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FEASIBILITY OF TREATING SEPTIC TANK WASTE BY ACTIVATED SLUDGE

Municipal Environmental Research Laboratory
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FEASIBILITY OF TREATING SEPTIC TANK WASTE BY ACTIVATED SLUDGE

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The study described in this report assesses the ability of a municipal wastewater activated sludge treatment plant to treat domestic septic tank pumpage on a continuous or intermittent basis. Such treatment provides a viable methodology for the disposal of this highly concentrated waste.

Francis T. Mayo
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ABSTRACT

The objective of the study reported herein was to evaluate the impact of household septic tank wastes on municipal activated sludge treatment plants. Septage addition was evaluated on a continuous basis over a four-month period in a 7500 l/day (1980 gpd) pilot plant. The septage was combined with municipal wastewater primary effluent in a series of increasing loadings to the activated sludge unit. Results were compared to a control unit receiving primary effluent only. Shock load studies were also conducted in the pilot plant system and with a series of batch aeration tests.

Septage addition was found to be feasible on either a continuous or intermittent basis. The response during the continuous feeding studies depended upon the organic loading and the septage characteristics. COD loadings below 3 g COD/g MLVSS/day could be handled without severe upset. Unacclimated systems also responded well when septage was added, and substantial organic removals were obtained within a relatively short time.

This report covers a period from February 1974 to November 1974 and work was completed as of September 1975.

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ACKNOWLEDGMENT

The pilot system was maintained and operated by the EPA-DC Pilot Plant staff under the direction of Calvin Taylor, chief operator, and Paul Ragsdale, head of instrumentation and mechanical repair. Laboratory analyses except for trace metal concentrations were performed in the EPA-DC Pilot Plant laboratory under the direction of David Rubis. Trace metal concentrations were determined by MERL Laboratories, Cincinnati, Ohio under the direction of Robert Williams.

The assistance offered by Thomas O'Farrell, chief of the pilot plant, in organizing and performing this study is gratefully acknowledged.

SECTION I

INTRODUCTION

Approximately 17,500,000 septic tanks are in use in the United States at this time (1). Of this number, a significant percentage are pumped each year to remove the accumulated sludge and scum. Because the behavior of these tanks is not predictable, there is no rational method for calculating the number of pumpings which might be expected in a single year. For the purpose of estimation, the frequency of pumping will be assumed as once every four years. An additional assumption will be that the average septic tank volume is 3 m^3 (793 gal). Since these assumptions are reasonably representative of the realities of today, the volume of septic tank pumpings (septage) which must be disposed of in this country each year is roughly 13,000,000 m^3 (3.5 billion gallons).

Most of the pumpings are transferred from the septic tank to trucks with varying capacities, but usually about 3.8 m^3 (1000 gal). The pumpers must then dispose of this particularly offensive material. In recent years, health authorities have imposed regulations which require that septage disposal be accomplished in a controlled manner at sanitary landfills, other approved disposal areas, central septage handling facilities and sewage treatment plants (STP). At a STP, the septage has often been added directly to the wetwell where it is mixed with the incoming raw sewage prior to the treatment processing.

Tales of problems caused by this form of septage disposal at small STP's abound. Plants have reportedly been upset for periods from a few hours to a few months by this practice. As a result, many (if not most) small treatment plants have banned septage disposal for all but that generated within the political boundaries of the authority served. The difficulties created by such bans can be manifold, but primary among them are higher costs to the septic tank owners due to additional time and travel requirements on the part of the pumpers. A secondary (and more serious) effect is the increased reluctance on the part of the septic tank owner to request pumping services until absolutely necessary, a condition which is generally exhibited by "day-lighting" or appearance of effluent at the ground surface above the leaching area. This condition usually means that the soil disposal field has failed and a new one must be excavated - a costly situation at best.

Since the bans are often based on hearsay evidence or effects only partially related to septage addition, there is a significant need to determine why plants may be upset and what safe limits of septage can be handled by a plant of a given configuration and capacity when septage is added to the wetwell. In order to fully appreciate the problem, it must be broken down and analyzed.

The trucked septage should be received at the treatment plant in a special handling facility, or receiving station, which may employ coarse screening, rock traps, comminution or maceration, and odor control. Unfortunately, many existing plants do not have these receiving stations and use the aforementioned wetwells as the receiving locations. In these cases, the septage becomes a shock load to the treatment facility. In smaller plants this shock load can be overpowering. For example a 3.8 m^3 (1000 gal) truck emptying its contents in 10 to 20 minutes represents a hydraulic surge of 6.3 to 3.2 l/s (100 to 50 gpm). At a 760 m^3/day (0.2 mgd) STP, this would represent an instantaneous increase in flow of between 36 and 72 percent. This hydraulic surge, when coupled with the concentrated suspended solids, BOD and other pollutants of septage, represents a major shock load on the treatment plant.

The ability of a plant to handle a given shock loading is a function of its design. Obviously, a plant which has primary sedimentation would be better protected than one which does not. The ability of a trickling filter plant or an aerated lagoon to handle such a shock would be different from that of an activated sludge plant, and each modification of the latter would also exhibit differences in resistance to upset by these shock loadings. An additional factor is the actual vs. design loading on the plant (load factor). Also, the solids handling capacity of the STP must be capable of processing the additional sludges which will be produced by septage addition.

Smith and Wilson (2) indicate that three factors must be considered in determining the capacity of handling trucked wastes at an activated sludge plant. These factors are the additional organic solids load, the reserve oxygenation capacity of the plant, and the toxicity. Although toxicity might be a factor in some cases of upsets by septage addition due to cross contamination of domestic septage in the pumpers tank from a previous load of industrial waste, it is less likely to be a factor if proper maintenance procedures are employed by the pumper. The toxicity factor becomes most important when dealing with boat or trailer holding tank wastes where zinc and formaldehyde compounds are employed in great concentrations for odor control. The reserve oxygenation capacity of a plant is a function of the design and the load factor. Since the loading of a plant and the design oxygenation capacity are known, the reserve capacity can be calculated and compared to the oxygen demand of the trucked wastes. Since these wastes are arriving at the STP in varying frequencies, the most important factor according to Smith and Wilson would be the effects of influent solids and solids synthesized from the oxidation of soluble organic matter.

If a properly designed receiving station and holding tank are available, numerous alternatives are possible. The most obvious one would permit a controlled discharge to the treatment facility in order to minimize the hydraulic and organic shocks. This continuous "bleeding" of septage to the treatment system is commonly recommended as good design procedure. However, little data exist on the performance of STP's receiving septage in controlled or uncontrolled modes.

SECTION II

SUMMARY

The objective of the experimental program summarized in this report was to determine the feasibility of treating material pumped from domestic septic tanks (septage) in activated sludge sewage treatment plants. Two approaches for adding septage were evaluated. Septage was added: (1) on a continuous basis to a system receiving a combination of septage and sewage in varying ratios and (2) on a shock load basis to a system treating municipal waste only. The continuous feed studies were conducted on a 7500 l/d (1980 gpd) pilot plant. The shock load studies employed both the pilot plant facilities and a series of batch aeration tests. In both approaches, primary sedimentation was simulated prior to adding septage to the activated sludge. In both approaches a control unit receiving only municipal waste was operated for comparative purposes.

Septage addition was found to be feasible on either a continuous or intermittent basis. The particular response of the continuous flow activated sludge system receiving septage depended upon organic loading and septage characteristics. Unacclimated systems were not unduly upset by septage addition and substantial removals of septage were obtained within a relatively short time.

SECTION III

CONCLUSIONS

1. Septage disposal to sewage treatment plants employing primary clarification and conventional activated sludge processing is feasible when sufficient excess aeration and sludge handling capacities are available.

2. Continuous addition of septage upstream of the primary clarifier could be handled without severe upsets when the COD loading was below 3 g COD/g MLVSS/day.

3. Conversion of maximum COD loadings to maximum acceptable hydraulic flows of strong septage allows a treatment plant operator to determine the maximum number of septage loads his plant can handle without being upset, if all other factors are favorable.

4. Batch shock load studies indicated that domestic septage is not toxic and that extended aeration times may be required for sufficient septage stabilization.

5. The residual COD in the activated sludge effluent was found to increase with the COD loading added to the plant.

SECTION IV

RECOMMENDATIONS

1. All future studies of the effects of septage addition on an activated sludge facility should include material balances to determine the quantities of the additional sludges produced and should include an analytical method for quantifying the biodegradable fraction of septage solids.

2. Future studies should be performed to characterize the sludge produced after septage addition so that the affect on the solids handling facility may be fully evaluated.

3. Further studies of septage addition to activated sludge facilities are necessary, preferably at a somewhat larger scale. These studies should consider several activated sludge modifications to determine the capabilities of each to handle septage additions in both shock and continuous modes.

SECTION V

EXPERIMENTAL FACILITY

Continuous Feed Study

The experimental pilot plant system consisted of two 7500 l/d (1980 gpd) activated sludge systems operating in parallel as indicated in Figure 1. Primary effluent from the District of Columbia primary clarifiers was pumped to a splitter box at 15,000 l/d (3960 gpd). The flow was split equally with half passing directly into the first stage of the control activated sludge system and half passing into a clarifier where septage was also added. The purpose of the second clarifier was to simulate septage addition into a primary clarifier since this would probably be the normal operating procedure at most plants receiving septage.

The septage was stored in two 9100 l (2400 gal) covered and vented storage tanks. One tank was kept on standby while the contents of the other were added to the activated sludge system. When a truckload of septage was received, it was pumped to a storage tank. Next the septage was continuously pumped in a closed-loop manner through a Moyno "maz-o-rator" and back into the storage tank. The pumping time was approximately 8 hours at a 38 l/min (10 gpm) flow. The macerated septage was then held in the storage tank until needed.

When the contents of one of the storage tanks were exhausted, the feed was changed to the standby storage tank and a new truckload of septage was procured for the empty tank. The feed tank was continuously mixed with a 2.2 kw (3 hp) Lightnin mixer equipped with a 61 cm (24 in) diameter impeller. In addition, the septage was continuously recycled from the bottom of the storage tank. That portion of the cycled septage which was not fed to the primary clarifier was returned to the top of the storage tank. The mechanism which fed septage into the primary clarifier is shown in Figure 2. It consisted of a piece of 5.1 cm (2 inch) PVC pipe with automatic valves at each end. The automatic valves were operated by a timer. The valves were operated such that valve A would open while valve B remained closed allowing septage from the recycle line to fill the pipe. After the pipe was filled, valve A closed and then valve B opened discharging the contents by gravity into the primary clarifier. To prevent air lock, a portion of the piping above the feed mechanism was vented to atmosphere. A delay timer was used to assure that the pipe was full before valve A closed. The frequency of fill and discharge was determined by the timer setting. This feed sequence resulted in septage being added to the clarifier every 1-7 minutes depending upon the particular loading being investigated.

The septage discharged about 5.1 cm (2 in) above the surface of the clarifier. A baffle was provided at the discharge point to distribute the septage

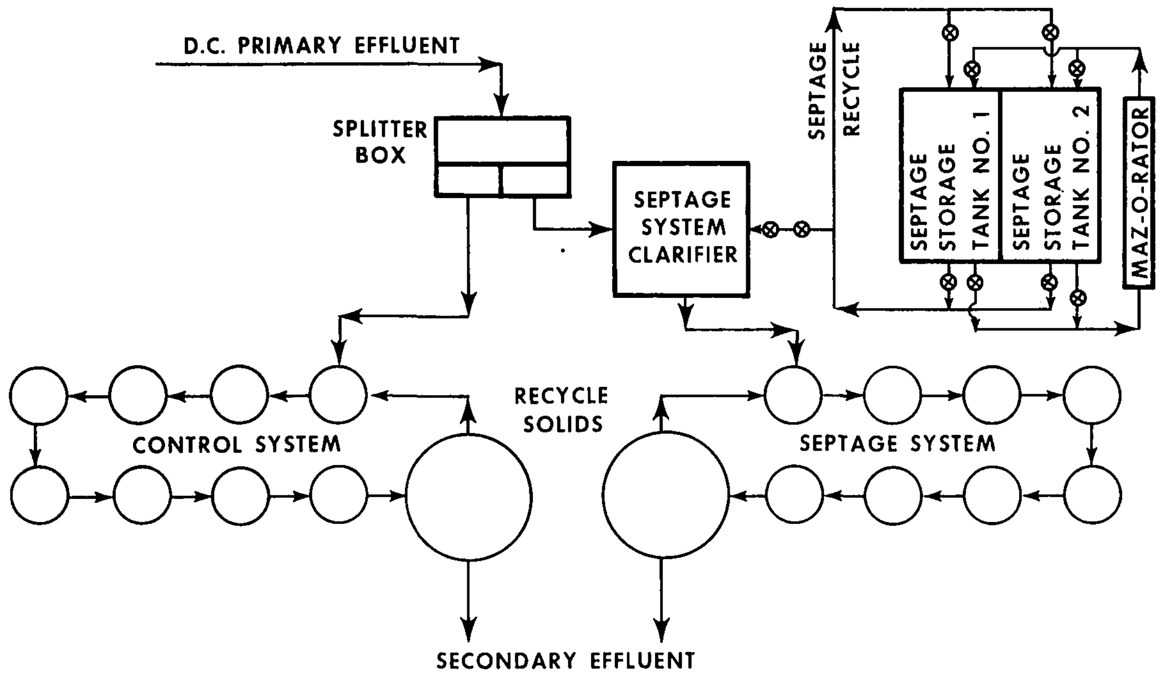

Figure 1. Schematic of Parallel Piug Flow Activated Sludge Pilot Plant.

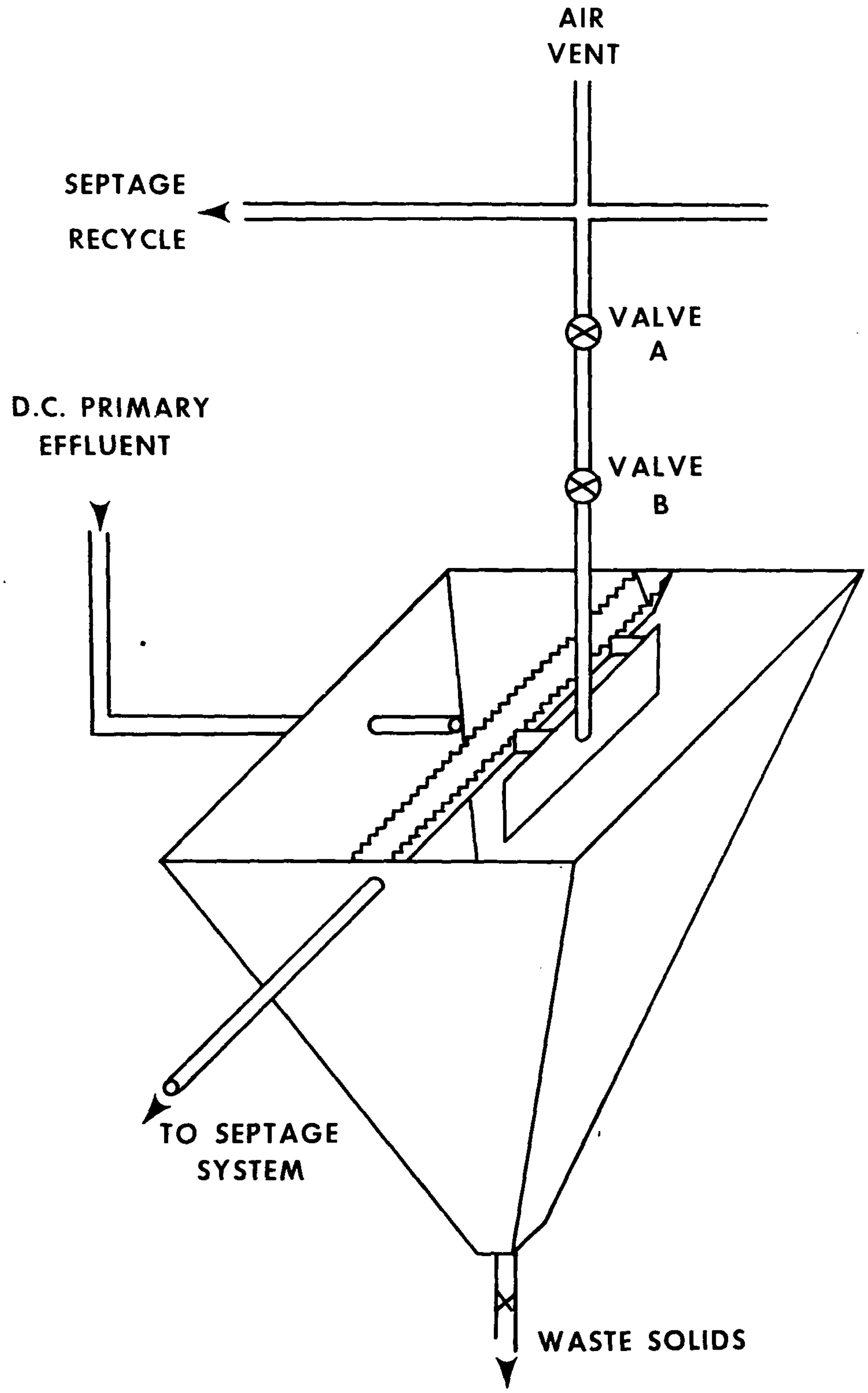

Figure 2. Septage Feed Mechanism.

throughout the clarifier. The clarifier was shaped like an inverted pyramid. It was 1.22 m (4 ft) square at the top and tapered to a 1.52 m (5 ft) depth. Solids were wasted from the bottom of the clarifier one or two times weekly to prevent a backup of settled material. The mixture of primary effluent and septage exiting the clarifier passed directly into the first stage of the septage activated sludge system.

Each activated sludge system consisted of a series of eight 208 l (55 gal) drums connected in series and followed by a 0.76 m diameter x 1.49 m depth (2.5 ft diameter x 4.9 ft depth) secondary clarifier. The 208 l (55 gal) drums were filled to a liquid depth of 66-74 cm (26-29 inches) with at least 25 cm (12 in) of freeboard to prevent solids loss during aeration. Compressed air was supplied to the bottom of each of the drums with manual control of the air flow rates. The reactor volumes of the control system and the septage system were 1454 l (384 gal) and 1340 l (354 gal), respectively. This resulted in corresponding hydraulic retention times based on the influent flow of D.C. primary effluent of 4.7 and 4.3 hours. Both secondary clarifiers were equipped with conical bottoms to facilitate solids recycle. Underflow solids from each clarifier were recycled to the first pass of each system with a Milton Roy positive displacement pump.

Shock Load Study

The shock load studies also employed the above pilot facility. In addition the shock load studies employed a series of metal drums for aerating MLSS and several containers for settling septage and mixing septage and primary effluent. Further details are presented in the section describing the shock load studies (Section IX).

SECTION VI

SEPTAGE CHARACTERISTICS

The septic tank wastes employed in the study were obtained from household sources. Each load of septage was delivered by "Potters Septic Tank Service", a local hauler in the D.C. area, with the exception of the first load which was delivered by "San-I-Kan", also a local hauler.

Characteristics of the septage used in both the continuous feed and shock load studies are summarized in Tables 1 and 2. During the course of the study, 14 different loads of septage were employed. Septage loads Nos. 1-9 were used in the continuous feed studies. Each of these loads contained the combined waste of two different household sources. Therefore the septage used in the continuous feed studies represents septage from 18 different sources. Throughout the entire study septage from 23 different sources was used.

The values presented in Table 1 for the continuous feed study are average values of daily composite samples. There was some concern that the septage characteristics could change during storage. Therefore, samples of septage were taken from the continuous recycle line every 4 hours and composited over a 24 hour period on Sunday thru Thursday to obtain the daily composite sample. Throughout the continuous feed studies, the analytical results obtained from the composited samples with any given load exhibited a random variation because of the difficulty of keeping a homogenous septage feed. The values for septage loads Nos. 10-14, shown in Table 1, were obtained by analysis of a single grab sample of each load.

One grab sample from each load (Nos. 1-14) was collected in a one-liter polyethylene cube container which was specially cleaned. The cube container was rinsed with a 25% solution (by volume) of nitric acid followed by rinsing with de-ionized water. This rinsing cycle was performed at least seven times. Ten ml of concentrated nitric acid were added to the cube container before the septage samples were taken. These samples were sent to the NERC Laboratory in Cincinnati, Ohio for trace metal analysis. The results of these analyses are presented in Table 2.

The septage characteristics varied widely from load to load. For example, COD varied from 5,965 to 43,400 mg/l and BOD varied from 1,460 to greater than 18,600 mg/l. The volatile suspended solids ranged from 59 to 85% of the suspended solids and the NH_4-N ranged from 12 to 55% of the total nitrogen. In addition the COD: BOD ratio for any given load varied from 2.7 to 8.4.

TABLE 1. Septage Characteristics

Load No.	COD mg/l	BOD mg/l	SS mg/l	(Vol.) (%)	PO_4 mg/l	TKN mg/l	(NH_4-N) (%)	TOC mg/l	COD/BOD
Continuous Feed (1)									
1	22,800	6,300	22,600	(51)	760	1250	(55)	--	3.6
4	7,340	--	6,800	(73)	190	190	(53)	--	--
5	21,980	4,400	19,000	(72)	390	490	(33)	--	5.0
6	6,880	2,520	6,280	(70)	140	200	(30)	--	2.7
7	21,480	3,820	21,440	(70)	390	560	(18)	--	5.6
8	13,870	3,320	14,370	(59)	370	460	(12)	--	4.2
9	14,870	2,910	14,110	(65)	290	390	(19)	--	5.1
Shock Load									
Batch									
10	43,400	>18,600	18,000	(82)	515	750	(25)	12,690	<2.3
11	12,260	1,460	9,600	(63)	184	216	(21)	3,470	8.4
12	5,965	1,780	1,770	(85)	166	346	(50)	1,316	3.4
Pilot Plant									
13	12,920	--	13,630	(60)	502	493	(28)	4,000	--
14	11,450	1,870	9,120	(60)	322	316	(18)	3,330	6.1

(1) Results not presented for loads No. 2 and 3 because of sampling error

TABLE 2. Heavy Metal Concentrations in Septage, mg/l.

Load No.	Fe	Mn	Hg	Ni	Cd	As	Zn	Cu	Al	Cr	Pb	Se
<u>Continuous Feed</u>												
1	750	4.4	0.024	0.4	0.2	--	120	4.2	40	0.4	1.8	0.30
2	7	1.2	0.018	0.3	0.2	<0.04	21	6.8	--	--	--	0.20
3	3	0.6	0.028	0.2	0.2	<0.04	8	1.0	--	--	--	0.20
4	90	0.8	0.005	0.3	<0.05	0.4	11	18.5	--	--	--	<0.02
5	210	2.3	4.000	0.9	10.8	0.5	17	5.1	--	--	--	0.05
6	71	0.8	0.110	0.5	0.3	0.05	5	4.4	2	0.3	--	0.05
7	275	3.6	0.740	1.2	1.7	0.08	42	9.6	17	1.5	--	0.05
8	163	20.0	0.081	1.2	0.3	0.20	16	0.5	50	1.8	--	<0.02
9	146	18.0	0.084	1.2	0.3	0.03	35	0.7	37	1.0	--	<0.02
<u>Shock Load</u>												
Batch												
10	230	2.8	<0.001	0.9	0.2	0.40	51	13.0	68	1.5	5.2	<0.02
11	100	0.8	0.200	0.4	0.18	<0.04	14	3.3	3	1.3	2.5	<0.02
12	31	0.5	0.055	0.3	<0.05	<0.04	8	6.8	18	0.3	1.5	<0.02
Pilot Plant												
13	--	--	--	--	--	--	--	--	--	--	--	--
14	395	6.5	0.002	1.2	0.21	<0.04	43	34.0	200	2.2	31.0	0.02

SECTION VII

ANALYTICAL PROCEDURES

Total phosphorus was determined by the persulfate method (3) and total organic carbon (TOC) was measured on a Beckman Carbonaceous Analyzer (4). The procedure specified in the EPA Manual (5) was used for determination of NH_4-N and (NO_2+NO_3)-N with a Technicon Autoanalyzer. Trace metal analyses at the NERC-Cincinnati Laboratory were performed on a Perkin-Elmer Model 303 atomic adsorption unit. Procedures specified in the Perkin-Elmer instruction manual were employed. All other analyses were performed in accordance with Standard Methods (6). Dissolved oxygen content in the aeration chambers was measured with a model 1010 Delta Scientific field probe.

SECTION VIII

CONTINUOUS FEED STUDY

Operation

The continuous feed studies were performed in the parallel activated sludge systems previously described in Section V. The D.C. primary effluent to the control activated sludge system was maintained at 5200 ml/min (1.4 gpm) and the inlet flow to the septage system clarifier was also maintained at 5200 ml/min. Grab samples of primary effluent were analyzed to determine if any additional settling of the D.C. primary effluent occurred in the septage system primary clarifier. As shown in Table 3, the septage system clarifier did not noticeably alter the concentrations of COD, BOD, TOC and SS.

The rate of septage addition was a function of its organic strength and the particular organic loading rate under investigation. Throughout the study, COD was the parameter used for controlling the organic load applied. The particular combination of primary effluent and septage was determined by attempting to provide a fixed average influent COD concentration. Since the COD of each septage load was variable, the rate of septage addition was adjusted to attempt to maintain the fixed COD value with each change in the septage load. Initially the concentration was set at roughly twice that of primary effluent alone. As the investigation progressed, the magnitude of the fixed COD level was increased. During the course of the study, the septage flow to the septage system clarifier varied from 2-14% of the primary effluent flow.

Samples for analyses (BOD, COD, TKN, NH_4-N, (NO_2+NO_3)-N, P, SS and VSS) in the EPA-DC Pilot Plant Laboratory were manually taken every 4 hours and composited over either 24 or 48 hours. All samples except those taken for BOD and suspended solids analysis were preserved with 1 drop of H_2SO_4 per 30 ml of sample while they were being held in storage. During storage all samples were maintained at 3^oC to minimize biological activity.

From April 1 until July 11, all samples except for the D.C. primary effluent feed to the control system were composited over 24-hour periods on Sunday through Thursday; no laboratory samples except D.C. primary effluent were collected on Friday or Saturday. The D.C. primary effluent feed to the control system was sampled every day and the non-acidified sample composited over 24-hour periods only, while the acidified samples were composited over 24 hours on Tuesday, Wednesday and Thursday, and over 48 hours on Friday-Saturday and Sunday-Monday. BOD_5 analyses were performed on a seven-day-a-week basis. Starting July 12, influent and effluent samples from both systems were collected for BOD_5 analysis every day and composited over 24 hours. Also starting July 12, samples for all suspended solids analysis were composited over 24 hours on Tuesday, Wednesday and Thursday, and over 48 hours on

TABLE 3. Comparison of the Feed to the Parallel Plug Flow Activated Sludge Systems without Septage Addition.

Date	System	COD mg/l	BOD mg/l	TOC mg/l	SS mg/l
03-25-74	Control	196	113	--	52
	Septage	--	119	--	70
03-26-74	Control	205	113	--	100
	Septage	199	125	--	82
03-27-74	Control	213	105	--	88
	Septage	215	129	--	76
03-28-74	Control	199	115	--	74
	Septage	207	100	--	76
10-19-74	Control	--	--	88	108
	Septage	--	--	74	116
10-20-74	Control	--	--	75	140
	Septage	--	--	71	120
11-12-74	Control	281	131	77	146
	Septage	251	141	74	116

NOTE: All analyses were performed on grab samples.

Friday-Saturday and Sunday-Monday.

The operators checked flow rates and dissolved oxygen levels every four hours on a continuous seven-day-a-week basis. The solids recycle rate in both systems was set at approximately 20% of the influent flow (1040 ml/min) through most of the study. The dissolved oxygen content was maintained at 1-5 mg/l. Thirty minute sludge volumes in 1-liter cylinders were obtained on recycle solids and mixed liquor from the second and eighth drums (Figure 1) once every eight hours. The reactor sludge volumes and approximate mixed liquor suspended solids analysis from the seventh drum were used to control the wastage rate. The approximate solids analyses were performed Monday through Friday on grab samples which were filtered and dried at 105°C for 30 minutes. Any upward or downward trend over several days of operation resulted in an adjustment in the wastage rate. On weekends, the wastage rate was not changed unless there was an abnormal change in sludge volumes.

Solids were manually wasted from the control system throughout the study. The solids were wasted from a tee in the recycle line which was located ahead of the recycle pump. The tee was located below the bottom of the clarifier and flow was by gravity. Initially, 76-95 l (20-25 gal) of waste solids were removed from the system only once per day. It was visually apparent during wasting that the waste solids concentration was decreasing considerably near the end of the waste cycle. This indicated channelling in the clarifier because of the high waste flow rate. Therefore, the frequency of wasting was gradually increased until it reached once every 4 hours.

Channelling in the clarifier during wasting was more severe in the septage system because the volume of waste was 2-5 times greater than in the control. When solids were manually wasted every 4 hours, similar to the control system, channelling still occurred. An automatic blow-down system operated by a timing mechanism was installed in June, and from that time onward the waste frequency was approximately once per hour depending upon the particular waste rate desired. Because of channelling and various mechanical problems, a representative sample of the solids being wasted from the system was not always obtained. Starting May 28, the operators obtained the sample to determine waste solids concentration from the volume of sludge actually wasted rather than from the sludge recycle line. The operators obtained the sample during a regularly scheduled time of wasting. Each time the operators sampled the system, the full volume of solids wasted at that time was collected, mixed and sampled. Prior to May 28, the waste solids concentration was improperly sampled because of channelling during wasting. For this reason sludge production data prior to May 28 are not available.

Throughout the study, the variability of the mixed liquor suspended solids concentration was greater in the septage system than in the control. Prior to septage addition both systems were operated at a high (4000-5000 mg/l) MLSS concentration. After septage addition commenced on April 10, the MLSS concentrations in both systems were gradually reduced over approximately a month's time to near 2000 mg/l, a value typical of a conventional activated sludge system. From May 24 through August 12, the MLSS in the septage system averaged 2050 mg/l. However,as shown in Figure 3, there was considerable variation. The MLSS in the control system were generally maintained at 2000

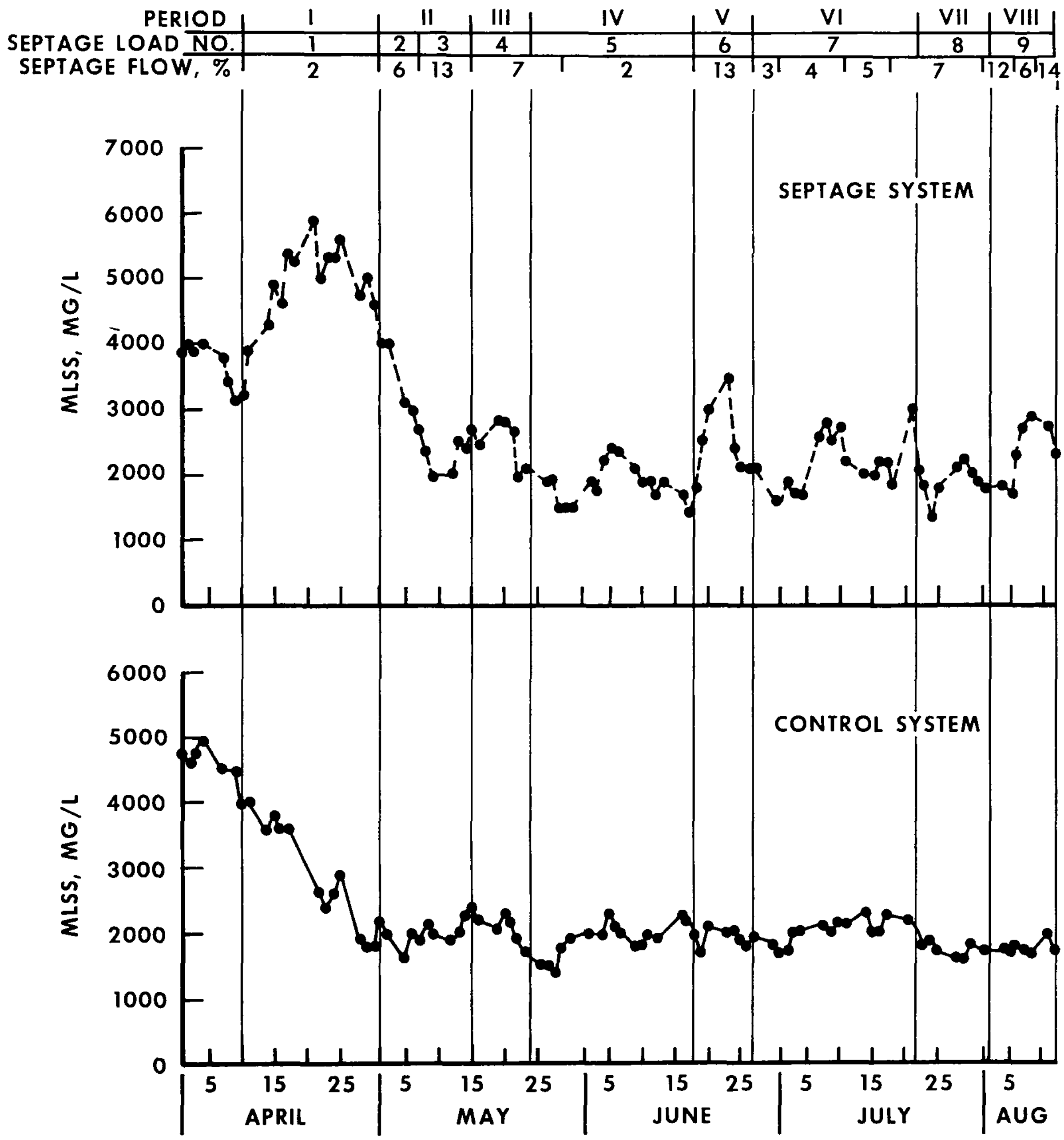

Figure 3. Variation of Mixed Liquor Suspended Solids.

mg/l with only minor variations until July 22 when they were intentionally reduced to approximately 1700 mg/l.

The variations in MLSS in the septage system can be attributed to erratic fluctuations in influent SS and BOD, mechanical difficulties, and the frequency of changing loads of septage. The variability of the influent to the septage system compared to the control is shown in Figures 4-A, 5-A, 6-A, and 7-A. Although the septage storage tank was equipped with a mixer and septage was continually recycled, there was variability in the daily septage sample being pumped to the primary clarifier as a result of insufficient mixing. This variability was the primary reason for fluctuation in influent characteristics.

Although the septage was macerated, the septage recycle line as well as the feed mechanism periodically plugged (approximately once every week) with septage solids consisting mainly of hair and fibrous material. Recurring mechanical problems were also present in the automatic blow-down system. Maintenance personnel were on call 24 hours a day to correct any malfunctions which could not be handled by the normal operating crews.

Another factor which made maintaining a steady MLSS concentration difficult was the frequency of changing loads of septage. With each load of septage, the operators had to establish a new waste rate to attempt to maintain the desired solids level. However, establishing the correct waste was a gradual process. Several times before the waste rate could be accurately established, a different load of septage was added requiring an immediate change in waste rate. Consequently, maintaining a constant MLSS level was difficult. Even during full scale operation, a constant MLSS concentration could be difficult to maintain because of the changing nature of the septage.

Performance

The performance of the parallel activated sludge systems during continuous addition of septage is summarized in Figures 3-8 and in Tables 4 and 5. Because of the wide variation of the influent BOD and COD loadings to the septage system and because of other day-to-day variations which occurred, it is difficult to accurately characterize periods of average performance based on uniform process loadings. Although the research plan called for stable operation of the septage system with a series of increasing loading rates, the variations in septage characteristics, etc. made the actual process loadings different than desired at certain times. Another problem experienced in the analysis of the data was that effluent suspended solids from the control were very erratic (Figure 4-C), causing abnormal fluctuations in effluent quality. The erratic variation of effluent solids continued until period VI due to an excessive growth of Nocardia organisms which floated to the surface of the secondary clarifier, causing a mat of floating solids and an effluent quality of marked variability. During period VI, clarification and effluent quality improved considerably and remained relatively stable for the balance of the study. Other studies at the pilot plant have shown that the Nocardia growths are less competitive at the higher loadings experienced in the latter phases of this study.

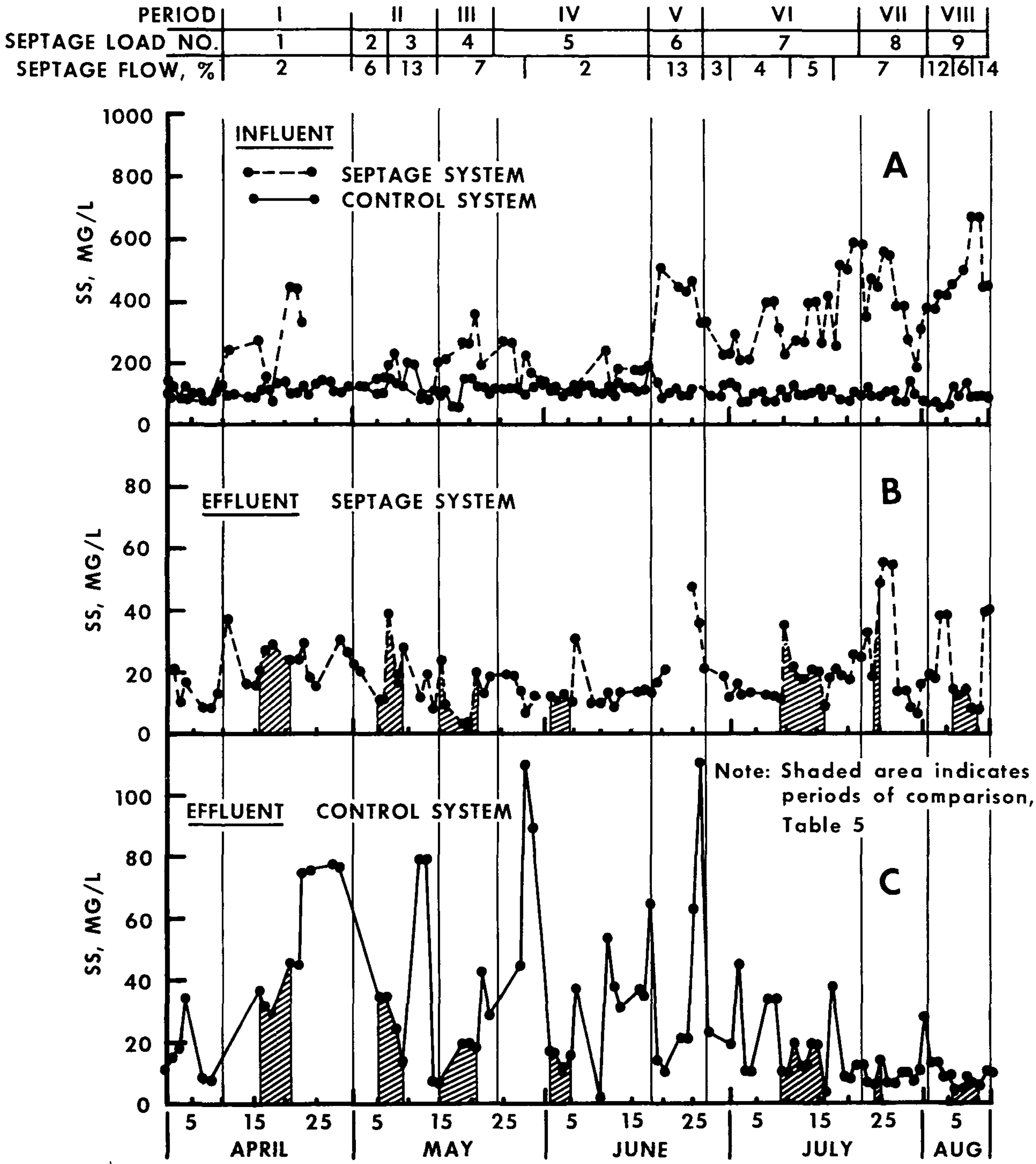

Figure 4. Variation of Influent and Ef*luent Suspended Solids.

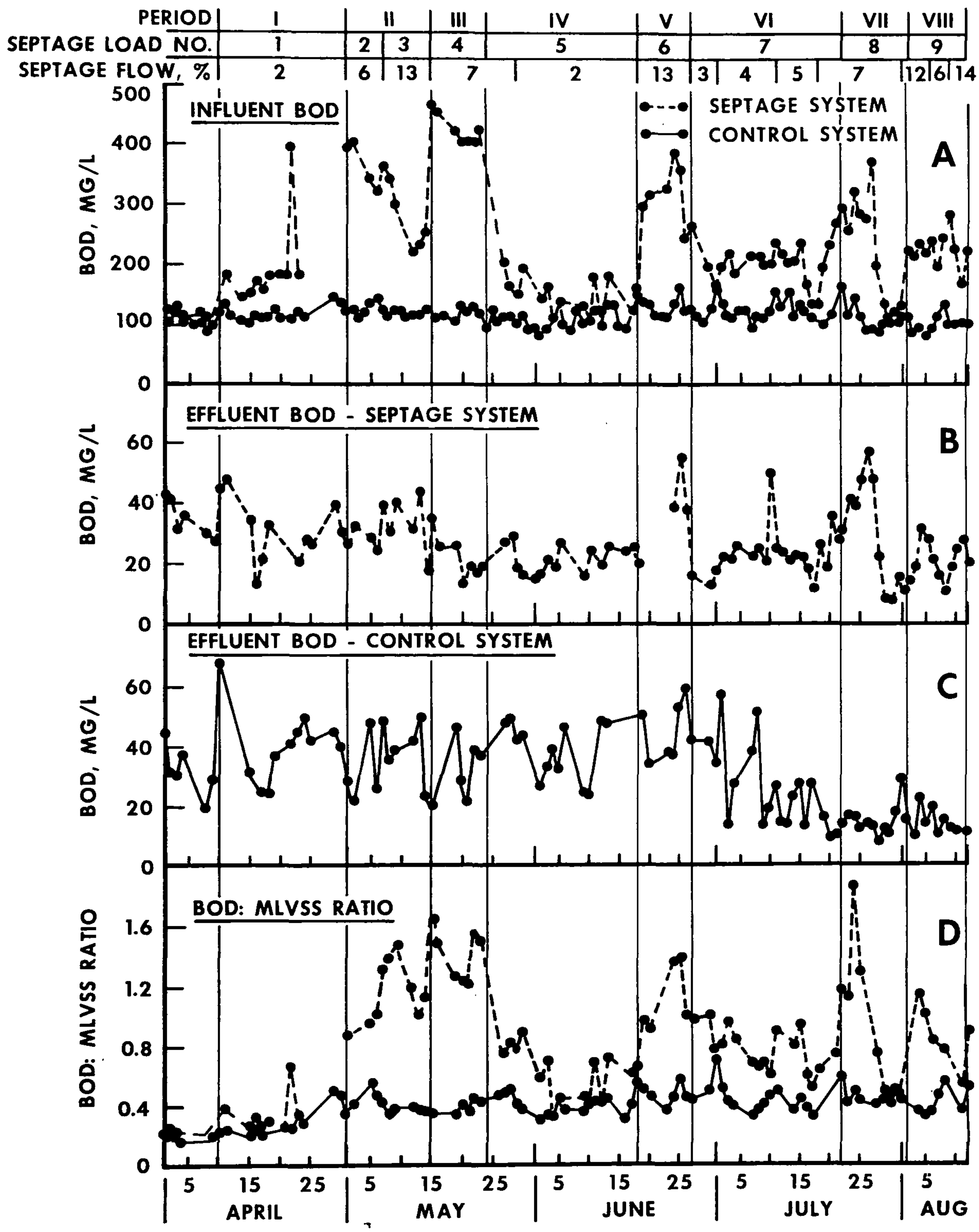

Figure 5. Variation of Influent and Effluent BOD and BOD: MLVSS Ratio.

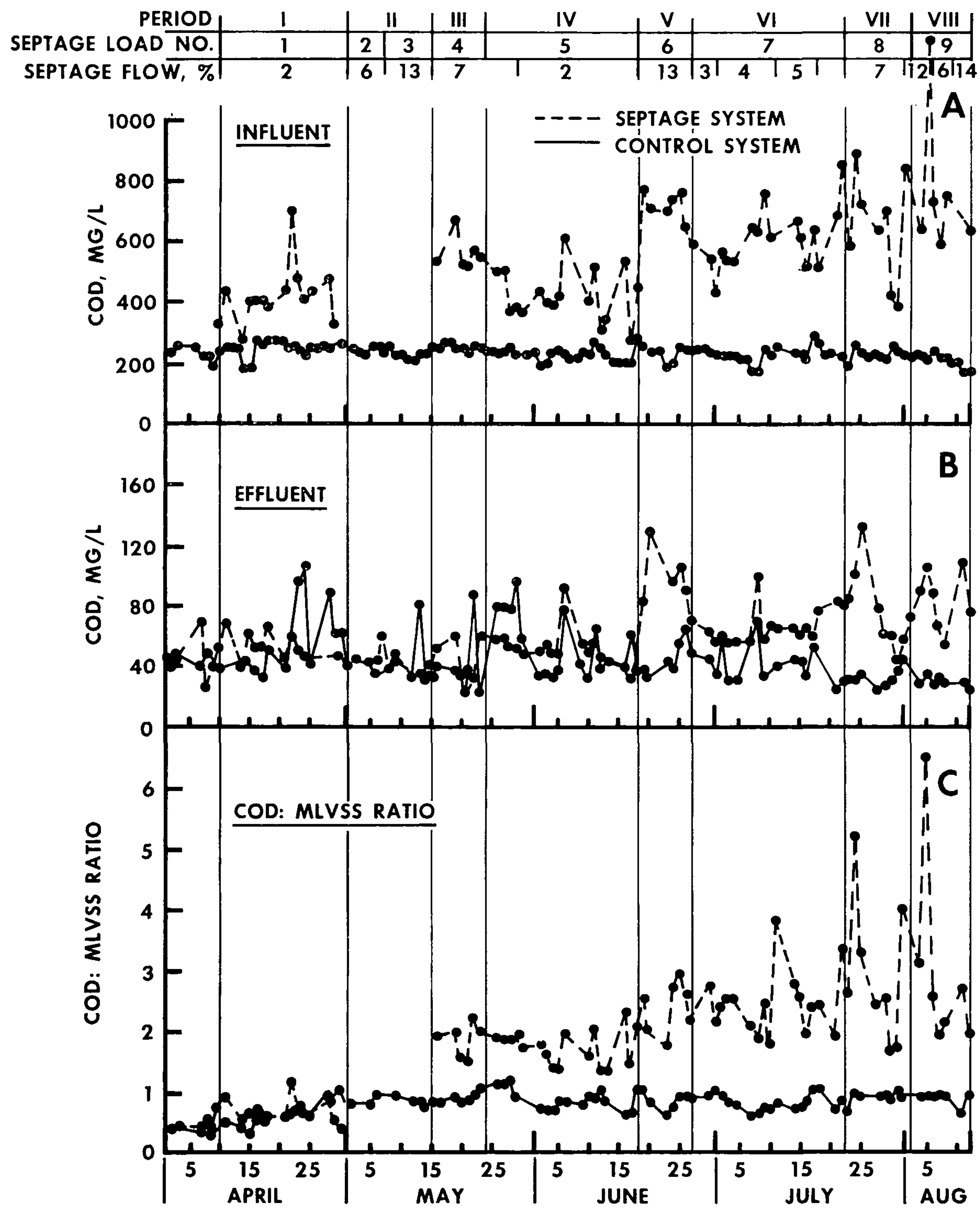

Figure 6. Variation of Influent and Effluent COD and COD: MLVSS Ratio.

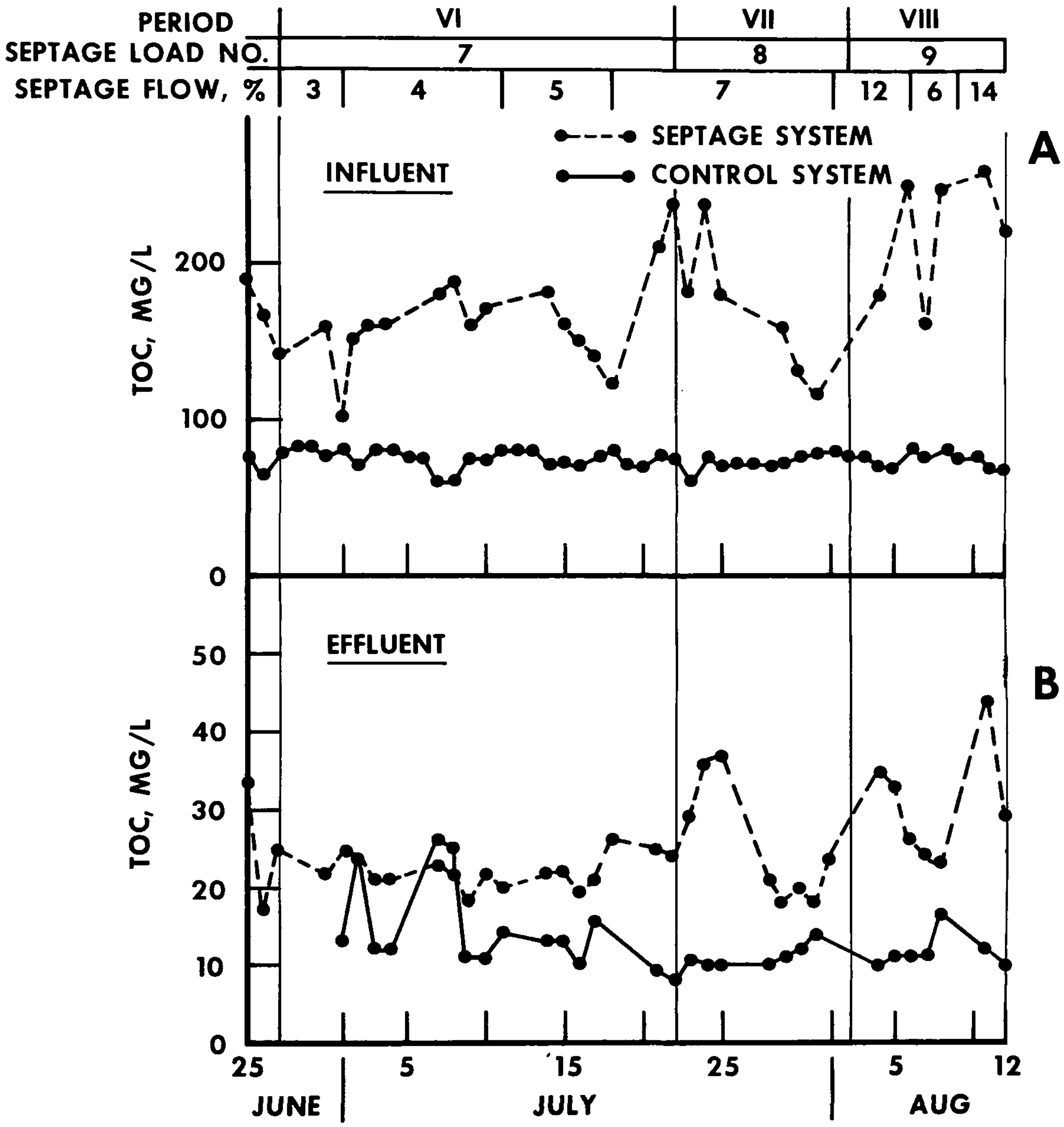

Figure 7. Variation of Influent and Effluent TOC.

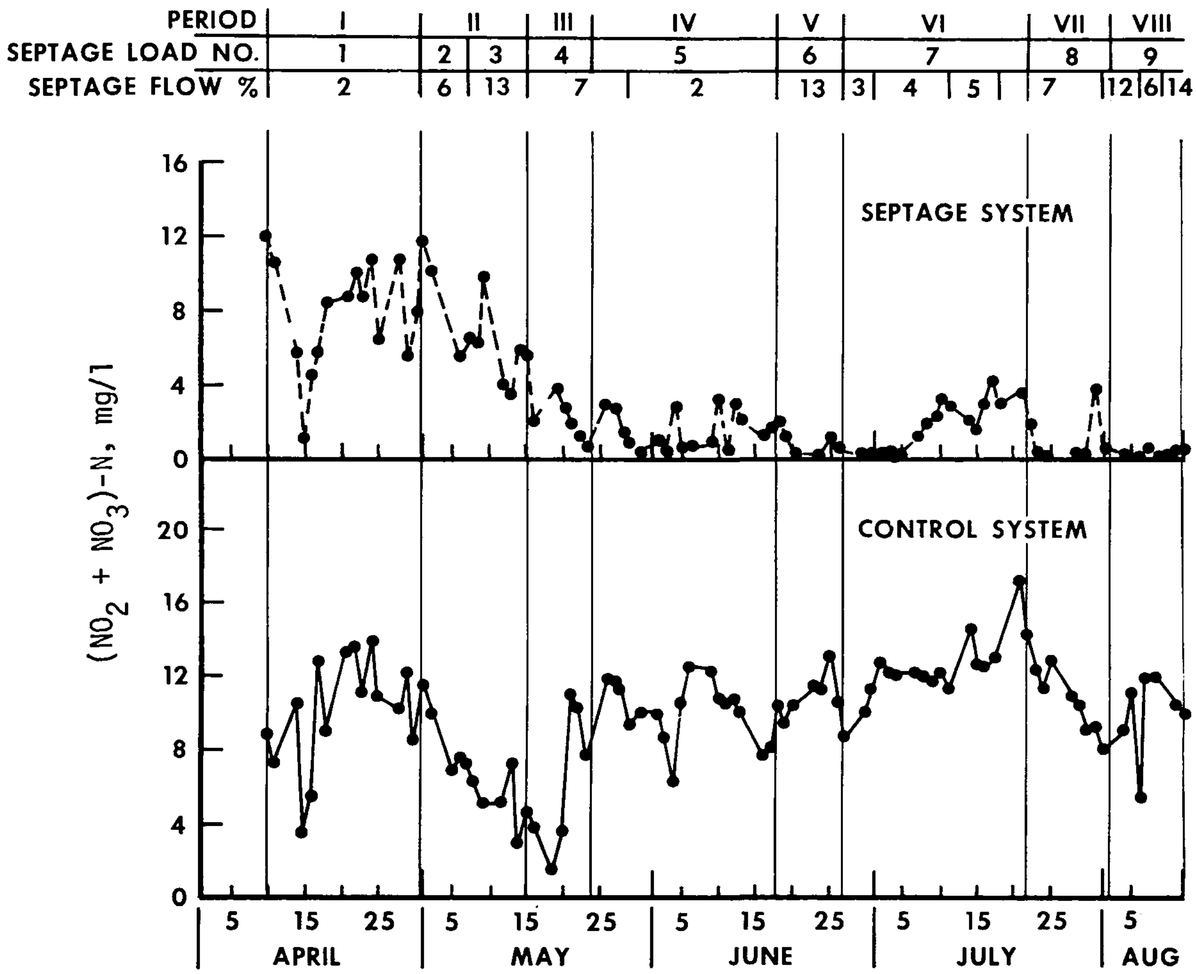

Figure 8. Variation of Effluent $(NO_2 + NO_3)$-N.

TABLE 4. Operation of Plug Flow Activated Sludge System with Septage Addition.

Period	I	II	III	IV	V	VI	VII	VIII
Septage Load No.	1	2-3	4	5	6	7	8	9
Time Period	4/10-4/30	5/01-5/14	5/15-5/23	5/24-6/17	6/18-6/26	6/27-7/21	7/22-7/28	8/02-8/12
MLSS-Reactor, mg/l	4870	2800	2510	1870	2490	2150	1790	2300
Volatiles, %	67.4	64.8	71.6	76.2	75.5	72.0	75.4	71.3
COD-Influent, mg/l	404	--	557	438	683	590	730	755
COD:MLVSS, day^{-1}	0.7	--	1.8	1.7	2.3	2.2	3.2	2.8
Effluent, mg/l	52	41	43	52	91	65	94	83
BOD-Influent, mg/l	191 (1)	316	415	153	316	198	282	225
BOD:MLVSS, day^{-1}	0.33	1.1	1.4	0.61	1.0	0.74	1.3	0.84
Effluent, mg/l	31	32	22	21	44 (2)	23	41	19
SS-Influent, mg/l	284 (1)	136	252	171	394	355	480	480
Effluent, mg/l	25	19	13	14	27	18	36	24
TOC-Influent, mg/l	--	--	--	--	--	158	208	196
Effluent, mg/l	--	--	--	--	--	22	30	30

(1) Average Values for 4/10-23 only.

(2) June 24, 25 and 26 only.

TABLE 5. Comparison of the Septage System with the Control System.

System	Time Period	MLVSS mg/l	BOD		COD		TOC		SS		Septage Load No.	Period
			Inf. mg/l	Eff. mg/l	Inf. mg/l	Eff. mg/l	Inf. mg/l	Eff. mg/l	Inf. mg/l	Eff. mg/l		
Control	4/16-21	2500	113	28	263	42	--	--	133	37	1	I
Septage		3600	172	22	403	52	--	--	281	25		
Control	5/5-9	1500	123	36	--	39	--	--	119	29	2-3	II
Septage		1750	336	33	--	45	--	--	170	21		
Control	5/15-21	1650	111	24	252	34	--	--	107	17	4	III
Septage		1900	419	24	555	41	--	--	264	11		
Control	6/2-5	1500	102	32	220	34	--	--	106	15	5	IV
Septage		1550	138	18	407	50	--	--	117	11		
Control	7/9-16	1600	130	18	258	38	75	12	105	14	7	VI
Septage		1650	200	25	632	62	163	20	305	19		
Control	7/24-25	1410	124	14	247	32	73	10	102	11	8	VII
Septage		1170	301	43	803	115	209	36	460	34		
Control	8/6-10	1300	106	13	214	29	77	13	115	6	9	VIII
Septage		1900	231	18	691	69	222	24	479	12		

Although the MLSS concentrations in the septage system were maintained near 2000 mg/l from period III to the end of the study, the SRT was considerably less than in the control because of a greater sludge wasting rate. For example, during period V the SRT in the septage system was near 1 day. The Nocardia was never competitive at these low SRT values, and therefore the effluent quality from the septage system represents a more typical operation of the activated sludge process than does the control system during periods I-VI.

Owing to the problems discussed above, it is apparent that any method selected for presenting and analyzing the data must be somewhat arbitrary. It was felt that the results from the septage system could best be described by characterizing the operation of this system during eight discrete time periods. The duration of each of these periods is shown at the top of Figures 4 thru 8, and the average characteristics of the septage system during these eight periods are summarized in Table 4. Because of the highly erratic variability in the effluent suspended solids from the control system during most of the study, it is not reasonable to attempt to quantify any changes in effluent quality attributable to the septage by making a direct comparison of the effluent qualities from the septage and control systems for each of the eight periods shown. However, by selecting relatively short periods of operation where the effluent suspended solids concentrations from the control system were reasonably uniform and relatively free of Nocardia organisms, it is possible to compare the two effluent qualities in a manner which provides additional useful information. A comparison of the two systems during seven of the above short time periods is summarized in Table 5, and these periods are indicated by the shaded areas in Figure 4. The particular reason for selecting each of these seven short periods is included in the discussion of system operation during each of the eight periods described below.

Period I

The first time period to be considered was from April 10-30. Septage addition was initiated on April 10. During the period April 10-30, only one septage load (load No. 1) was fed to the septage system at a constant flow rate of 2 percent of the D.C. primary effluent flow. Prior to April 10, the two parallel systems had been operating for a period of approximately two months on primary effluent only. When septage addition began, the MLSS concentrations in both the septage system and in the control were considerably higher than the intended operating level of 2000 mg/l. Consequently, the waste rate in both systems was increased to gradually reduce the reactor MLSS from 3000-4000 mg/l to near 2000 mg.l. As shown in Figure 3, the MLSS in the control unit gradually decreased to near 2000 mg/l but the MLSS in the septage system increased and remained high throughout the period averaging 4870 mg/l. This was the result of insufficient wasting in the septage system. Examination of Figure 6-C reveals that the average daily COD loadings (mass of daily COD/MLVSS mass of reactor) for each of the two systems were similar although the MLSS in each system were not equal. The average COD loading to the septage system was 0.70 g COD/g MLVSS/day and the average COD loading to the control system was 0.63 g COD/g MLVSS/day. Over the entire period the influent COD to the septage system averaged 404 mg/l which was approximately 1.6 times that in the control. The effluent COD, BOD and SS averaged 52, 31 and 25 mg/l, respectively.

It should be noted that until clarification in the control system improved during period VI, the BOD from the control (Figure 5-C) was generally greater than that from the septage system (Figure 5-B). This was due mainly to the BOD associated with the increased suspended solids in the control effluent (Figure 4). In addition, since the control system was nitrifying throughout the study (Figure 8), the effluent suspended solids from the control contained nitrifying organisms which resulted in nitrification in the BOD_5 test. It is also apparent from Figure 8 that septage addition did not prevent biological nitrification during the period when the SRT was maintained at a sufficiently high level.

As indicated in Figures 6-C and 5-D, the COD and BOD loadings during period I were relatively low. The performance of the septage system is compared with the control system from April 16-21 in Table 5. Although the average SS from the control system were higher than from the septage system, 37 mg/l compared to 25 mg/l, the COD from the control system was less, 42 compared with 52 mg/l. Based on this comparison, it appears that even at low loadings there was a small increase in effluent COD attributable to the septage. Additional laboratory analyses not shown in Table 4 revealed 10-11 mg/l PO_4 in the effluent from each system, indicating that excess phosphorus was present for biological growth.

Period II

The second period of system operation to be characterized is from May 1-14. During this period septage loads No. 2 and No. 3 were added to the septage system clarifier at flow rates of 6 and 13% of the influent flow of D.C. primary effluent, respectively. Increased wasting reduced the MLSS in the septage system during the addition of septage load No. 2 but they were relatively stable during the addition of load No. 3. The intended influent COD to the septage system during this period was 400-500 mg/l, but because of sampling error with the acidified composite sample, neither the COD of the influent nor the COD of the daily septage sample were accurately determined.

The BOD loading to the septage system averaged 1.1 g BOD/g MLVSS/day. This was a considerable increase over period I, which averaged 0.33 g BOD/g MLVSS/day. Although this was a substantial increase in BOD loading, the average effluent BOD during periods I and II was essentially the same. Also, during this period the COD and SS from the septage system averaged 41 and 19 mg/l, respectively.

Comparison of effluent quality from the septage system with that from the control for the period of May 5-9(Table 4) indicates that nearly the same average effluent BOD and COD were obtained from both systems on the days when the average effluent solids differed by only 8 mg/l. The systems were both nitrifying at this time, and this is reflected in the effluent BOD_5 analysis.

Period III

The operation of the parallel activated sludge system from May 15-23 is summarized as period III. During this period, the MLSS in both systems were relatively stable (Figure 2) and averaged 2510 mg/l in the septage system and 2110 mg/l in the control system. Only one load of septage, load No. 4, was added during this period. The influent COD to the septage system averaged 557 mg/l resulting in a COD loading of 1.8 g COD/g MLVSS/day which was 2.0 times that in the control.

Although this was a relatively short period of operation, it was considered separately because during this period the highest sustained BOD loading was imposed on the septage system. The BOD_5 loading for this period was 1.4 g BOD/g MLVSS/day, while that in the control for the same period was only 0.4 g BOD/g MLVSS/day. During this period the effluent COD, BOD, SS from the septage system averaged 43, 22, and 13 mg/l, respectively. As shown in Figure 6-B, the effluent COD during this relatively short period was not stable, and varied from roughly 20-60 mg/l.

The period May 15-21 was selected for comparing the septage system with the control system because the effluent SS from both systems were relatively low and stable during this time (Figures 4-C and 4-B). As shown in Table 5, there was no difference in average effluent BOD_5 between the two systems although a much higher BOD loading was imposed on the septage system. It should be kept in mind, however, that there was nitrification occuring in the BOD_5 tests of the control system effluent and, possibly, in the effluent from the septage system. As in previous comparisons, a slight increase in COD from the septage system was observed, and averaged 41 mg/l, compared to 34 mg/l for the control system.

Period IV

Period IV covers 25 days of operation from May 24 to June 17. The reactor MLSS in both systems were relatively stable and similar during this period (Figure 3). The MLSS in the septage system averaged 1870 mg/l. This was somewhat less than during the previous period, but similar to the control system which averaged 1900 mg/l. Only one load of septage, load No. 5, was added during this time.

The influent COD to the septage system averaged 438 mg/l. This was less than in the previous period but the reduced MLSS level in the reactor produced a COD loading of 1.7 g COD/g MLVSS/day. Although the COD loading was nearly the same as the loading during Period III, the BOD loading was only 0.61 g BOD/g MLVSS/day. In contrast, the COD and BOD loadings to the control system at this time averaged 0.85 g COD/g MLVSS/day and 0.4 g BOD/g MLVSS/day. The COD and BOD loadings to the control system were maintained close to these values through the remainder of the continuous feed study.

During Period IV the septage system produced an effluent averaging 52 mg/l COD, 21 mg/l BOD and 14 mg/l SS. As shown in Figure 6-B, the effluent COD was stable except for one day where the effluent suspended solids were higher than normal. The average effluent BOD and SS were similar to those values in the previous period of operation (Period III) but the COD was 9 mg/l greater.

The period June 2-5 (Table 5) was selected for comparing the control and septage systems because the effluent SS from the control were stable and similar to those from the septage system during this time. The effluent COD from the septage system was 50 mg/l whereas that from the control was 34 mg/l. Examination of the control system through Period IV (Figure 6-B) during times of good clarification indicates an effluent COD which generally varied from 35-45 mg/l. Examination of the septage system through Period IV (Figure 6-B) indicates an effluent COD of roughly 40-60 mg/l. Based on these ranges of COD from the control and septage systems, it appears that with COD loadings to 1.8 g COD/g MLVSS/day the effluent COD from the septage system was 10-15 mg/l greater than from the control. During the June 2-5 period, the BOD in the control system was greater than in the septage system, 32 mg/l compared to 18 mg/l, probably because of nitrification in the BOD_5 analysis as previously discussed. During this time period the high waste rate reduced the amount of nitrification in the septage system considerably.

Period V

The fifth period of operation to be discussed covers the period from June 18-26 when septage load No. 6 was added to the septage system clarifier at a rate of 13 percent of the D.C. primary effluent flow. Because of a malfunctioning of the automatic wasting mechanism and a sharp increase in the influent suspended solids concentration over that observed with load No. 5, the MLSS in the septage system increased from 1800 mg/l on the 18th to 3500 mg/l by the 23rd. A very high waste rate was then applied to the system and the MLSS were reduced to 2100 mg/l by the 26th of the month. This extreme variability makes it unrealistic to compare the septage and control systems during this period.

The brief nine-day operating period in conjunction with the large variation in reactor solids also makes it difficult to adequately summarize system operation during this time. The COD loading averaged 2.3 g COD/g MLVSS/day, and was as high as 2.6 g COD/g MLVSS/day. Other system parameters are summarized in Table 4. Although the effluent COD and BOD values were somewhat higher than normal, there was really no adverse affect on the system which can be attributed to the septage per se. The absence of effluent BOD_5 values during the first six days of septage addition resulted from all oxygen being depleted in the BOD test. These values were all in excess of 30 mg/l. Average effluent BOD for the last three days during this period was 44 mg/l.

Period VI

Septage load No. 7 was added to the septage system clarifier during the period of June 27-July 21 and this operation will be summarized as Period VI. Although the septage flow was increased from 3 to 7 percent of the flow of D.C. primary effluent during this period, there was also a general trend towards increasing MLSS concentrations in the septage system. As a result the organic loading to the septage system during this period exhibited a rather random variation about the average value. The COD loading averaged 2.2 g COD/g MLVSS/day and the BOD loading was 0.74 g BOD/g MLVSS/day.

The process performance of the septage system was entirely satisfactory. The influent COD was reduced from an average of 590 mg/l to 65 mg/l. The effluent BOD_5 averaged 23 mg/l. There was some nitrification in the septage system during much of this period and thus the BOD_5 values probably also represent some nitrogenous demand. TOC analyses were initiated at the beginning of this period and these values are presented in Figure 7.

The effluent suspended solids from the septage and control systems were similar and reasonably stable during the period of July 9-16, and the results obtained from each of the two systems during this period are compared in Table 5. The COD loading was 2.7 times greater and the BOD loading 1.7 times greater in the septage system than in the control system. During this period the septage feed was only varied from 4 to 5 percent of the influent flow of D.C. primary effluent. The effluent COD from the septage system was 24 mg/l higher and the TOC 8 mg/l higher than the corresponding values in the control system. The effluent BOD_5 values differed by 7 mg/l. Once again the difference in effluent quality of the two systems was small.

Period VII

Period VII describes the operation from July 22-August 1 when septage load No. 8 was added. With the exception of one day, July 24, the MLSS in the septage system were reasonably stable for the 11 days of operation. During the first seven days of operation, the influent COD, BOD and SS were high and relatively stable but they decreased sharply on succeeding days because of operational problems with the septage feed mechanism. For example, the influent COD decreased from 600-800 mg/l to near 400 mg/l and the BOD decreased from roughly 300 to 100 mg/l by the 30th of the month. Because of the decrease in organic concentrations, only the first seven days of the operation with load No. 8 have been summarized in Table 4. As shown in Figure 6-C and 5-D the daily COD and BOD loadings to the septage system during the first seven days of operation were not uniform because of a sharp increase in COD and BOD loadings on July 24 when the MLSS were lowest (1300 mg/l) and the influent COD was highest (890 mg/l). During the seven day period, the influent COD, BOD, TOC and SS averaged 730, 282, 208 and 480 mg/l, respectively. This influent COD was the highest average COD thus far in the study. The corresponding COD and BOD loading averaged 3.2 g COD/g MLVSS/day and 1.3 g BOD/g MLVSS/day. The day of the sharp increase in loading, July 24, is considered in these averages, and it is emphasized that the average effluent characteristics do not represent the results of a uniform loading. The effluent from the septage system averaged 94 mg/l COD, 41 mg/l BOD, 30 mg/l TOC and 36 mg/l SS during this time. There were the highest average concentrations of pollutants in the effluent thus far. The deterioration of effluent quality appeared to be related to clarification efficiency since there was an increase in effluent SS at this time. The poor clarification was the result of the high organic and solids loading to the aeration system.

The influent and effluent characteristics of the septage system are compared with those from the control during July 24-25, in Table 5. Of course, a comparison based on 2, 24-hour composite samples can hardly be considered a definitive evaluation, but the data are useful in showing that the septage system responded well to a temporary very high loading. The loading on

July 24 was about 5 g COD/g MLVSS/day and the BOD loading, 1.9 g BOD/g MLVSS/day. The effluent quality on the 25th was somewhat worse than measured on the 24th and therefore the 2-day average was presented in Table 5. By the 29th of the month, the effluent BOD from the septage system was only 7 mg/l which shows that there were no long-term effects on the septage system.

Period VIII

The operation of the septage system from August 2-12 is described as Period VIII. As shown in Figure 2, the MLSS were unstable during this period varying from near 1800 mg/l during the beginning of the period to as high as 2900 mg/l. The average MLSS for the period were 2300 mg/l. Because of the variation in MLSS and influent COD, the daily COD loadings to the septage system were erratic during this period (Figure 6-C). The effluent characteristics are not typical of operation with a uniform COD loading.

Although the COD loading to the septage system was similar to that maintained during operation with septage load No. 8, the BOD loading only averaged 0.84 g BOD_5/g MLVSS/day. The effluent quality was very good with a carbonaceous effluent BOD_5 of just 19 mg/l and average effluent suspended solids of 24 mg/l.

The effluent quality from the septage system is compared with that from the control system from August 6-10 in Table 5. During this time the effluent SS from both systems were relatively stable and similar (Figures 4-B and 4-C). The effluent quality from the control system was similar to that in the previous period with load No. 8. During both septage loads No. 8 and No. 9, the control system operated well with steady MLSS concentrations in the reactor and an average SVI of 110. Fluctuations in effluent SS were minor and clarification was good. Operating with an average influent COD of 691 mg/l during the 5 days of comparison, the septage system produced an effluent with a COD 40 mg/l greater than the control, a BOD_5 only 5 mg/l greater, a TOC 11 mg/l greater and SS only 6 mg/l greater.

SECTION IX

SHOCK LOAD STUDIES

Since the continuous flow studies did not indicate any significant problems with septage addition to an acclimated system, several shock load studies were performed to assess the potential impact on an unacclimated system. Both batch aeration tests and the 7500 l/day (1980 gpd) pilot plant system were used in these evaluations.

Batch Aeration Test - Procedure and Results

The experimental procedure for each batch aeration test was as follows. Approximately 150 l (40 gal) of septage were placed in a 190 l (50 gal) drum, mixed, and sampled for laboratory analysis. The contents of the drum were then allowed to settle under quiescent conditions for a period of one hour. Next, the top third of the settled septage was siphoned off and different volumes of the siphoned septage were added to 38 l (10 gal) containers. Primary effluent was also added to each of the containers to produce a total liquid volume of 30 l (8 gal). The contents of each container were then mixed and samples were withdrawn for laboratory analysis. The liquid volume was then adjusted to 27 l (7 gal).

For each test a total of six containers was used. One of the containers received only primary effluent and served as a control. The other five containers contained varying ratios of septage to primary effluent.

Approximately 8 l (2 gal) of recycle solids from a 189 m^3/day (50,000 gpd) plug flow activated sludge system operating at a 3-4 day SRT and treating D.C. primary effluent were added to each of the six containers. The D.O. was then quickly adjusted to between 2-5 mg/l by throttling the air line to each container and maintained within this range. Mixed liquor samples were withdrawn from each of the drums after 0.5, 2.0, 4.0 and 24 hours. The samples were settled in a two-liter graduate cylinder for 30 minutes and then approximately 1300 ml of the clarified supernatant were siphoned off for laboratory analysis. Supernatant samples taken for soluble COD analysis were filtered immediately through a Reeve Angel-Grade 934 AH glass fiber filter. TOC analysis was performed on the same day each sample was taken. Samples which were stored overnight were refrigerated at 3^{o}C.

Three separate batch aeration tests were performed. A different source of septage was used for each test. The septage characteristics are presented in Tables 1 and 2 (Load Nos. 10, 11 and 12). It can be seen that each of the septage loads was considerably different. Load No. 10 was the strongest organic load encountered both in terms of COD and BOD. Load No. 11 had a typical COD value, but was the weakest load encountered with respect to BOD. This septage had the highest COD to BOD ratio. Load No. 12 had the lowest COD value of any septage investigated, but the COD to BOD ratio was typical of several other septage loads.

Characteristics of the primary effluent-settled septage mixture used in the batch shock load studies are presented in Table 6. During the studies with load Nos. 10 and 12, the maximum COD of the mixture was near 2400 mg/l (approximately ten times that of D.C. primary effluent). However during the addition of load No. 11, the maximum COD was only 915 mg/l. The reduction in organic strength with load No. 11 was the result of much better solids removal than anticipated during the one-hour septage settling period. With load Nos. 10 and 12, only 10-15% of the solids were removed during settling but during load No. 11 nearly 90% of the solids were removed.

The organic loading to each batch activated sludge unit was calculated in terms of the COD: MLVSS, BOD: MLVSS and TOC: MLVSS ratios. In all cases the MLVSS concentrations measured in the control unit were used in these calculations. This was done because the increased reactor MLVSS indicated in Table 6 resulted from solids which were introduced by the septage as the percent of septage was increased. The calculated loading represents an instantaneous loading and was determined as follows:

$$L = \frac{(V_s + V_p)\ (C_{s+p})}{(V_s + V_p + V_r)(X_c)}$$

where;

L = organic loading (COD, BOD or TOC)

V_s = volume of septage

V_p = volume of primary

V_r = volume of recycle

C_{s+p} = concentration of septage-primary mixture

X_c = VSS concentration in the control unit

The effect of organic loading on effluent quality for the various loads of septage at aeration times at 0.5, 2, 4 and 24 hours is shown in Figures 9, 10 and 11. Unless otherwise noted, the values plotted for the least organic loading represent the results from the control units where no septage was added. Also the effluent COD values and soluble COD values obtained during the studies with load Nos. 10, 11 and 12 are shown in Figures 12, 13 and 14, respectively. The initial values shown were calculated as follows:

TABLE 6. Characteristics of Primary Effluent-Septage Mixtures and Reactor Solids Concentrations used in Batch Shock Loads.

Septage %	COD mg/l	TOC mg/l	BOD mg/l	SS mg/l	Reactor Solids MLSS mg/l	Reactor Solids MLVSS mg/l
Load No. 10						
0.0 (Control)	161	84	73	94	1460	1100
0.7	428	175	205	184	1490	1100
2.1	981	283	550	400	1680	1250
3.4	1330	375	666	730	1730	1330
4.8	1880	556	982	850	1710	1300
6.7	2390	693	1220	800	2070	1630
Load No. 11						
0.0 (Control)	191	75	80	122	1360	1070
4.4	279	108	95	128	1290	1030
14.5	434	139	96	180	1480	1190
26.8	582	197	110	290	1550	1220
42.0	786	247	110	370	1610	1270
61.3	915	309	120	450	1680	1360
Load No. 12						
0.0 (Control)	297	90	144	162	1520	1300
5.3	480	151	215	244	1520	1280
19.1	892	258	408	380	1540	1320
36.4	1370	400	625	570	1740	1460
59.7	1810	460	777	740	1860	1620
92.7	2390	640	1050	770	1880	1560

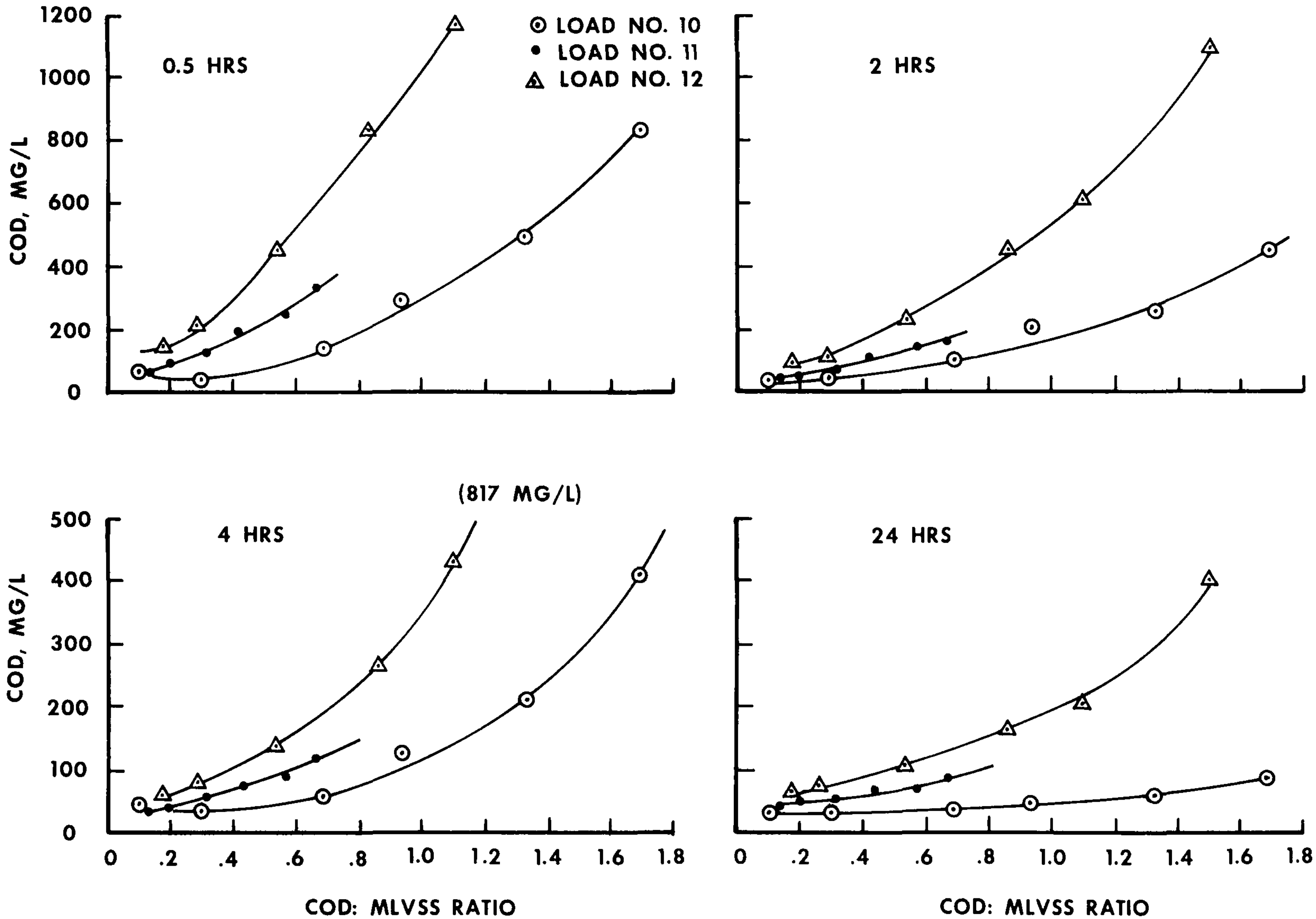

Figure 9. Effect of Loading On Effluent COD at Various Aeration Times and Septage Loads.

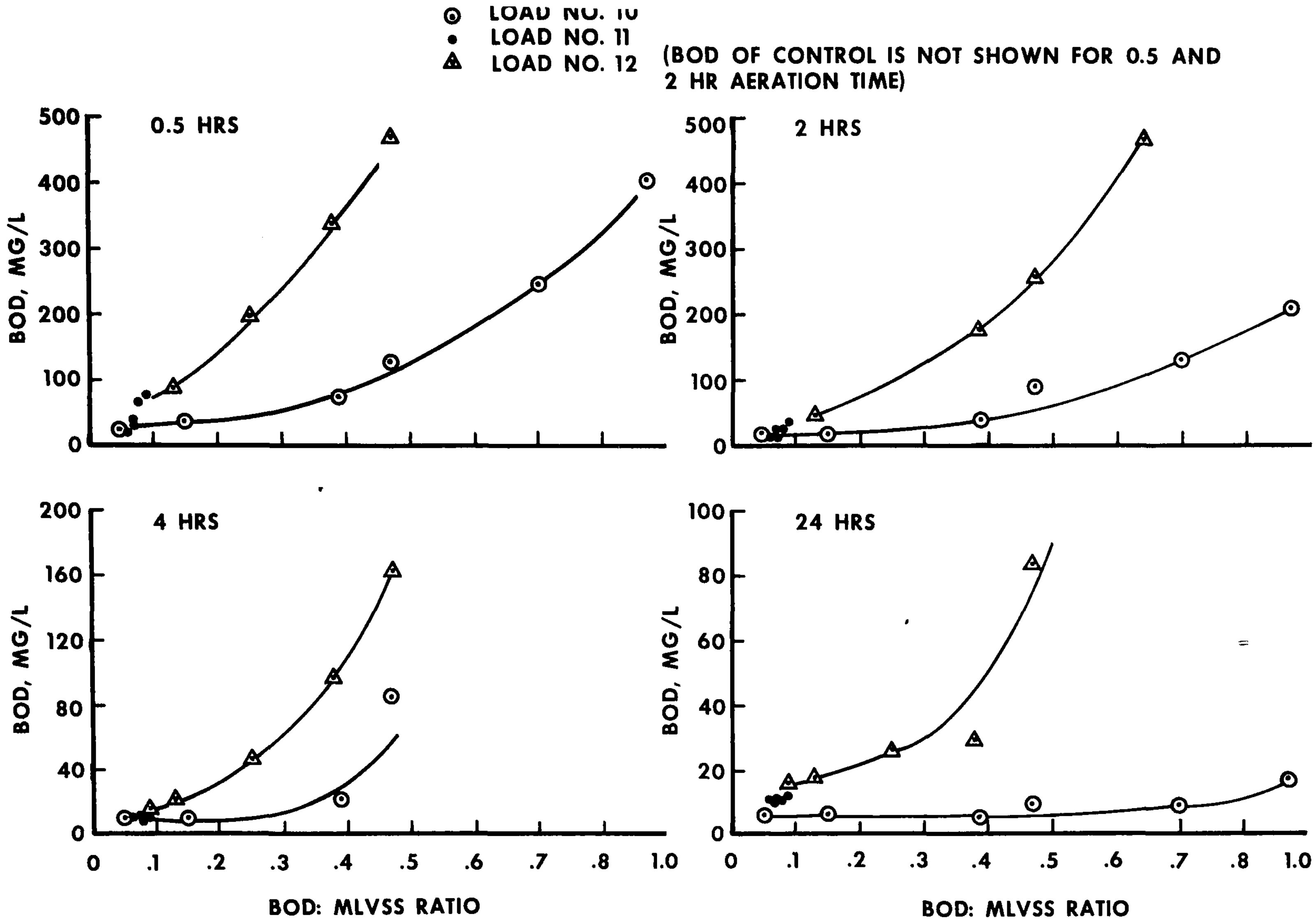

Figure 10. Effect of Loading On Effluent BOD at Various Aeration Times and Septage Loads.

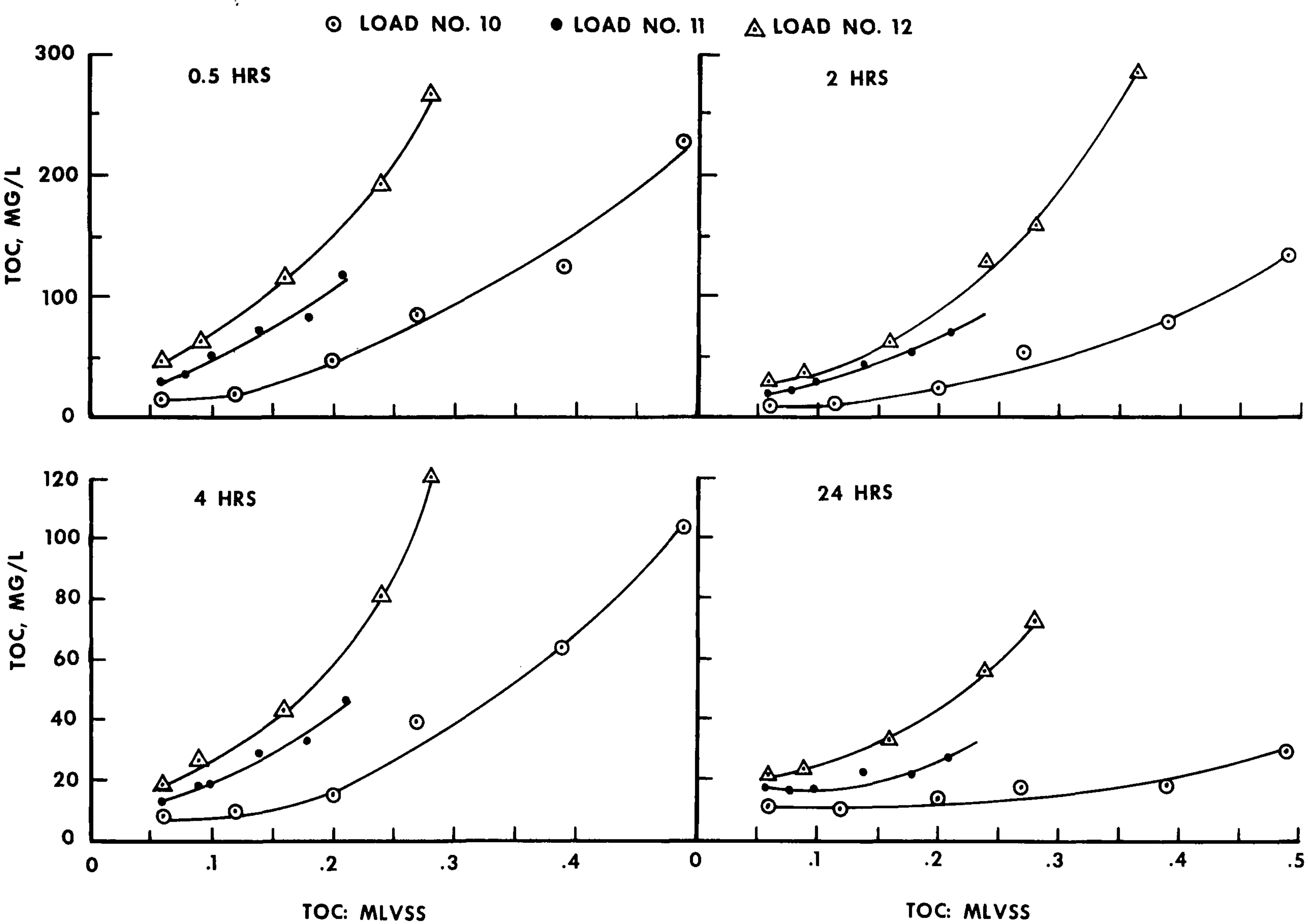

Figure 11. Effect of Loading on Effluent TOC at Various Aeration Times and Septage Loads.

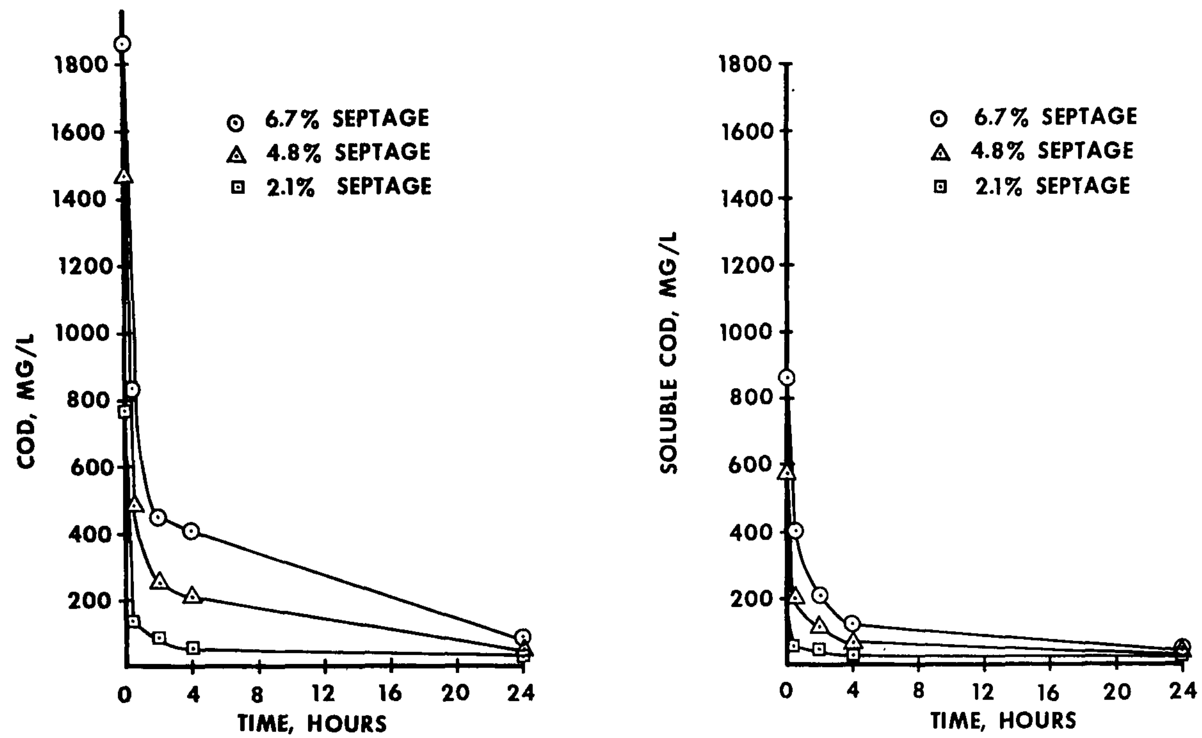

Figure 12. COD Reduction for Various Mixtures of Septage and Primary Effluent, Septage Load No. 10.

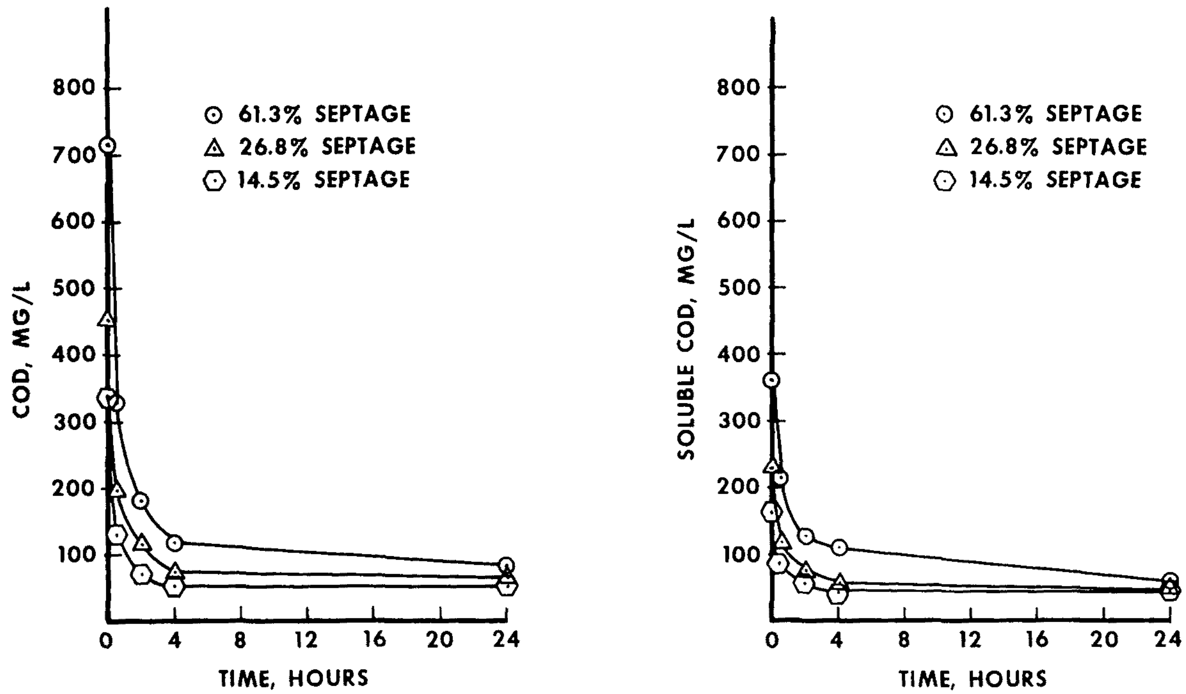

Figure 13. COD Reduction for Various Mixtures of Septage and Primary Effluent, Septage Load No. 11.

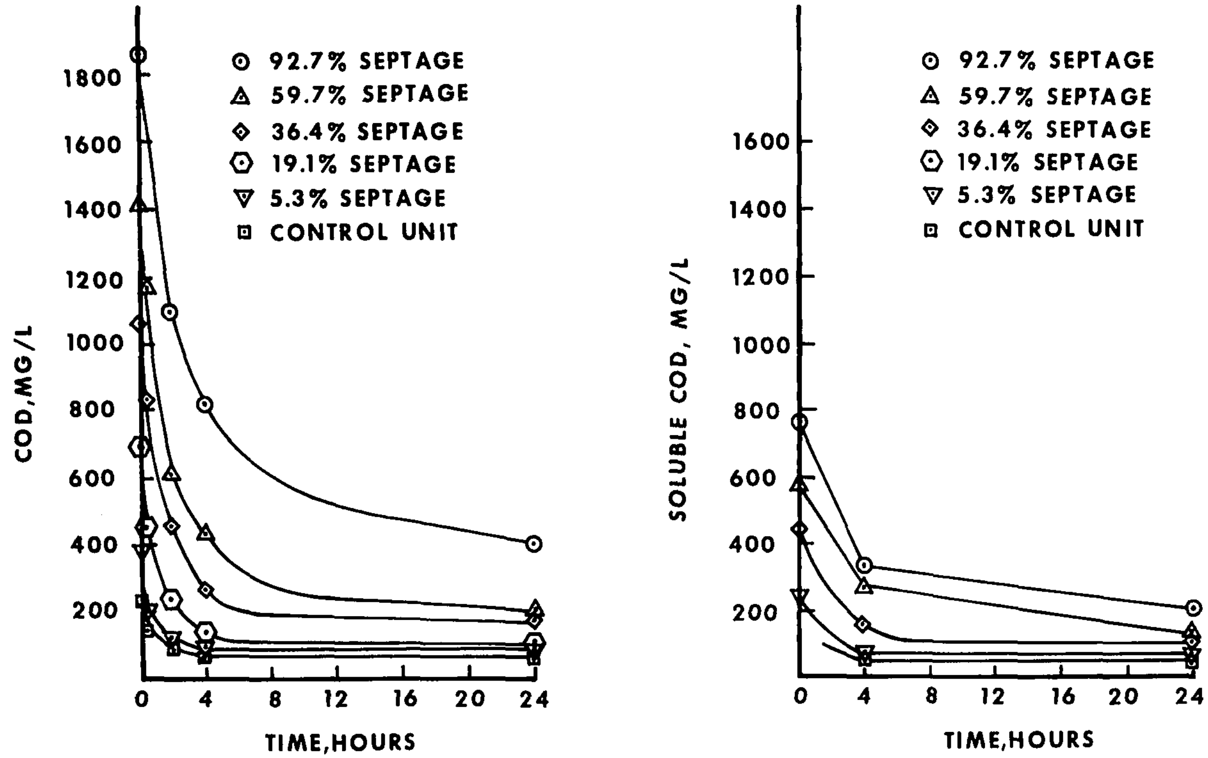

Figure 14. COD Reduction for Various Mixtures of Septage and Primary Effluent, Septage Load No. 12.

$$\text{Initial Organic Concentration} = \frac{(V_s + V_p)\,(C_{s+p})}{V_s + V_p + V_r}$$

The effluent SS concentrations of the clarified effluent samples are presented in Table 7. The calculated initial BOD_5 concentrations and the effluent BOD_5 concentrations are presented in Table 8. Since each load of septage has its own unique characteristics, the results from each test need to be considered in relation to these characteristics.

As shown in Table 1, septage load No. 10 was quite high in COD and BOD. A significant portion of the organic material was in soluble form. The suspended solids fraction was not high when considered in relation to the other septage loads which were examined.

Septage removal from all units shocked with the settled "supernatant" from load No. 10 was extremely rapid. As shown in Figure 12, the soluble component was readily removed along with the non-settleable suspended organic material present in the septage "supernatant." The use of settled septage was intended to maximize the removal of the suspended organic materials as a result of sorption/degradation reactions with the mixed liquor biomass. Only the results of three shock load studies are shown in Figure 12 for clarity. The performance of all five shock systems can be compared to the control unit in Figures 9-11. The effect of the shock loads on the effluent suspended solids concentrations is shown in Table 7. This study clearly showed that most of the septage "supernatant" from septage load No. 10 was readily removed by an unacclimated culture. Most of the soluble material was assimilated quite rapidly as shown in Figure 12. A small component of the soluble material was resistant to rapid degradation, however, and the differences in soluble COD values between the control and shocked units after 24 hours were 2.8, 11.0, 13.0, 20.8 and 30.6 mg/l. These concentrations correspond to the increased amount of septage addition. An acceptable "effluent" quality (30 SS and 30 BOD_5) was obtained with 0.7% septage after 2 hours, with 2.1% septage after 4 hours, and with all septage loadings after 24 hours.

Examination of Table 1 shows that septage load No. 11 contained a large percentage of chemically oxidizable organic matter which was resistant to biodegradation as measured by the BOD_5 analysis. Most of the chemically oxidizable material was associated with the suspended solids and most of this material was removed in the one-hour settling period prior to mixing the septage "supernatant" with primary effluent. The results of the shock load studies with the settled septage from load No. 11 are presented in Figures 9-11 and Figure 13. Even at the highest loading the initial COD was only 915 mg/l which was barely 4 times the value in the control. Once again both the nonsettleable suspended organic and soluble COD in the septage-sewage mixture were rapidly removed from the shocked units. After two hours of aeration an acceptable effluent quality was obtained from the units receiving up to 26.8% septage. Within four hours all units produced an effluent of acceptable quality. After 24 hours the difference in soluble COD between the units receiving 4.4% septage and 61.3% septage was only 14 mg/l.

TABLE 7. Suspended Solids Concentrations of Clarified Effluents from Batch Aeration Studies.

	Aeration Time, Hrs.					Settled Septage
	0.0[(1)]	0.5	2.0	4.0	24.0	%
Load No. 10	94	12	11	10	13	0.0
	184	26	16	14	11	0.7
	400	48	30	11	7	2.1
	730	108	72	52	11	3.4
	850	170	104	86	13	4.8
	800	260	150	128	21	6.7
Load No. 11	122	24	11	7	6	0.0
	128	28	11	9	10	4.4
	180	55	14	10	11	14.5
	290	56	24	14	11	26.8
	370	74	32	14	13	42.0
	450	104	42	23	12	61.3
Load No. 12	162	39	26	11	13	0.0
	244	62	33	20	9	5.3
	380	184	73	38	28	19.1
	570	260	162	54	54	36.4
	740	340	200	132	--	59.7
	770	990	320	308	166	92.7

(1) Initial Value of Primary Effluent-Septage Mixture. All concentrations are given in mg/l.

TABLE 8. Initial BOD_5 Concentrations and BOD_5 Concentrations of Clarified Effluents from Batch Aeration Studies.

	BOD Concentrations, mg/l					Settled Septage
	Aeration Time, Hrs.					
	0.0	0.5	2.0	4.0	24.0	%
Load No. 10	57*	27.1	19.8	11.6	7.5	0.0
	160*	36.7	18.5	11.8	6.9	0.7
	428*	74	43	22.1	5.9	2.1
	519*	129	90	87	10.1	3.4
	765*	247	129	93	10.6	4.8
	953*	404	209	89	18.4	6.7
Load No. 11	62*	22.4	11.3	10.9	11.6	0.0
	74*	30.2	10.2	12.8	12.0	4.4
	75*	41.5	14.8	9.4	11.5	14.5
	86*	67	26.4	8.9	12.6	26.8
	86*	65	30.4	9.6	13.2	42.0
	93*	83	36.7	19.0	13.0	61.3
Load No. 12	115*	> 44	> 36	15.4	17.9	0.0
	171*	91	44.5	22.6	18.8	5.3
	324*	197	----	48.8	25.6	19.1
	497*	340	175	97	30.2	36.4
	620*	466	258	163	84	59.7
	830*	830	468	376	202	92.7

* Calculated Initial Concentrations

Septage load No. 12 had the lowest COD of any load characterized, but the COD to BOD ratio indicated that much of the material was biologically degradable. The ratio of COD to suspended solids was the highest of any load investigated. Results of the shock load studies with the settled septage from load No. 12 are presented in Figures 9-11 and in Figure 14. It can be seen that the residual COD, BOD or TOC was higher at any given loading and time than was the case for the shock loading with loads Nos. 10 and 11. The reasons for this are two-fold. First, the soluble COD fraction consisted of a component which was fairly difficult to degrade. As indicated in Figure 14, the residual soluble COD after 24 hours increased in each unit in proportion to the percentage of septage present. The difference between the control unit and the unit receiving 92.7% septage was 153 mg/l of soluble COD after the 24 hour period. By comparison, the soluble residuals with the units shocked with septage load No. 10 were quite similar after 24 hours, even in the system with a higher initial soluble COD content than present with load No. 12. Also, load No. 12 contained a non-settleable suspended COD fraction which was more resistant to degradation/sorption than the other loads. This is apparent when comparing the soluble and total "effluent" COD values in Figure 14 as well as the clarified suspended solids concentrations shown in Table 7. Although the "effluent" residuals were higher than encountered with the other two shock load studies, there was no indication of any inhibition or toxicity with the unacclimated activated sludge system.

Pilot Plant Shock Loadings - Procedure and Results

The three batch aeration tests indicated that an unacclimated activated sludge system treating domestic wastewater could readily accept shock loadings of septage without any apparent long-term deleterious effects. The temporary affect on effluent quality was obviously dependent on loading, septage characteristics, etc.

To further evaluate the transient response of an activated sludge system receiving a shock load of septage as well as to evaluate any possible longer term effects on effluent quality, two additional shock load studies were performed on the previously described parallel activated sludge systems (Section V). Prior to these shock load studies, both parallel systems were operated on a feed of just D.C. primary effluent for a period of 2.0 months. The flow rates to the systems were the same during this time period 7500 l/day (1980 gpd) and the MLSS were maintained as close to the same level as possible.

The procedure for these shock load studies was as follows:

(1) Septage and primary effluent were mixed in a 1140 l (300 gal) drum and then allowed to settle quiescently for a period of one hour.

(2) Approximately 757 l (200 gal) of the settled mixture was carefully siphoned into a separate tank where it was continually mixed.

(3) This mixture was used to shock load one of the two parallel activated sludge systems for a period of one hour duration. During this period the normal flow of D.C. primary effluent was applied to the control unit only.

(4) The flow rate of the mixture of septage and primary effluent was maintained identical to that of the control unit, 5200 ml/min.

(5) The recycle rate in both activated sludge units was 50% of the influent flow. The hydraulic retention time in each unit including recycle flow was approximately 3 hours.

(6) After one hour the shock load was discontinued and the flow of the primary effluent returned to the shocked system.

The influent to both the control and shocked systems was sampled two hours prior to the addition of the shock load. During each study, the shock began near 0930 hours. After initiating the shock, both systems were sampled intensively. After the intensive grab sampling, additional effluent samples were collected from each of the two systems and composited for various time periods. The compositing period varied with each study and the exact schedule is presented in Table 9. Grab samples collected on the day of the shock load were stored at 3°C and all laboratory analyses except for TOC were performed the following day. The TOC concentration of samples taken before 1630 hours on the day of the shock load study was determined immediately. Samples collected for TOC after this time were analyzed the following day. No acid was added to the grab samples. The composite samples were treated as in the continuous feed study.

Septage load Nos. 13 and 14 (Table 1 and 2) were used to prepare the mixtures of primary effluent and septage for the shock load studies in the pilot system. The two septage loads were similar with a COD near 12,000 mg/l and a TOC near 3500 mg/l.

The septage-sewage mixture consisted of 20% septage with load No. 13 and 50% septage with load No. 14. The characteristics of the influent fed to each of the pilot activated sludge units during both shock load studies are summarized in Table 10.

The first shock load study was conducted with septage load No. 13. As shown in Table 10, the influent COD to the shocked system was approximately 3 times that applied in the control unit. The one-hour shock loading was equivalent to a loading of 3.5 g COD/g MLVSS/day. This increase was almost entirely attributable to non-settleable suspended material since the increased soluble COD of the sewage-septage mixture was only 37 mg/l higher than in the primary effluent alone. Since the unsettled mixture can be calculated to have a COD of about 2,800 mg/l, the measured influent COD of 790 mg/l represents a COD

TABLE 9. Effluent Quality Following Addition of Shock Loads to the Pilot Activated Sludge System.

Time After Shock	Shocked System SS mg/l	COD mg/l	TOC mg/l	BOD mg/l	Control SS mg/l	COD mg/l	TOC mg/l	BOD mg/l
Load No. 13								
8.5-20.5 (1)	22	40.4	14	25	--	36.4	12	22
20.5-44.5 (1)	18	35.9	14	27	23	--	15	30
44.5-68.5 (1)	34	35.5	13	23	10	30.8	11	18
Load No. 14								
11.3	54	93.9	32.5	40.7	35	66.6	26.2	30.7
14.3	73	95.5	32.8	45.5	42	89.6	27.8	40.1
17.3	43	83.5	27.5	32.1	36	65.9	23.5	30.9
20.3-44.3 (1)	30	63.4	20.2	29.5	40	61.1	20.0	37.0
44.3-68.3 (1)	31	65.6	--	36.9	33	49.3	16.0	33.6
80.3	75	87.2	33.0	--	27	63.2	21.0	22.7
104.3	35	--	21.0	23.3	40	59.7	21.0	--

(1) Represents composite sample of 4-hour grab samples taken between times indicated.

TABLE 10. Characteristics of Influents to Parallel Activated Sludge Systems During Shock Loads.

Time Hrs.	Shocked System SS mg/l	Shocked System COD mg/l	Shocked System TOC mg/l	Shocked System BOD mg/l	Control System SS mg/l	Control System COD mg/l	Control System TOC mg/l	Control System BOD mg/l
Septage Load No. 13								
-2[1]	128	230	75	104	128	230	75	104
0[2]	640	791	225	131	112	216	65	92
0.5[2]	590	788	220	133	--	--	--	--
1[2]	670	791	230	132	--	--	--	--
2	92	191	61	85	92	191	61	85
4	102	215	67	86	102	215	67	86
6	94	267	86	136	94	267	86	136
Septage Load No. 14								
-2[1]	228	346	116	116	228	346	116	116
0[2]	2,100	3,110	880	571	190	307	98	141
0.5[2]	2,060	3,080	824	501	--	--	--	--
1[2]	2,080	3,050	884	--	--	--	--	--
2	164	264	84	114	164	264	84	114
4	128	236	83	108	128	236	83	108
6	124	242	84	113	124	242	84	113

(1) Shock load added at time "0". A "-2" designation indicates samples taken 2 hours before the shock load was applied.

(2) Shock Load Applied.

removal of almost 75 percent during settling. This very high removal cannot normally be expected in a conventional primary sedimentation tank, especially in view of only 20-45% COD removal in the primary during the continuous addition studies. The increase in BOD applied to the shocked system was only about 40 mg/l over that applied to the control unit.

The response of the shocked and control systems is indicated in Figure 15 and Table 9. The reactor MLSS concentrations shown in Figure 15 represent the average of the values obtained from the first and fourth drum in the respective systems at the times indicated. The sampling times and locations essentially avoided including the suspended solids contributed from the septage-sewage mixture. The effluent samples were obtained from the clarifier overflow. It is apparent that the shock loading had no measurable impact on the product quality as the septage component moved through the reactor and into the final effluent. Furthermore there were no longer-term effects on effluent quality as indicated by the similarity of the three composite samples from the shocked system in relation to the results obtained from the control system (Table 9).

The second shock load study was conducted 30 days after the first study. During this interim period the previously shocked unit was fed primary effluent only. The strength of the settled septage-sewage mixture in the second study was considerably higher than in the previous investigation. The COD was about 3100 mg/l with a soluble COD of 320 mg/l. The average BOD was 536 mg/l. Suspended solids were approximately 2100 mg/l. The impact of the shock loading (equivalent to a one-hour loading of 8 g COD/g MLVSS/day) is summarized in Figures 16 and 17 and Table 9. There was a noticeable breakthrough of organic material in the shocked system. Approximately 4.5 hours after applying the shock load, the effluent COD, BOD and TOC reached peak values of 302, 81 and 95 mg/l, respectively. Most of this material was associated with colloidal and suspended particulates. This is apparent by examining the differences in the soluble and total COD in the effluent from the shocked and control units as well as by the large rise in effluent suspended solids in the shocked unit (Figure 16). Visual examination of the clarified effluent from the shocked unit during the period of breakthrough revealed that it was very "murky" and "dirty". Once the rather severe shock load passed through the system, the effluent quality rapidly returned to normal. As indicated in Table 9, there were no apparent delayed effects on the effluent quality from the shock-loaded system, with the possible exception of a slightly higher COD concentration.

Samples of mixed liquor were periodically withdrawn during the second shock load study and the oxygen uptake rates were measured with a Model 1010 Delta Scientific dissolved oxygen meter in a stirred BOD bottle. The results are presented in Table 11. There was no indication of any toxic effects or inhibition in the shocked unit. The number of measurements is insufficient to carefully compare the oxygen uptake rates in the two systems, but, there are certainly no noticeable large differences in oxygen demand. This would indicate that a substantial part of the shock load was apparently either adsorbed onto the floc and/or converted into cellular storage products.

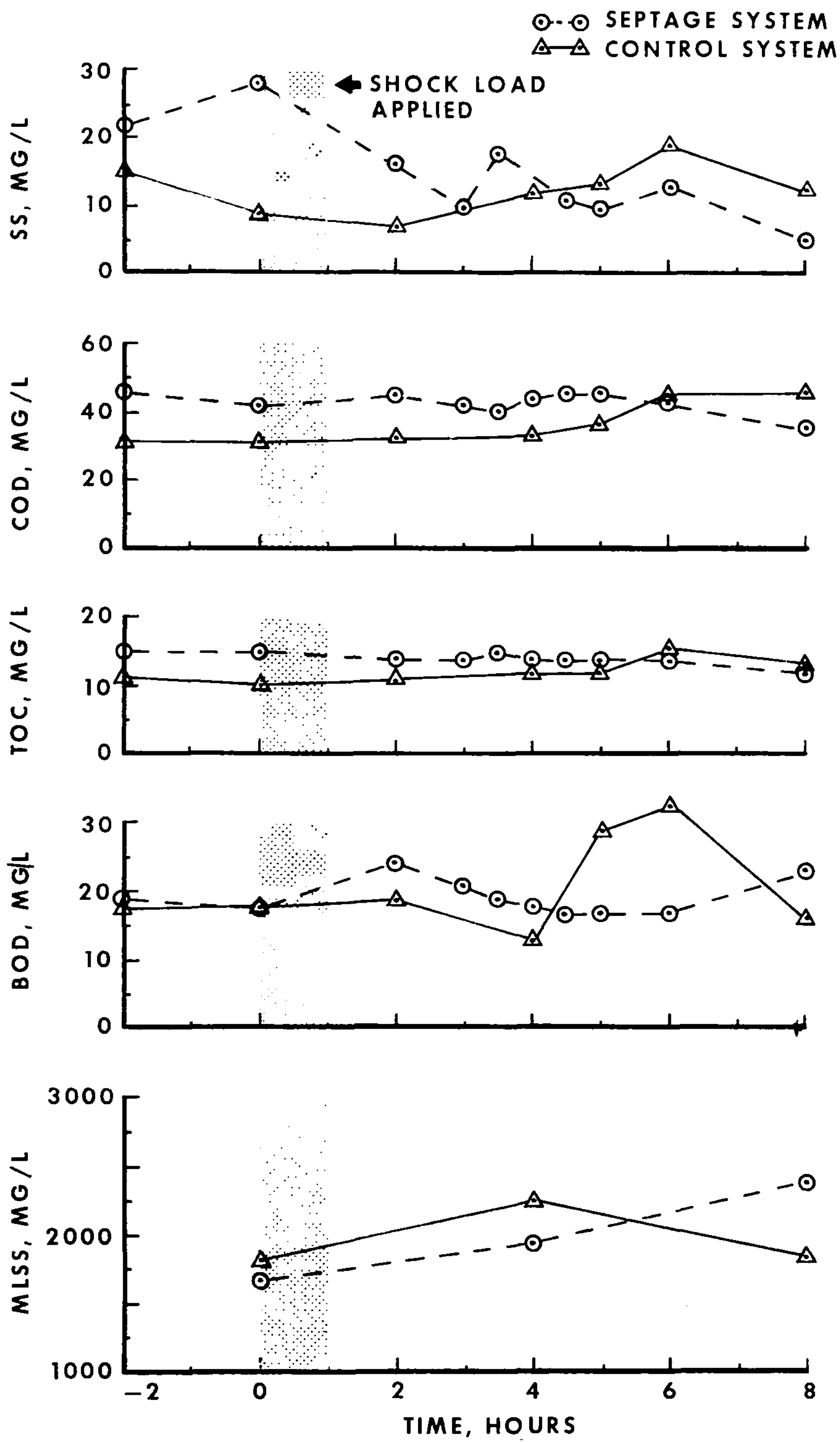

Figure 15. Effect of Shockload to the Pilot Activated Sludge Unit Using Septage Load No. 13.

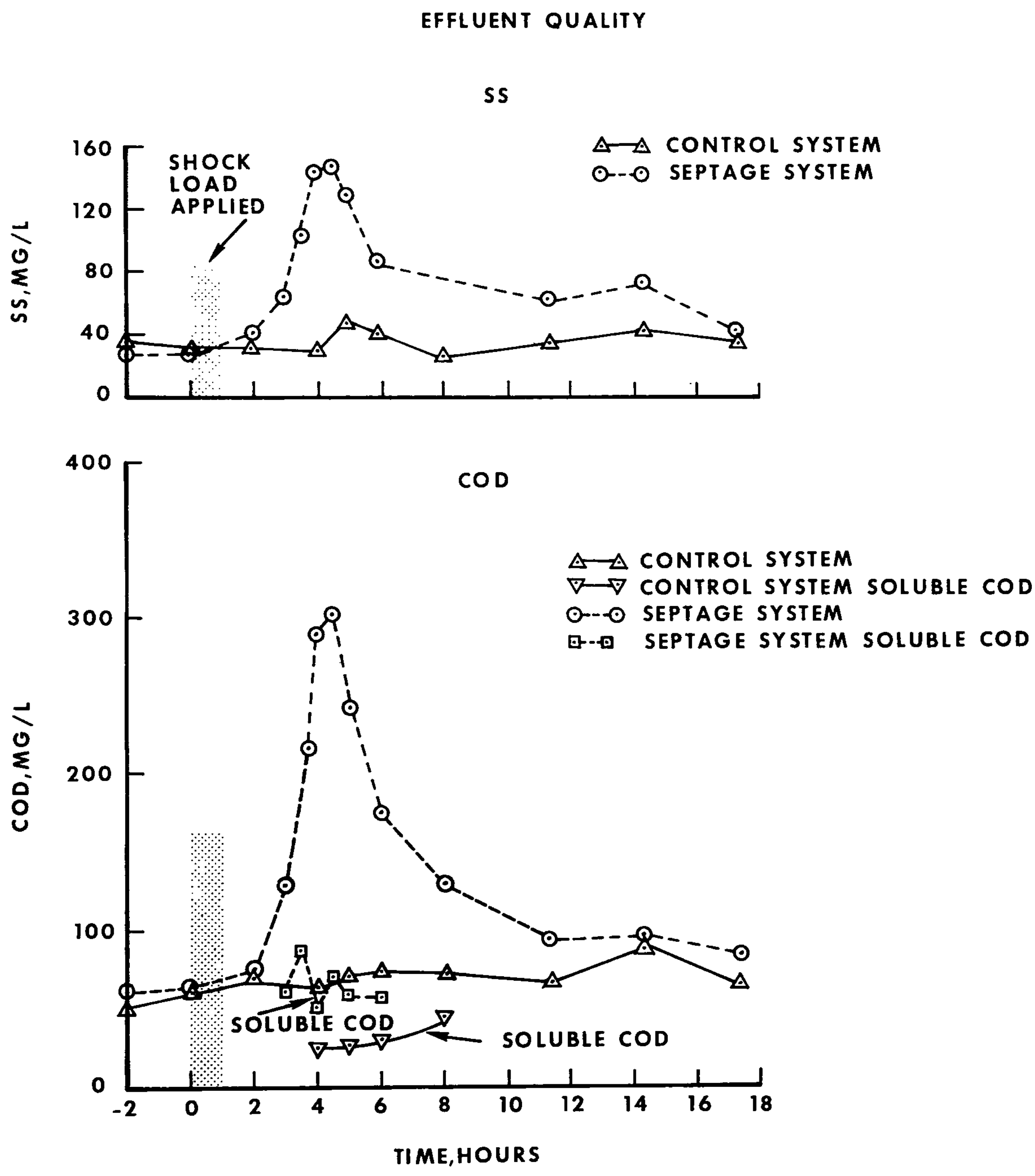

Figure 16. Effect of Shockload On Effluent Suspended Solids and COD Using Septage Load No. 14.

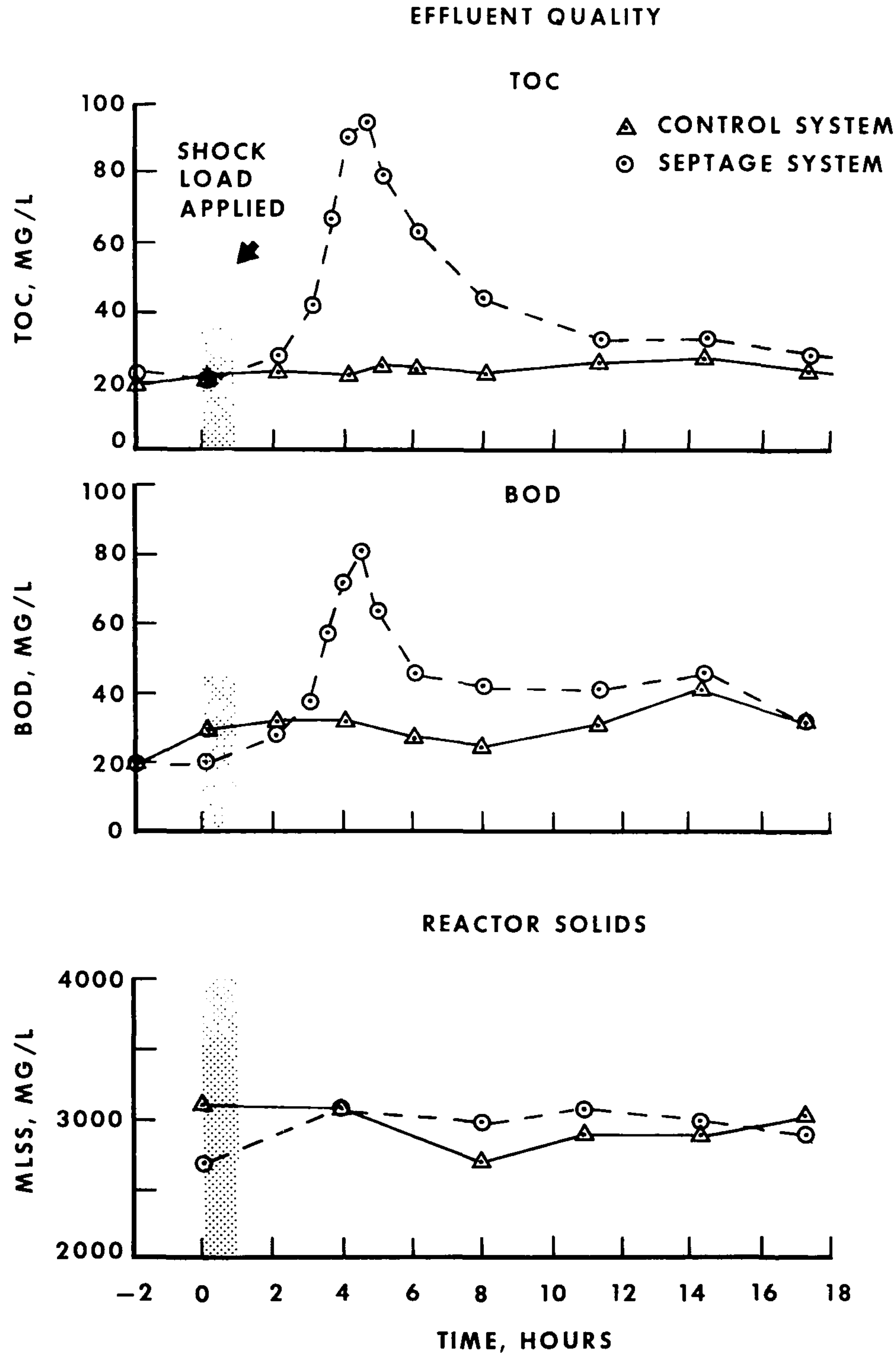

Figure 17. Effect of Shockload on Effluent TOC and BOD and Variation of MLSS Using Septage Load No. 14.

TABLE 11. Oxygen Uptake Values in the Control and Shocked System (Septage Load 14)

Time After Shock Hrs.	Pass No. 1 $mgO_2/l/hr$ Control	Shock	Pass No. 4 $mgO_2/l/hr$ Control	Shock	Pass No. 7 $mgO_2/l/hr$ Control	Shock
0	70	74	--	--	--	--
0.3	--	--	58	52	--	--
0.4	--	--	--	--	--	21
0.5	--	80	--	--	--	--
0.6	--	--	--	--	32	--
0.9	--	77	--	--	--	--
1.8	91	87	--	--	--	--
1.9	--	--	67	69	--	--
2.3	--	--	--	--	--	37
3.0	--	--	--	56	31	--
4.1	--	--	--	44	--	30
4.5	--	--	--	--	30	--
5.0	--	--	--	--	21	29

SECTION X

DISCUSSION

Although the septage used in these studies was obtained entirely from domestic sources, the composition varied considerably from load to load. The organic concentrations were quite variable as were the ratios of BOD/COD/SS. For example, the COD of load No. 10 was approximately 7 times that of load No. 12 and the COD/BOD ratio of load No. 11 was 3 times that of load No. 6 (Table 1). This variability has been observed by others (7, 8) and is basically what would be expected. The large variation in COD/BOD ratio is an indication of the difference in the degree of stabilization of each septage load. Some loads, such as Load No. 11, contained a lot of organic material which was well stabilized while in other loads, such as load No. 6, a substantial portion of the organic material was more readily degradable.

As shown in Table 1, all loads were sufficiently high in nitrogen and phosphorus for biological growth. Therefore, there was no need to be concerned about nutrient deficiency as a possible cause for impairment of the biological processes. In addition, the concentrations of heavy metals also varied considerably from load to load (Table 2) but at no time were any results obtained which suggested toxicity or inhibition of the activated sludge process.

Septage was fed on a continuous basis over a four month period without any significant problems related to the performance of the activated sludge system. The organic load to the activated sludge process receiving septage was controlled by changing the COD concentration of the influent septage-sewage mixture. The influent COD ranged from an average of 404 mg/l during Period I to 755 mg/l during Period VIII. These values are approximately 1.6 and 3.6 times that of D.C. primary effluent, respectively.

By gradually increasing the influent COD, relatively uniform COD loadings were obtained at 0.7 (Period I), 1.7-1.8 (Periods III-IV) and 2.2-2.3 (Periods (Periods V-VI) g COD/g MLVSS/day. These loadings were approximately 1.1, 2.0 and 2.8 times those in the control unit. Higher loadings of 3.2-2.8 g COD/g MLVSS/day were obtained during Periods VII-VIII. These loadings were 3.3 and 4.0 times those in the control, but they were non-uniform.

The increase in effluent COD above that from the control during periods when the COD loading was equal to or twice that in the control was roughly 10-15 mg/l. At higher loadings the increase was 20-80 mg/l greater than the control depending on the characteristics of the particular load of septage. To illustrate the role of septage characteristics on effluent COD, the performance during Periods V and VI can be compared. The COD loadings, in terms of g COD/g MLVSS/day, were nearly the same and were roughly 2.8 times the control, but in Period V the effluent COD averaged 91 mg/l while in Period VI the effluent COD averaged 65 mg/l for a difference of 26 mg/l.

The increase in effluent COD with increasing COD loading may not represent a serious deterioration in effluent quality since there was not a corresponding increase in biologically oxidizable material (as measured by the BOD_5 analysis). Considering the nature of septage, it is not surprising that the effluent COD values were higher than the control system since one would expect the presence of some stabilized material in septage which was quite resistant to further degradation. Therefore, it appears that BOD_5 is probably the best indicator of the strength of a load of septage and its probable effects on the effluent quality.

Throughout the study, as the effluent COD increased, there was no sustained increase in effluent BOD. It is difficult to compare the effluent BOD from the control and septage systems because most of the time the control system nitrified and the septage system did not. There was also the difficulty with the high effluent suspended solids concentrations occurring in the control system effluent during periods when Nocardia covered the final clarifiers and influenced the effluent total BOD values. Both systems were nitrifying to nearly the same degree during the addition of septage loads Nos. 1-4 (Figure 8). The effluent BOD values in Table 5, corresponding to the periods when these loads were added, were not significantly different. With two septage loads (Nos. 6 and 8), there was a slight increase in effluent BOD above 40 mg/l (Figure 5B). The influent BOD was near 300 mg/l during this time. The increase in effluent BOD, however, was probably related to the nature of the septage and not excessive BOD loading, since with similarly high loadings during periods II and III, the effluent BOD was only 32 and 22 mg/l, respectively.

During the continuous feed study the wastewater temperatures varied from around 18°C during the addition of load No. 1 to around 26°C during July and August. As shown in Table 12, the SVI tended to be higher in both systems during operation at the colder temperatures. Overall, there was no noticeable impact one way or the other regarding the effect of septage addition on process SVI.

Similarly there is no indication that septage addition inhibited nitrification. The effluent $(NO_2 + NO_3)$-N levels shown in Figure 8 differed for the two systems because the SRT in the septage system was less than in the control during the latter part of the study. For instance, in Periods V, VII and VIII the SRT was 0.7-1.0 days compared to 3-4 days for the control system. Poduska (9) summarized the results of several studies on the growth rate of nitrifying organisms and showed that at these lower SRT's nitrification is limited. Therefore the lack of nitrification can not be attributed to the characteristics of the septage. Septage addition does not necessarily require SRT's below the range for nitrification since the system could be operated with higher MLSS to increase the SRT. During Period I when the MLSS in the septage system were high and the loadings to both systems were similar the effluent $(NO_2 + NO_3)$-N concentrations were quite comparable. Prior to Period V sludge production data were not available because of improper sampling of the waste sludge. During Periods V, VII and VIII the solids production was 1.6-1.7 g SS/g BOD_5 applied. During Period VI a higher value of 2.0 g SS/g BOD_5 applied was obtained. These sludge production values correspond to SRT's of 0.7-1.0 days. Figure 8 indicates that during Period VI nitrification was occurring; therefore,

TABLE 12. Average SVI for the Control and Septage Systems During the Continuous Feed Study.

Period	SVI, ml/gm	
	Control System	Septage System
4/10-4/30	130	140
5/01-5/14	185	145
5/15-5/23	190	155
5/24-6/17	95	160
6/18-6/26	95	130
6/27-7/21	85	85
7/22-7/28	100	80
8/02-8/12	115	75

based on Poduska's summary of data (9) it is questionable that an SRT of 1.0 day is accurate for this period. The SRT was probably ~ 2 days. Because of this apparent error in SRT the high sludge production value for Period VI (2.0 g SS/g BOD_5) is questionable. These sludge production values obviously do not represent long term operation with steady state wasting. The solids production from the control system was 0.85 g SS/g BOD_5 applied.

On the basis of solids production per mass of BOD applied the sludge production values from the septage system are approximately twice those which are expected from a conventional biological system treating domestic sewage and operating with a similar SRT. This is the result of a large fraction of inert solids in the influent to the septage system. The BOD/SS ratio in the control system averaged 1.0 g BOD/g SS while that in the septage system (Periods V-VIII) was 0.5-0.8 g BOD/g SS.

Since the sludge production values from the septage system were so high, the results from the septage system were compared with the results from conventional systems where the influent SS were also considered. Sludge production was calculated on the basis of mass of (BOD + SS) applied based on the following relationship (10):

$$\frac{1}{SRT} = \frac{0.6\ (BOD + SS)}{Xt} - 0.075$$

where X is the MLSS concentration and t is the hydraulic detention time. The sludge production values from both the septage system and the control are in good agreement with the results of others (10). Therefore the sludge production values observed do not seem unreasonable.

The effect of primary clarification as a means of protecting the plug-flow activated sludge system was not investigated. However, removals of SS varied from 55 to 65 percent in the primary clarifier, which is about what would normally be expected. Removals of BOD, however, were only about 15 to 25 percent. This might suggest that heavier inorganic solids were preferentially removed in the primary settler. In any event, it is reasonable to suggest that primary clarification provides significant protection for the activated sludge system when septage is added ahead of this unit. However, the additional primary sludge along with the increased waste activated sludge due to increased loading constitute a significant additional burden on the sludge handling facilities of a treatment plant.

The shock load studies yielded little evidence of toxicity or any lasting affect on an unacclimated sludge process as a result of a transient septage loading. Much of the soluble and non-settleable organic material was very readily adsorbed/metabolized. The exact response depended on the characteristics of the particular load of septage. For example, with septage loads No. 10 and No. 11 most of the soluble and non-settleable suspended fraction of COD was removed after 24 hours aeration, but with load No. 12 a portion remained after this time. Furthermore, the portion remaining was proportional to the septage concentration. Even when the activated sludge process was severly shocked, such that sufficient aeration time was not available for satisfactory removals, the process returned to normal in less than 18 hours after the shock loading commenced.

The results obtained here are not consistent with the numerous stories and rumors of septage addition "wiping out a plant." Many operators, however, feel that this is the inevitable result of septage addition, and the acceptance of septage loads is a controversial issue in many locations. The results obtained here do not indicate that reasonable septage addition need be a problem provided that: (a) the septage does not contain any industrial waste which contains toxic or unusual materials, and (b) the plant has adequate aeration, settling and sludge handling capacity to handle the increased load.

In most small plants, facilities are not available for adding septage based on organic (BOD or COD) loading. This would require laboratory facilities for analyzing the septage and several completely mixed storage tanks: one to handle the incoming septage, at least one to hold full loads of septage while strength is being determined, and one to hold septage being added to the system. Since such arrangements are not practical for small treatment plants, the next best arrangement would be an adequately sized and designed receiving station with flexible pumping capabilities for controlling the rate and point of septage addition. On the basis of this study a plant which includes primary clarification may even accept some random septage loads if sufficient aeration, settling and sludge handling capability exist. Since the small plant operator has limited capability for laboratory assessment of septage strength, his most logical method for controlling septage loading within the capabilities of his plant is by determining maximum allowable flow (continuous) of septage or a maximum number of septage loads per unit time.

This study indicates that if sufficient oxygenation and sludge handling capacities are available and control of the waste MLSS is possible, the activated sludge system can accept significant septage flows. Based on the results of this study an activated sludge plant with 4-hours of aeration time preceded by a primary clarifier can accept a COD loading of up to 3 g COD/g MLVSS/day to the activated sludge unit. One way such a value can be used is by picking the strongest load and converting this to a hydraulic loading from the receiving station. For example consider a hypothetical case where a MLVSS of 2000 mg/l is to be maintained and the strongest load of septage is similar to septage load No. 1. The potential maximum septage pumping rate from the receiving station to the head of the plant can be calculated as follows:

$$\frac{COD}{MLVSS} = \frac{(COD_w)\ Q_w + (COD_s)\ Q_s}{(MLVSS)\ V}$$

where:

Q = flow, in l/d

V = volume of aerator, in l

w = subscript for wastewater

s = subscript of septage

It is obvious that no credit is given to septage COD removal in the primary clarifier in order to provide a sufficient factor of safety. Additional assumptions are that the plant wastewater influent flow is 22 l/s (0.5 mgd), and primary clarifier effluent (no septage), has a COD concentration of about 250 mg/l. Therefore, Qs can be approximated by:

$$3 = \frac{(250)\ (22)\ (1440)\ (60) + (22{,}800)\ Qs}{(2000)\ (22)\ (14{,}400)}$$

and

$$Q_s = \frac{19 \times 10^8 - 4.75 \times 10^8}{2.28 \times 10^4}$$

$$Q_s = 62{,}500 \text{ l/d } (16{,}500 \text{ gpd})$$

This septage flow is equivalent to about 3.3 percent of the average daily flow and assumes that aeration capacity, sludge handling capacity and mixed liquor solids control are sufficient to handle the additional loading.

Since contact stabilization (~ 0.5-hr. aeration) and extended aeration (~ 24-hour aeration) systems are normally used in package plant designs without primary clarification, the results have limited applicability for package plant systems. However, these systems are usually quite small in capacity and would be marginal choices to receive septage loads anyway. For those small plants of sufficient size to consider septage acceptance and which have primary clarification, the following conclusions may be drawn:

1. Extended aeration systems provide the best assurance of being able to handle septage shock loadings. Nitrification should be considered, however, if that is an effluent requirement of the system.

2. Contact stabilization systems represent the poorest activated sludge modification for handling shock loads due to septage addition.

3. BOD and SS effluent concentrations from units receiving septage as a shock loading depend on the nature of the septage, the septage flow/total flow, the reactor MLSS concentration, and the length of the aeration period.

SECTION XI

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

The objective of the study reported herein was to evaluate the impact of household septic tank wastes on municipal activated sludge treatment plants. Septage addition was evaluated on a continuous basis over a four-month period in a 7500 l/day (1980 gpd) pilot plant. The septage was combined with municipal wastewater primary effluent in a series of increasing loadings to the activated sludge unit. Results were compared to a control unit receiving primary effluent only. Shock load studies were also conducted in the pilot plant system and with a series of batch aeration tests.

Septage addition was found to be feasible on either a continuous or intermittent basis. The response during the continuous feeding studies depended upon the organic loading and the septage characteristics. COD loadings below 3 g COD/g MLVSS/day could be handled without severe upset. Unacclimated systems also responded well when septage was added, and substantial organic removals were obtained within a relatively short time.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Activated Sludge Process Sewage Treatment	Septage Septic Tank Pumpings Continuous Flow Shock Loads	13B

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