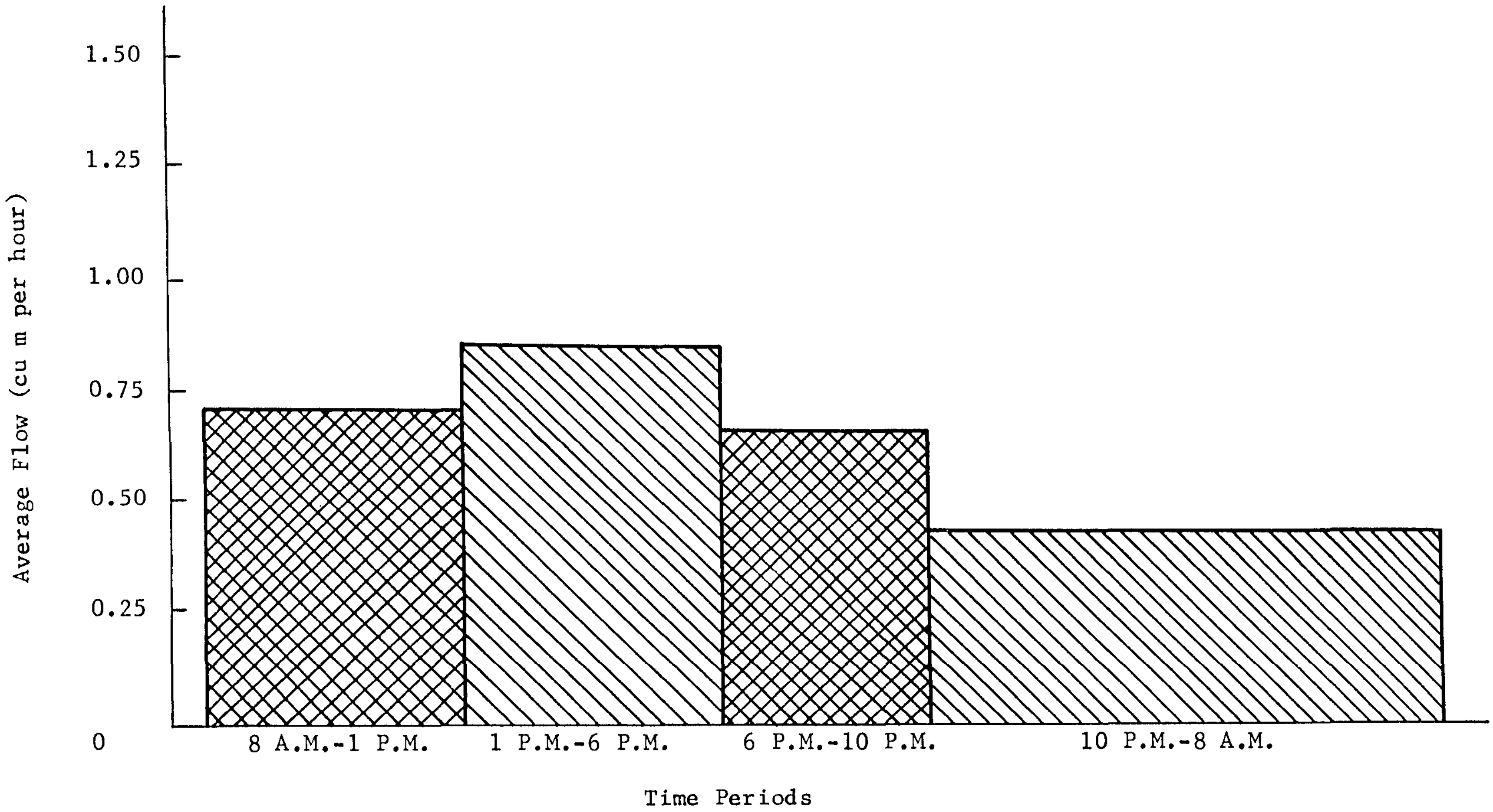

Figure 6. Daily Flow Pattern

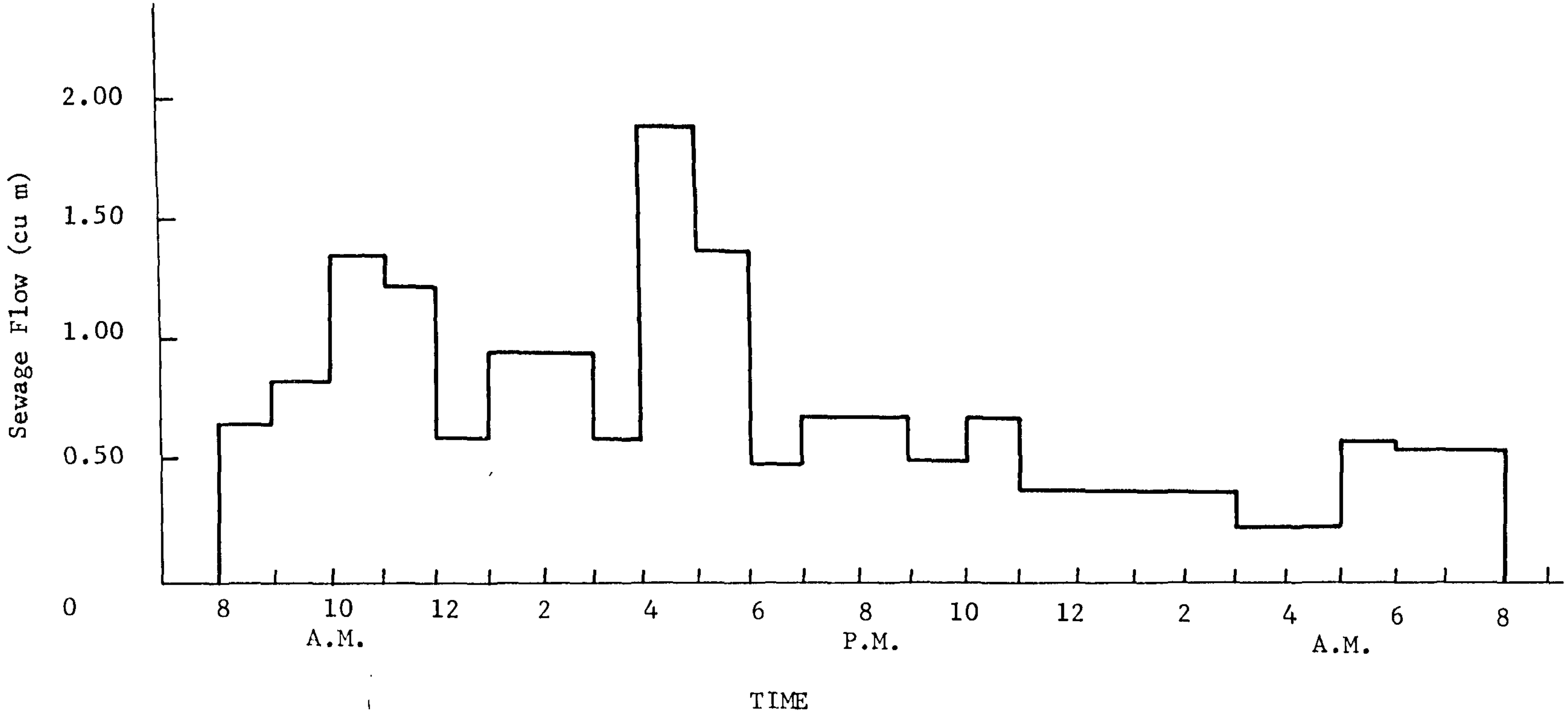

Figure 7. Typical Hourly Flow Pattern Using Sample Day of June 27, 1972

TABLE 4

Relation of Daily Flow Pattern to Total Flow and Camp Activity

Time Period	Average Flow cu m/hr	Percent of Average Daily Flow	Normal Camp Activity
8 A.M. - 1 P.M.	0.69	24	Morning cleanup Breakfast Lunch
1 P.M. - 6 P.M.	0.85	29	Dinner Some showers
6 P.M. - 10 P.M.	0.65	17	Majority of showers
10 P.M. - 8 A.M.	0.43	30	Minimum Activity

Note: 1 cu m/hr = 264.1 gph

Solids production was 36.3 gms (0.08 lbs.) SS per capita per day. These values were calculated for periods when campers were present. Other workers have reported daily flows at similar camps with central bath and toilet facilities and no privies to be 0.15 to 0.19 cu m/cap/day (40 to 50 gpcd). The Camp Horseshoe per capita flow is comparable to this range considering that flow from the privies was not measured.

Rainfall data for the Camp Horseshoe area was obtained from the U. S. Forest Service at Elkins, West Virginia, and analyzed for correlation to flow and sewage strength. No apparent correlation existed. Heavy rains caused by Hurricane Agnes in June caused a hydraulic overload on the plant. Because flow measuring equipment was not yet installed, actual flow was not measured, but the septic and buffer tanks were surcharged for a period of about one day. The bio-disc unit itself was not overloaded because of its fixed feed rate. General flooding conditions and high water flowing in a culvert between the camp area and the plant made it impossible to collect samples during these periods of heavy rain. Therefore no data was available to determine the effect of the rain on plant performance at the time. No washout of the biomass occurred and samples collected after the rains subsided did not reflect any dilution effects.

START-UP AND OVERALL PLANT PERFORMANCE

On June 11th, the first regular group of campers arrived and the plant began to discharge an effluent. This date was taken as plant start-up since it marked the beginning of plant operation under continuous-flow conditions. However the plant received its first sewage of the season on May 26 with the arrival of 100 weekend campers. Two weeks later on June 9, approximately 7.58 cu m (2000 gallons) of sewage and sludge from a nearby National Forest Recreation Area were discharged into the camp's sewer system. The waste thus received during this pre-start-up period, was continuously recirculated through the plant to begin seeding the discs.

By the end of the second week of operation (June 25th), biological growth had reached a thickness of 0.32 cm (1/8 inch) in some areas at the front of the first stage and 0.16 cm (1/16 inch) at the rear of this stage. The subsequent stages developed only a very thin coating of growth during this time.

Organic removals during the first week were quite erratic as may be noted in Appendix B, Table 6. During the early part of the week, the settled BOD, COD and SS concentrations were higher than the raw. In addition the effluent values during this period suggested negative removals through the plant. These unusual values resulted, in part, from problems with an automatic sampler on the raw stream as discussed in Section V. The high effluent concentrations are thought to be primarily due to a tank load of sewage and sludge which was slug-discharged in the plant on June 9 as noted above. As a result of these problems, the data from the first week was not used in calculating the averages in Table 3 nor in plotting subsequent curves.

Figures 8, 9, and 10 show overall plant removals of BOD, COD, and SS for the entire summer season. It may be seen that after one week of operation the percent removals of these parameters had reached 91.7, 98.5 and 92.5 respectively. The average values during the summer of BOD, COD, and SS were 87.5, 79.0, and 97.5 percent. Thus, overall plant removal had reached essentially average efficiency after the first full week of continuous operation. It will be shown later however, that removals across the disc section continued to increase up to about the fifth or sixth week.

Inspection of Figures 8 and 9 shows that while overall BOD and COD removals were reasonably stable during the first five to six weeks of operation, they became erratic during the final weeks of the project. It will be shown below that the operation of the septic tank was primarily responsible for these erratic removal efficiencies during the latter part of the summer. It is interesting to note from Figure 10 that SS removals were quite consistent after about the third week of operation, remaining well above 95 percent for the balance of the summer. Daily values of BOD, COD, TOC, and SS are plotted in Appendix B, Figures 19 through 30 for reference.

Influence of Septic Tank Operation on Plant Performance

The septic tank had been pumped out after the first summer's operation and hence contained very little sludge during the initial weeks of operation. As a result, the upper portion of the tank remained aerobic (See Appendix B, Table 6) and very little gas production occurred in the early weeks. About the sixth week of plant operation, the majority of the tank was anaerobic as indicated by the black color of the waste, a small

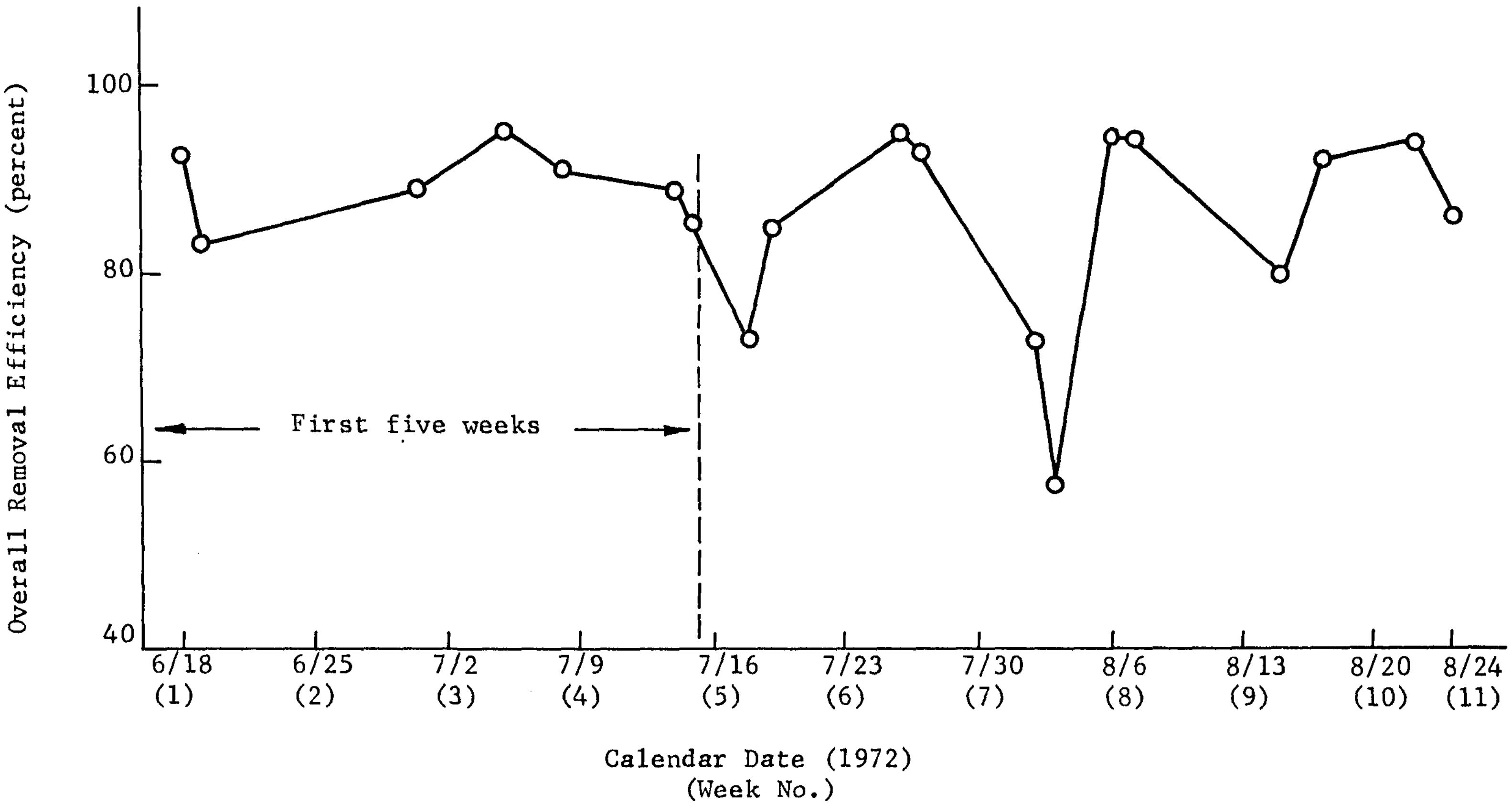

Figure 8. Daily Overall BOD Removal Efficiencies

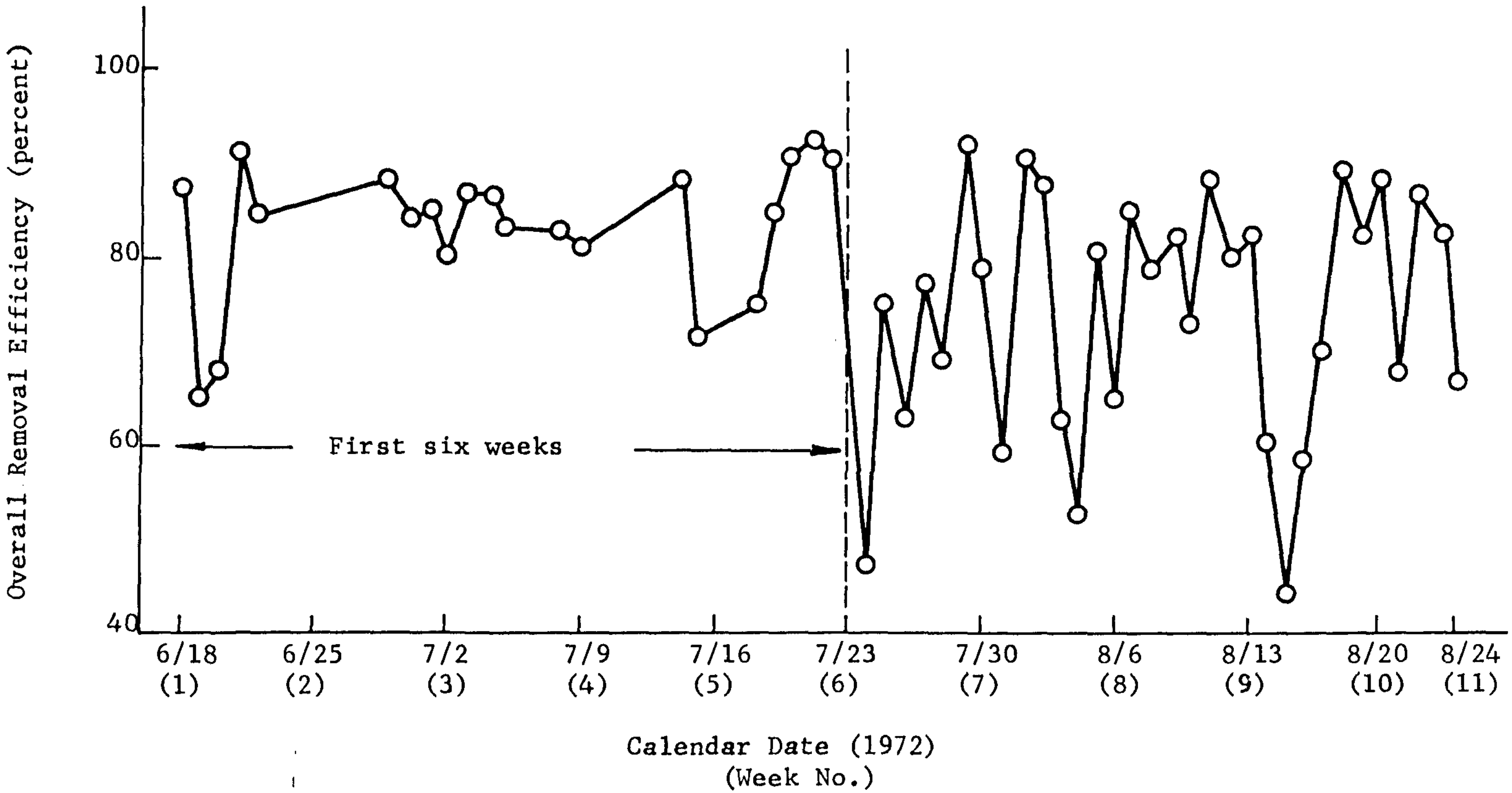

Figure 9. Daily Overall COD Removal Efficiencies

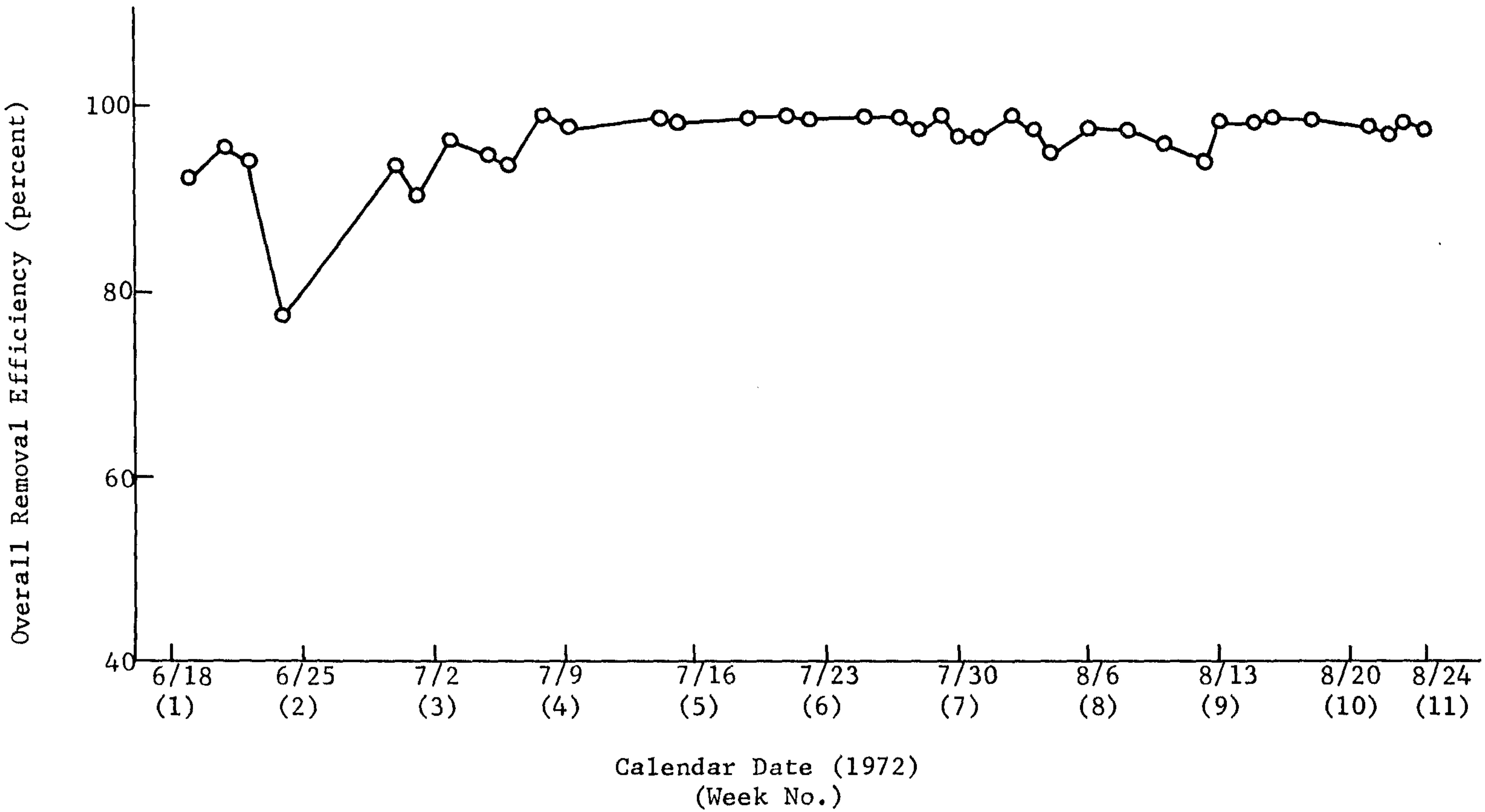

Figure 10. Daily Overall Suspended Solids Removal Efficiencies

amount of bubbling at the surface, and only traces of dissolved oxygen in the septic tank and its effluent. However, the bubbling observed was much less vigorous than that normally observed in a well operating digester. Another indication of increasing anaerobic activity in the septic tank was pH. During the first five weeks of operation, "average weekly pH values increased slightly or remained the same, as the raw waste passed through the septic tank. However, from the sixth to the tenth week, "average" weekly pH fell from 0.1 to 0.5 of a unit, or remained the same.

To gain further insight into the effect of septic tank operation on plant efficiency a comparison was made of waste strength through the plant for weeks 1 through 5 (June 18 to July 22) and 6 through 11 (July 23 to August 24). The data are tabulated in Appendix B, Table 8, and plotted in Figures 11 and 12. Figure 11 reveals that the average values of the septic tank (settled) BOD, COD, and TOC were considerably higher during the second time period than the first. For example, settled COD increased from an average of 249 mg/l in the first time frame to 559 mg/l in the second period. This was also true of the effluent values although to a lesser extent. It may be seen that the average effluent COD increased from 93 to 144 mg/l from the first to the second period. Examination of Figure 11 also shows that while the raw organic strength also increased during the second time frame, the increase was not of sufficient magnitude to account for the large increase in the septic tank values. Figure 12 shows that the SS values, in opposition to the above mentioned trends, were actually lower during the second time period than the first. The percent removal values for the septic tank and overall plant for the two time periods, and the entire summer are presented in Table 5. The Table further points out the dramatic change in septic tank efficiency over the two periods and the resultant influence on overall removal. For example, COD removal in the septic tank decreased from 49.6 to 9.1 percent from the first to the second period. The influence on overall removal, which decreased respectively from 91.2 to 76.5 percent was smaller, but certainly of consequence. It should be noted that the overall organic removals are somewhat below those reported in other bio-disc studies (3,5,6,7). When considering septic tank operation, it must be kept in mind that it also received excess biological solids which sloughed off of the bio-discs. Since the film on the discs was still in the process of forming during the early weeks, very little would have been sent to the septic tank until the last five weeks. This undoubtedly contributed to the higher organic strength of the waste leaving the septic tank during the latter portion of the study.

The high SS removal in the septic tank (90 percent) was due to two main factors. These factors were long the detention times resulting from the low flow (two days at average flow), and lack of vigorous bubbling which normally occurs in anaerobic units.

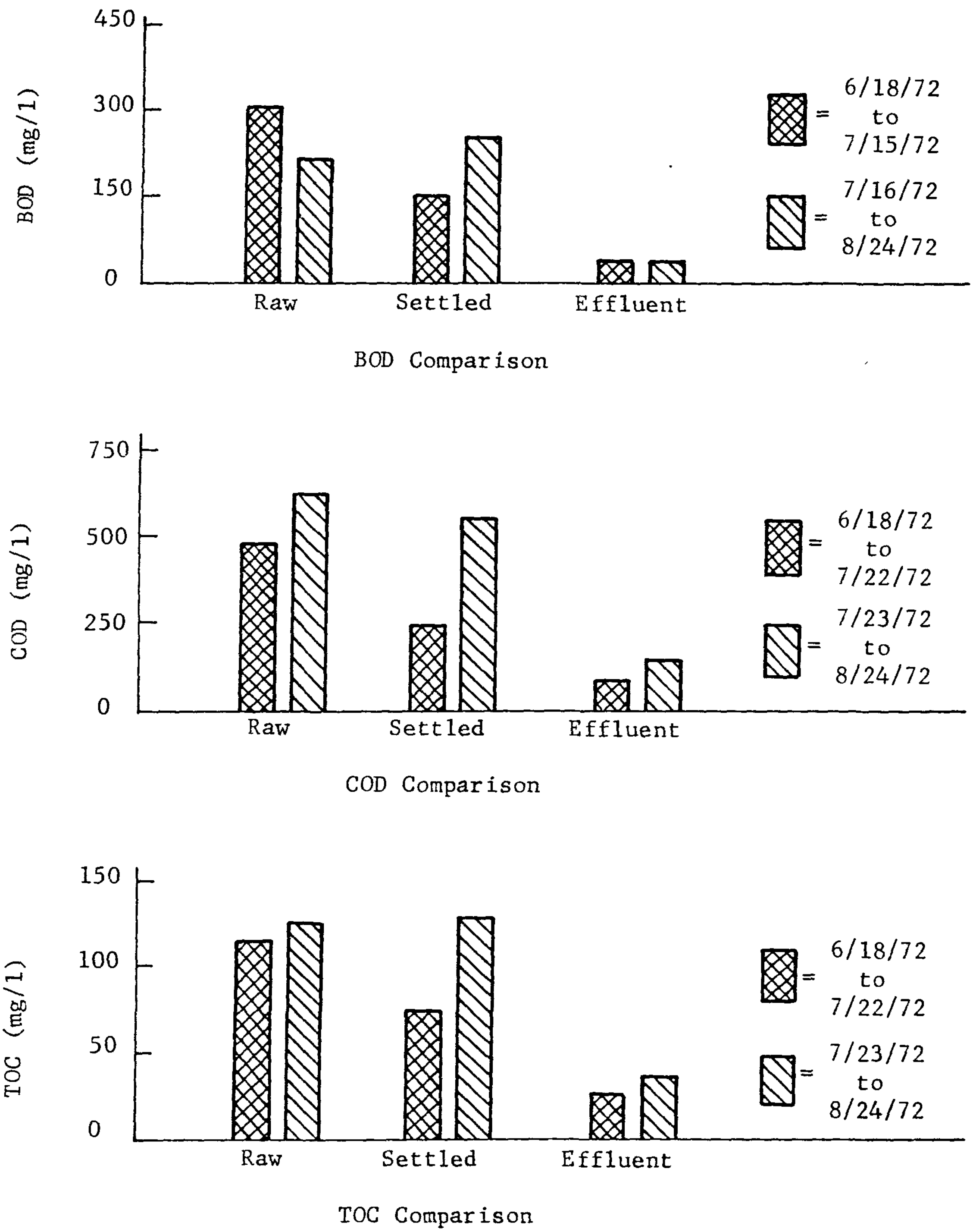

Figure 11. Comparison of Wastewater Characteristics During Two Time Segments of Study

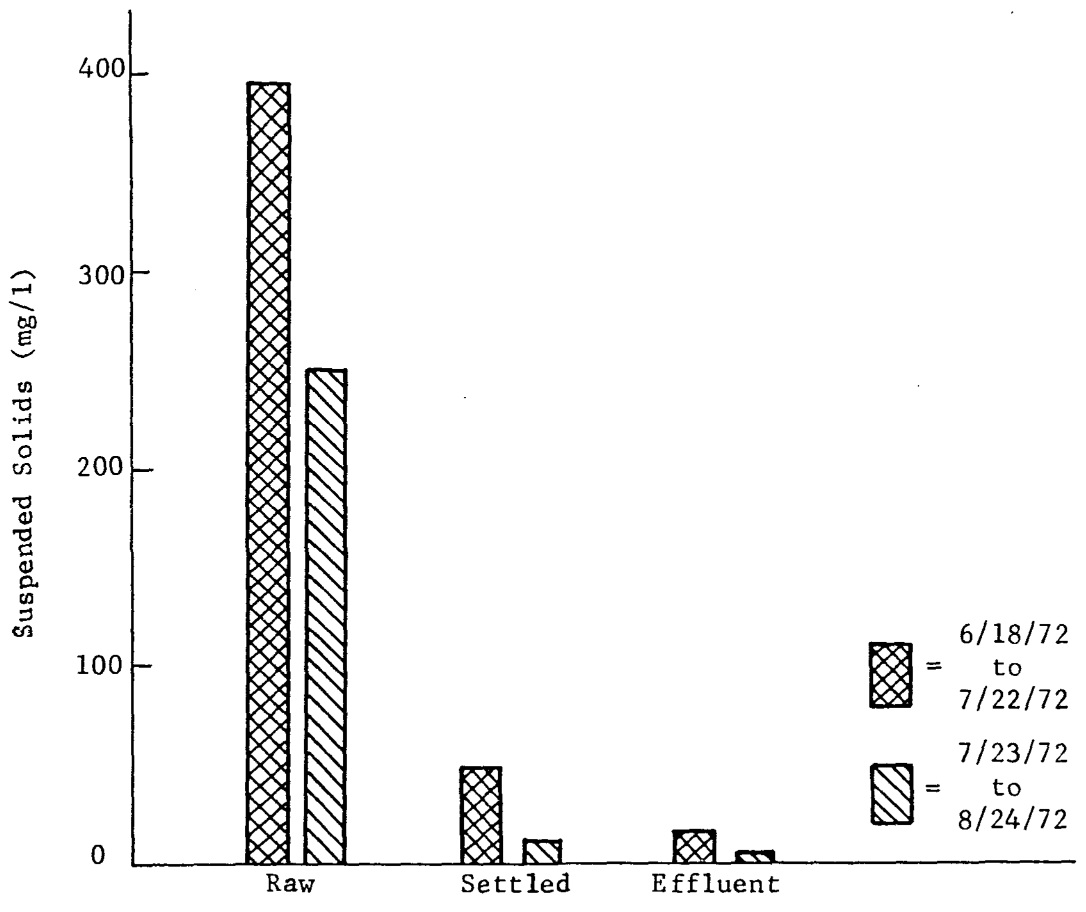

Figure 12. Comparison of Suspended Solids Values During Two Time Segments of Study

TABLE 5

Comparison of Removal Efficiencies for Two Time Periods

	Septic Tank Removal			Overall Removal		
	6/18-7/22	7/23-8/24	Average During Summer	6/18-7/22	7/23-7/24	Average During Summer
BOD	50.6	No Removal	16.0	89.2	85.0	87.5
COD	49.6	9.1	26.3	91.2	76.5	78.7
TOC	34.5	No Removal	13.4	76.1	73.2	74.8
SS	87.3	95	90.2	97.0	98.8	97.5

The above results point to a release of soluble organics from the digesting sludge in the septic tank during the last five to six weeks of operation. This release can probably best be explained by the occurrence of incomplete anaerobic digestion in the septic tank. As discussed by Eckenfelder and O'Connor (8), complete anaerobic digestion occurs in three phases. These phases are the acid fermentation phase, the acid regression phase, and the alkaline fermentation phase, also known as the methane phase. In the acid fermentation phase, complex organics are hydrolyzed, fermented, and biologically converted to less complex organics such as acetic and propionic acid. Nitrogenous compounds are converted to ammonia to some degree in this phase also. In the acid regression phase, the volatile and organic acids, and soluble nitrogenous compounds are further broken down to form ammonia, amines, acid carbonates, and small quantities of carbon dioxide, nitrogen, methane, and hydrogen. This activity is accomplished by a group of facultative and anaerobic bacteria called the acid formers. The third, or methane phase, occurs when a highly specialized and sensitive group of bacteria, known as the methane formers, continue the fermentation of the volatile and organic acids to methane, and carbon dioxide, thus stabilizing the waste. If only the acid phases of anaerobic digestion are taking place, and no methane formation occurs, the resulting supernatant would be high in soluble organics such as the above mentioned volatile and organic acids, and in ammonia.

The occurrence of incomplete anaerobic digestion was indicated by an increase in soluble organics, as well as by the lack of continuous vigorous bubbling at the septic tank surface. Since the temperature of the tank never exceeded 70°F, and the camp only lasted for 11 weeks, the rapid growth of methane forming bacteria would not be favored. As noted earlier, pH also fell through the septic tank during the latter period, again pointing to incomplete digestion. It is recommended that 1 to 2 feet of well digested sludge from a functioning digester be pumped into the septic tank at the start of each season to encourage good digestion from the outset and avoid the problems mentioned above.

BIO-DISC UNIT PERFORMANCE

Figure 13 shows that the average weekly BOD and COD percent removals through the bio-disc tended to increase with time up to about the fifth to sixth week of operation. This result seems to correspond to biomass development, which was essentially complete by the beginning of the fifth week when all stages reached their maximum coverage. As noted in a previous section, after about the fifth or sixth week, the waste fed to the bio-disc was septic and increased in strength due to decreased removals in the septic tank. Despite these problems, the bio-disc provided treatment that was comparable to conventional activated sludge systems. The average BOD of the settled and effluent waste respectively was 210 and 32 mg/l (see Table 3) yielding an efficiency of 85 percent. This represents 82 percent of the total BOD removal. The unit removal of 85 percent was somewhat lower than that provided by bio-disc units treating fresh wastes which have been reported (3,5,6,7) to achieve 90 percent removal of BOD applied. Considering COD removal, 71 percent was removed across the bio-disc unit resulting in an average effluent value of 120 mg/l. This represents a removal of 67 percent of the total COD applied to the plant. TOC removal through the unit was 71 percent or 82 percent of the total TOC removed.

Since the actual average flow of 14.63 cu m/day (3860 gpd) was well below design flow 33.73 cu m/day (8900 gpd), the bio-disc and final clarifier had relatively high detention times of 3.5 hours and 7.6 hours respectively. The biological solids entering the clarifier settled well providing an average SS concentration in the plant effluent of 8 mg/l. Overflow rate in the clarifier was extremely low at 3.12 cu m/day/sq m (66.5 gpd/ft^2).

Organic Loading

Although the strength of the waste applied to the bio-disc unit was relatively high for a domestic waste, low flows tempered this effect to produce low organic loadings. As will be shown later, an estimated organic load factor (O.L.F.) for this plant was 0.08 gm BOD/day/gm MLSS. This value is considerably below the normal range of 0.25-0.45 in which conventional activated sludge plants operate. It is however, within the normal operating range of extended aeration activated sludge plants.

A comparison to the organic loading on a unit studied by-Antonie (3) was made by expressing organic loading as gms BOD applied to the discs per day per square meter of disc surface area. The average loading at the Horseshoe Plant was 6.58 gms BOD/day/sq m (1.35 lb BOD/day/10^3 ft^2). The majority of loadings in Antonie's study ranged from 9.27 to 15.12 gms BOD/day/sq m (1.9 to 3.1 lbs BOD/day/10^3 ft^2). These values and the O.L.F. expressed above indicated that the Horseshoe Plant operated at relatively low organic loadings. Because of these low loadings, the bacteria on the discs existed in a food limiting environment. In such an environment, removal of organics is affected only by the ability of the bacteria to

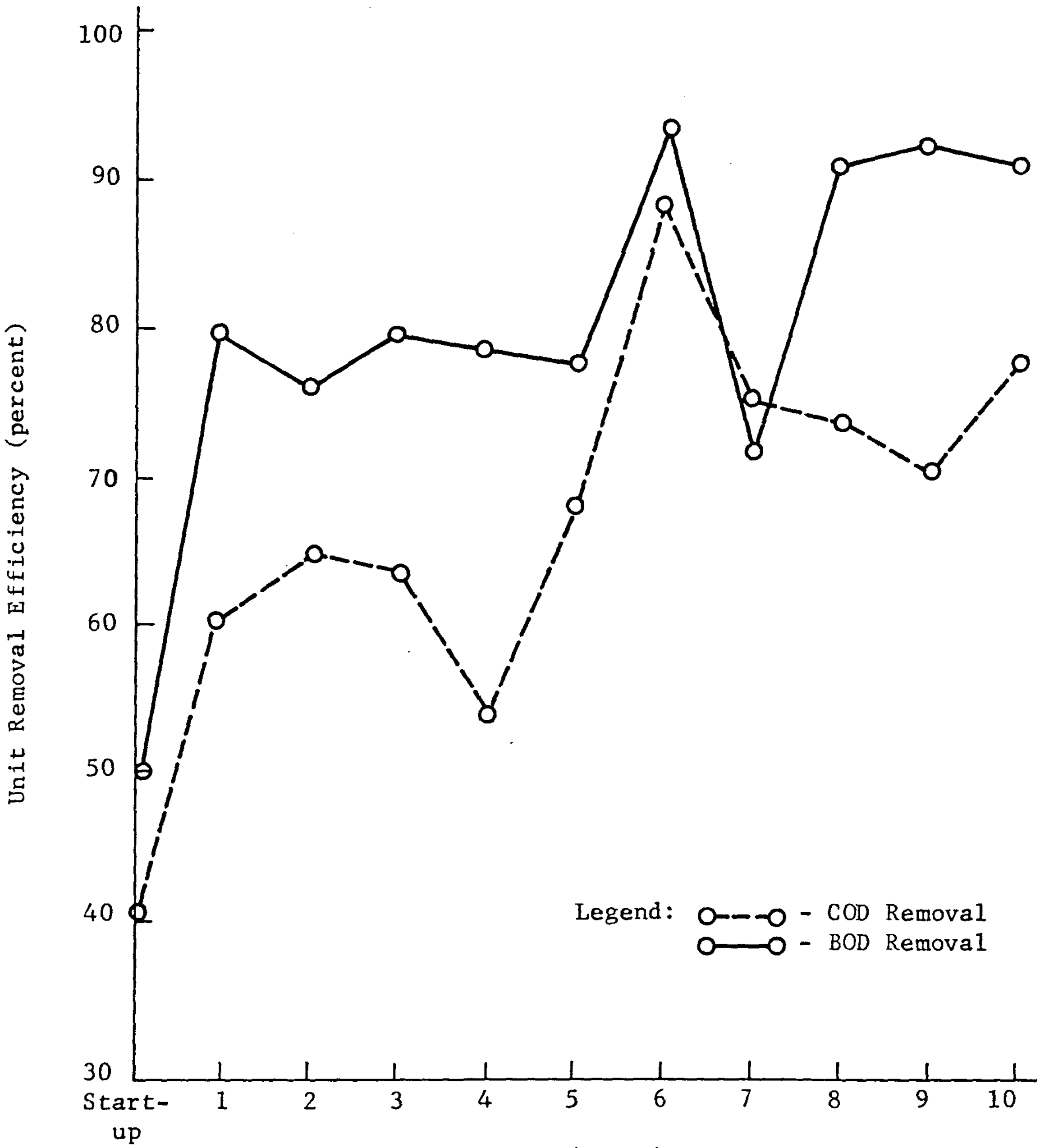

Figure 13. Average Weekly Bio-Disc Unit Removal Efficiencies

metabolize the waste, if no reaction limiting conditions (such as low temperature, D.O., or toxicity) exist. Since organic loadings were low and no rate limiting conditions existed, the operation of the bio-disc unit was relatively unaffected by the variation in organic loading encountered. Thus, plots of BOD, COD, and TOC percent removal versus organic loading expressed as gm of BOD, COD, and TOC applied per day showed no trend and are not presented here.

Hydraulic Loading

Figure 14 shows the effect of hydraulic loading on BOD removal efficiency. Hydraulic loading is expressed as cubic meters of sewage applied to the discs daily per thousand square meters of disc surface area cu m/day/10^3 sq m. Hydraulic loadings at the Camp Horseshoe Plant were low, ranging from 4.07 to 40.7 cu m/day/10^3 sq m (0.1 to 1.0 gpd/ft^2). Loadings reported in other studies have ranged from 40.7 to 203.5 cu m/day/10^3 sq m (1 to 5 gpd/ft^2) (3,6) and 81.4 to 488.4 cu m/day/10^3 sq m (2 to 12 gpd/ft^2) (7).

As may be seen from Figure 14, BOD removal efficiencies across the unit decreased as hydraulic loading increased. This relationship was reported in other studies (3,6,7). The relationship is fairly well defined at the high end of the loading range and poorly defined at the low end. As with organic loadings, low hydraulic loadings have little effect on disc performance. It should be pointed out that the entire range encountered corresponded to the lowest range investigated by Antonie (3). In this range, Antonie's data similarly reflected very little effect of hydraulic loading on BOD removal. Figure 15 illustrates the effect of hydraulic loading on COD removal. No trend of the data is strongly defined. Viewing the data as a band suggests that increased hydraulic loading reduced removal efficiency of the process. Investigation of TOC relationships revealed that hydraulic loading had no effect on this parameter.

Biomass Characteristics

Biomass development on the discs took place rapidly. The development of the growth progressed stage by stage, with all stages being essentially 100 percent covered by the end of the fourth week. Average thicknesses of growth were as follows: first stage - 0.32 cm (1/8 inch); second stage - 0.32 cm (1/8 inch); third stage - 0.16 cm (1/16 inch); fourth stage - 0.16 cm (1/16 inch). The maximum growth observed was 0.48 cm (3/16 inch) in some areas of the front disc. The minimum growth noted was 0.08 cm (1/32 inch) in some areas of the rear disc.

Relatively large amounts of the growth 6.45 cm^2 (covering approximately one square inch) would occasionally slough off, leaving bare spots on the discs. This was most predominant on the very first disc of the unit. The overall appearance of the biomass ranged from a black

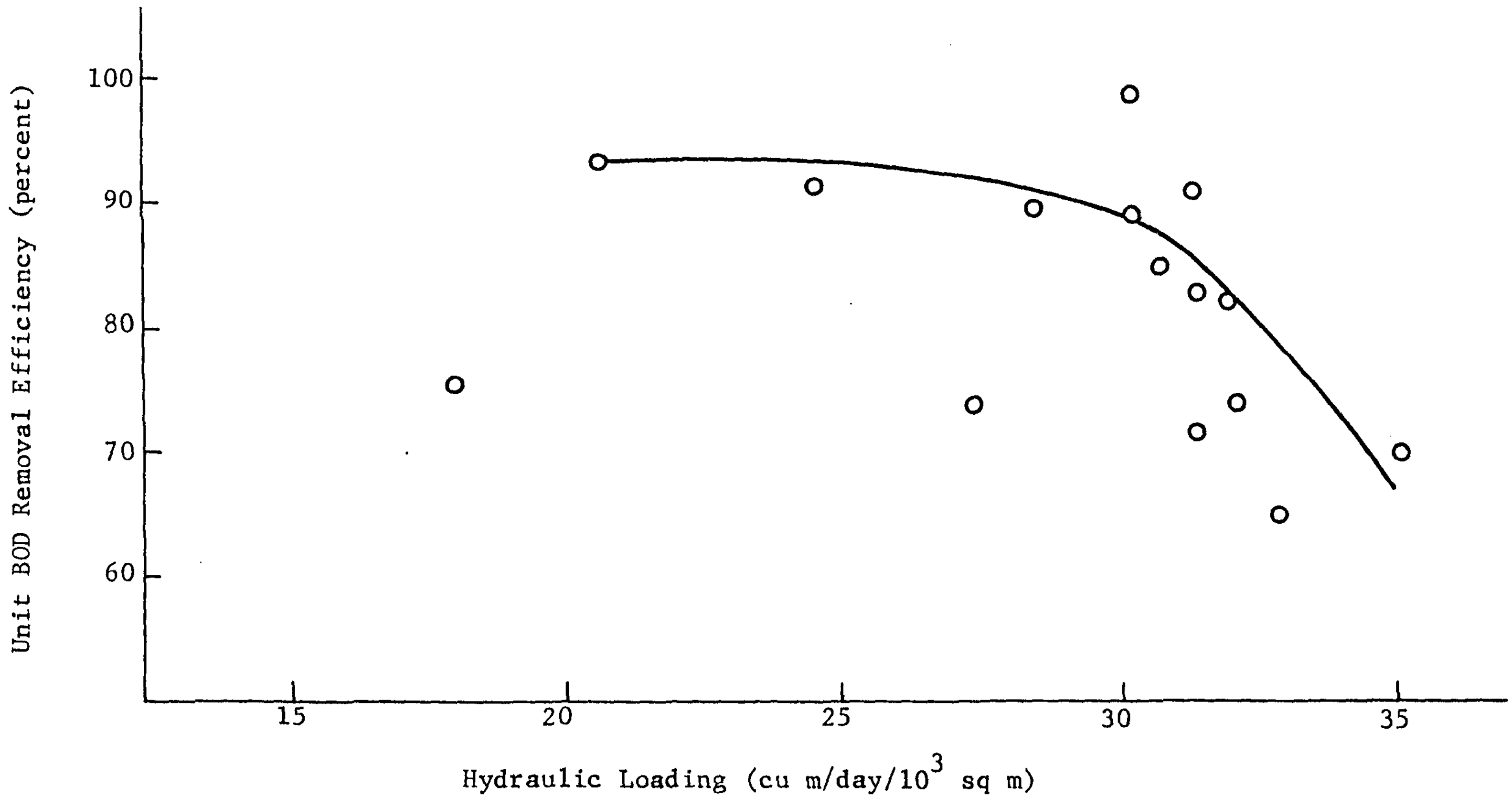

Figure 14. Effect of Hydraulic Loading on Bio-Disc Unit BOD Removal Efficiency

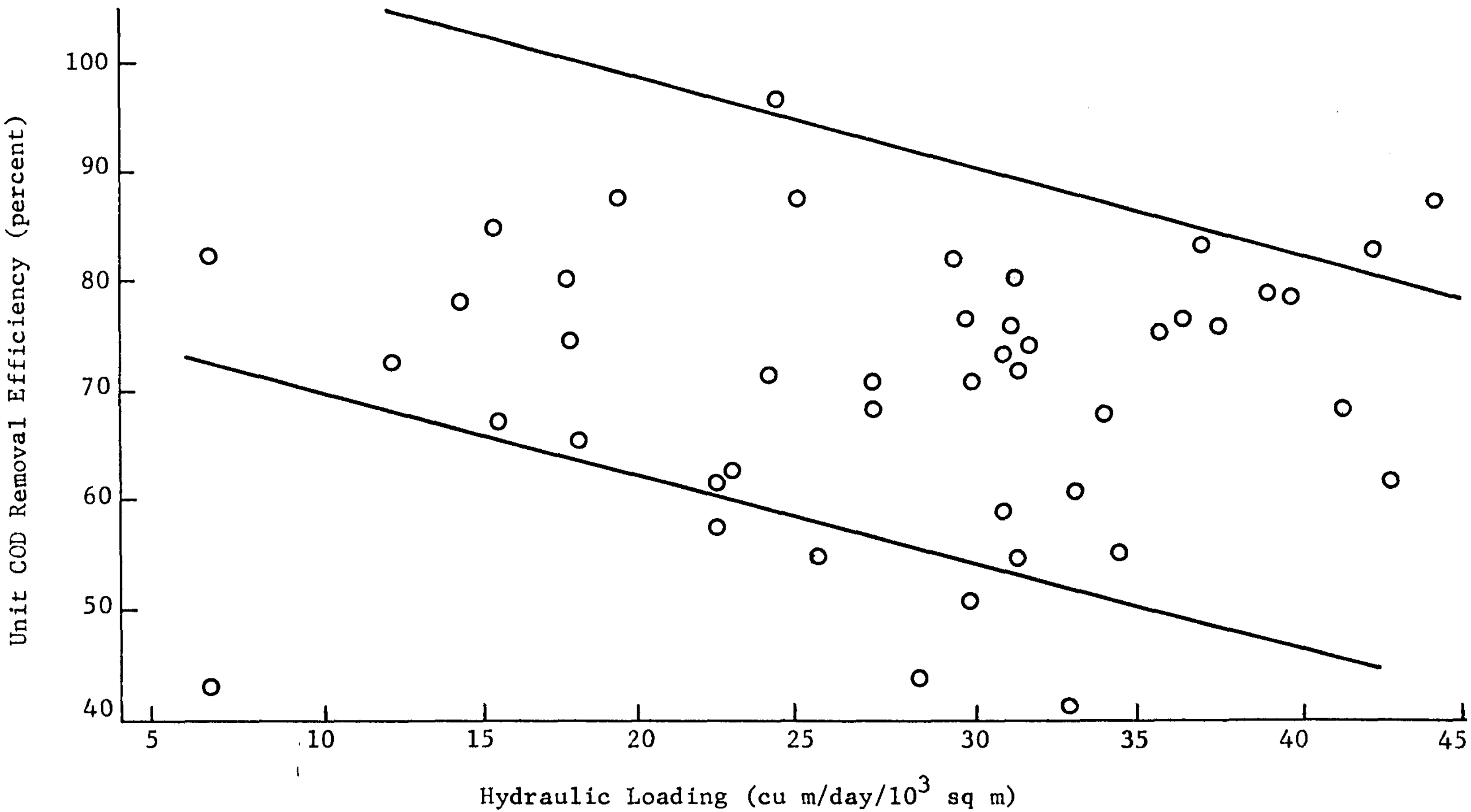

Figure 15. Effect of Hydraulic Loading on Bio-Disc Unit COD Removal Efficiency

stringy growth with white gelatinous patches on first and second stages, to a greenish-brown slime on the third and fourth stages.

Following the method of Borchardt (4), the MLVSS was calculated to be 30,000 mg/l at the front of the unit, and 6000 mg/l at the rear. Random patches of known area of biomass were scraped from the discs and the weight of the biomass determined. Knowing the total area of discs and the volume of liquid in the tank, the MLVSS concentration could be readily calculated. This technique was utilized one time taking three 6.45 sq cm (1 square inch) patches of growth and using the average weight for calculation. The biomass weight found in this way was used to calculate the O.L.F. of 0.08 gm BOD/day/gm MLSS mentioned earlier.

The progression of fauna noted by Torpey, et. al. (5) was evident in this plant. Both Sphaerotilus and zoogloeal bacteria were present on all discs, the Sphaerotilus probably functioning as the support media. Other organisms present included ciliates (Paramecium, Carachesium, Vorticella, Tintinnidium), rotifers (Philodina, Epiphanes), and nematodes.

Generally speaking, the non-bacterial organisms present increased across the stages, both in types and numbers. Ciliates first appeared in the middle of the first stage, rotifers at the end of the first stage, and nematodes at the beginning of the second stage. Overall, the predominant protozoans were the stalked ciliates. The last stage of the bio-disc unit, particularly the final disc, had many bare spots, possibly resulting from animal predation of the higher organisms on the bacterial slime. Such a progression of fauna is indicative of relatively efficient and stable biological treatment.

Staging Effects

In order to determine the effect of staging on organic removals, a series of eight grab samples through the disc section was taken over the last three weeks of operation. These samples were analyzed for TOC content after 30 minutes of quiescent settling. Figure 16 illustrates the results showing that average cumulative removals across the stages were as follows: first stage - 28.5 percent; second stage - 42.5 percent; third stage - 57 percent; fourth stage - 59 percent. As can be seen, the incremental TOC removal between the third and fourth stages was quite low.

Turbulence generated by the rotation of the discs resulted in a definite increase in the dissolved oxygen content of the mixed liquor across the stages. This effect is illustrated in Figure 17 where dissolved oxygen values at the end of each stage are presented. The D.O. is shown to increase from 0.8 mg/l in the settled feed to 2.8 mg/l at the last stage. The dissolved oxygen content usually fell through the final clarifier due to the long detention (7.6 hours) in this unit. The increasing dissolved oxygen levels through the bio-disc served to support the progression of fauna through the stages noted earlier. The average dissolved oxygen content of the feed tank (stage No. 0 on Figure 17) was

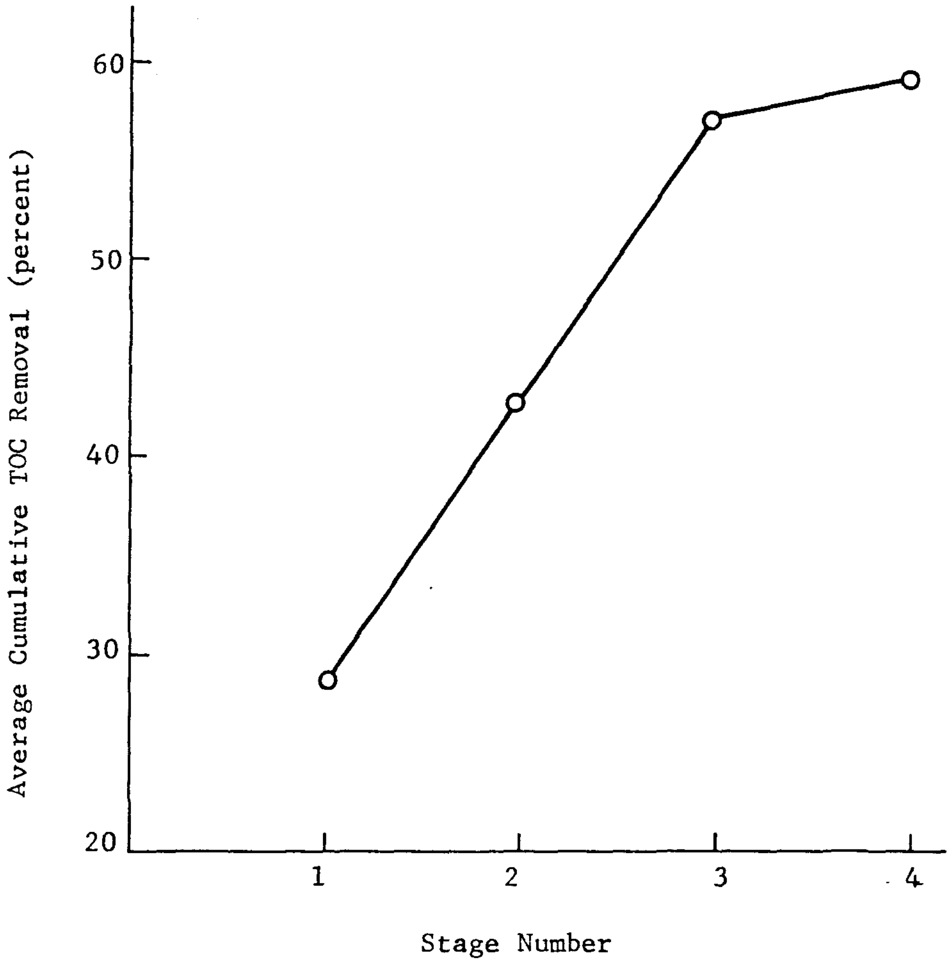

Figure 16. Effect of Staging on TOC Removal

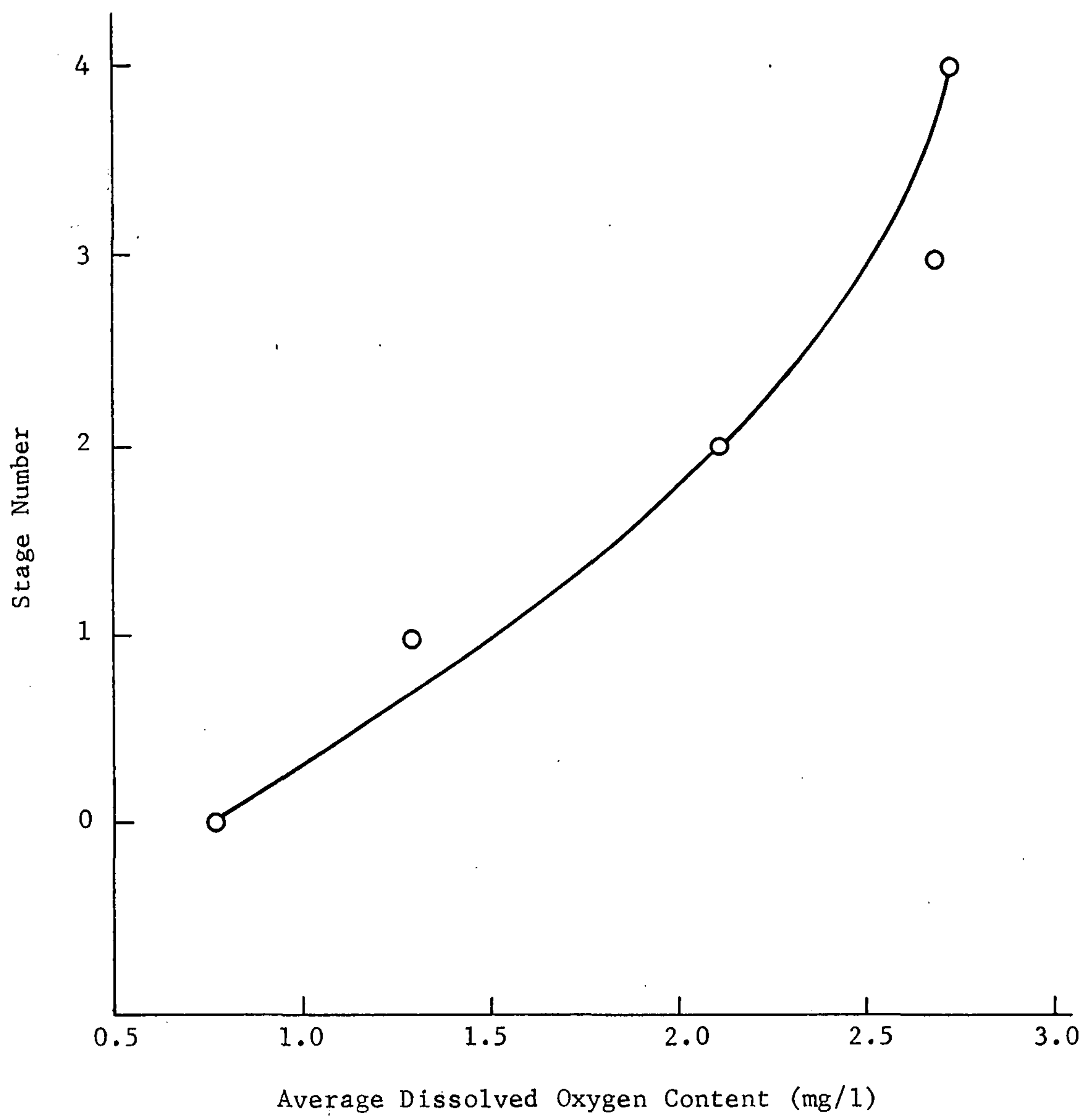

Figure 17. Mixed Liquor Average Dissolved Oxygen Content Across Bio-Disc Stages

close to zero during the latter half of the project reflecting the anaerobic conditions in the septic tank, and showing that little increase in oxygen level took place in the buffer tank.

REMOVAL OF NITROGEN AND PHOSPHORUS

Average nitrogen values through the plant are given in Table 3. Total nitrogen decreased through the septic tank from 75.8 to 57.4 mg/l giving a reduction of 24 percent. As expected, most of this removal was in the organic nitrogen fraction. The ammonia fraction actually increased slightly in the septic tank from 39.0 to 41.3 mg/l due to anaerobic breakdown of nitrogen containing organics in the sludge. Since the concentrations of nitrite and nitrate-N nitrogen were very small through the septic tank, the TKN values were essentially the same as the total nitrogen concentrations.

Through the disc section, total nitrogen fell from 57.4 to 45.2 mg/l giving an overall plant reduction of 40.3 percent. Nitrification through the bio-disc is illustrated in Figure 18. It may be seen that the average effluent ammonia concentration was still high at 30.9 mg/l yielding an ammonia reduction through the bio-disc of 25.2 percent. Effluent nitrite and nitrate values rose from fractional values to 4.0 to 5.7 mg/l respectively. Low nitrification was probably a result of relatively high concentrations of carbonaceous matter through the discs. This favored predominance of heterotrophs and limited the activity of the nitrifiers, even through the last stage. In studies reported by Antonie (6), it was found that with an effluent BOD concentration of 30 mg/l, only 20 percent of the ammonia nitrogen was removed across the discs. At the Camp Horseshoe Plant, effluent BOD concentration was 32 mg/l and average ammonia nitrogen removal across the secondary unit was 25.2 percent as noted above.

TKN showed a decrease of 37.5 percent in the disc section leaving 35.6 mg/l as the effluent with 4.7 mg/l of this due to organic nitrogen and the remainder consisting of ammonia nitrogen. Total phosphorus removals varied widely during the project (Appendix B, Table 6). Raw, settled, and effluent phosphorus averaged 11.3, 9.2, and 9.6 mg/l respectively. Overall plant removal was therefore 15 percent. Phosphorus in biological waste treatment plants usually ranges from 5 to 25 percent. The low removal of phosphorus is due, in part, to phosphorus release which occurred during anaerobic digestion of the biological sludge.

TOTAL COLIFORM REMOVAL

Average reduction in total coliforms through the plant was 90.5 percent. This is within the range of 85 to 95 percent reduction provided by other aerobic processes such as trickling filters and activated sludge. Disinfection with chlorine improved the reduction in total coliforms to 99+ percent, represented by an average effluent value of 0.8 per 100 ml, as shown in Table 3.

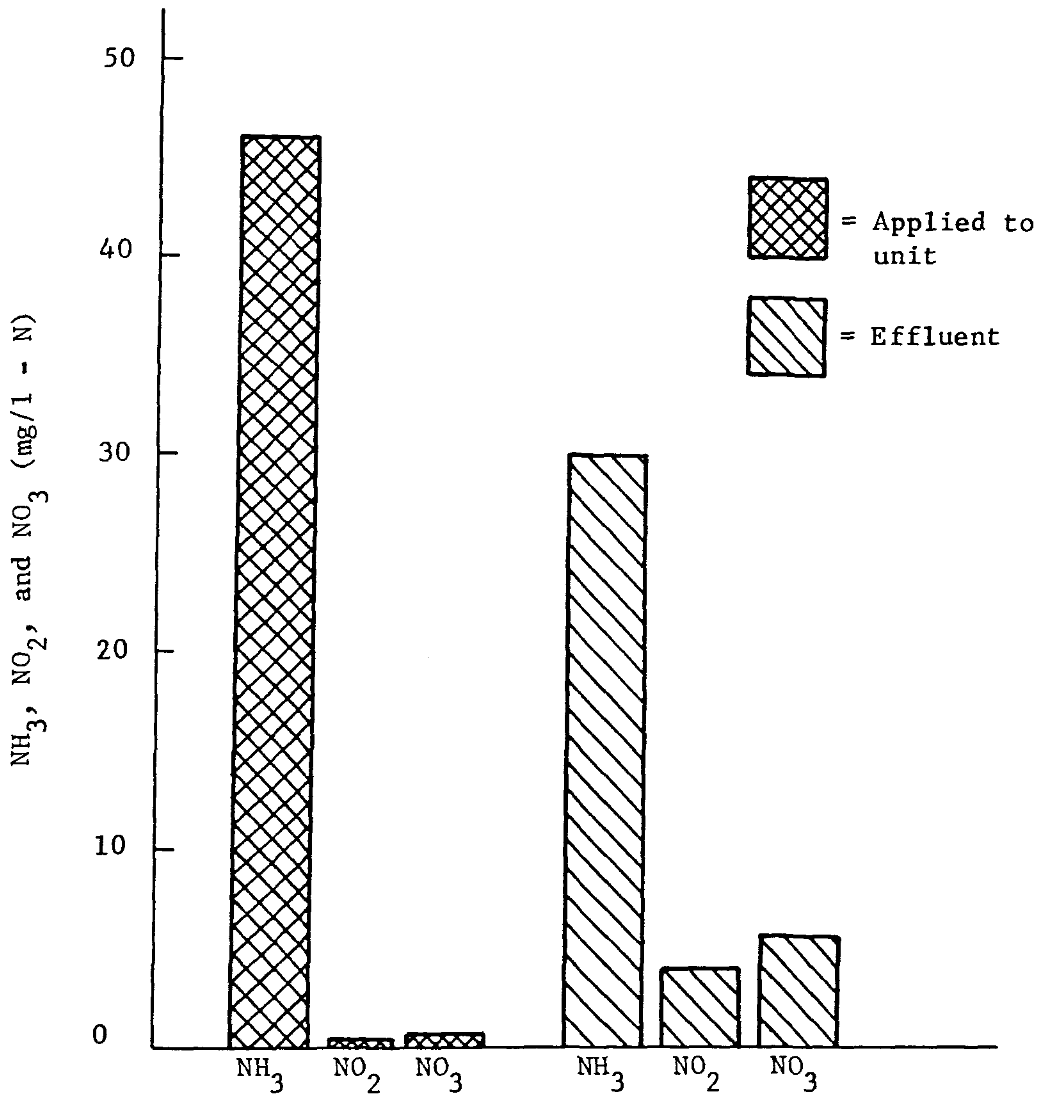

Figure 18. Average Ammonia Reduction and Nitrification Occurring Across Bio-Disc Unit

SLUDGE ACCUMULATION

An accurate measurement of sludge accumulation in the septic tank was impossible to obtain because of its physical arrangement. It was estimated, however, using a probing pole that the depth of sludge at the end of the study was approximately 30.48 cm (one foot). This would make a sludge accumulation of 440 cu m/10^6 cu m of sewage treated. Accumulation of sludge in primary-secondary plants has been reported to be 6900 cu m/10^6 cu m sewage treated (9). This latter value was at a loading of 113.5 gms suspended solids per capita per day, or three times that of the Camp Horseshoe plant. At any rate, sludge accumulation obviously was not a problem at this plant. Cleaning the septic tank at the end of each summer is more than adequate to prevent the accumulation of a large volume of sludge.

MAINTENANCE AND OPERATOR ATTENTION

As mentioned in the introduction to this report, the maintenance and operator attention required for a sewage treatment plant of this nature is of great concern. Since a full-time or trained operator is seldom available, these factors must be carefully weighed when selecting the process to be used. The Camp Horseshoe plant operated continuously for approximately 11 weeks during this study. During this period, a total of only fourteen hours of maintenance time was required to keep the plant running for an average of 1.3 hours per week. Repair time consisted of cleaning and drying contacts in the buffer tank pump float controls (three times), and tightening the main shaft sprocket chain (one time) for a total of six hours. The balance of operator attention consisted of preparing the chlorine solution three times a week for a total time of 45 minutes per week. The operator reported that start-up and shutdown procedures required a total of five hours.

AESTHETICS

The aesthetic impact of the bio-disc process on the camp was minimal. The enclosing of the facility in a structure conforming to the surroundings was a significant factor contributing to this effect. The discs themselves were kept out of view, noise levels were kept to a minimum, and odors were restricted to the immediate vicinity of the plant itself. A stale sewage smell which appeared to emanate from the septic tank was noted inside the building during the last 2 to 3 weeks of the study. No flies or similar insects were drawn to the plant. The casual observer would have no indication of the contents of the building.

SECTION VII

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of several persons whose efforts were instrumental in the completion of this project.

Mr. Dale Ashby, U. S. Forest Service Engineer, provided assistance by selecting and installing flow measuring equipment.

Appreciation is also expressed to Mrs. Virginia Meadows and Mr. Walter Kines. As Camp Supervisor and Treatment Plant Operator respectively, their efforts in the daily collection of samples, the providing of information on camp activities, and general cooperation and assistance were invaluable.

A grant from the Environmental Protection Agency provided support for the study. The aid of Dr. R. L. Bunch, who served as Project Officer for the grant is gratefully acknowledged.

SECTION VIII

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SECTION IX

GLOSSARY

BOD	-	Biochemical Oxygen Demand (5-day)
COD	-	Chemical Oxygen Demand
cm	-	centimeter
cu m	-	cubic meter
D.O.	-	Dissolved Oxygen
gm	-	gram
gpcd	-	gallons per capita per day
gpd	-	gallons per day
gpm	-	gallons per minute
m	-	meter
mg/l	-	milligrams per liter
MLSS	-	Mixed Liquor Suspended Solids
MLVSS	-	Mixed Liquor Volatile Suspended Solids
NH_3-N	-	Ammonia nitrogen
NO_2-N	-	Nitrite nitrogen
NO_3-N	-	Nitrate nitrogen
O.L.F.	-	Organic Load Factor
ORG-N	-	Organic nitrogen
PO_4-P	-	Phosphorus (total)
rpm	-	revolutions per minute
sq m	-	square meter
SS	-	Suspended Solids
T	-	Trace
TKN	-	Kjeldahl nitrogen
TOC	-	Total Organic Carbon

SECTION X

APPENDICES

APPENDIX A

FLOW MEASUREMENT

Daily flow was determined by a mass balance around the buffer tank. The net rise and fall of the liquid level in the buffer tank was measured by a float and recorder combination manufactured by Leupold and Stevens, Inc. The recorder pen also traversed the chart horizontally at a fixed rate. Knowing the vertical rise and fall in the buffer tank over a given time period provided the net liquid volume change in the tank.

Observation of the float-recorder under all conditions of flow revealed that two distinct types of chart traces occurred. The type of trace produced depended upon the operation of the pumps in the buffer tank at the time, that is, continuous or intermittent. Continuous pump operation indicated that inflow volume was large enough to keep the unit's feed tank full and overflowing back to the buffer tank. Intermittent operation indicated only enough incoming sewage to partially fill the feed tank before the pumps shut off again, due to the drop in the level of the buffer tank. Knowing the net volume change in the buffer tank and mode of pump operation provided the following general mass balance equation:

Buffer Tank
Net Volume Change = Inflow - Outflow + Return

Where: Inflow = Overflow from septic tank (hence raw sewage inflow)

Outflow = Quantity pumped to feed tank

Return = Overflow from feed tank back to buffer tank with feed tank full

Rearrangement of the equation permitted the inflow to be determined under conditions of either continuous or intermittant pump operation.

The above rather unusual method of flow measurement was used to avoid problems of weir fouling at low flows in raw sewage. It proved to be quite reliable and was found to be accurate by checking against several other methods of flow determination.

APPENDIX B

SUPPLEMENTAL DATA AND FIGURES

TABLE 6. Daily Wastewater Characteristics

Week of June 11, 1972 - Week #1

	BOD-5 (mg/1)				COD (mg/1)			
Date	Raw	Sett.	Eff.	Cl Eff.	Raw	Sett.	Eff.	Cl Eff.
6/11	230	322	352	231	301	792	669	613
6/12	222	250	125	131	220	453	331	268
6/13					430	420	276	331
6/14					194	504	126	240
6/15					229	549	378	194
6/16					460	344	241	254
6/17					344	413	80	91

	TOC (mg/1)			SS (mg/1)			Total Solids
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Eff.
6/11				102	420	595	
6/13				75	105	55	
6/15				50	87	52	200
6/17				58	118	32	

	NO_2-N (mg/1)			NO_3-N (mg/1)		
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.

No data obtained this week

	NH_3-N (mg/1)			TKN (mg/1)			Total P (mg/1)		
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Raw	Sett.	Eff.

No data obtained this week

	pH (mg/1)			D.O. (mg/1)			Temp (°C)	
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Raw	Eff.
6/14	6.6	6.9	7.4				22	18
6/16	6.8	6.7	6.8	1.0	2.0	0.5	23	19

	Total Coliform (per 100 ml)			
Date	Raw	Sett.	Eff.	Cl Eff.

No data obtained this week

TABLE 6. (cont'd)

Week of June 18, 1972 - Week #2

Date	BOD-5 (mg/l) Raw	Sett.	Eff.	Cl Eff.	COD (mg/l) Raw	Sett.	Eff.	Cl Eff.
6/18	410	180	34	59	530	248	68	
6/19	253	216	45	24	518	338	180	
6/20					248	113	79	
6/21					530	195	48	
6/22					427	280	70	
6/24					40*	136*	107*	

Date	TOC (mg/l) Raw	Sett.	Eff.	SS (mg/l) Raw	Sett.	Eff.	Total Solids Eff.
6/19	100	80	36	292	80	22	
6/21	85	60	36	520	68	20	100
6/22	50	90	28	370	110	20	
6/24	20	17	7	30	18	7	

Date	NO_2-N (mg/l) Raw	Sett.	Eff.	NO_3-N (mg/l) Raw	Sett.	Eff.

No data obtained this week

Date	NH_3-N (mg/l) Raw	Sett.	Eff.	TKN (mg/l) Raw	Sett.	Eff.	Total P (mg/l) Raw	Sett.	Eff.

No data obtained this week

Date	pH (mg/l) Raw	Sett.	Eff.	D.O. (mg/l) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
6/18				1.25	0.75	0.5	28	19
6/20	6.55	6.8	6.7				18	18
6/22	6.7	6.8	6.6	2.5	4.0	3.5	15	15
6/24	6.15	6.2	6.8	3.5	5.25	5.5	13	13

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
6/20	870×10^6	290×10^6	12×10^6	0.0
6/22				0.0
6/24				14.0

* Data not used

TABLE 6. (cont'd.)

Week of June 25, 1973 - Week #3

Date	BOD-5 (mg/l) Raw	Sett.	Eff.	Cl Eff.	COD (mg/l) Raw	Sett.	Eff.	Cl Eff.
6/26	492	150	44		1410*	82	43	30
6/27					1060*	276	73	21
6/28					192	196	159*	
6/29					652	204	73	
6/30					434	182	70	
7/1	231	85	16	60	446	248	66	

Date	TOC (mg/l) Raw	Sett.	Eff.	SS (mg/l) Raw	Sett.	Eff.	Total Solids Eff.
6/26	175	27	15	1170*	90	5	
6/27	364	115	24	1980*	135	7	425
6/29	136	90	24				
6/30				445	80	27	
7/1				285	60	27	

Date	NO_2-N (mg/l) Raw	Sett.	Eff.	NO_3-N (mg/l) Raw	Sett.	Eff.
6/26	0.01	0.01	4.87	T	0.04	9.4

Date	NH_3-N (mg/l) Raw	Sett.	Eff.	TKN (mg/l) Raw	Sett.	Eff.	Total P (mg/l) Raw	Sett.	Eff.
6/26	36.4	12.2	6.05	75.8	15.9	8.29	10.1	4.0	3.44

Date	pH (mg/l) Raw	Sett.	Eff.	D.O. (mg/l) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
6/28	6.5	7.0	6.9	0.25	5.0	5.5	17	16
6/30	6.9	6.5	6.6	0.5	6.0	3.5	16	17

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
6/28	720×10^6	230×10^6	9×10^6	0.0
6/30				0.0

*Data not used

TABLE 6. (cont'd.)

Week of July 2, 1972 - Week #4

Date	BOD-5 (mg/l) Raw	Sett.	Eff.	Cl Eff.	COD (mg/l) Raw	Sett.	Eff.	Cl Eff.
7/2					555	290	112	
7/3					781	392	103	107
7/4					748	368	107	219
7/5	295	100	16	49	523	192	90	
7/6					1313*	155	90	
7/8	332	113	29	37	324	174	56	93

Date	TOC (mg/l) Raw	Sett.	Eff.	SS (mg/l) Raw	Sett.	Eff.	Total Solids Eff.
7/3	112	80	31	575	52	20	365
7/5	144	45	16	870	97	37	
7/6				630	62	32	
7/8	106	40	22	555	17	1	

Date	NO_2-N (mg/l) Raw	Sett.	Eff.	NO_3-N (mg/l) Raw	Sett.	Eff.
7/5	0.01	0.23	4.1	0.04	1.19	0.4

Date	NH_3-N (mg/l) Raw	Sett.	Eff.	TKN (mg/l) Raw	Sett.	Eff.	Total P (mg/l) Raw	Sett.	Eff.
7/5	12.1	17.6	16.7	23.4	26.4	16.7	6.42	3.85	3.65

Date	pH (mg/l) Raw	Sett.	Eff.	D.O. (mg/l) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
7/5	6.8	6.5	6.75				16	18
7/7	6.7	7.0	7.1	0.75	4.5	4.5	16	16

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
7/7	400×10^6	220×10^6	180×10^6	0.0

*Data not used

TABLE 6. (cont'd.)

Week of July 9, 1972 - Week #5

Date	BOD-5 (mg/l) Raw	Sett.	Eff.	Cl Eff.	COD (mg/l) Raw	Sett.	Eff.	Cl Eff.
7/9					490	134	93	69
7/14	325	186	32	40	976	420	120	162
7/15	295	182	47	81	468	298	137	183

Date	TOC (mg/l) Raw	Sett.	Eff.	SS (mg/l) Raw	Sett.	Eff.	Total Solids Eff.
7/9	100	32	19	505	37	10	335
7/14	252	187	50	360	14	3	
7/15	145	140	45	110	8	1	

Date	NO_2-N (mg/l) Raw	Sett.	Eff.	NO_3-N (mg/l) Raw	Sett.	Eff.

No data obtained this week

Date	NH_3-N (mg/l) Raw	Sett.	Eff.	TKN (mg/l) Raw	Sett.	Eff.	Total P (mg/l) Raw	Sett.	Eff.

No data obtained this week

Date	pH (mg/l) Raw	Sett.	Eff.	D.O. (mg/l) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.

No data obtained this week

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.

No data obtained this week

TABLE (cont'd.)

Week of July 16, 1972 - Week #6

	BOD-5 (mg/1)				COD (mg/1)			
Date	Raw	Sett.	Eff.	Cl Eff.	Raw	Sett.	Eff.	Cl Eff.
7/16					1480*	267	160	246
7/17					1545*	281	97	109
7/18	137	192	37	45	309	280	77	
7/19	300	147	46	30	540	309	82	
7/20					790	268	69	
7/21					800	250	66	
7/22					1050	400	100	

	TOC (mg/1)			SS (mg/1)			Total Solids
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Eff.
7/16	182	50	31	2790	40	0.5	
7/17				135	9	0.4	
7/19				610	5	3	280
7/21	1085	50	15	460	6	0.75	
7/22				180	9	2	

	NO_2-N (mg/1)			NO_3-N (mg/1)		
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.
7/17	T	0.02	4.3	0.17	0.23	7.2

	NH_3-N (mg/1)			TKN (mg/1)			Total P (mg/1)		
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Raw	Sett.	Eff.
7/17	21.5	37.8	24.5	48.1	53.7	32.0	11.3	11.1	11.1

	pH (mg/1)			D.O. (mg/1)			Temp (°C)	
Date	Raw	Sett.	Eff.	Raw	Sett.	Eff.	Raw	Eff.
7/16	7.2	6.9	7.1	2.0	1.0	0.5	20	22
7/18	7.1	6.9	7.05				19.5	22
7/20	6.7	6.95	7.1				22	22
7/22	7.4	6.95	7.0	1.5	2.5	0.25	21	23

	Total Coliform (per 100 ml)			
Date	Raw	Sett.	Eff.	Cl Eff.
7/16				0.0
7/18	560×10^6	120×10^6	0.0	0.0
7/20				0.0

*Data not used

TABLE 6. (cont'd.)

Week of July 23, 1972 - Week #7

Date	BOD-5 (mg/1) Raw	Sett.	Eff.	Cl Eff.	COD (mg/1) Raw	Sett.	Eff.	Cl Eff.
7/24					562	650	296	
7/25					608	475	149	189
7/26	123	253	6	10	262	504	97	101
7/27	218	183	16	12	413	400	97	
7/28					332	288	105	
7/29					908	490	72	

Date	TOC (mg/1) Raw	Sett.	Eff.	SS (mg/1) Raw	Sett.	Eff.	Total Solids Eff.
7/25	73	65	23	230	9	2.5	
7/26	60	78	19				
7/27	93	90	19	230	6	1.0	390
7/28	112	62	25	160	17	2.5	
7/29				865	8	0.5	

Date	NO_2-N (mg/1) Raw	Sett.	Eff.	NO_3-N (mg/1) Raw	Sett.	Eff.
7/27	T	0.02	3.75	0.14	0.24	10.0

Date	NH_3-N (mg/1) Raw	Sett.	Eff.	TKN (mg/1) Raw	Sett.	Eff.	Total P (mg/1) Raw	Sett.	Eff.
7/27	57.3	39.5	28	73.1	56.2	33.76	12.6	12.6	4.2

Date	pH (mg/1) Raw	Sett.	Eff.	D.O. (mg/1) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
7/24				2.0	3.0	0.5	21	23
7/26	6.9	6.7	6.6	0.1	4.5	0.1	22	20
7/28	6.4	6.7	7.0			0.5	20	22

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
7/26	500×10^6	230×10^6	40×10^6	0.0
7/28				0.0

TABLE 6. (cont'd.)

Week of July 30, 1972 - Week #8

Date	BOD-5 (mg/1) Raw	Sett.	Eff.	Cl Eff.	COD (mg/1) Raw	Sett.	Eff.	Cl Eff.
7/30					319	485	68	151
7/31					390	465	159	79
8/1					925	449	88	116
8/2					841	445	100	114
8/3	211	205	57	56	359	336	136	
8/4	148	228	63	70	363	383	172	
8/5					700	436	136	

Date	TOC (mg/1) Raw	Sett.	Eff.	SS (mg/1) Raw	Sett.	Eff.	Total Solids Eff.
7/30	100	117	17				
7/31	125	125	22	150	12	3.4	
8/2				195	5	2	
8/3	100	88	31	180	11	3	
8/4	95	122	40	185	10	7.5	580

Date	NO_2-N (mg/1) Raw	Sett.	Eff.	NO_3-N (mg/1) Raw	Sett.	Eff.
8/1	T	0.01	3.67	0.42	0.23	6.5

Date	NH_3-N (mg/1) Raw	Sett.	Eff.	TKN (mg/1) Raw	Sett.	Eff.	Total P (mg/1) Raw	Sett.	Eff.
8/1	58.8	41.3	33.5	139.3	60.4	40.2	12.0	9.8	15

Date	pH (mg/1) Raw	Sett.	Eff.	D.O. (mg/1) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
7/30	6.65	6.3	6.2	1.75	0.5	2.25	18	19
8/1	6.1	6.6	7.0	0.5	0.75	0.5	19	20
8/3	7.8	6.55	7.0			0.75	19	22

Date	Total Coliform (per 100) Raw	Sett.	Eff.	Cl Eff.
7/30				0.0
8/1				0.0
8/3	520×10^6	210×10^6	90×10^6	0.0

TABLE 6. (cont'd.)

Week of August 6, 1972 - Week #9

Date	BOD-5 (mg/l) Raw	Sett.	Eff.	Cl Eff.	COD (mg/l) Raw	Sett.	Eff.	Cl Eff.
8/6	244	138	13	11	682	546	240	
8/7	299		15	21	1040	667	159	213
8/8					772	517	166	
8/9					834	1145	151	
8/10					656	463	174	
8/11					1012	597	108	199
8/12					614	440	120	

Date	TOC (mg/l) Raw	Sett.	Eff.	SS (mg/l) Raw	Sett.	Eff.	Total Solids Eff.
8/6				190	15	2.75	
8/7	217	150	34				
8/8	205	120	41	465	15	6.5	
8/10				175	12	5.75	
8/11	115	102	32				
8/12	112	92	30	220	11	10	430

Date	NO_2-N (mg/l) Raw	Sett.	Eff.	NO_3-N (mg/l) Raw	Sett.	Eff.
8/11	T	T	2.77	0.27	0.32	0.8

Date	NH_3-N (mg/l) Raw	Sett.	Eff.	TKN (mg/l) Raw	Sett.	Eff.	Total P (mg/l) Raw	Sett.	Eff.
8/11	64.3	78.5	80	86.5	102.1	85.5	11.2	10.8	15.6

Date	pH (mg/l) Raw	Sett.	Eff.	D.O. (mg/l) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
8/7	7.05	6.3	7.2	0.5	1.0	1.0	20	21
8/9	7.45	6.9	7.45				19	21
8/11	7.05	7.0	7.5	2.5	1.5	1.5	21	19

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
8/7				0.0
8/9	540×10^6	230×10^6	100×10^6	0.0
8/11				0.0

TABLE 6 (cont'd.)

Week of August 13, 1972 - Week #10

Date	BOD-5 (mg/1) Raw	Sett.	Eff.	Cl Eff.	COD (mg/1) Raw	Sett.	Eff.	Cl Eff.
8/13					814	688	143	
8/14					513	366	209	
8/15	175	256	36	60	304	688	170	153
8/16					394	328	160	145
8/17	176	330	12	7	361	616	107	
8/18					779	410	90	
8/19					685	780	123	

Date	TOC (mg/1) Raw	Sett.	Eff.	SS (mg/1) Raw	Sett.	Eff.	Total Solids Eff.
8/13				520	9	1.25	
8/14	120	155	66				
8/15	100	155	32	120	11	1.0	
8/16	151	172	26	310	11	1.25	
8/17	75	150	10				
8/18				155	13	1.0	340

Date	NO_2-N (mg/1) Raw	Sett.	Eff.	NO_3-N (mg/1) Raw	Sett.	Eff.
	No data obtained this week					

Date	NH_3-N (mg/1) Raw	Sett.	Eff.	TKN (mg/1) Raw	Sett.	Eff.	Total P (mg/1) Raw	Sett.	Eff.
	No data obtained this week								

Date	pH (mg/1) Raw	Sett.	Eff.	D.O. (mg/1) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
8/13	6.8	7.4	7.7	0.6	0.4	0.5	20	22
8/15	7.75	7.2	7.45	2.5	0.75	2.0	19	21
8/17				2.0	0.5	1.25	20	21
8/19	6.8	6.85	6.5				19	22

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
8/13				0.0
8/17	210×10^6	180×10^6	0	2.0
8/19				0.0

TABLE 6. (cont'd.)

Week of August 20, 1973 - Week #11

Date	BOD-5 (mg/1) Raw	Sett.	Eff.	Cl Eff.	COD (mg/1) Raw	Sett.	Eff.	Cl Eff.
8/20					1475*	836	175	
8/21					589	621	191	
8/22	521	355	38	5	1219	490	143	139
8/23					1016*	677	177	
8/24	316	494	40	20	387	1225	129	145

Date	TOC (mg/1) Raw	Sett.	Eff.	SS (mg/1) Raw	Sett.	Eff.	Total Solids Eff.
8/20	155	187	63				
8/21	157	155	44	175	15	2.24	310
8/22	187	172	54	180	15	3.25	
8/23	200	130	37	170	15	1.25	
8/24				155	15	1.25	

Date	NO_2-N (mg/1) Raw	Sett.	Eff.	NO_3-N (mg/1) Raw	Sett.	Eff.
8/20	T	T	4.25	0.27	0.41	11.6
8/23	T	T	2.7	0.9	0.34	0.24
8/25	T	0.01	5.65	0.67	0.37	4.4

Date	NH_3-N (mg/1) Raw	Sett.	Eff.	TKN (mg/1) Raw	Sett.	Eff.	Total P (mg/1) Raw	Sett.	Eff.
8/20	23.4	55.6	7.95	47.5	74.7	7.95	17	15	15.5
8/23	29.1	64.5	44.9	73.4	84.4	54.6	15	10.5	13.2
8/24	15.3	67	29.9	63.3	83.9	35.5	13	11.2	14.8

Date	pH (mg/1) Raw	Sett.	Eff.	D.O. (mg/1) Raw	Sett.	Eff.	Temp (°C) Raw	Eff.
8/21	6.75	7.1	7.4	1.5	0.5	2.25	19	19
8/23							20	21.5
8/24	7.05	7.0	7.2	1.25	0.5	1.75	20	22

Date	Total Coliform (per 100 ml) Raw	Sett.	Eff.	Cl Eff.
8/21	140×10^6	90×10^6	10×10^6	2.0
8/25				0.0

*Data not used

TABLE 7

Daily Sewage Flows - 1972

Date	Day of Week	Flow (cu m)	Date	Day of Week	Flow (cu m)
7/01	Saturday	16.86	7/31	Monday	18.09
7/02	Sunday	12.26	8/01	Tuesday	20.40
7/03	Monday	12.97	8/02	Wednesday	22.08
7/06	Thursday	15.51	8/03	Thursday	17.02
7/07	Friday	5.54	8/04	Friday	13.89
7/08	Saturday	9.67	8/05	Saturday	8.62
7/12	Wednesday	10.20	8/06	Sunday	12.23
7/13	Thursday	14.75	8/07	Monday	21.53
7/14	Friday	16.28	8/08	Tuesday	18.31
7/15	Saturday	17.29	8/09	Wednesday	23.93
7/16	Sunday	17.85	8/10	Thursday	12.37
7/17	Monday	23.26	8/11	Friday	22.91
7/18	Tuesday	17.17	8/12	Saturday	7.02
7/19	Wednesday	20.69	8/13	Sunday	zero
7/20	Thursday	19.87	8/14	Monday	4.03
7/21	Friday	19.68	8/15	Tuesday	16.10
7/22	Saturday	9.77	8/16	Wednesday	16.26
7/23	Sunday	5.96	8/17	Thursday	16.00
7/24	Monday	18.86	8/18	Friday	7.68
7/25	Tuesday	22.48	8/19	Saturday	4.12
7/26	Wednesday	17.00	8/20	Sunday	9.63
7/27	Thursday	17.07	8/21	Monday	14.68
7/28	Friday	18.19	8/22	Tuesday	14.60
7/29	Saturday	8.58	8/23	Wednesday	17.29
7/30	Sunday	13.66	8/24	Thursday	10.63

Note: 1 cu m = 264.1 gallons

TABLE 8

Comparison of Wastewater Characteristics for Time Periods 6/18/72 to 7/22/72 and 7/23/72 to 8/24/72

6/18/72 to 7/22/72

	Raw (mg/1)	Settled (mg/1)	Effluent (mg/1)
BOD	305.8	151.5	32.8
COD	494.4	249.1	92.7
TOC	113.2	73.5	26.6
SS	393.8	49.8	12.4

7/23/72 to 8/24/72

	Raw (mg/1)	Settled (mg/1)	Effluent (mg/1)
BOD	213.3	252.8	31.8
COD	615.0	559.5	144.0
TOC	122.7	124.3	33.2
SS	251.5	11.8	2.8

NOTE: BOD time periods are 6/18/72 - 7/15/72 and 7/16/72 - 8/24/72

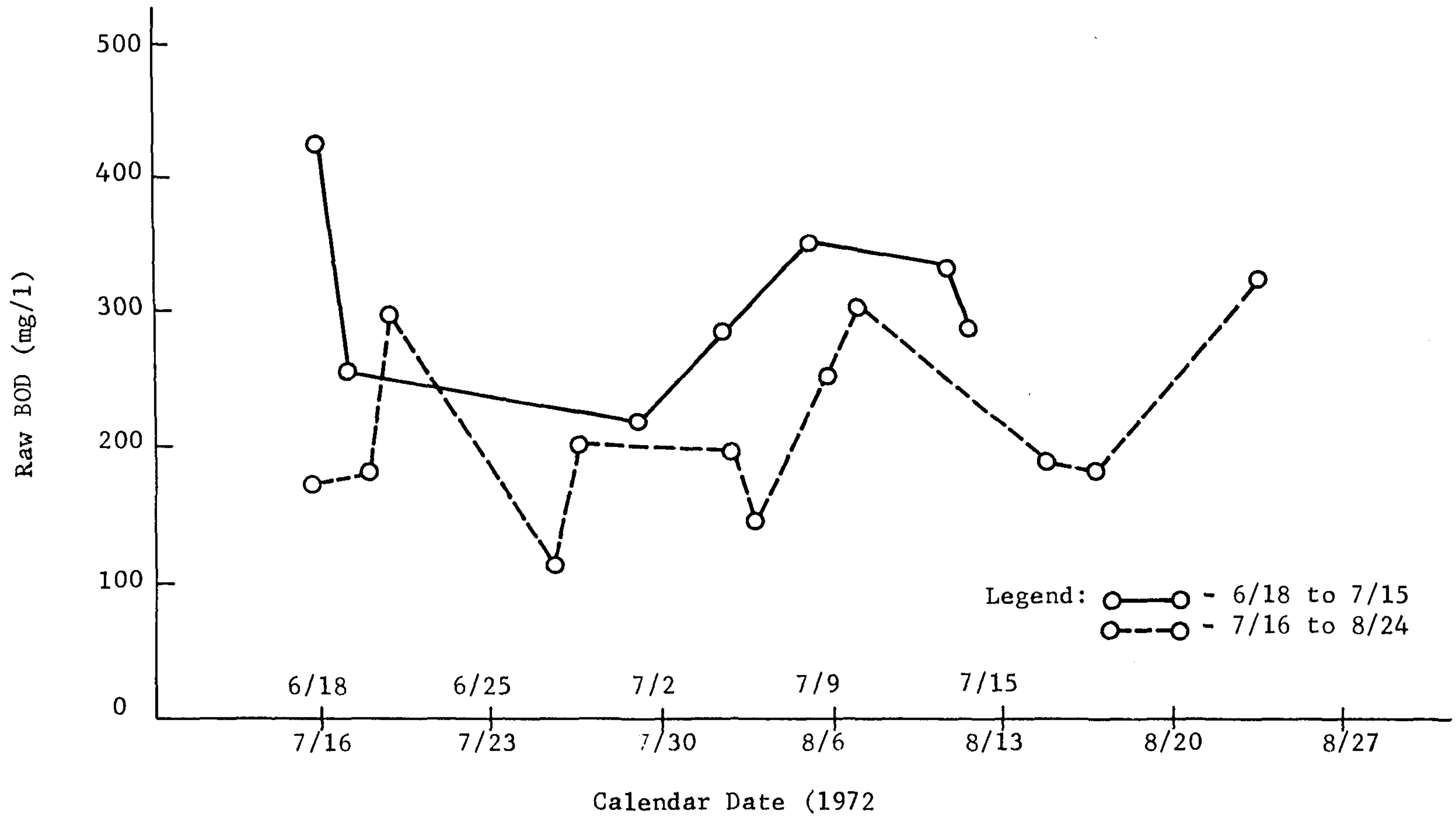

Figure 19. Comparison of Raw BOD Values Before and After First Five Weeks of Plant Operation

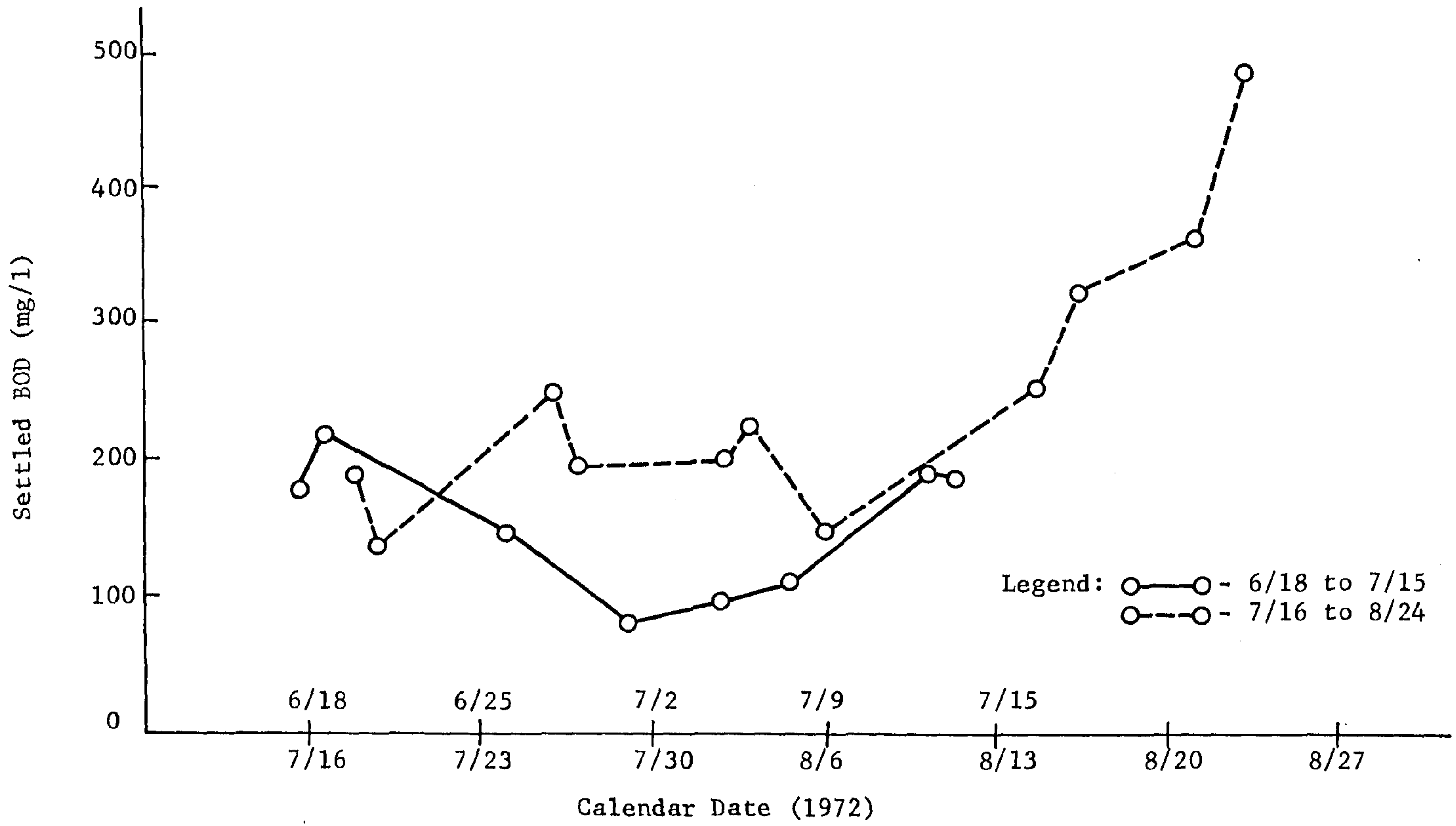

Figure 20. Comparison of Settled BOD Values Before and After First Five Weeks of Operation

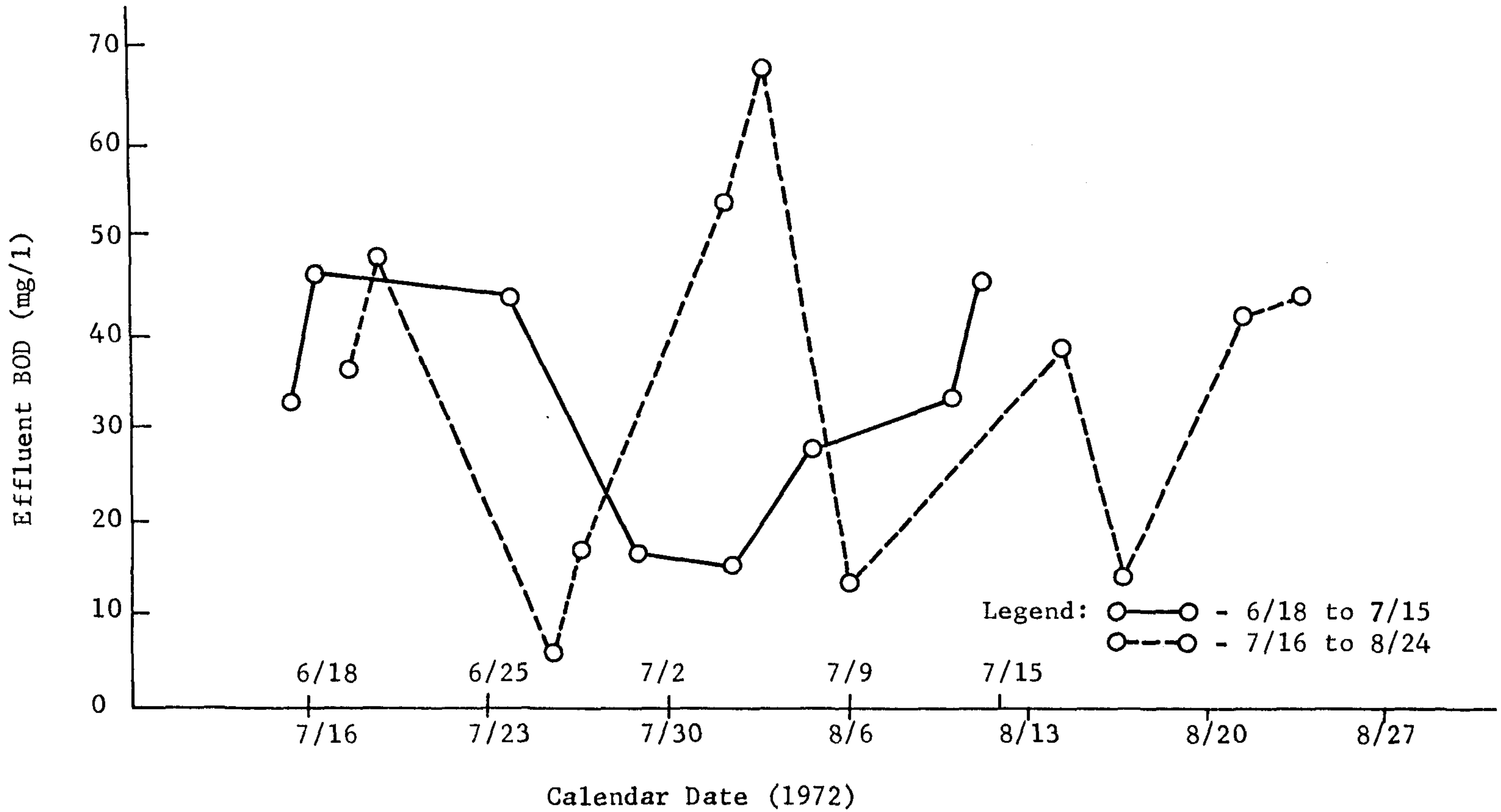

Figure 21. Comparison of Effluent BOD Values Before and After First Five Weeks of Operation

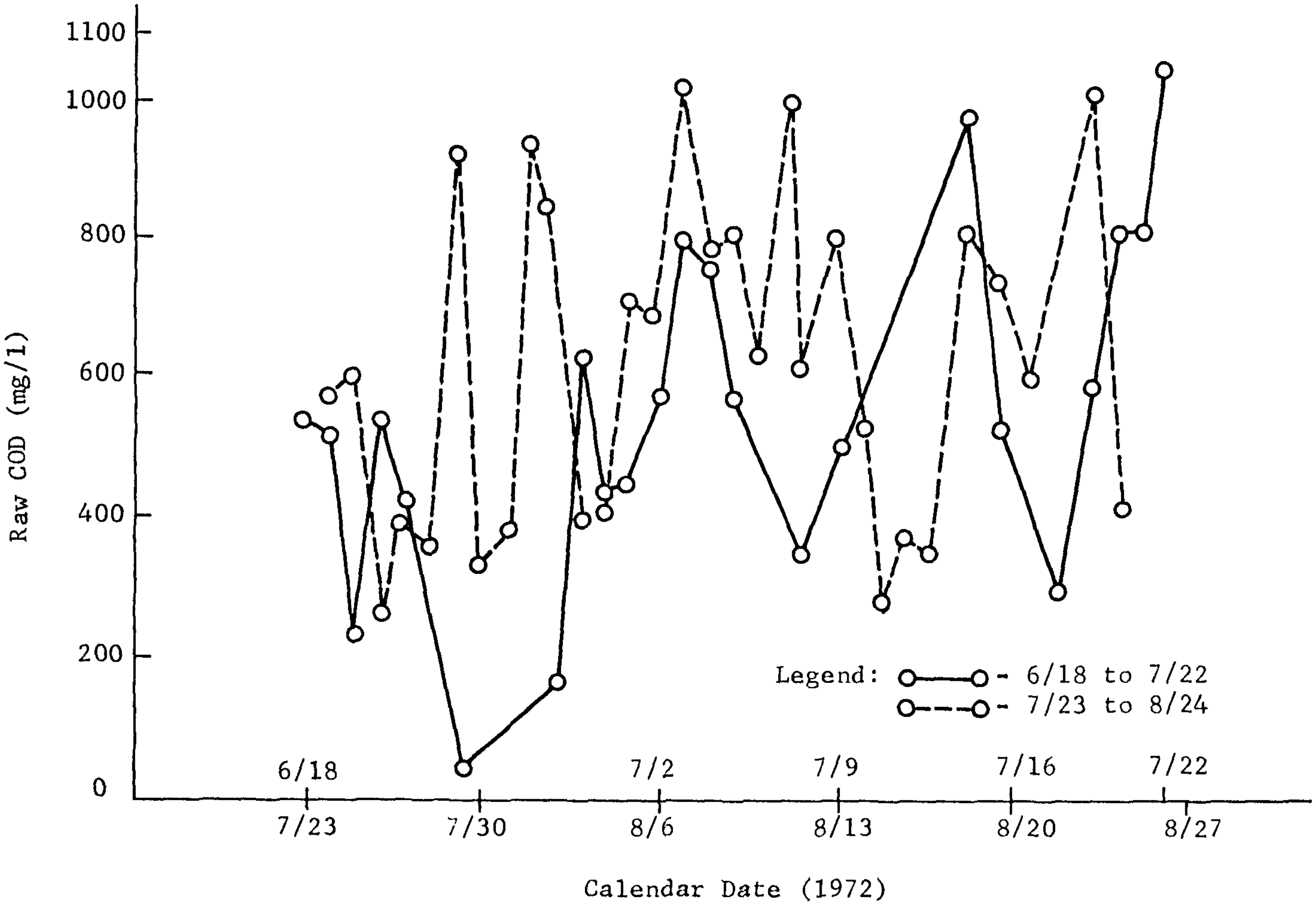

Figure 22. Comparison of Raw COD Values Before and After First Six Weeks of Operation

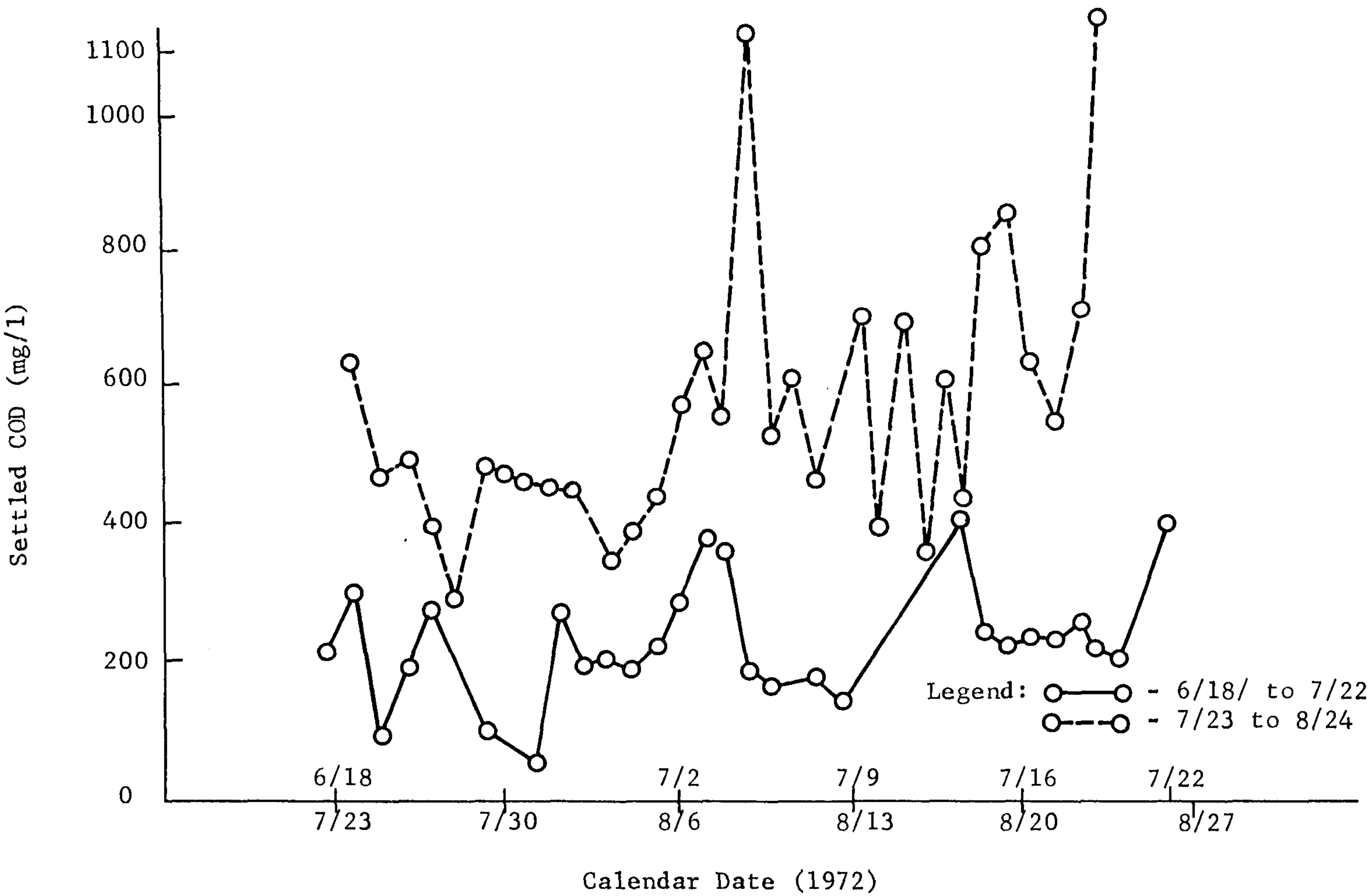

Figure 23. Comparison of Settled COD Values Before and After First Six Weeks of Operation

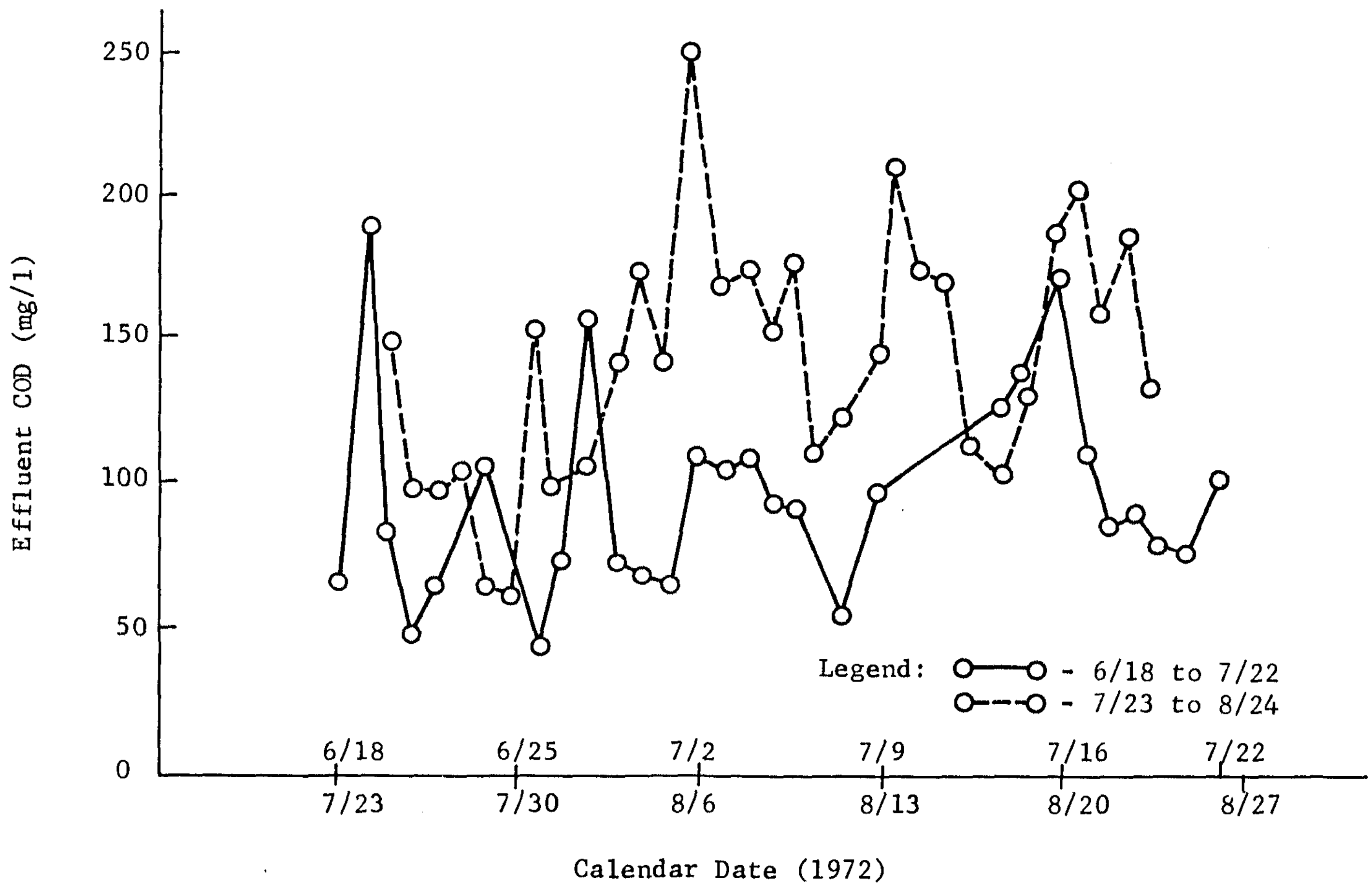

Figure 24. Comparison of Effluent COD Values Before and After Six Weeks of Operation

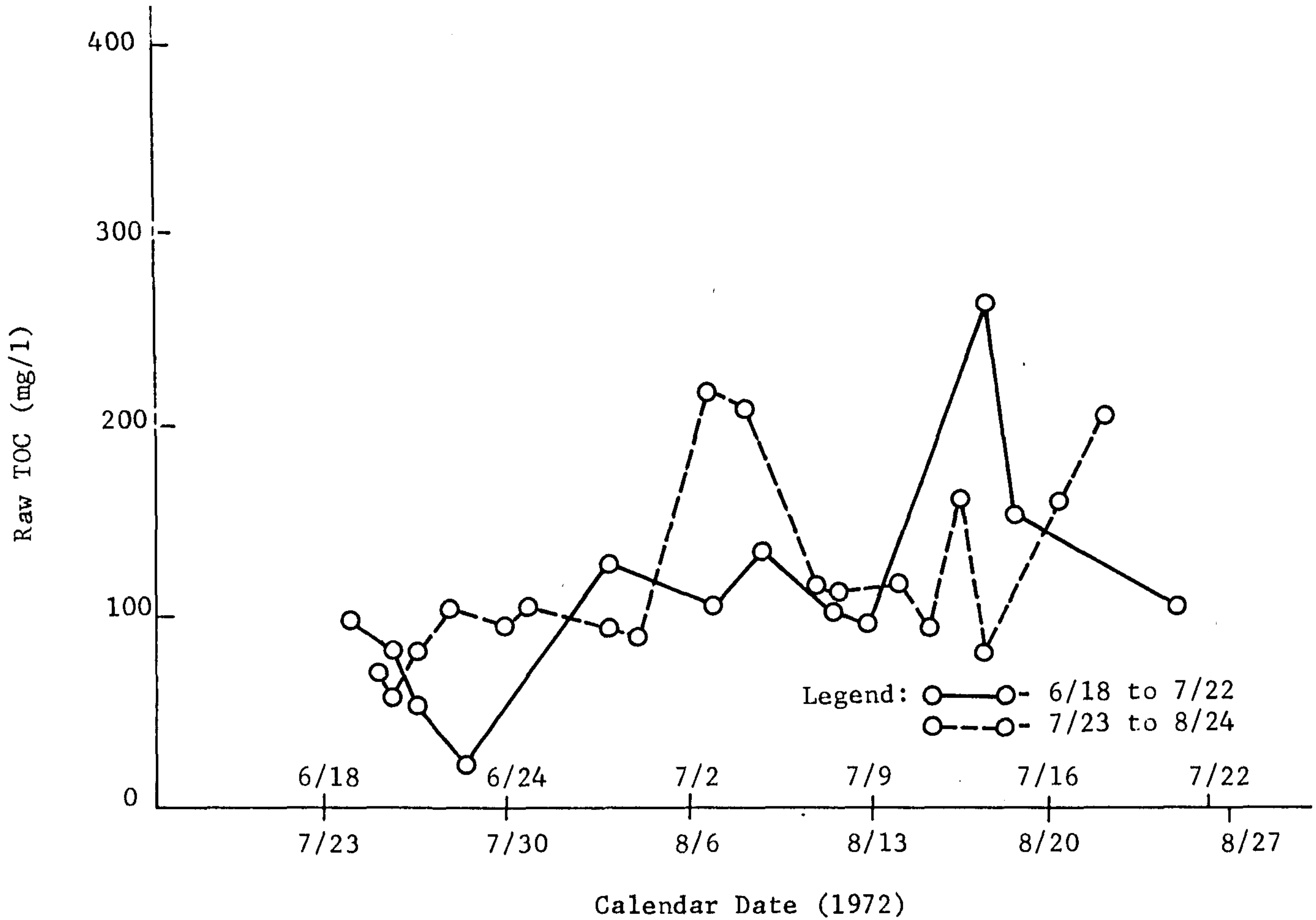

Figure 25. Comparison of Raw TOC Values Before and After First Six Weeks of Operation

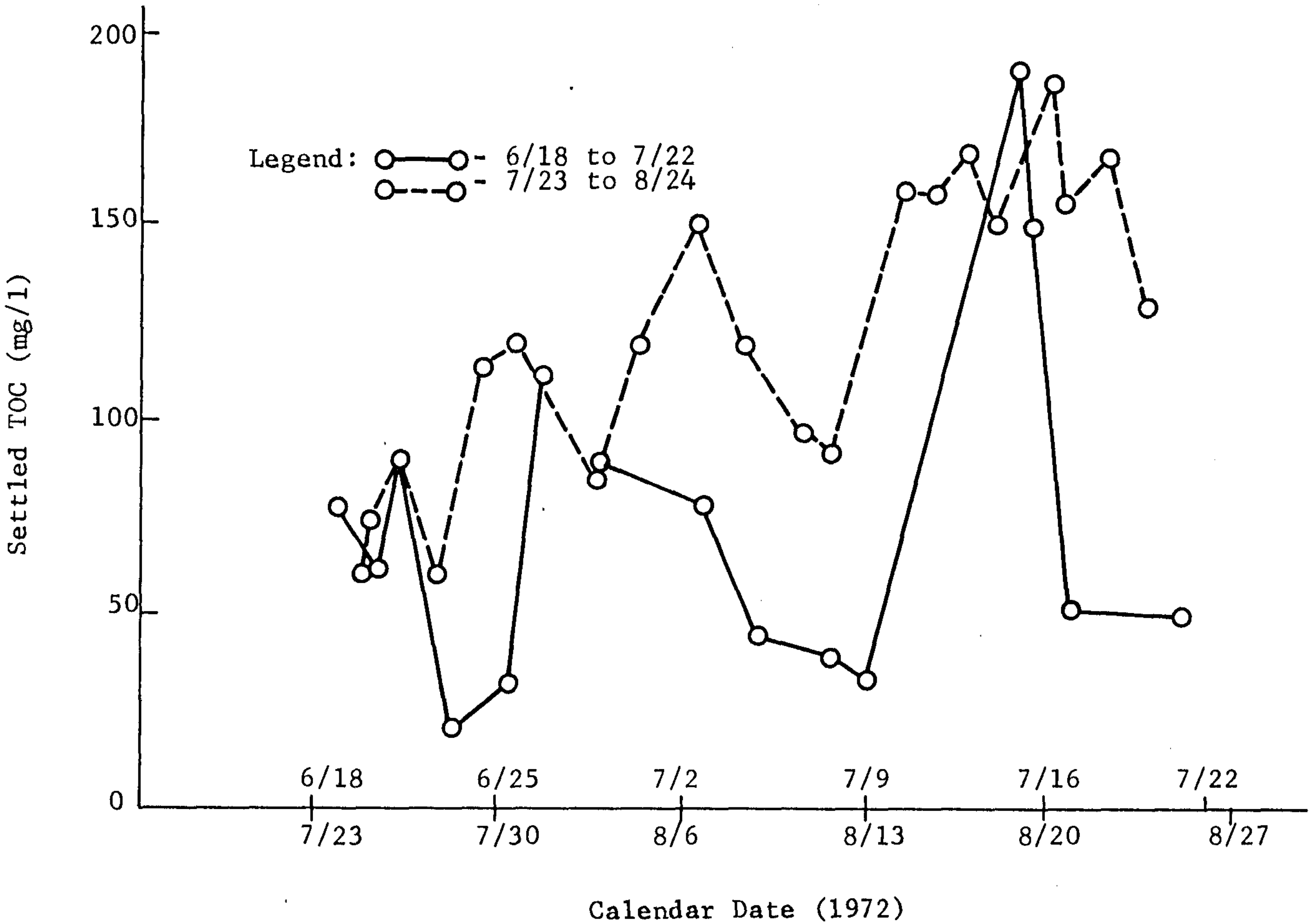

Figure 26. Comparison of Settled TOC Values Before and After First Six Weeks of Operation

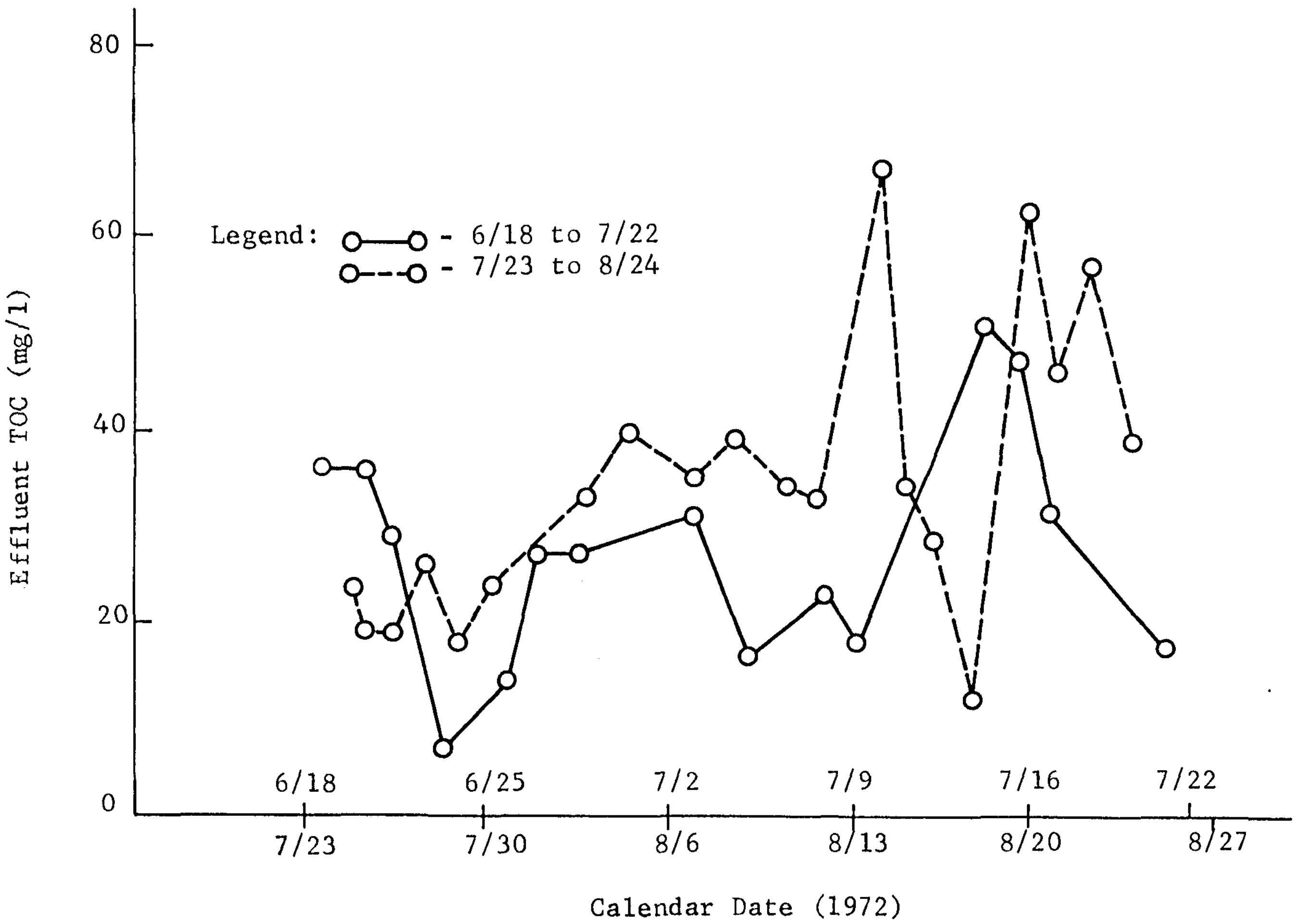

Figure 27. Comparison of Effluent TOC Values Before and After First Six Weeks of Operation

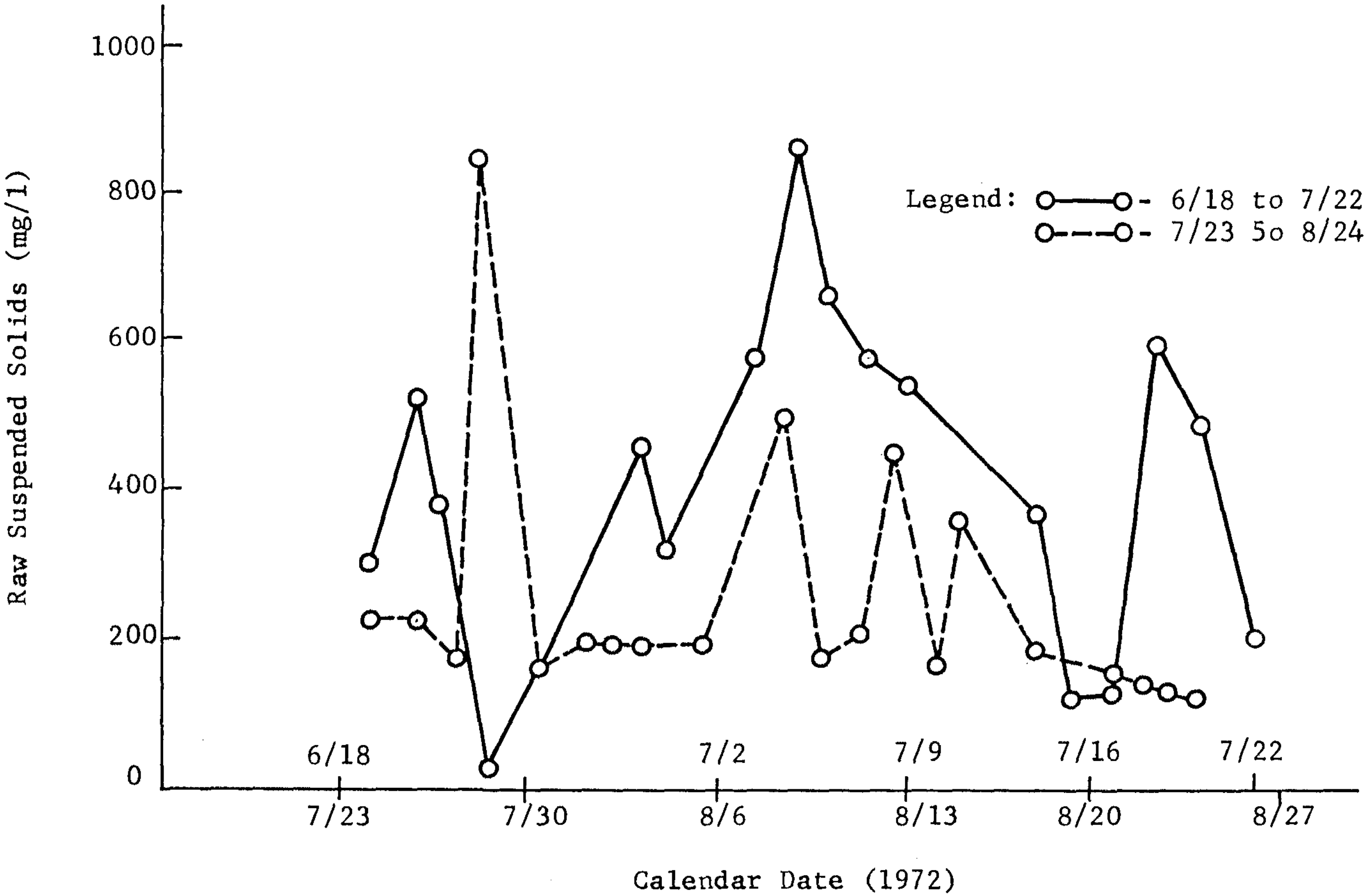

Figure 28. Comparison of Raw Suspended Solids Values Before and After First Six Weeks of Operation

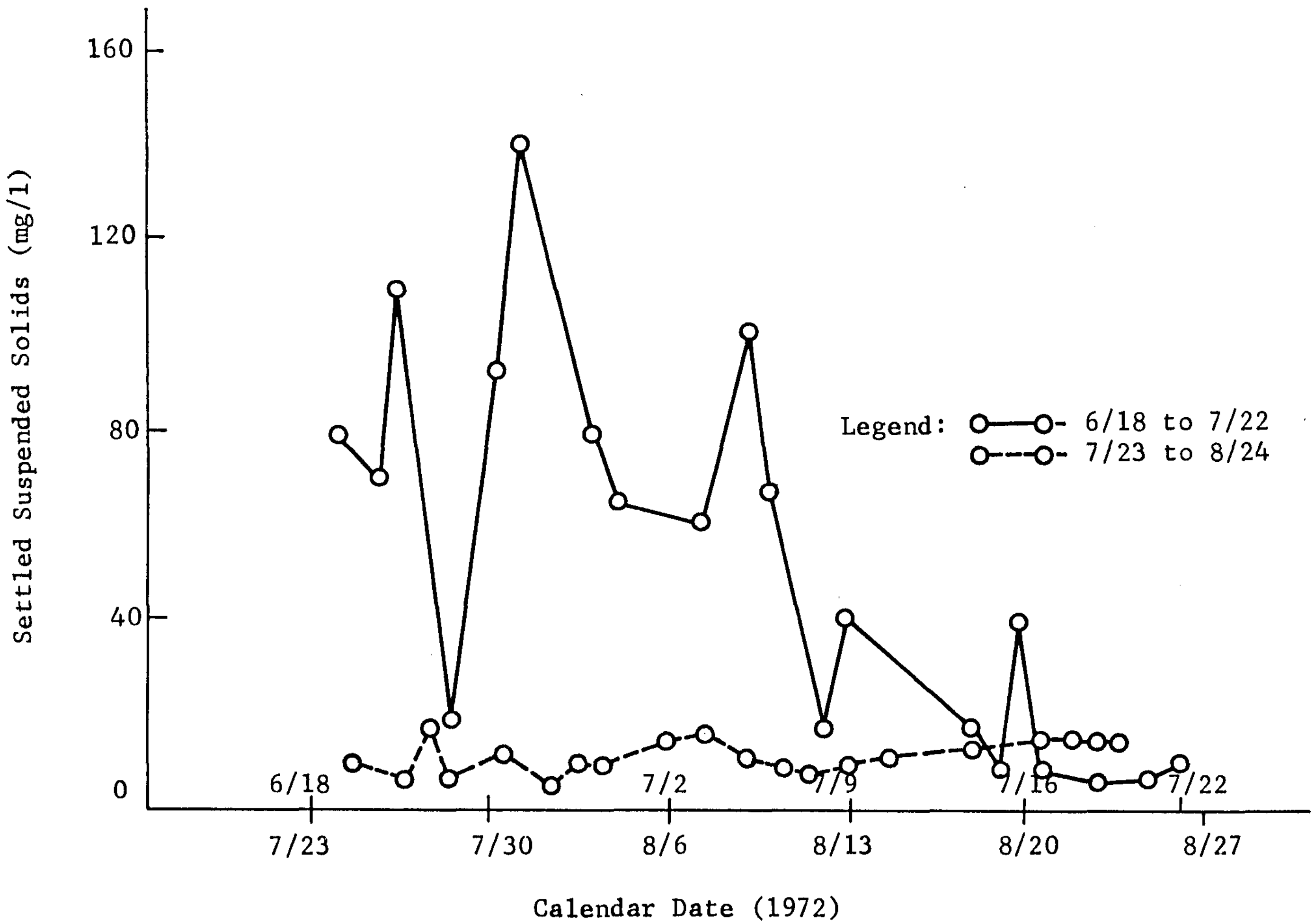

Figure 29. Comparison of Settled Suspended Solids Values Before and After First Six Weeks of Operation

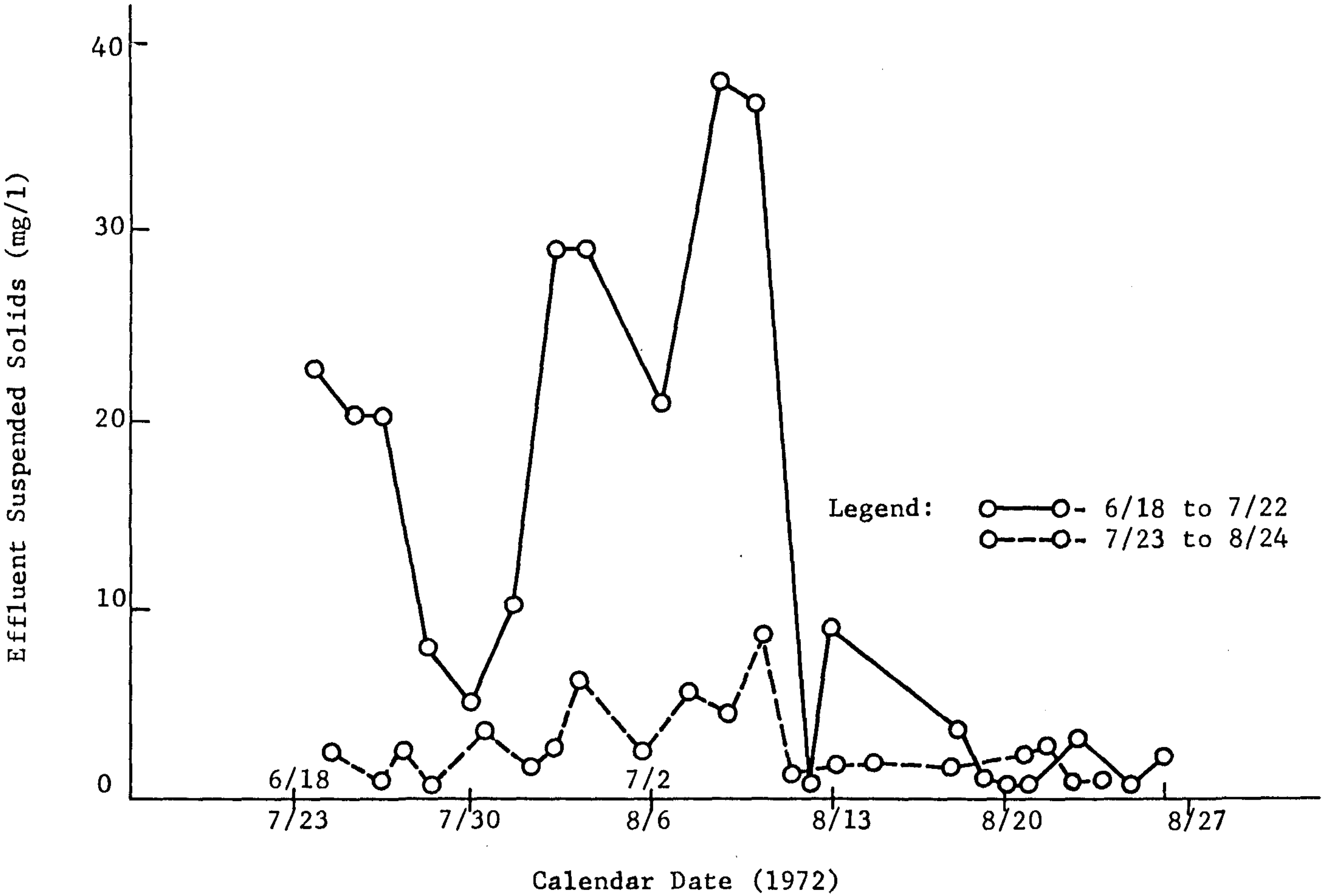

Figure 30. Comparison of Effluent Suspended Solids Values Before and After First Six Weeks of Operation

APPENDIX C

DISCUSSION OF CHLORINATED VALUES

The average values of BOD and COD in the final effluent were 32 mg/l and 120 mg/l respectively, while the BOD and COD of the chlorinated effluent were 50 mg/l and 172 mg/l. The higher average chlorinated effluent values were not anticipated since the chlorine is expected to oxidize a small fraction of the wastewater organics. Although the average strength of the chlorinated waste was higher, examination of Appendix B, Table 6 will show that in many cases the reverse was true for individual samples.

The higher average COD's could have been caused by chloride interference if not enough $HgSO_4$ was added to eliminate this problem. However, since the average total solids concentration of the effluent was only 355 mg/l, the waste obviously did not have an unusually high chloride concentration, and the 0.4 gm of $HgSO_4$ recommended by Standard Methods should have been more than adequate. In addition, chloride interference could not have caused the higher BOD values.

It was observed during the project that a scum layer of oil and grease formed in the chlorine contact chamber at times. When this was noticed, sample takers were instructed to sample below this layer. However, it is now believed that organics concentration in this layer are responsible for the erroneously high values of BOD and COD in the chlorinated effluent.

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16. Abstract

The bio-disc wastewater treatment process was evaluated during operation for one summer at a recreational camp. The bio-disc section consisted of four stages, each of 22 polystyrene discs 1.98 m (6.5 ft) in diameter, and was preceeded by a septic tank that served to handle both the primary and the biological sludge produced.

Evaluation of the plant included time required for start-up, organic removal efficiency, response to flow variations, nutrient removals, aesthetic impact, and required maintenance and operation attention.

Overall organic removals reached essentially full efficiency by the end of the first week of operation. However, removals across the bio-disc section continued to increase somewhat till about the fifth or sixth week of operation. Average bio-disc unit percent removals were BOD - 84.5, COD - 71, TOC - 71, and suspended solids - 75. Average overall plant percent removals were 87.5, 79, 75, and 97.5 respectively.

Total nitrogen removal through the plant averaged 40.3 percent. Ammonia nitrogen removal in the disc section was only 25.2 percent. Overall total phosphorus removal was 15 percent. Maintenance and operational requirements for the plant were minimal requiring an average of 1.3 hours per week during the summer.

17a. Descriptors

*Wastewater Treatment, *Biological Treatment, Nutrient Removal

17b. Identifiers

*Bio-disc Process, *Rotating Biological Contractor, *Tauchtropkorper

17c. COWRR Field & Group

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

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