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Pilot Scale Evaluations of Septage Treatment Alternatives

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PILOT SCALE EVALUATIONS OF SEPTAGE TREATMENT ALTERNATIVES

by

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Grant No. R804804-01

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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 research documented herein gives further definition to the pollutant characteristics of septage, methods of physical, chemical and biological treatment, and system designs and associated costs for effectively treating this material at either municipal wastewater treatment plants or facilities constructed exclusively for septage treatment.

Francis T. Mayo, Director
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ABSTRACT

This research program was undertaken to define technologies for the treatment of septage. To facilitate this objective, a pilot plant capable of treating up to 3.79 m^3/day (1,000 gpd) was constructed at the Falmouth, Maine wastewater treatment plant.

Preliminary investigations revealed that approximately 75 percent TSS removal could be achieved by screening raw septage. This operation yielded a liquid fraction that could be consistently coagulated. If the septage was not screened, effective coagulation was very difficult to realize.

Conditioning of screened septage with conventional chemicals such as alum, ferric chloride and lime was possible. However, optimization of chemical requirements proved to be involved. A two-stage acid/lime coagulation process was developed which consistently yielded a clear supernatant fraction approximating 70 percent of the total volume treated.

The supernatant fractions resulting from the various conditioning processes contained mainly soluble BOD_5 and ammonia as residual pollutants. These acqueous fractions were ammenable to biological treatment by either intermittent sand filtration or addition to the municipal wastewater treatment plant influent.

The sludge fractions resulting from the various conditioning processes were dewatered using various techniques. Sand bed and pressure filter dewatering consistently yielded high TSS capture and dry sludge cakes. Dewatering by solid bowl centrifuge or cloth belt vacuum filter led to less desirable results. This may have been due, in part, to limitations of the pilot scale equipment.

Combined fraction treatment was investigated by addition of screened, neutralized septage to various components of the municipal contact stabilization secondary treatment system. These included the aerobic digester, the contact zone and the reaeration zone. Because of the current low municipal loadings to the system no deliterious effect induced by septage addition was noted. However, it must be pointed out that 3.79 m^3 (1,000 gal.) of screened septage has a BOD_5 population equivalent of approximately 240 and a TSS population equivalent of about 360. The impact of introducing such a concentrated waste stream to a given municipal facility should be analyzed before this mode of treatment is employed.

Dewatered solids disposal by burial in a soil mantle was investigated and it was found that the pollutant retention capabilities of different soil mantles vary dramatically.

Septage may be effectively treated either by utilizing certain existing equipment at municipal wastewater treatment plants or at facilities constructed exclusively for its treatment. Depending on the treatment process selected and the size of the septage treatment facility installed, total annual operating costs may range from \$4 to \$10/m^3 (\$14 to \$37/ 1,000 gal.) treated.

This report was submitted in fulfillment of Contract No. R804804-01 by the Maine Municipal Association under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period October 1, 1976 to March 31, 1978, and work was completed as of March 31, 1978.

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SECTION 1

INTRODUCTION

Septage is defined as the sludge-type material which collects in on-site wastewater disposal systems (septic tanks). The almost universal generation and disposal of septage in rural areas has been responsible, in part, for it not being recognized as a major pollutant source. However, it has been estimated that the volume of this material generated annually exceeds 15 million m^3 (4 billion gal). On a dry solids basis, this is equivalent to approximately one-third of the national secondary treatment plant sludge production rate. Reported ranges of selected pollutant parameter concentrations are presented in Table 1.

Perhaps the main deterrent to the evolution of knowledge on septage has been the rural nature of its origin. A limited amount of research on septage treatment has been reported in the literature. Certain of these studies have indicated positive results while others have been either inconclusive or negative in outcome. Partially as a result of the above, currently employed methods of septage disposal include, among others, (1) spreading on the land; (2) lagooning; (3) discharge to municipal wastewater treatment facilities; and/or (4) direct discharge to water courses.

The generation of septage in rural areas essentially dictates that the treatment of this material be undertaken close to its point of origin to minimize treatment costs. Two strategies exist for its proper treatment:

1. The utilization of local municipal wastewater treatment facilities as a receiver for this waste, or

2. The construction of facilities exclusively for the handling of this material.

Both of these approaches have their respective drawbacks, mainly due to the limited state-of-the-art on septage treatment technology.

In the case of using smaller wastewater treatment plants, improperly designed receiving facilities and/or inadequate operator knowledge can lead to upset conditions in the entire system. For example, the discharge of 3.79 m^3 (1,000 gal.) of raw septage to the influent of a 948 m^3/day (250,000 gpd) extended aeration facility over a one-hour period would result in an increased instantaneous BOD_5 loading to the facility of about 200 percent and an increased instantaneous TSS loading to the facility of approximately 900 percent. Such shock loadings cannot be readily absorbed by secondary

TABLE 1. SEPTAGE CHARACTERISTICS REPORTED IN THE LITERATURE (1,2,3,4)

Parameter	Mean	Std. Dev.	Range	No. Samples
TS	38,800	23,700	3,600-106,000	25
TVS, % of TS	65.1	11.3	32-81	22
SS	13,014	6,020	1,770-22,600	15
VSS, % of SS	67.0	9.3	51-85	15
BOD_5	5,000	4,570	1,460-18,600	13
COD_T	42,850	36,950	2,200-190,000	37
COD_S	2,570(.06 COD_T)	-	-	21
TOC	9,930	6,990	1,316-18,400	9
TKN	677	427	66-1,560	37
NH_3-N	157	120	6-385	25
Total P	253	178	24-760	37
pH (units)	6.9 (median)	-	6.0-8.8	25
Grease	9,090	6,530	604-23,468	17
LAS	157	45	110-200	3
Fe	205	184	3-750	37
Zn	49.0	40.2	4.5-153	38
Al	48	61	2-200	9
Pb	8.4	12.7	1.5-31	5
Cu	6.4	8.3	0.3-38	19
Mn	5.02	6.25	0.5-32	38
Cr	1.07	0.64	0.3-2.2	12
Ni	0.90	0.59	0.2-3.7	34
Cd	0.71	2.17	<.05-10.8	24
Hg	0.28	0.79	<.0002-4.0	35
As	0.16	0.18	0.03-0.5	12
Se	0.076	0.074	<0.02-0.3	13

All values in mg/l unless otherwise indicated treatment facilities and no level of operator control can offset the deleterious impact resulting from such loadings.

In the case of constructing facilities exclusively for treating septage, skepticism prevails since few systems are known to exist and to perform consistently well.

Septage is composed of organic and inorganic pollutants, both dissolved and suspended, in a water carrier. Total treatment of this waste can be approached in a number of ways. A comprehensive plan for investigating applicable septage treatment schemes either at existing wastewater treatment plants or at facilities constructed exclusively for septage processing is presented in Figure 1.

As shown on Figure 1, once septage is received at a facility, a number of alternatives exist. The most direct, though not necessarily the most effective alternative, is combined fraction treatment which could encompass the addition of raw septage to the influent of a municipal wastewater treatment plant. A more circuitous alternate could involve conditioning of the raw septage with chemicals, allowing this conditioned septage to undergo phase separation, and subjecting the thickened solids-bearing fraction to further dewatering. To complete treatment, both the aqueous and the dewatered solids-bearing fractions might have to be further treated to minimize pollutant leaching when these fractions are ultimately disposed.

The following sections of this report define the function, approaches, variables and problem areas associated with each of the unit operations presented in Figure 1 as well as typical experimental results from the conduct of various pilot plant studies. Raw data from all experimental studies, if not presented in the text, are contained in the Appendix.

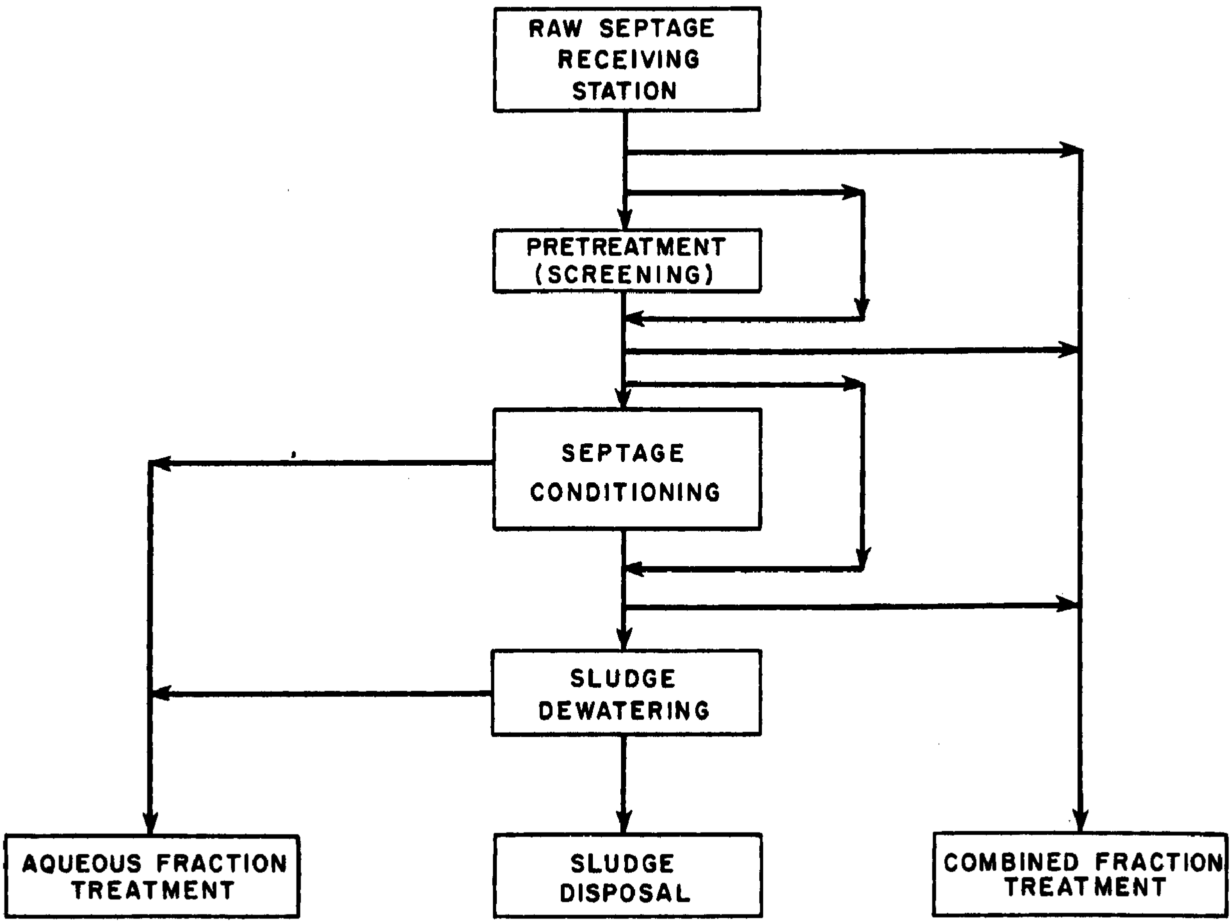


FIGURE I. COMPREHENSIVE SEPTAGE TREATMENT PLAN

SECTION 2

CONCLUSIONS

The results of laboratory and pilot scale studies on the treatment of septage have indicated that a number of alternatives exist for effectively reducing the gross pollution potential of this material.

Paramount to the effective application of any alternative is the incorporation of a preliminary screening process. This process not only provides for the continuous protection of equipment in the treatment system, but also allows for the separation of septage into an aqueous and a sludge fraction when coagulated by conventional chemicals. If screening is not undertaken, consistent effective coagulation cannot be realized.

The pollutant characteristics of screened septage vary dramatically from load to load. Average (maximum:minimum) values for 18 parameters ranged from a low of 7:1 for iron and manganese to a high of 56:1 for grease and oil. A mean (maximum:minimum) value of approximately 18:1 for all parameters was noted.

Raw screened septage may be coagulated with conventional chemicals such as ferric chloride, alum and lime. However, optimizing the chemical dose to achieve effective phase separation is difficult. Effective phase separation can be consistently achieved by the application of a two-stage sulfuric acid/lime coagulation process.

The sludge fraction resulting from the coagulation of raw screened septage can be dewatered, either alone or in combination with municipal waste secondary sludge, by a number of processes. Sand drying bed and filter press dewatering were found to be very effective. Vacuum filtration and centrifugation were less effective, possibly because of limitations associated with the equipment utilized. The application of specific dewatering equipment at a given site should be carefully evaluated by supplemental testing.

The introduction of screened septage at a continuous rate to any component of a municipal wastewater treatment facility may be considered if it is recognized that 3.79 m^3 (1,000 gal.) of this material has an average BOD_5 population equivalent of approximately 240 and an average TSS population equivalent in the vicinity of 360.

The aqueous fractions resulting from the effective coagulation and dewatering of septage contain essentially soluble BOD_5 and ammonia nitrogen as residual pollutants. This aqueous fraction is ammenable to biological treatment and may be processed by either controlled addition to a municipal treatment plant influent or intermittent sand filtration treatment.

The ultimate disposal of dewatered septage solids may be accomplished by, among others, burial in a soil mantle. Investigations should be undertaken to insure the soil mantle has adequate pollutant retention capabilities.

Depending on the quantity of septage processed and the mode of treatment employed, total annual operating costs may range from $4 to $10/m^3$ ($14 to $37/1,000 gal.) of raw septage processed.

SECTION 3

DESCRIPTION OF PILOT PLANT FACILITIES

To establish the most effective methods of septage treatment, the physical, chemical, and/or biological transformations occurring across each of the unit processes presented in Figure 1 should be established. To facilitate the conduct of such measurements, a pilot scale facility capable of processing up to 3.79 m^3 (1,000 gal.) of raw septage per day was constructed. A schematic diagram of this facility is presented in Figure 2 and a description of each component is as follows:

1. A 30.5 cm (12-in.) diameter by 2.44 m (8 ft) high coarse screen made of 0.64 cm (0.25 in.) opening wire mesh. The purpose of this screen was to protect the pilot plant equipment by removing large objects from the raw septage as it was discharged from the haulers' trucks.

2. A 4.73 m^3 (1,250-gal.) raw septage receiving tank set approximately 2.44 m (8 ft) below grade to facilitate transfer of septage from the haulers' trucks.

3. A 61.0 cm (24-in.) diameter vibrating screen equipped with a 40-mesh screen. The purpose of this screen was to remove material which would cause pump or pipeline plugging.

4. A 4.74 m^3 (1,250 gal.) screened septage storage tank.

5. Septage conditioning tanks, each with a capacity of 1.04 m^3 (275 gal.). A 186 J/sec (0.25 hp) mechanical mixer was installed in each tank as well as air mixing equipment.

6. A 2.84 m^3 (750 gal.) collection/storage tank for the aqueous fractions resulting from various treatment investigations.

7. A 3.79 m^3 (1,250 gal.) tank for the collection/storage of either the solids-bearing fraction or the total volume subjected to pretreatment and/or other investigations.

8. A 38-190 l/min (10-50 gpm) diaphragm pump used for the transfer of untreated and treated septage (and its fractions) throughout the entire pilot plant.

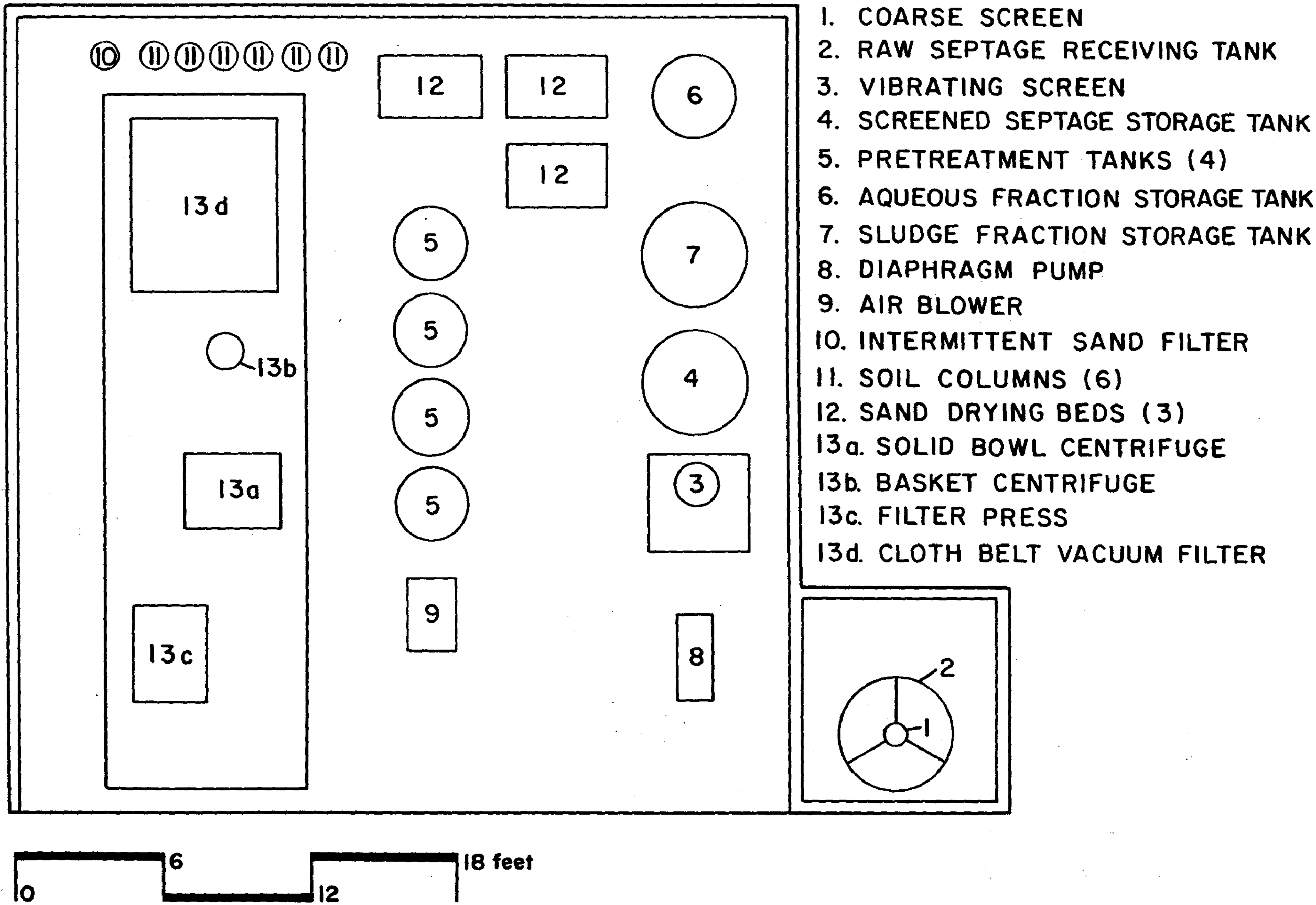


FIGURE 2. PLAN VIEW OF PILOT PLANT FACILITIES

9. A 0.57 m^3/min (20 cfm) blower installed to provide air mixing, when required, in any of the pilot plant tanks.

10. One 30.5 cm (12 in.) diameter by 91.5 cm (3 ft) deep sand column for the investigation of intermittent sand filtration treatment of various aqueous fractions.

11. Six 30.5 cm (12 in.) diameter by 122 cm (4 ft) deep soil columns for the investigation of the leaching of heavy metals from dewatered sludge solids buried in a soil mantle.

12. Three 0.93 m^2 (10 ft^2) by 30.5 cm (1 ft) deep sand drying beds for the investigation of conditioned septage sludge solids dewatering.

13. A trailer equipped with the following pilot scale dewatering equipment:

    a. Solid bowl centrifuge,
    b. Basket centrifuge,
    c. Filter press, and
    d. Cloth belt vacuum filter.

The pilot plant facilities shown in Figure 2 were constructed at the Falmouth, Maine municipal wastewater treatment plant. This plant was designed as a dual train 6,690 m^3/day (1.5 MGD) contact stabilization plant. Each 2,840 m^3/day (0.75 MGD) treatment train consists of a sludge reaeration zone, a contact zone, a secondary clarifier and an aerobic digester. Common facilities include the headworks, chlorine contact chamber and centrifugal air blowers. The parallel treatment trains at this location enabled the comparison of system performance when septage was added to the individual components of one of the treatment trains.

SECTION 4

SCREENING OF RAW SEPTAGE

Initial observations of raw septage in the laboratory showed a substantial content of large size particulate material. Included were sand, gravel, solidified oil and grease, fruit and vegetable seeds, pieces of plastic, rags, and hair.

A series of studies using a 20-mesh (0.84 mm opening) vibrating screen was undertaken in the laboratory to measure the impact of preliminary screening on the raw septage characteristics. TSS concentration was used as the parameter for evaluation of this process and the results are presented in Table 2.

TABLE 2. IMPACT OF SCREENING ON RAW SEPTAGE TSS CONCENTRATIONS (LABORATORY DATA)

	TSS Concentration, mg/l		Percent
Run No.	Before Screening	After Screening	TSS Removal
1	27,300	3,280	88
2	25,000	6,860	73
3	49,200	8,930	82
4	27,200	10,400	62
Average	32,200	7,370	77

Screening with a 20-mesh screen in the laboratory had a pronounced effect on the raw septage TSS concentration, resulting in an average reduction of 77 percent. The resultant screenings volume approximated 5 to 10 percent of the original volume and had a total solids content of 25 to 50 percent by weight.

Screening of raw septage in the field using a vibrating screen equipped with 6-mesh (3.35 mm opening) screen led to non-functioning of the apparatus. It was noted that hair would get interwoven in the screen, resulting in eventual complete blinding. Subsequent replacement of the screen with one of 40-mesh size (0.42 mm opening) led to proper operation of the vibrating screen with negligible blinding problems. Screenings volume employing the 40-mesh (0.42 mm opening) screen approximately 7.5-37.4 l/m^3 (1-5 ft^3/1,000 gal.) of septage processed.

The non-homogeneity of septage as received at the pilot plant facility made it extremely difficult to obtain representative samples for accurate analyses. Even with intense mixing (by air diffusion) in the raw septage receiving tank, it was observed that the larger particulate matter such as hair and solidified oil and grease had a tendency to concentrate on the surface of the tank. As a result, thorough analyses were completed only on raw septage that had been passed through a 40-mesh (0.42 mm opening) screen. Table 3 presents the characteristics of screened septage encountered during this study.

The data presented in Table 3 for the most part, are coincident with values reported in the literature. Variations are interpreted as resulting from the screening of the raw septage. Individual sample analyses data are contained in the Appendix.

TABLE 3. SCREENED SEPTAGE CHARACTERISTICS FOR THIS STUDY

Parameter	Concentration, mg/l Average	Minimum	Maximum	No. of Samples
TS	11,800	2,560	42,100	30
TVS	9,280	1,830	32,600	30
TSS	8,680	2,140	40,200	39
VSS	6,720	1,820	20,700	39
pH, S.U.	-	2.8	9.8	39
BOD_5 (total)	5,850	1,040	50,000	39
BOD_5 (soluble)	1,050	315	5,450	39
COD	20,400	4,530	132,000	30
NH_3-N, as N	64	3	102	30
Organic-N, as N	204	64	549	30
PO_4 (total), as P	57	20	135	30
PO_4 (ortho), as P	31	8	100	30
Alkalinity, as $CaCO_3$	346	0	910	39
Fe	51	18	120	11
Ni	0.24	0.05	0.42	3
Cd	0.07	<0.02	0.2	5
Cu	10.1	2.0	30.0	11
Mn	0.65	0.2	1.4	11
Zn	7.8	2.9	18.0	11
Grease & Oil	3,380	208	11,600	15

SECTION 5

SCREENED SEPTAGE CONDITIONING

The conditioning of septage by chemicals or other means is probably the most important operation in an overall septage treatment program. Physical, chemical, and/or biological transformations initiated in this unit operation can greatly influence the results attainable from supplemental treatment operations.

The function of conditioning is to induce desired septage quality alterations including improved suspended solids settleability and sludge dewaterability, complexation of metallic ions, precipitation of phosphorus, initiation of biological kill, removal of ammonia and sulfide, and odor inhibition. These alterations can be brought about by the addition of gases, chemicals, or energy. The degree of alteration is a function of not only the level of additives listed above, but also the type and degree of mixing and the reaction time provided. Problem areas could include the generation of odors or toxic compounds as well as the possibility of mutually exclusive desired quality alterations resulting from a given conditioning methodology. For example, the addition of chlorine could yield substantial bacterial kill, but could as well lead to the formation of toxic chloramines.

Since most of the desired quality alterations sought were allied with separation of the screened septage into an aqueous phase and a suspended solids-bearing phase, the results of these as well as other conditioning investigations are included in this section of the report.

An extensive series of studies were undertaken and the results of these efforts are presented in the following subsections. All raw data are presented in the Appendix.

SEDIMENTATION OF SCREENED SEPTAGE

Batch settling tests were undertaken to determine the degree of phase separation achievable by plain sedimentation. Table 4 shows typical supernatant quality following 24 and 48 hours of settling based on the average characteristics of screened septage presented in Table 3. Individual test data are presented in the Appendix.

TABLE 4. SEDIMENTATION OF SCREENED RAW SEPTAGE

Parameter	Supernatant Quality Following Sedimentation For 0 Hours	24 Hours	48 Hours
TS, mg/l	11,800	10,300	9,630
TVS, mg/l	9,280	8,310	8,310
SS, mg/l	8,680	5,950	4,880
VSS, mg/l	6,720	4,860	3,890
BOD_5 (total), mg/l	5,850	5,850	4,900
NH_3-N, mg/l as N	64	62	64
Organic-N, mg/l as N	204	201	180
PO_4 (total), mg/l as P	57	26	31

Plain sedimentation was partially effective in separating screened septage into two phases. The phases, however, were not distinct because of substantial residual turbidity remaining in the supernatant fraction. Forty-eight hours of sedimentation resulted in the following average removals: TSS - 44 percent; BOD_5 - 16 percent; organic nitrogen - 12 percent; and total phosphate - 45 percent.

AERATION OF SCREENED SEPTAGE

It is common practice at many municipal treatment facilities to aerate septage for a designated period of time prior to metering it into the plant. A series of runs were undertaken at the pilot plant level to investigate transformations induced by aeration alone. Aeration times ranged from 16 to 96 hours. Following aeration, the septage was allowed to settle for two hours and representative supernatant samples were collected and analyzed. Table 5 presents the relative changes in selected parameters for 24 and 96 hours of aeration time based on average raw screened septage characteristics.

TABLE 5. EFFECT OF AERATION AND TWO HOURS OF SETTLING ON SCREENED SEPTAGE SUPERNATANT CHARACTERISTICS

Parameter	Concentration Following Aeration For 0 Hours	24 Hours	96 Hours
TSS, mg/l	8,680	9,550	1,480
BOD_5 (total), mg/l	5,850	5,210	295
NH_3-N, mg/l as N	64	49	6
Organic-N, mg/l as N	204	249	33
PO_4 (total), mg/l as P	57	45	4

Negligible changes occurred as a result of 24 hours of aeration. However, 96 hours of aeration induced a number of desired transformations including: (1) the improvement of settling characteristics; (2) the removal of BOD_5 through biological activity and sedimentation; (3) the removal of nitrogenous material by air stripping, bioassimilation, and sedimentation; and (4) the removal of phosphates by bioassimilation and sedimentation.

Although substantial partitioning was realized by four days of aeration, complete phase separation was not achieved. The aqueous fraction approximated 50 percent of the original volume treated and still contained relatively high concentrations of, among others, TSS and BOD_5. However, a distinct sludge layer could be noted in the bottom of the reaction tank.

FERRIC CHLORIDE ADDITION

Screened septage has the physical appearance of partially digested domestic treatment plant primary sludge. Numerous chemicals can be employed to coagulate/condition such material, one of which is ferric chloride. Preliminary laboratory investigations were undertaken to define applicable ferric chloride doses for screened septage and it was found that 400 to 600 mg/l (as $FeCl_3$) was required to achieve consistent desired quality alterations. Table 6 summarizes the results of 12 studies where 400 to 600 mg/l of ferric chloride was added to screened septage, a rapid/slow mix reaction time of 30 minutes and 90 minutes, respectively, was employed, and supernatant samples were collected and analyzed following 22 hours of sedimentation.

The addition of ferric chloride yielded effective coagulation of the screened septage. However, optimization of the ferric chloride dose required that jar tests be run on each batch of raw screened septage.

Laboratory investigations indicated that if lime was added to the supernatant decanted from the ferric chloride addition process the mixture agitated for one hour and allowed to settle for 22 hours, additional pollutant capture could be realized. In an attempt to obtain better phase separation, ten pilot plant trials were undertaken to investigate this process. Required lime dose had to be established by jar tests for each run and ranged from 2,500 to 4,000 mg/l. Data from these trials are summarized in Table 7.

The supplemental lime addition yielded a relatively high quality supernatant. The only pollutants of concern remaining in the final supernatant were noted as being moderate levels of TSS, BOD_5, and nitrogenous compounds.

FERRIC CHLORIDE/LIME ADDITION

Following laboratory investigations, pilot plant trials using ferric chloride and lime together were undertaken. Chemical requirements were

TABLE 6. FERRIC CHLORIDE ADDITION TO RAW SCREENED SEPTAGE (AVERAGE VALUES FROM 12 TRIALS)

Parameter	Raw Septage	Supernatant Concen-tration	Supernatant % of Total	Sludge Concen-tration	Sludge % of Total
Volume, m^3	0.758	0.455	60.0	0.303	40.0
, gal	200	120	60.0	80	40.0
TSS, mg/l	9,790	271	1.7	24,100	98.3
VSS, mg/l	7,990	240	1.8	19,600	98.2
pH, S.U.	6.0	5.3	-	-	-
BOD_5 (total), mg/l	7,980	664	5.0	18,900	95.0
BOD_5 (soluble), mg/l	1,080	616	34.4	1,760	65.6
COD, mg/l	26,100	1,300	3.0	63,300	97.0
NH_3-N, mg/l N	58	53	54.8	65.5	45.2
Organic-N, mg/l N	233	81	20.8	461	79.2
PO_4 (total), mg/l P	47	<5.8	<7.4	>109	>92.6
PO_4 (ortho), mg/l P	29	3.5	7.2	67	92.8
Alkalinity, mg/l $CaCO_3$	293	135	-	-	-
Fe, mg/l	54	18	20.0	-	-
Ni, mg/l	-	-	-	-	-
Cd, mg/l	-	-	-	-	-
Cu, mg/l	11.0	0.19	1.0	27	99.0
Mn, mg/l	0.66	0.54	49.1	0.84	50.9
Zn, mg/l	8.9	1.2	8.1	20	91.9
Grease & Oil, mg/l	5,000	301	4.4	9,800	95.6

Experimental Conditions: $FeCl_3$ dose - 400 to 600 mg/l
Rapid mix time - 30 minutes
Slow mix time - 90 minutes
Settling time - 22 hours

TABLE 7. LIME TREATMENT OF FERRIC CHLORIDE FORMED SUPERNATANT (AVERAGE VALUES FROM 10 TRIALS)

Parameter	$FeCl_3$ Treatment Supernatant	Supernatant		Sludge	
		Concen-tration	% of Total	Concen-tration	% of Total
Volume, m^3	0.455	0.409	90.0	0.045	10.0
, gal	120	108	90.0	12	10.0
TSS, mg/l	245	81	29.7	1,720	70.3
VSS, mg/l	215	28	11.7	1,900	88.3
pH, S.U.	5.3	11.8	-	-	-
BOD_5 (total), mg/l	738	475	57.9	3,110	42.1
BOD_5 (soluble), mg/l	712	432	54.6	3,230	45.4
COD, mg/l	1,310	716	49.1	6,680	50.9
NH_3-N, mg/l N	52	41	71.0	513	29.0
Organic-N, mg/l N	112	111	89.2	121	10.8
PO_4 (total) mg/l P	6.6	1.9	25.9	49	74.1
PO_4 (ortho) mg/l P	3.8	1.5	35.5	25	64.5
Alkalinity, mg/l $CaCO_3$	145	1,479	-	-	-
Fe, mg/l	18	0.28	1.4	177	98.6
Ni, mg/l	-	-	-	-	-
Cd, mg/l	-	-	-	-	-
Cu, mg/l	0.19	<0.09	<42.6	>1.1	>57.4
Mn, mg/l	0.54	<0.1	<16.6	>4.5	>83.4
Zn, mg/l	1.2	<0.1	<7.5	>11	>92.5
Grease & Oil, mg/l	302	197	58.9	1,240	41.1

Experimental Conditions: Lime dose - 2,500 to 4,000 mg/l
Rapid mix time - 30 minutes
Slow mix time - 90 minutes
Settling time - 22 hours

found, from jar testing, to approximate 400 mg/l of ferric chloride and 4,000 mg/l of lime to achieve effective coagulation of the screened septage. Three trials were conducted in the field and the average results are presented in Table 8.

The average supernatant characteristics following 22 hours of sedimentation indicated good phase separation. However, supplemental treatment would have to be provided before final disposal of this fraction. Settling column data for these trials are contained in the Appendix.

Once again, it was necessary to run jar tests on each batch of screened raw septage to establish the optimum chemical doses.

ALUM ADDITION

In a further attempt to coagulate screened raw septage, alum addition was investigated. Laboratory investigations indicated that the optimum alum dose (as $Al_2[SO_4]_3$) was found to range from 2,250 to 8,250 mg/l, depending on the initial septage characteristics. A total of 18 alum addition studies were completed at the pilot scale level. The procedure involved addition of the appropriate concentration of alum, mixing for two hours, and allowing sedimentation to occur for 22 hours. A summary of the average results is presented in Table 9.

As with other chemical addition studies, effective phase separation was realized only when the optimum alum dose was applied. Adjustment of pH seemed to have little effect on the supernatant quality. Supernatant quality, however, was still not suitable for direct discharge and warranted further treatment.

ACID ADDITION

Laboratory investigations indicated that when the pH of screened raw septage was decreased to and held at a value of approximately 2.0, a rather consistent phase separation occurred. As a result, eight pilot scale studies were undertaken on pH adjustment. The procedure involved adjusting and maintaining the pH of the septage at approximately 2.0 with sulfuric acid, mixing for two hours, and allowing sedimentation to occur for 22 hours. Table 10 summarizes the results of these studies.

Average sulfuric acid requirements ranged from 3,000 to 4,000 mg/l. The benefit of the acid addition procedure was that a consistent phase separation could be achieved by simple pH adjustment as opposed to running extensive jar tests on each batch to find the optimum chemical dose to achieve a given supernatant quality.

Column tests were undertaken to define settling times and it was found that the minimum time for effective phase separation approximated six to eight hours. These data are contained in the Appendix.

TABLE 8. FERRIC CHLORIDE AND LIME TREATMENT OF RAW SCREENED SEPTAGE (AVERAGE VALUES FROM 3 TRIALS)

Parameter	Raw Septage	Supernatant Concentration	Supernatant % of Total	Sludge Concentration	Sludge % of Total
Volume, m^3	0.758	0.512	67.5	0.246	32.5
, gal	200	135	67.5	65	32.5
TSS, mg/l	9,220	108	0.8	28,200	99.2
VSS, mg/l	7,960	88	0.7	24,300	99.3
pH, S.U.	5.9	12.1	-	-	-
BOD_5 (total), mg/l	4,290	610	9.6	11,900	90.4
BOD_5 (soluble), mg/l	897	495	37.2	1,730	62.8
COD, mg/l	11,300	5,480	32.6	23,500	67.4
NH_3-N, mg/l N	55	51	62.5	63	37.5
Organic-N, mg/l N	172	85	33.3	353	66.7
PO_4 (total), mg/l P	41	<14	<23.0	>97	>77.0
PO_4 (ortho), mg/l P	25	10	27.0	56	73.0
Alkalinity, mg/l $CaCO_3$	743	1,780	-	-	-
Fe, mg/l	47	20	28.7	-	-
Ni, mg/l	-	-	-	-	-
Cd, mg/l	-	-	-	-	-
Cu, mg/l	11.7	<4.9	<28.2	>26	>71.8
Mn, mg/l	0.3	<0.1	<22.5	>0.7	>77.5
Zn, mg/l	7.6	3.2	28.4	17	71.6
Grease & Oil, mg/l	1,550	-	-	-	-

Experimental Conditions: Lime dose - 4,000 mg/l
$FeCl_3$ dose - 400 mg/l
Rapid Mix time - 30 minutes
Slow mix time - 90 minutes
Settling time - 22 hours

TABLE 9. ALUM CONDITIONING OF RAW SCREENED SEPTAGE (AVERAGE VALUES FROM 18 TRIALS)

Parameter	Raw Septage	Supernatant		Sludge	
		Concentration	% of Total	Concentration	% of Total
Volume, m^3	0.694	0.474	68.3	0.220	31.7
, gal	183	125	68.3	58	31.7
TSS, mg/l	13,400	183	0.9	41,900	99.1
VSS, mg/l	10,600	139	0.9	33,100	99.1
pH, S.U.	6.5	4.5	-	-	-
BOD_5 (total), mg/l	5,250	293	3.8	15,900	96.2
BOD_5 (soluble), mg/l	1,240	233	12.8	3,410	87.2
COD, mg/l	13,500	407	2.1	41,700	97.9
NH_3-N, mg/l N	61	47	52.6	91	47.4
Organic-N, mg/l N	165	22	9.1	473	90.9
PO_4 (total), mg/l P	51	<7	<9.4	>146	>90.6
PO_4 (ortho), mg/l P	28	<4	<9.8	>80	>90.2
Alkalinity, mg/l $CaCO_3$	217	161	-	-	-

Experimental Conditions: Alum dose - 2,250 to 8,250 mg/l
Rapid mix time - 30 minutes
Slow mix time - 90 minutes
Settling time - 22 hours

TABLE 10. ACID TREATMENT OF RAW SCREENED SEPTAGE (AVERAGE VALUES FROM 8 TRIALS)

Parameter	Raw Septage	Supernatant Concentration	Supernatant % of Total	Sludge Concentration	Sludge % of Total
Volume, m^3	0.758	0.587	77.5	0.171	22.5
, gal	200	155	77.5	45	22.5
TSS, mg/l	8,690	393	3.5	37,300	96.5
VSS, mg/l	7,720	264	2.6	33,400	97.4
pH, S.U.	6.0	2.2	-	-	-
BOD_5 (total), mg/l	5,530	337	4.7	23,400	95.3
BOD_5 (soluble), mg/l	1,230	286	18.1	4,460	81.9
COD, mg/l	10,900	785	5.6	45,700	94.4
NH_3-N, mg/l N	68	57	-	-	-
Organic-N, mg/l N	232	58	19.4	831	80.6
PO_4 (total), mg/l P	43.8	36	63.7	70.7	36.3
PO_4 (ortho), mg/l P	22.6	25	85.7	14.3	14.2
Alkalinity, mg/l $CaCO_3$	302	-	-	-	-
Fe, mg/l	59.7	21.5	27.9	191	72.1
Ni, mg/l	0.17	0.06	27.3	.55	72.6
Cd, mg/l	0.08	0.06	58.2	.15	41.8
Cu, mg/l	11.9	0.97	6.3	49.5	93.7
Mn, mg/l	0.87	0.42	37.4	2.42	62.6
Zn, mg/l	8.5	3.7	33.7	25.0	66.3
Grease & Oil, mg/l	4,720	253	4.1	20,100	95.9

Experimental Conditions: Sulfuric acid dose - 3,000 to 4,000 mg/l
Mix time - 2 hours
Settling time - 22 hours
Final pH - 2

The impact of acid addition to screened septage on bacterial kill was also of interest. It was found that the raw screened septage had a count generally ranging from 4 to 6 million coliform colonies/100 ml. Upon sulfuric acid addition to a pH of 2.0$\pm$, and allowing a reaction time of four hours, the residual viable coliform count was consistently less than 30,000 colonies/100 ml. After 16 hours of reaction, the residual count was less than 20 coliform colonies/100 ml.

ACID/LIME ADDITION

Neutralization of the previously discussed acid-formed supernatant resulted in the formation of a minor precipitate. Further laboratory investigations revealed that if lime was added to adjust the pH to approximately 11.0 and two hours of settling was provided, a very clear supernatant evolved. Pilot scale studies were undertaken to confirm this finding and the average supernatant quality from seven trials is presented in Table 11.

Lime addition to pH 11.0$\pm$ consistently yielded a very high quality supernatant in approximately two hours.

LIME/HEAT ADDITION

Previous work on septage treatment indicated that conditioning with lime not only enhanced dewaterability but also resulted in substantial biological kill. Laboratory studies were undertaken to expand upon this concept by: (1) varying the screened raw septage pH with lime (and sulfuric acid); (2) raising the temperature above ambient for a designated period of time; and (3) measuring phase separation potential and biological kill. Table 12 presents residual coliform counts and the phase separation results for 16 hours of reaction time.

TABLE 12. LIME AND HEAT TREATMENT OF RAW SCREENED SEPTAGE

	Coliform Count, 10^6 Colonies/100 ml			
	Temperature, °C			
pH	20	35	50	62
5	1.7	1.6	--	x
7	3.9	>100	--	x
9	10.3	>100	0.8	x
10	--	--	<0.05	--
11	<0.05	x	x	x

x = less the 20/100 ml

(Continued)

TABLE 11. LIME TREATMENT OF ACID FORMED SUPERNATANT (AVERAGE VALUES FROM 7 TRIALS)

Parameter	Acid Treatment Supernatant	Supernatant		Sludge	
		Concentration	% of Total	Concentration	% of Total
Volume, m^3	0.587	0.523	89.0	0.064	11.0
, gal	155	138	89.0	17	11.0
TSS, mg/l	393	69	15.6	3,020	84.4
VSS, mg/l	264	39	13.2	2,090	86.8
pH, S.U.	2.2	11.7	-	-	-
BOD_5 (total), mg/l	337	419	-	-	-
BOD_5 (soluble), mg/l	286	303	-	-	-
COD, mg/l	785	650	73.7	1,880	26.3
NH_3-N, mg/l N	57	48	75.0	130	25.0
Organic-N, mg/l N	58	30	46.0	285	54.0
PO_4 (total), mg/l P	36	3.1	7.7	303	92.3
PO_4 (ortho), mg/l P	25	2.1	7.5	211	92.5
Alkalinity, mg/l $CaCO_3$	-	-	-	-	-
Fe, mg/l	21.5	0.34	1.4	193	98.6
Ni, mg/l	0.06	0.03	44.5	0.30	55.5
Cd, mg/l	0.06	0.02	29.6	0.38	70.4
Cu, mg/l	0.97	0.19	17.4	7.3	82.6
Mn, mg/l	0.42	0.18	38.2	2.4	61.8
Zn, mg/l	3.7	0.22	5.3	32	94.7
Grease & Oil, mg/l	253	219	77.1	529	22.9

Experimental Conditions: Lime dose - 3,500 to 4,500 mg/l
Mix time - 30 minutes
Settling time - 2 hours
Final pH - 11.7

TABLE 12. (Continued)

pH	Sludge Volume, % of Total			
	Temperature, °C			
	20	35	50	62
5	100	100	--	100
7	95	95	--	65
9	80	80	65	50
10	--	--	50	--
11	80	65	30	30

The pH-temperature interaction had an impact on biological population as measured by total coliform count. Depending on pH and temperature, coliform growth or kill could result. For example, at a pH of 9 and a temperature of 35°C profound growth occurred while at a comparable pH and a temperature of 62°C, residual total coliform count was less than 20 colonies/100 ml.

The pH-temperature interaction also had a definite impact on separation of the septage into two phases, with better separation being realized with both elevated pH and temperature. Initial TSS was approximately 5,500 mg/l and in those cases where a supernatant fraction developed, the supernatant TSS concentration ranged from approximately 100 to 200 mg/l.

LIME/MAGNESIUM CHLORIDE ADDITION

It is known that lime, in conjunction with magnesium salts, can yield effective coagulation of suspended material. Laboratory studies on this combination were carried out and the results are presented in Table 13.

The above sludge volumes and supernatant qualities resulted following six hours of quiescent phase separation. Lime, in conjunction with magnesium salts, yielded a high quality supernatant. However, the magnesium salt concentration required to obtain such a quality was approximately 5,000 mg/l of $MgCl_2 \cdot 6H_2O$.

TABLE 13. LIME AND MAGNESIUM CHLORIDE TREATMENT OF RAW SCREENED SEPTAGE

Temperature C°	Chemical Dose, mg/l		Sludge Volume, % of Total	Supernatant TSS, mg/l
	$Ca(OH)_2$	Mg^{++}		
25	0	0	100	4,260
25	4,000	100	66	680
25	4,000	200	67	450
25	4,000	300	68	230
25	4,000	400	65	5
60	0	0	100	5,340
60	4,000	0	33	130
60	4,000	200	33	120
60	4,000	400	33	90
60	4,000	600	33	5
60	4,000	1,000	33	5

SECTION 6

SLUDGE DEWATERING

Screened septage conditioning processes were shown to be capable of separating 3.79 m^3 (1,000 gal) of this material into approximately 2.27 to 2.65 m^3 (600-700 gal) of supernatant and 1.14 to 1.52 m^3 (300-400 gal) of sludge. Average total solids concentration of this sludge was in the vicinity of 3.0 to 3.5 percent. At this consistency, further dewatering is desirable to enable easier handling for ultimate disposal purposes. A mathematical analysis has indicated that if this sludge fraction is further dewatered to obtain a consistency of 25 percent, the final sludge volume would approximate 0.15 to 0.19 m^3 (40-50 gal).

In an attempt to achieve a solids cake of up to 25 percent, a number of pilot scale studies were undertaken. Included were the utilization of sand drying beds, a solid-bowl centrifuge, a filter press, and a cloth belt vacuum filter. The following subsections present the results of these dewatering studies.

SAND DRYING BEDS

Three sand drying beds, each with an area of 0.93 m2 (10 ft^2) and a sand depth of 30.5 cm (12 in) were constructed. The sand employed had an effective size of 0.54 mm and a uniformity coefficient of 1.85. Septage sludges resulting from the various conditioning processes were applied and filtrate volumes and quality, with respect to drainage time, were noted.

As a preliminary study, 0.18 m^3 (48 gal) batches raw screened septage were placed on the beds in 20 cm (7.75 in) lifts. Table 14 presents the average characteristics of the raw septage and the supernatant resulting from one and two days of drainage time for four trials.

TABLE 14. SAND BED DEWATERING OF RAW SCREENED SEPTAGE (AVERAGE VALUES FROM 4 TRIALS)

Parameter	Raw Septage	Average Filtrate On Day 1	Average Filtrate On Day 2
Volume, m^3	0.182	0.114	0.045
, gal	48.0	30.0	12.0

(Continued)

TABLE 14. (Continued)

Parameter	Raw Septage	Average Filtrate On	
		Day 1	Day 2
TS, mg/l	10,200	1,840	1,080
TVS, mg/l	7,490	1,350	750
SS, mg/l	7,700	418	70
VSS, mg/l	6,240	375	70
pH, S.U.	5.8	6.4	6.9
BOD_5 (total), mg/l	5,670	1,288	650
BOD_5 (soluble), mg/l	1,710	1,003	615
Alkalinity, mg/l as $CaCO_3$	539	300	331
CST, sec	141	-	-

A materials balance on the utilization of sand drying beds for dewatering screened raw septage, employing a total drainage time of two days was undertaken and the results are presented in Table 15.

TABLE 15. MATERIALS BALANCE ON SAND BED DEWATERING OF RAW SCREENED SEPTAGE

Parameter	Raw Septage	Filtrate Fraction		Sludge Fraction	
		Concentration	% of Total	Concentration	% of Total
Volume, m^3	0.182	0.159	87.5	0.023	12.5
, gal	48	42	87.5	6	12.5
TS, mg/l	10,200	1,630	13.9	70,200	86.1
TVS, mg/l	7,490	1,180	13.7	51,600	86.3
SS, mg/l	7,700	319	3.6	59,300	96.4
VSS, mg/l	6,240	288	4.0	47,900	96.0
BOD_5 (total), mg/l	5,670	1,110	17.1	37,600	82.9
BOD_5 (soluble), mg/l	1,710	892	45.6	7,440	54.4
CST, sec	141	-	-	-	-

With a drainage time of two days, a 5.9 percent solids cake developed (TSS basis). Filtrate quality was indicative of the passage of substantial colloidal material through the sand drying bed.

Sludge from the ferric chloride/lime conditioning process was next investigated. Average sludge and filtrate characteristics based on four trials, with respect to time, are given in Table 16.

TABLE 16. SAND BED DEWATERING OF SLUDGE FROM THE FERRIC CHLORIDE/LIME CONDITIONING PROCESS

Parameter	$FeCl_3$ Sludge	Average Filtrate On Day 1	Average Filtrate On Day 2
Volume, m^3	0.182	0.109	0.036
, gal	48.0	28.8	9.6
TSS, mg/l	21,000	39	66
VSS, mg/l	11,000	19	33
BOD_5 (total), mg/l	9,250	931	1,230
BOD_5 (soluble), mg/l	2,410	886	920
CST, sec	23	-	-

A materials balance on the above ferric chloride/lime sludge was undertaken and the results are presented in Table 17.

TABLE 17. MATERIALS BALANCE ON SAND BED DEWATERING OF SLUDGE FROM THE FERRIC CHLORIDE/LIME CONDITIONING PROCESS (AVERAGE VALUE FROM 4 TRIALS)

		Filtrate		Sludge	
Parameter	$FeCl_3$ Sludge	Concentration	% of Total	Concentration	% of Total
Volume, m^3	0.182	0.146	80.0	0.036	20.0
, gal	48.0	38.4	80.0	9.6	20.0
TSS, mg/l	21,000	46	0.2	105,000	99.8
VSS, mg/l	11,000	23	0.2	54,900	99.8
BOD_5 (total), mg/l	9,250	1,010	8.7	42,200	91.3
BOD_5 (soluble), mg/l	2,410	895	29.7	8,490	70.3

Ferric chloride/lime conditioning substantially improved the filtrate quality over that resulting by sand drying bed treatment of raw screened septage alone. In addition, the cake solids increased from 5.9 for the raw screened septage to 10.5 percent for the ferric chloride/lime sludge.

Application of alum treated septage solids to the sand drying beds yielded a high quality supernatant and a 15.3 percent cake after only one day of drainage. The materials balance for alum sludge is presented in Table 18.

TABLE 18. MATERIALS BALANCE ON SAND BED DEWATERING OF SLUDGE FROM THE ALUM TREATMENT PROCESS (AVERAGE VALUES FROM 3 TRIALS)

Parameter	Alum Sludge	Filtrate		Sludge	
		Concentration	% of Total	Concentration	% of Total
Volume, m^3	0.182	0.146	80.0	0.036	20.0
, gal	48.0	38.4	80.0	9.6	20.0
TSS, mg/l	30,600	79	0.2	153,000	99.8
VSS, mg/l	25,500	29	0.1	127,000	99.9
pH, S.U.	4.0	5.1	-	-	-
BOD_5 (total), mg/l	10,200	240	1.9	50,200	98.1
BOD_5 (soluble), mg/l	1,180	220	14.9	5,020	85.1
CST, sec.	12	-	-	-	-

Sand drying bed treatment of sludge resulting from the acid/lime treatment process also led to very positive results. Table 19 presents average sludge and filtrate characteristics, with respect to time, for the acid/lime produced sludge from four trials.

TABLE 19. SAND BED DEWATERING OF SLUDGE FROM THE ACID/LIME TREATMENT PROCESS (AVERAGE VALUES FROM 4 TRIALS)

Parameter	Acid/Lime Sludge	Average Filtrate On	
		Day 1	Day 2
Volume, m^3	0.182	0.109	0.057
, gal	48.0	28.8	15.0
SS, mg/l	21,100	54	51
VSS, mg/l	13,400	51	27
pH, S.U.	8.2	6.8	6.7
BOD_5 (total), mg/l	19,600	695	484
BOD_5 (soluble), mg/l	1,750	647	442
PO_4 (total), mg/l as P	59	2	2

A materials balance following two day's drainage yielded the data presented in Table 20.

TABLE 20. MATERIALS BALANCE ON SAND BED DEWATERING OF SLUDGE FROM THE ACID/LIME TREATMENT PROCESS

		Filtrate		Sludge	
Parameter	Acid/Lime Sludge	Concen- tration	% of Total	Concen- tration	% of Total
Volume, m^3	0.182	0.166	91.0	0.016	9.0
, gal	48.0	43.8	91.0	4.2	9.0
TSS, mg/l	21,100	53	0.2	241,000	99.8
VSS, mg/l	13,400	43	0.2	153,000	99.8
BOD_5 (total), mg/l	19,600	622	2.9	217,000	97.1
BOD_5 (soluble), mg/l	1,750	576	30.0	14,000	70.0
PO_4 (total), mg/l as P	59	2	3.1	653	96.9

Average filtrate quality was excellent, except for residual BOD_5, and a cake solids of 24.1 percent was realized.

Subsequent studies involving the three different sludges from the chemical conditioning processes were undertaken and involved multiple applications of these sludges to the same drying beds. Following the application of 0.18 m^3 (48 gal) of sludge to a given bed, two days of drainage was given before the application of an additional 0.18 m^3 (48 gal) of chemical sludge on top of the existing cake. Two more days of drainage were allowed before the application of a third 0.18 m^3 (48 gal) batch of sludge. Following three days of supplemental drainage, cake consistencies approximated those listed in Tables 17, 18, and 20. In all cases, a terminal drainage time of five days yielded cakes that had dried to the extent that natural cracking of the mat occurred.

CENTRIFUGATION

Included in the sludge dewatering trailer loaned to the research project by the U. S. Environmental Protection Agency were a solid bowl and a basket centrifuge. The basket centrifuge was inoperative during the entire conduct of the studies and, therefore, efforts were exclusively on the solid bowl centrifuge.

In total, approximately 60 trials were undertaken on the solid bowl centrifuge. Pond depth was varied during the course of the studies and it was found that optimum results were achieved at a median pool depth setting (#3). Design flow rate to this unit was in the range of 4 to 11 l/min (1 to 3 gpm), and most studies were conducted at the minimum feed rate. Feed to this unit was sludge resulting from ferric chloride/lime conditioning, alum conditioning, acid/lime conditioning, and a 90/10 (volume percent) mixture of aerobically digested secondary sludge from the Falmouth treatment plant and acid/lime conditioned septage sludge. Supplemental conditioning, established by laboratory evaluations, included the utilization of cationic or anionic polymers depending on the feed material to the centrifuge. In most cases, the dewatering performance of the centrifuge using no supplemental conditioning was not acceptable, even at an influent flow rate of 3.8 l/min (1.0 gpm). Table 21 presents the results of the most positive runs achieved at the minimum possible flow rate of 3.8 l/min (1.0 gpm) using no polymer addition.

TABLE 21. SLUDGE DEWATERING BY SOLID-BOWL CENTRIFUGATION

Feed Source	TSS, mg/l Influent	TSS, mg/l Centrate	Cake, % Solids	% Capture of TSS
Ferric Chloride/Lime Septage Sludge	31,000	3,970	16.5	90.5
Alum Septage Sludge	33,000	14,000	20.6	62.4
Acid/Lime Septage Sludge	30,700	17,600	23.0	45.0
90/10 Mixture Sludge	23,400	18,400	20.0	25.7

The centrifuge was so constructed that polymer addition could only be to the influent flow and not part way down the bowl. Addition of polymer at this point in the system led to equivalent or less desirable results than those presented in Table 21. It is felt that if polymer could have been introduced part way down the bowl, enhanced solids capture would have been realized.

FILTER PRESSING

The EPA sludge dewatering trailer was also equipped with a 0.046 m^2 (0.5 ft^2) filter press. Sludge is introduced to the press using a progressive cavity pump. When pump pressure reaches 10.5 kg/cm^2 (150 psi), the pump is shut off and air pressure incrementally applied to 10.5 kg/cm^2 (150 psi). The air pressure is employed to decrease the moisture content of the filter cake.

As in the centrifugation studies, ferric chloride/lime, alum, and acid/lime septage sludges from their respective conditioning processes as well as a 90/10 (volume percent) mixture of aerobically digested secondary sludge and septage sludge from the acid/lime conditioning process were investigated.

Initial trials indicated no supplemental conditioning of these sludges was required. Table 22 presents the experimental results derived from the filter press studies.

TABLE 22. SLUDGE DEWATERING WITH FILTER PRESS

	TSS, mg/l		Cake		%
Feed Source	Influent	Filtrate	% Solids	Thickness, mm (in)	Capture of TSS
Ferric Chloride/Lime Septage Sludge	31,000	38	50.1	6.35 (0.25)	99.91
Alum Septage Sludge	33,000	14	55.0	12.70 (0.50)	99.99+
Acid/Lime Septage Sludge	30,700	3	26.0	12.70 (0.50)	99.99+
90/10 Mixture Sludge	27,000	6	45.7	6.35 (0.25)	99.99+

In all cases, filter press dewatering worked very well, yielding a high filter cake solids content and a filtrate low in TSS. Run times approximated 45 minutes, 12 to 15 minutes required for sludge pumping and 25 to 30 minutes required for drying with air pressurization.

VACUUM FILTRATION

The pilot scale cloth belt vacuum filter in the EPA sludge dewatering trailer had a diameter of 0.92 m (3.0 ft) and a drum length of 0.46 m (1.5 ft). Drum speed could be varied from 1.5 to 16 minutes/revolution and vacuum could be varied between 127-559 mm (5-22 in) of mercury.

Septage sludges from the various conditioning processes were subjected to dewatering. Preliminary laboratory investigations utilizing capillary suction time measurements as well as filter leaf testing revealed that: 1) polymer addition generally would not assist dewaterability; 2) applied vacuum should be 381 mm (15 in) mercury; and 3) a drum speed of 16 minutes per revolution should be employed. Five runs were made on each sludge and typical results are presented in Table 23.

TABLE 23. VACUUM FILTER DEWATERING OF VARIOUS SEPTAGE CONDITIONED SLUDGES

	TSS, mg/l		Cake		Yield
Feed Source	Influent	Filtrate	% Solids	Thickness, mm (in)	kg/m^2/hr lb/ft^2/hr)
Ferric Chloride/ Lime Septage Sludge	22,200	117	35.0	1.59 (0.06)	2.44 (0.5)

(Continued)

TABLE 23. (Continued)

Feed Source	TSS, mg/l Influent	TSS, mg/l Filtrate	Cake % Solids	Cake Thickness, mm (in)	Yield $kg/m^2/hr$ ($lb/ft^2/hr$)
Alum Septage Sludge	33,000	80	28.0	1.59 (0.06)	1.95 (0.4)
Alum Septage Sludge (1)	33,000	56	27.0	6.35 (0.25)	7.33 (1.5)
Acid/Lime Septage Sludge	30,700	44	27.0	3.18 (0.13)	3.91 (0.8)

(1) Conditioned with 2,000 mg/l lime and 25 mg/l of anionic polymer.

In general, cake release from the filter cloth was good for both the ferric chloride/lime and the acid/lime septage sludges. Alum septage sludge would release only if it was conditioned with both lime and polymer.

Vacuum filtration of a 90/10 (volume percent) mixture of aerobically digested secondary sludge and septage sludge from the acid/lime conditioning process was also investigated. Preliminary laboratory investigations were undertaken to establish supplemental conditioning requirements. Approximately twenty trial runs were undertaken on the pilot scale vacuum filter and typical results are presented in Table 24.

TABLE 24. VACUUM FILTER DEWATERING OF COMBINED SLUDGE

Trial	Conditioning*	TSS, mg/l Influent	TSS, mg/l Filtrate	Cake % Solids	Yield $kg/m^2/hr$ ($lb/ft^2/hr$)
A	None	29,000	49	13.9	1.95 (0.4)
C	15 mg/l anionic polymer	46,000	20	24.0	3.42 (0.7)
E	800 mg/l $FeCl_3$ 4,000 mg/l $Ca(OH)_2$ 10 mg/l anionic polymer	24,000	87	17.8	2.44 (0.5)
H	2,000 mg/l $FeCl_3$ 8,000 mg/l $Ca(OH)_2$ 160 mg/l cationic polymer	26,000	200	13.0	1.47 (0.3)

(Continued)

TABLE 24. (Continued)

Trial	Conditioning*	TSS, mg/l Influent	TSS, mg/l Filtrate	Cake % Solids	Yield $kg/m^2/hr$ ($lb/ft^2/hr$)
I	2,000 mg/l alum pH adjusted to 6.3	17,000	190	9.3	0.98 (0.2)
M	2,000 mg/l alum 15 mg/l anionic polymer	28,000	84	16.0	1.95 (0.4)

$$*\frac{\text{Conc. of conditioning chemical}}{\text{Influent TSS Concentration}} \times 2{,}000 = \text{conditioning dose, lb/ton}$$

*lb/ton x 0.501 = kg/t

Cake thickness for all runs was approximately 3.17 mm (0.13 in) and in essentially all trials, the release of the cake from the cloth was not complete. Combinations of supplemental conditioning agents could not be found to either enhance cake release or filter yield.

Supplemental trials on 90/10 (volume percent) mixtures of aerobically digested waste secondary sludge and screened raw septage were also undertaken. Even under massive chemical conditioning, cake release was poor and vacuum filter yield was mediocre, approximating those values presented in Table 24.

SECTION 7

SOLIDS FRACTION DISPOSAL

Once septage solids have been dewatered, they must be ultimately disposed. The most common practice is burial in a soil mantle. Questions have existed on the release of pollutants from dewatered septage solids disposed of in this manner. To investigate this potential problem, 30.5 cm (12 in) diameter by 1.07 m (3.5 ft) deep soil columns were constructed, dewatered sludge solids buried in them, and the equivalent of 2.54 cm (1.0 in) of rain deposited on the soil surface each day. Leachate was collected and analyzed for selected heavy metals.

Three typical soil mantles found in the State of Maine were used in these studies. Paxton soil is a well-drained, fine sandy loam glacial till. This soil, when found in situ, has a compacted layer of material at a depth of about 0.61 m (2.0 ft) below ground elevation which hinders the downward movement of water through the soil mantle. Windsor soil is very well drained outwash derived loamy sand. The texture of this soil is coarser than a convential glacial till. The third soil used was a Canton soil. Canton soils are a well drained glacial till usually found on hills and ridges.

Control columns were set up with no sludge in them. Leachate was collected from the three control columns and the average concentrations of various heavy metals found over a nine-week period were as presented in Table 25.

TABLE 25. METALS IN LEACHATE FROM CONTROL SOIL COLUMNS

	PARAMETER				
Soil Type	pH, S.U.	Fe, mg/l	Cu, mg/l	Mn, mg/l	Zn, mg/l
Paxton	7.8	<0.01	<0.01	0.05	0.03
Windsor	7.4	<0.01	<0.01	0.03	0.03
Canton	7.4	<0.01	0.02	0.07	0.01

In general, very low concentrations of metals leached from the three control soil columns.

Dewatered septage solids from the acid conditioning process was the material placed in the three soil columns under investigation. The dewatered solids were approximately 25 percent solids by weight and had a pH of 2.5. These solids were selected to measure metals retention by the soil as opposed to metals retention by insoluble matrix formations at elevated pH's. Approximately 76 cm (30 in) of soil was placed in the bottom of each column, followed by a 15 cm (6 in) thick layer of dewatered sludge, and capped with 31 cm (12 in) more of soil.

Leachate from each soil column was collected and analyzed. The results of the analyses are presented in Table 26. Values presented in this table reflect changes in concentrations that occurred over a nine-week period and the values are corrected for the leachate concentrations found in the control columns.

The Paxton soil effectively retained all metals measured except manganese. Average pH of the leachate from this column was 7.7 compared to the control value of 7.8. The Windsor soil retained only copper, with iron, manganese, and zinc concentrations in the leachate substantially above the control. Average leachate pH from this column was 7.3 or 0.1 S.U. less than the control. The Canton soil similarly retained only copper well. The pH of the leachate from this column decreased to 7.0 compared to 7.4 for the control.

TABLE 26. METALS IN LEACHATE FROM SOIL/SLUDGE COLUMNS

Paxton Soil

Week	Concentration, mg/l			
	Fe	Cu	Mn	Zn
2	0.01	0.01	0.01	0.01
3	0.01	0.01	0.01	0.01
4	0.01	0.01	0.01	0.01
5	0.01	0.01	0.03	<0.01
6	0.01	0.01	0.65	<0.01
7	0.01	0.01	0.59	<0.01
8	0.10	0.01	0.33	<0.01
9	0.07	0.01	0.23	<0.01

Windsor Soil

Week	Concentration, mg/l			
	Fe	Cu	Mn	Zn
2	0.28	0.01	0.20	0.01
3	3.6	0.01	0.01	0.01
4	13.5	0.01	0.01	0.01
5	21	0.01	35	0.07
6	26	0.01	28	0.11
7	20	0.01	-	0.18
8	22	0.01	20	0.17
9	18	0.01	13	0.12

Canton Soil

Week	Concentration, mg/l			
	Fe	Cu	Mn	Zn
2	0.01	0.01	0.17	0.01
3	0.01	0.01	0.09	0.01
4	0.01	0.01	0.15	0.01
5	0.7	<0.01	6.5	0.26
6	0.6	<0.01	3.2	0.34
7	0.5	0.01	2.8	0.33
8	0.7	<0.01	2.1	0.67
9	0.7	<0.01	1.9	0.91

SECTION 8

AQUEOUS FRACTION TREATMENT

With proper conditioning and/or dewatering of screened septage, a relatively good quality aqueous fraction should result. Typical characteristics of such an aqueous fraction have been estimated and are presented in Table 27.

TABLE 27. ANTICIPATED AQUEOUS FRACTION QUALITY

Parameter	Range of Concentrations
TSS, mg/l	25 - 100
BOD_5 (total), mg/l	300 - 500
NH_3-N, mg/l as N	50 - 100
Organic-N, mg/l as N	25 - 50
PO_4 (total), mg/l as P	0 - 2
Metals, mg/l	1.0
pH, S.U.	5 - 11

Wastewater of such quality is not suitable for direct discharge and thus must receive supplemental treatment. Possible treatment alternatives include: (1) addition to the influent of a municipal treatment plant; (2) chemical oxidation by ozone or chlorine; (3) activated carbon adsorbtion; (4) spray irrigation/land disposal; (5) intermittent sand filtration; and/or (6) combinations of the above.

Influent addition of the aqueous fraction was not investigated because resultant pilot plant volumes available were insignificant compared to the Falmouth treatment plant flow. Chemical oxidation by ozone was not undertaken because no ozone generator was available. Spray irrigation/ land disposal was not pursued because of the complexity in monitoring the performance of such systems.

Several alternatives were investigated at the laboratory/pilot plant level: activated carbon adsorption, chemical oxidation with chlorine, and intermittent sand filtration. The following subsections summarize the results of these investigations.

ACTIVATED CARBON ADSORPTION

In an attempt to achieve supplemental pollutant removal from aqueous fractions, several activated carbon adsorption studies were conducted in the laboratory.

The first study was run on filtered supernatant from the acid/lime addition process which had been neutrailized to a pH of 7 with sulfuric acid. Powdered activated carbon and a contact time of 24 hours was used in this study. The results are presented in Table 28.

TABLE 28. ACTIVATED CARBON ADSORPTION OF ACID/LIME SUPERNATANT

Activated Carbon Dose, mg/l	TOC, mg/l
0	930
600	920
800	900
2,000	850
20,000	830

Because of the very low levels of organic carbon adsorbed per gram of activated carbon added, further studies were discontinued.

A similar study using neutralized filtered supernatant from the alum addition conditioning process was undertaken. The results are presented in Table 29.

TABLE 29. ACTIVATED CARBON ADSORPTION OF ALUM SUPERNATANT

Activated Carbon Dose, mg/l	TOC, mg/l
0	730
1,000	720
2,000	660
5,000	620
50,000	520

Once again, calculations yielded extremely low adsorption values and thus further investigative efforts were discontinued.

CHLORINE OXIDATION

As previously noted, one of the pollutants remaining in the aqueous fraction following coagulation was ammonia. In the case of the supernatant from the acid addition process, the pH was in the vicinity of 2 and thus presented a case for destruction of ammonia via acidic chlorination.

A series of laboratory studies was undertaken to define the chlorine dose required for ammonia destruction. Table 30 presents typical results of these ammonia destruction studies using sodium hypochlorite.

TABLE 30. SODIUM HYPOCHLORITE DESTRUCTION OF AMMONIA

NaOCl Dose, mg/l	Residual Ammonia, mg/l as N
0	90
2,500	51
5,000	5.8
7,500	<0.2
10,000	<0.2

The data indicate that ammonia, as measured by a specific ion probe, is readily destroyed by the addition of sodium hypochlorite under acidic conditions. However, the required sodium hypochlorite dose was relatively high. In the example cited above, the requirement approximated 6.59 kg/m^3 (55 lb/1,000 gal).

INTERMITTENT SAND FILTRATION

In cold climates, the pumping of septic tanks is usually a seasonal activity, with most tanks being pumped in either the spring, summer or early fall. In addition, most haulers do not pump seven days a week during this period. This makes consistent treatment of the aqueous fraction of septage difficult if a biological process is to be employed at a facility designed exclusively for the treatment of septage.

One biological treatment process held potential for application under such potentially erratic organic loading conditions. This process is intermittent sand filtration. A 30.5 cm (12 in) diameter intermittent sand filter column was constructed and filled with 91.4 cm (3.0 ft) of sand. Characteristics of the sand included a uniformity coefficient of 1.85 and an effective size of 0.54 mm.

To establish a biopopulation in the columns, 18.9 l (5.0 gal)of unchlorinated secondary effluent from the Falmouth treatment plant was passed through the columns. Following this innoculation, the columns were dosed at a rate of 1,400 m^3/ha (150,000 gal/acre) approximately every other day. Feed to the columns was supernatant from the acid/lime addition process which had been neutralized to a pH in the range of 6 to 8. The results of intermittent sand filtration studies are presented in Table 31.

Average BOD_5 loading to the intermittent sand filter was 650 kg/ha (580 lb/acre) per loading cycle. At this loading, a 53 percent BOD_5 removal was achieved. Of interest is the high level of ammonia destruction achieved by the process, averaging 76 percent removal.

The effluent quality from the intermittent sand filtration process, though not truly acceptable for direct discharge, was of relatively high quality. It is felt that an effluent suitable for direct discharge could be realized if the organic loading to such a system were decreased. This should be confirmed by supplemental testing.

TABLE 31. INTERMITTENT SAND FILTRATION TREATMENT OF NEUTRALIZED ACID/LIME SUPERNATANT

Day	pH, S.U. Inf	pH, S.U. Eff	Total BOD_5, mg/l Inf	Total BOD_5, mg/l EFF	TSS, mg/l Inf	TSS, mg/l Eff	NH_3-N, mg/l as N Inf	NH_3-N, mg/l as N Eff
1	7.0	7.0	400	230	56	70	100	15
3	7.0	7.4	400	370	56	34	100	39
5	7.2	7.5	950	420	7	33	100	46
7	6.8	7.0	720	360	9	18	76	24
10	6.4	7.4	840	470	10	31	82	31
13	7.2	6.8	630	330	20	26	86	27
18	6.2	7.0	390	180	61	30	72	34
20	5.0	7.0	510	180	66	38	28	1
22	6.8	7.6	310	140	103	45	48	10
28	6.5	7.3	300	140	18	21	52	3
32	11.4	7.9	390	90	25	46	48	2
34	6.5	7.5	460	140	41	22	50	2
37	5.7	7.5	480	230	53	21	64	2
39	6.3	7.2	690	330	28	23	73	12
44	6.4	7.4	135	115	84	30	62	13
46	6.8	7.3	375	160	38	40	74	13
48	5.1	7.3	465	230	31	32	64	9
51	6.9	7.3	420	170	72	24	99	16
53	5.3	7.0	270	130	65	19	88	19
58	5.2	7.4	180	30	58	20	66	18
AVG.	6.6	7.3	465	220	45	31	72	17

SECTION 9

SEPTAGE ADDITION TO MUNICIPAL WASTEWATER TREATMENT PLANT

Each of the two treatment trains at the Falmouth water pollution control facility is composed of a 246 m^3 (65,000 gal) contact zone, a 108 m^2 (1,160 ft^2) secondary clarifier, a 625 m^3 (165,000 gal) reaeration zone, and a 246 m^3 (65,000 gal) aerobic digester. At the design flow of 5,690 m^3/day (1.5 mgd), each treatment train should have a BOD_5 loading of approximately 590 kg/day (1,300 lb/day). Currently, the dry weather flow to each treatment unit approximates 569-758 m^3/day (0.15-0.20 mgd), the BOD_5 loading, 79.5 kg/day (175 lb/day), and the TSS loading 56.8 kg/day (125 lb/day).

For a one-week period, 5.69 m^3/day (1,500 gpd) of raw screened septage was introduced into the contact zone of one of the treatment trains. The average characteristics of the septage are presented in Table 32.

TABLE 32. SEPTAGE INTRODUCED INTO CONTACT ZONE

Parameter	Concentration
Volume	5.69 m^3/d
	1,500 gpd
TSS	3,965 mg/1
VSS	3,285 mg/1
BOD_5 (total)	2,657 mg/1
BOD_5 (soluble)	547 mg/1
pH	6.5 S.U.
NH_3-N, as N	65 mg/1

The above septage was introduced to treatment train number 1 and treatment train number 2 acted as a control. The respective loading on the units is presented in Table 33.

TABLE 33. LOADINGS DURING SEPTAGE ADDITION TO CONTACT ZONE

Parameter	Unit 1		Unit 2	
	kg/day	lb/day	kg/day	lb/day
TSS	79.5	175	56.8	125
VSS	57.2	126	38.6	85
BOD_5 (total)	99.0	218	79.5	175
BOD_5 (soluble)	39.5	87	36.3	80

The impact of the septage loading on the effluent from the contact zone is presented in Table 34.

TABLE 34. CONTACT ZONE OPERATIONAL PARAMETERS DURING SEPTAGE ADDITION

Parameter	Unit 1	Unit 2
pH, S.U.	6.2	6.3
TSS, mg/l	4,754	3,757
VSS, mg/l	3,700	2,763
O_2-Uptake Rate, mg/l/hr	16.7	16.0

Secondary clarifier effluent quality during this same period is presented in Table 35. These data are derived from 24-hour composite sample analyses.

TABLE 35. SECONDARY CLARIFIER EFFLUENT QUALITY DURING SEPTAGE ADDITION TO THE CONTACT ZONE

Parameter	Unit 1	Unit 2
pH, S.U.	6.9	6.9
TSS, mg/l	8	11
BOD_5 (total), mg/l	7	8
NH_3-N, mg/l as N	4	3
TOC (soluble), mg/l	12	7

The above data indicated that the impact of 5.69 m^3/day (1,500 gpd) of screened septage had a negligible effect on final effluent quality. It was visually noted, however, that more grease had accumulated in the treatment unit receiving septage. Supplemental data are presented in the Appendix.

Similarly, 5.69 m^3/day (1,500 gpd) of raw screened septage was introduced to the reaeration zone of treatment unit number one for a one-week period. The supplemental loadings to unit number 1 during this period are presented in Table 36.

TABLE 36. SEPTAGE INTRODUCED INTO REAERATION ZONE

Parameter	Quantity	
Volume	5.69 m^3/day	(1,500 gpd)
TSS	18.6 kg/day	(41 lb/day)
VSS	15.0 kg/day	(33 lb/day)
BOD_5 (total)	15.9 kg/day	(35 lb/day)
BOD_5 (soluble)	2.3 kg/day	(5 lb/day)
pH	6.7 S.U.	
NH_3-N, as N	0.3 kg/day	(0.7 lb/day)

The impact of this loading was measured at the mid-point of the reaeration zone and these data are presented in Table 37.

TABLE 37. REAERATION ZONE OPERATIONAL PARAMETERS DURING SEPTAGE ADDITION

Parameter	Unit 1	Unit 2
pH, S.U.	6.5	6.4
TSS, mg/l	4,566	3,964
VSS, mg/l	3,256	2,732
O_2-Uptake Rate, mg/l/hr	12.4	10.6

Secondary clarifier effluent quality during this same period is presented in Table 38. These data are derived from 24-hour composite sample analyses.

TABLE 38. SECONDARY CLARIFIER EFFLUENT QUALITY DURING SEPTAGE ADDITION TO THE REARATION ZONE

Parameter	Unit 1	Unit 2
pH, S.U.	7.1	6.9
TSS, mg/l	33	20
BOD_5 (total), mg/l	11	5
NH_3-N, mg/l as N	2.6	2.8
TOC (soluble), mg/l	13	9

The above data indicate that the addition of 5.69 m^3/day (1,500 gpd) of screened septage had a slight effect on final effluent quality. However, during this study there was a break in the wastewater collection system which allowed measurable quantities of sea water infiltration to occur. Thus, the actual cause of the decrease in final effluent quality could not be totally attributed to the addition of screened septage to the reaeration zone of the treatment plant. It was visually noted, once again, that more grease had accumulated in the unit receiving septage than in the control unit. Supplemental data are presented in the Appendix.

In summary, the addition of septage to the Falmouth treatment plant resulted in minor changes in final effluent quality. This was felt to be mainly because the BOD_5 and TSS loadings to the plant were approximately 20 percent of design capacity. Operational control measurements such as oxygen uptake rate and sludge volume index increased slightly. Of concern was the noticeable increase in MLSS which eventually end up as waste secondary sludge solids which must be dewatered.

SECTION 10

DISCUSSION OF PILOT PLANT RESULTS

The previous sections of this report presented summaries of the results from the pilot plant studies. The purpose of this section is to provide an interpretation of the data and the application of various unit processes to either: (1) utilization of local municipal wastewater treatment facilities as a receiver for septage, or (2) the construction of facilities exclusively for the treatment of this material.

SCREENING

Septage, as pumped from septic tanks, varies dramatically in physical and chemical character. In addition, it contains a substantial quantity of readily screenable material which, if not removed, can lead to the plugging of piping and valving as well as impaired pump operation. It was found that screening raw septage through a 40-mesh (0.42 mm opening) vibrating screen at a rate of 244-293 l (5-6 gpm/ft^2) yielded effective removal of this undesirable material and resulted in screenings in the vicinity of 25 to 50 percent solids. It is recommended that any facility receiving septage install a preliminary screening system.

Even following preliminary screening, the characteristics of septage were noted to vary markedly from load to load. Independent of the subsequent septage treatment process to be employed, an equalization tank equal in volume to the anticipated maximum day treatment requirements should be installed. This volume should afford a more consistent quantitative and qualitative character to any subsequent treatment processes. The pilot plant studies indicated that air diffusion at a rate of 20 m^3/min/1,000 m^3 (20 cfm/1,000 ft^3) ensured adequate mixing to obtain homogenity of the tank contents. Equivalent mixing should be installed in any screened septage storage/equalization facility.

CONDITIONING

Screened raw septage has associated with it a relatively high percentage of very fine/colloidal suspended organic and inorganic solids. Effective treatment of septage can be realized only if these solids can be consistently captured.

It should be emphatically noted that chemical coagulation of raw unscreened septage yielded poor results. Consistent, positive results could be achieved only if the raw septage was first subjected to the above described screening operation.

Chemical conditioning of raw screened septage is possible with a number of chemicals including ferric chloride, lime, alum, acid and combinations of the above. Utilization of ferric chloride, lime, and/or alum necessitated the conduct of extensive jar testing to optimize chemical dose requirements. On the other hand, utilization of the acid/lime conditioning process required only that: (1) the pH of the raw screened septage be adjusted to and maintained at approximately 2 with sulfuric acid; (2) batch settling occur for six to eight hours or longer, if desired; (3) the sludge fraction be separated from the supernatant fraction; (4) the pH of the supernatant fraction be adjusted to approximately 11 with lime; and (5) gravity settling occur for an additional two hours. The acid and lime produced sludges could then be combined and subjected to further treatment as could the high quality supernatant.

Chemical requirements and associated costs for the various conditioning alternatives investigated are summarized in Table 39.

TABLE 39. ESTIMATED CHEMICAL COSTS FOR CONDITIONING

	Chemical				
		Dose		Cost	
Alternate	Used	kg/m^3	$lb/10^3$ gal	$\$/m^3$	$\$/10^3$ gal
A	$FeCl_3$	0.50	4.2	0.06	0.23
B	$FeCl_3$+	0.40	3.3	0.21	0.78
	$Ca(OH)_2$	4.00	33.4		
C	$Al_2(SO_4)_3 \cdot 14H_2O$	9.12	76.1	1.39	5.25
D	H_2SO_4+	3.58	29.9	0.33	1.26
	$Ca(OH)_2$	2.99	25.0		

The ferric chloride alternate is the least expensive based on chemical costs listed in the January 30, 1978 issue of the Chemical Marketing Reporter. However, the acid/lime conditioning achieves consistent results and therefore should be highly considered.

Settling column tests on all of the above alternates indicated effective separation in six to eight hours. Consideration was given to utilizing continuous flow equipment. Average flow rates at such a facility would, in all probability, be less than 37.9 l/min (10 gpm). The commercial availability of such continuous flow equipment was felt to discourage this approach. The above, coupled with the inconsistent delivery rates of septage to a treatment facility, encourages the utilization of batch sedimentation in the selected conditioning process to be employed.

DEWATERING

The dewatering of septage solids to a consistency of at least 15 percent can be accomplished by a number of processes. However, essentially all processes require conditioning of the raw screened septage prior to the actual dewatering process to be employed.

Sand drying beds proved to be practical for dewatering sludges from the various conditioning processes. Using the multiple application technique for dewatering sludge from the acid/lime pretreatment process, sand drying bed area requirements would approximate 3.6-4.9 m^2/m^3 (15-20 ft^2/1,000 gal) of raw screened septage processed. This technique holds substantial promise for application.

Centrifugation of septage sludge solids, alone or mixed with aerobically digested secondary sludge led to acceptable cake solids consistencies but poor solids capture. With a more advantageous point of polymer application than that available on the pilot scale solid bowl centrifuge, enhanced solids capture would, in all probability, be achieved. However, centrifugation, as undertaken in the pilot plant studies, should not be considered as a method for dewatering septage solids.

The use of a filter press for dewatering septage sludge solids derived from the various conditioning processes, either alone or admixed with aerobically digested secondary sludge, yielded excellent filtrate clarity as well as high cake solids consistencies. To dewater 3.79 m^3 (1,000 gal) of pretreated raw screened septage, it has been estimated that the chamber volume of a filter press should approximate 0.113 m^3 (4.0 ft^3). Filter presses as small as this are commercially available and thus this dewatering process is a viable alternative.

The vacuum filter dewatering of septage solids yielded good solids capture and cake solids consistencies. However, achieving consistent release of the cake from the filter cloth was difficult and the filter yield was consistently low, usually in the range of 0.18-0.36 $kg/m^2/hr$ (0.4-0.8 $lb/ft^2/hr$). The dewatering of mixed septage/aerobically digested secondary sludges by vacuum filtration yielded comparably poor cake release and filter yield. In addition, extensive efforts were required to define the levels of supplemental conditioning agents required for these mixtures to obtain optimum results. As a result of the above, utilization of vacuum filters for dewatering screened septage solids should be carefully scrutinized.

ADDITION TO MUNICIPAL WASTEWATER TREATMENT PLANT

Because of the current municipally derived influent loadings at the Falmouth water pollution control facility, the impact of septage addition on the plant's performance could not be realistically assessed. The only truely apparent impact was a substantial increase in the MLSS and MLVSS concentrations during the period of screened septage addition.

Raw screened septage, based on a volume of 3.79 m^3 (1,000 gal), has an average BOD_5 population equivalent of 240 and an average TSS population equivalent of 360. General knowledge of secondary treatment plant operations indicates that random increases in influent organic loadings of up to about 50 percent (above normally anticipated variations) may be absorbed by treatment plants before effluent quality deterioration becomes readily discernable. On this basis, not more than 3.79 m^3 (1,000 gal) of raw screened septage should be randomly introduced on any given 24-hour day to secondary facilities with influent flows of less than 5.68-974 m^3/day (0.15-0.25 mgd) if they are operating at design capacity. If a given secondary facility of this size is operating at less than design capacity, facilities should be installed to introduce raw screened septage at a low, controlled rate.

The introduction of raw screened septage to a secondary treatment facility at a controlled rate leads to, among others, BOD_5 and ammonia nitrogen removal. Research by others has shown that approximately 40 percent of the TSS in septage are degradable by aerobic bio-oxidation (5). On this basis, net accumulation of MLSS could amount to at least 4.78-5.37 kg/day/m^3 (40-45 lb/day/1,000 gal) of raw screened septage introduced to a secondary treatment plant. At a concentration of 1.0 percent TSS, this would amount to a minimum supplemental secondary sludge wasting and dewatering volume of approximately 0.5 m^3/m^3 (0.5 gal/gal) of septage treated by this technique. This is in contrast to a sludge volume resulting from, for example, the acid/lime conditioning process of about 0.3 m^3/m^3 (0.3 gal/gal) of septage treated by this technique.

AQUEOUS FRACTION TREATMENT

The aqueous fraction evolving from conditioning and/or dewatering processes contains mainly BOD_5 and ammonia nitrogen and minor levels of TSS as pollutants. This wastewater, though more concentrated in BOD_5 and ammonia than domestic wastewater, is ammenable to biological treatment. If septage is being treated at a municipal wastewater treatment facility, the aqueous fraction could be metered into the treatment plant influent since each 3.79 m^3 (1,000 gal) of this liquid contains roughly only 2.27 kg (5 lb) BOD_5, 0.23 kg (0.5 lb) TSS, and 0.23 kg (0.5 lb) NH_3-N. At a remote facility constructed exclusively for the treatment of septage, a viable aqueous fraction treatment process could be intermittent sand filtration. Because of the waste's strength, organic loading would be the controlling parameter. Previous work by others (6) in the area of intermittent sand filtration has indicated that if the BOD_5 loading is kept to less than 168 kg/ha (150 lb/acre), approximately 90 percent BOD_5 removal can be consistently achieved. To treat 3.79 m^3/day (1,000 gpd) of aqueous fraction by this technique would thus require an intermittent sand filter approximately 204 m^2 (2,200 ft^2) in area.

SOLIDS FRACTION DISPOSAL

One of the practices to be considered for the ultimate disposal of dewatered septage solids is burial in a soil mantle. Pilot scale studies were set up to evaluate soil retention capabilities under extreme conditions. These conditions included the utilization of an acidic sludge as well as an average rainfall intensity of 2.54 cm/day (1.0 in/day). Under these conditions, it was shown that soil type influenced leachate quality.

If septage solids disposal is to be by burial, the dewatered sludge should have an alkaline pH to optimize insoluble metallic matrix formations, water flow through the soil/sludge mass should be minimized, and a soil mantle with desired retention capabilities utilized.

SECTION 11

SYSTEM DESIGN

The incorporation of the pilot scale results presented in this report can lead to numerous approaches to the treatment of septage, either at a municipal wastewater treatment plant or at facilities designed exclusively for the treatment of septage. Four of these possible alternatives are presented in the following subsections; two are capable of treating 9.48 m^3/day (2,500 gpd) and the other two, 37.9 m^3/day (10,000 gpd). One of each size is designed for the exclusive treatment of septage; the other two are for the treatment of this material at municipal wastewater treatment plants.

The four alternatives presented do not necessarily reflect optimum combinations of the substantial number of unit operations and processes that may be employed. Rather, they reflect possible combinations that were shown to yield positive results during the conduct of the pilot plant studies. In the actual design of a treatment facility, supplemental testing should be undertaken to confirm the application of the specific methodologies selected.

Each of the four facilities has been set up to operate in the batch treatment mode. The main reasons for taking this approach are: (1) the continuous delivery of finite quantities of septage to a given facility cannot necessarily be guaranteed, and (2) continuous flow equipment capable of operating in the range of 7.6 to 26.5 l/min (2 to 7 gpm) are not readily available.

The installed costs of the systems presented in this section were established as follows:

1. Purchase prices on all equipment and materials were obtained from various suppliers and an 18 percent contractor mark-up added to cover shipping charges and taxes (5 percent), electrical wiring (3 percent) and profit (10 percent).

2. Installation costs were developed from the 1978-1979 Edition of the Richardson Process Plant Construction Estimating Standards.

3. A 15 percent contingency was added to the sum of 1 and 2, above, to obtain the total installed cost.

Total installed cost was then amortized over ten years using an interest rate of 7.0 percent.

Maintenance costs were assumed to be one percent of the total installed cost of the facility per year. Chemical costs were obtained from the January 30, 1978 issue of the Chemical Marketing Reporter. Electrical costs were based on a rate of \$0.03/kwh and water on a rate of \$0.17/m^3 (\$0.47/100 cu ft). The labor rate was based on a total cost of \$15,000/year per person or \$7.21/hr and included salary and fringe benefits. The cost for hawling and ultimate disposal of the dewatered septage solids have not been included in any of the four alternates.

ALTERNATE 1: 9.48 M^3/DAY (2,500 GPD) FACILITY EXCLUSIVELY DESIGNED FOR SEPTAGE TREATMENT

A series of processes have been selected for a facility exclusively designed for the treatment of 9.48 m^3/day (2,500 gpd) of septage. The processes involve: (1) the screening and equalization of the raw septage, (2) the application of the acid/lime addition process, (3) aqueous fraction treatment by intermittent sand filtration, and (4) sludge dewatering by sand drying beds. Figure 3 presents a schematic of this system as well as the associated flow, BOD_5, and TSS balances based on the average performances of each operation noted in this study. Calculated intermittent sand filter effluent quality indicates less than 50 mg/l of both BOD_5 and TSS. Dewatered sludge after three days of drainage, is estimated to be approximately 30 percent solids and to occupy a volume of 0.035 m^3/m^3 (4.65 cu ft/1,000 gal.) treated.

A list of the required equipment and installed cost estimates is given in Table 40. Estimated total installed cost is \$88,275.

Table 41 gives a tentative scheduling of events at the 9.48 m^3 (2,500 gal.) capacity septage facility. It has been estimated that approximately five person-hours would be required to process 9.48 m^3 (2,500 gal.) of raw septage and perform required maintenance duties at this facility.

Assuming a maximum of 47.4 m^3 (12,500 gal.) of raw septage is processed per week and facility life is ten years, estimated minimum treatment costs have been calculated and are presented in Table 42.

TABLE 42. ALTERNATE 1 CAPITAL AND OPERATING COSTS

Category	Cost $/m^3	Cost $/1,000 Gal.
Amortization of Capital	5.10	19.34
Maintenance	0.36	1.36
Chemicals	0.41	1.57

(Continued)

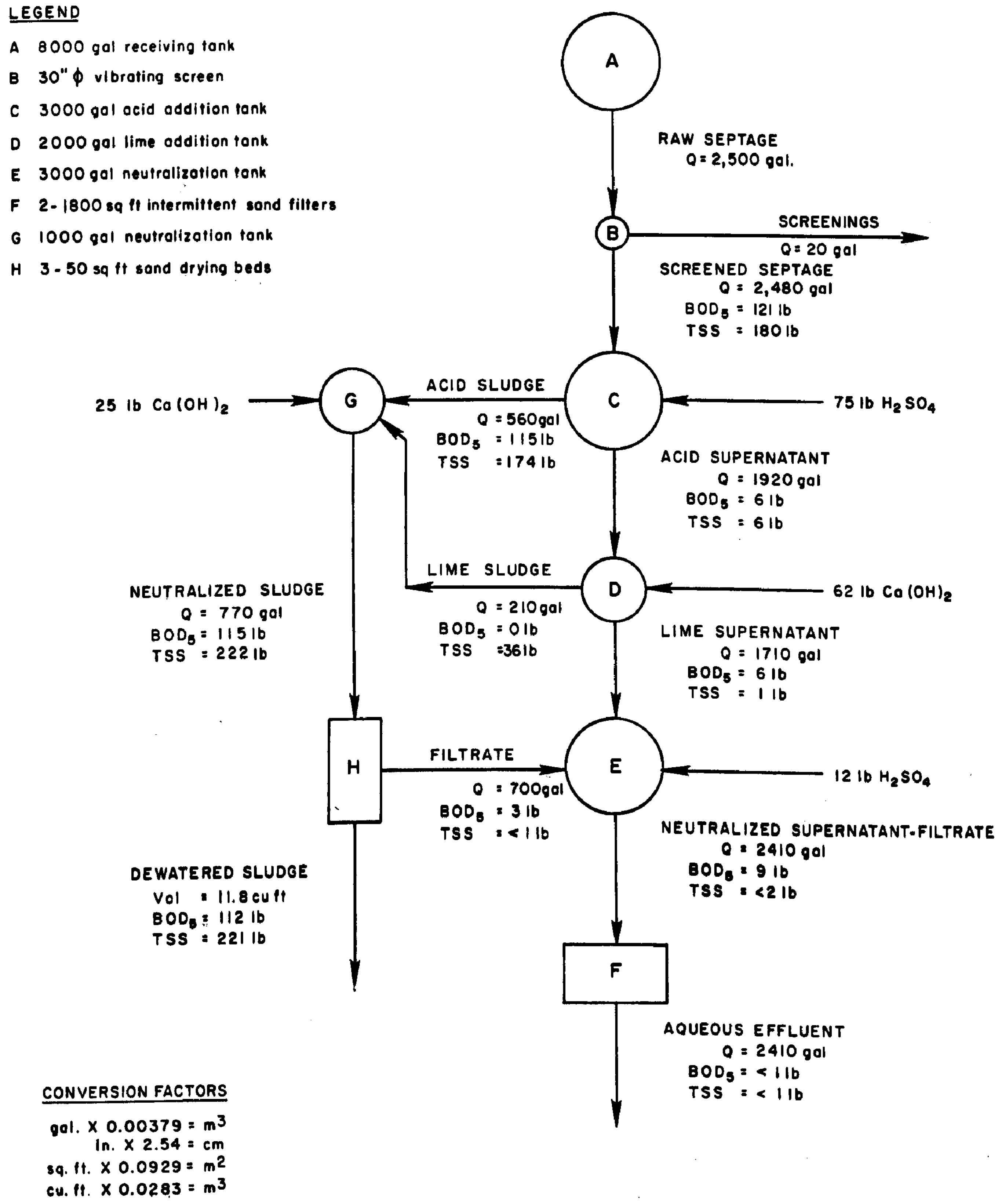


FIGURE 3. ALTERNATE I SYSTEM SCHEMATIC

TABLE 40. ALTERNATE 1 EQUIPMENT LIST

Component		Installed Cost, $
3.03 m^3 (8,000 gal) raw septage receiving tank*		$ 6,500
11.4 m^3 (3,000 gal) acid addition tank		3,385
7.6 m^3 (2,000 gal) lime addition tank		2,845
11.4 m^3 (3,000 gal) supernatant/filtrate neutralization tank*		2,950
3.8 m^3 (1,000 gal) sludge neutralization tank*		950
0.76 m (30 in) diameter 40-mesh vibrating screen		5,080
95-190 l/min (25-50 gpm) positive displacement sludge transfer pump		4,000
95 l/min (25 gpm) supernatant/filtrate transfer pump		215
0.28 m^3/min (10 cfm) air blower for mixing		860
0.57 m^3 (150 gal) sulfuric acid storage tank		910
3.8 l/min (1 gpm) sulfuric acid metering pump		1,730
0.76 m^3 (200 gal) lime slurry tank		755
57 l/min (15 gpm) lime slurry pump		170
Two 167 m^2 (1,800 ft^2) intermittent sand filters		22,000
Three 4.6 m^2 (50 ft^2) sand drying beds		2,000
Sand drying bed covers		340
5.6 m^2 (600 ft^2) building for housing equipment		12,600
Piping and valving		2,970
Pickup truck		5,000
Electrical		1,500
	Subtotal	$76,760
Contingency (15 percent)		11,515
	Total	$88,275

*Installed below grade

TABLE 41. ALTERNATE 1 ACTIVITY SCHEDULE

Time	Activity
6:45 - 8:00*	Transfer lime supernatant to supernatant filtrate tank using centrifugal pump
8:00 - 8:15	Drain lime sludge to sludge neutralization tank
8:15 - 9:30	Transfer acid supernatant to lime addition tank using centrifugal pump
8:30 - 9:30	Clean one sand drying bed
9:30 - 9:45	Drain acid sludge to sludge neutralization tank and make up lime slurry
9:45 - 10:45	Screen 2,500 gal of raw septage using positive displacement pump and place in acid addition tank
10:00 - 10:15	Adjust pH of supernatant-filtrate to 6.5 to 8.5
10:15 - 10:30	Adjust pH of acid supernatant to 11.0±
10:30 - 10:45	Adjust pH of combined acid and lime sludges to 9 to 10
10:45 - 11:00	Adjust pH of screened septage to 2.0±
11:00 - 12:30**	Transfer neutralized supernatant-filtrate to intermittent sand filter using centrifugal pump
11:15 - 11:45	Transfer neutralized sludge to sand drying bed using positive displacement pump
11:30 - 12:30	Perform required maintenance and/or dewatered solids and screenings disposal

*Initiated with automatic timer.

**Automatic shutoff.

TABLE 42. (Continued)

Category	Cost $/m^3$	Cost $/1,000 Gal.
Electricity and Water	0.05	0.18
Labor	3.81	14.42
Total	$9.73	$36.87

ALTERNATE 2: TREATMENT OF 9.48 M^3/DAY (2,500 GPD) OF SEPTAGE AT A MUNICIPAL WASTEWATER FACILITY

A series of processes have been selected for the treatment of 9.48 m^3/day (2,500 gpd) of septage at a municipal wastewater treatment facility. The processes involve: (1) screening, pH adjustment and equalization of the raw septage, (2) aerobic digestion of the neutralized material with the treatment plant's waste secondary sludge, and (3) dewatering of the mixed aerobically digested sludge utilizing the treatment plant's existing equipment. Figure 4 presents a schematic of this system as well as the associated flow, BOD_5 and TSS balances.

Aerobic digestion of septage for ten days has been noted to yield a 20 percent reduction in TSS (6). Based on this factor and the average characteristics of raw screened septage, supplemental aerobic digestion volumetric capacity of approximately 114 m^3 (30,000 gal.) should be installed if the treatment plant is at or near design capacity. As a result, approximately 66 kg (145 lb) of TSS must be dewatered per 9.48 m^3 (2,500 gal.) of raw septage processed. It has been calculated that the treatment of 9.48 m^3/day (2,500 gpd) of septage at a 948 m^3/day (250,000 gpd) municipal treatment plant, using the above outlined process, could result in increased dewatering requirements of 30 to 40 percent including chemicals, labor, electric power, and dewatering equipment running time.

The pilot plant studies indicated that the utilization of centrifugation or vacuum filtration equipment for dewatering should be carefully scrutinized. However, it must be recalled that centrifuge performance was limited because of the point of application of the appropriate polymer. Similarly, only one cloth was available for use on the cloth belt vacuum filter and this particular media may have led to the marginal results reported.

A list of the required equipment and installed cost estimates is given in Table 43. Estimated total installed cost is $61,075. If adequate aerobic digester capacity exists at the treatment plant, the total installed cost of appropriate equipment would approximate $30,000.

LEGEND

A 8000 gal receiving tank

B 30" ϕ vibrating screen

C 3000 gal neutralization tank

D Expanded municipal aerobic digester (30,000 gal)

E Existing municipal dewatering equipment

CONVERSION FACTORS

gal. X 0.00379 = m^3

in. X 2.54 = cm

sq. ft. X 0.0929 = m^2

cu. ft. X 0.0283 = m^3

NOTE:

36 lb TSS destroyed by the aerobic digestion process

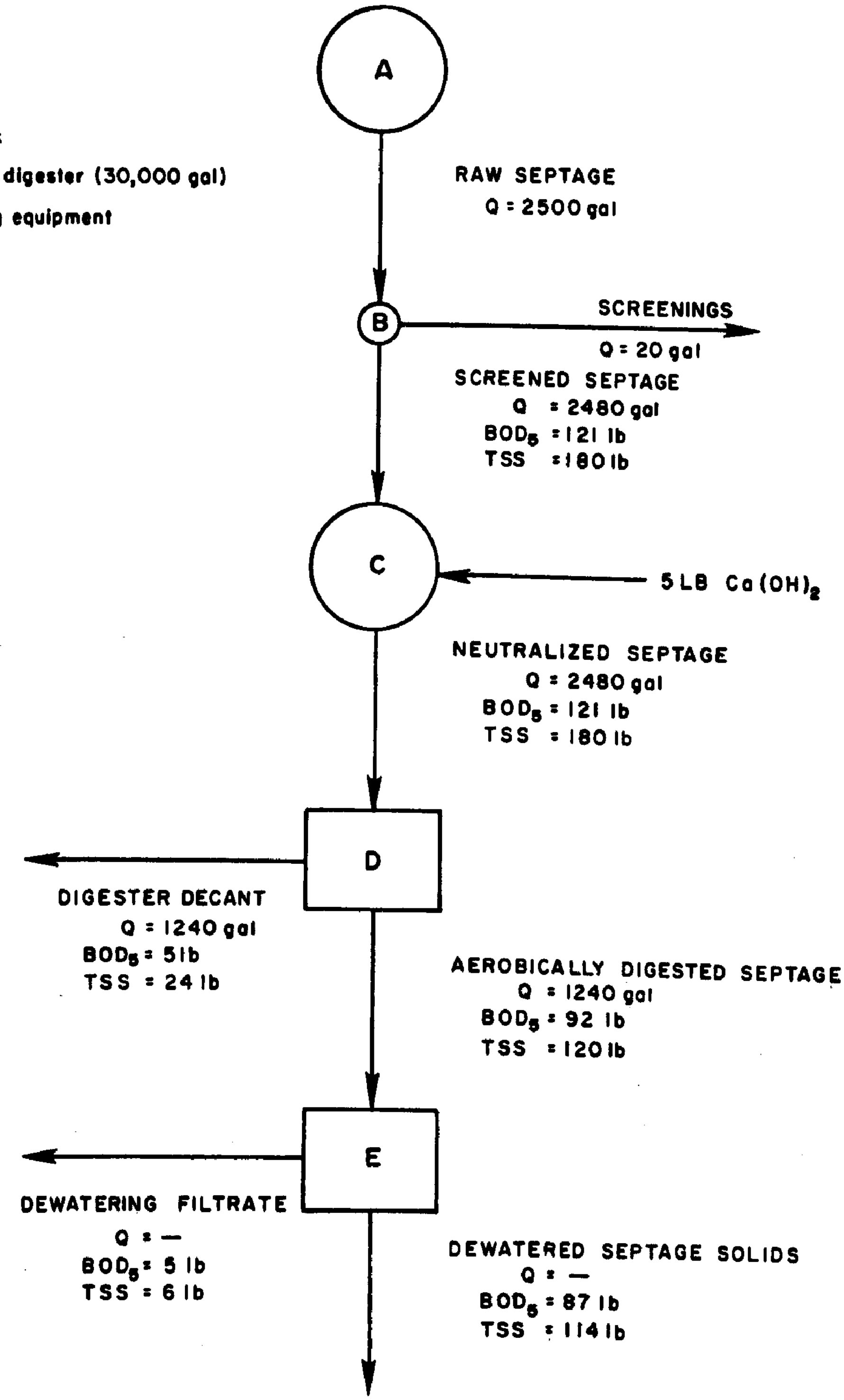


FIGURE 4. ALTERNATE 2 SYSTEM SCHEMATIC

TABLE 43. ALTERNATE 2 EQUIPMENT LIST

Component		Installed Cost, $
30.3 m^3 (8,000 gal) raw septage receiving tank*		$ 6,500
11.4 m^3 (3,000 gal) screened septage neutralization tank*		3,000
0.76 m (30 in) diameter 40-mesh vibrating screen		5,080
19-190 l/min (5-50 gpm) positive displacement sludge transfer pump		4,000
0.76 m^3 (200 gal) lime slurry tank		755
57 l/min (15 gpm) lime slurry pump		170
3.4 m^3/min (120 cfm) air blower		1,200
114 m^3 (30,000 gal) aerobic digester		19,000
Piping and valving		6,305
27 m^2 (270 ft^2) building for housing equipment		6,090
Electrical		1,010
	Subtotal	$53,110
Contingency (15 percent)		7,965
	Total	$61,075

*Installed below grade

Approximately one and one-half person-hours would be required to screen and neutralize the raw septage, and maintain the equipment for each 9.48 m^3 (2,500 gal.) processed. Time commitments for dewatering would be 30 to 40 percent above that currently being expended at a given municipal facility. A time for septage sludge dewatering has been estimated to be one hour/9.48 m^3 (2,500 gal) of septage processed.

Assuming a maximum of 47.4 m^3 (12,500 gal.) of raw septage is processed per week and facility life is ten years, estimated minimum treatment costs, including those associated with dewatering, are presented in Table 44.

TABLE 44. ALTERNATE 2 CAPITAL AND OPERATING COSTS

Category	Cost $/m³	Cost $/1,000 Gal.
Amortization of Capital	3.53	13.38
Maintenance	0.25	0.94
Chemicals*	0.33	1.24
Electricity and Water	0.36	1.36
Labor	1.90	7.21
Total	$6.37	$24.13

*Includes 5 kg/t (10 lb/ton) of polymer for dewatering on municipal equipment at a cost of $4.41/kg ($2.00/lb)

ALTERNATE 3: 37.9 M^3/DAY (10,000 GPD) FACILITY EXCLUSIVELY DESIGNED FOR SEPTAGE TREATMENT

Processes selected for this alternate include: (1) screening and equalization of the raw septage, (2) acid/lime conditioning process, (3) sludge dewatering by filter press, and (4) aqueous fraction treatment by intermittent sand filtration. Figure 5 presents a schematic of this system as well as flow, BOD_5 and TSS balances based on the average performances of each operation noted in the study.

Essentially, the system is the same as that presented in Alternate 1 except that sludge dewatering is accomplished with a filter press. Dewatered sludge volume has been estimated to be approximately 0.03 m^3/m^3 (4 cu ft/1,000 gal.) of raw septage processed. Two 650 m^2 (7,000 sq ft) intermittent sand filters are required for the aqueous fraction treatment.

A list of the required equipment and installed cost estimates is given in Table 45. Estimated total capital cost is $452,615.

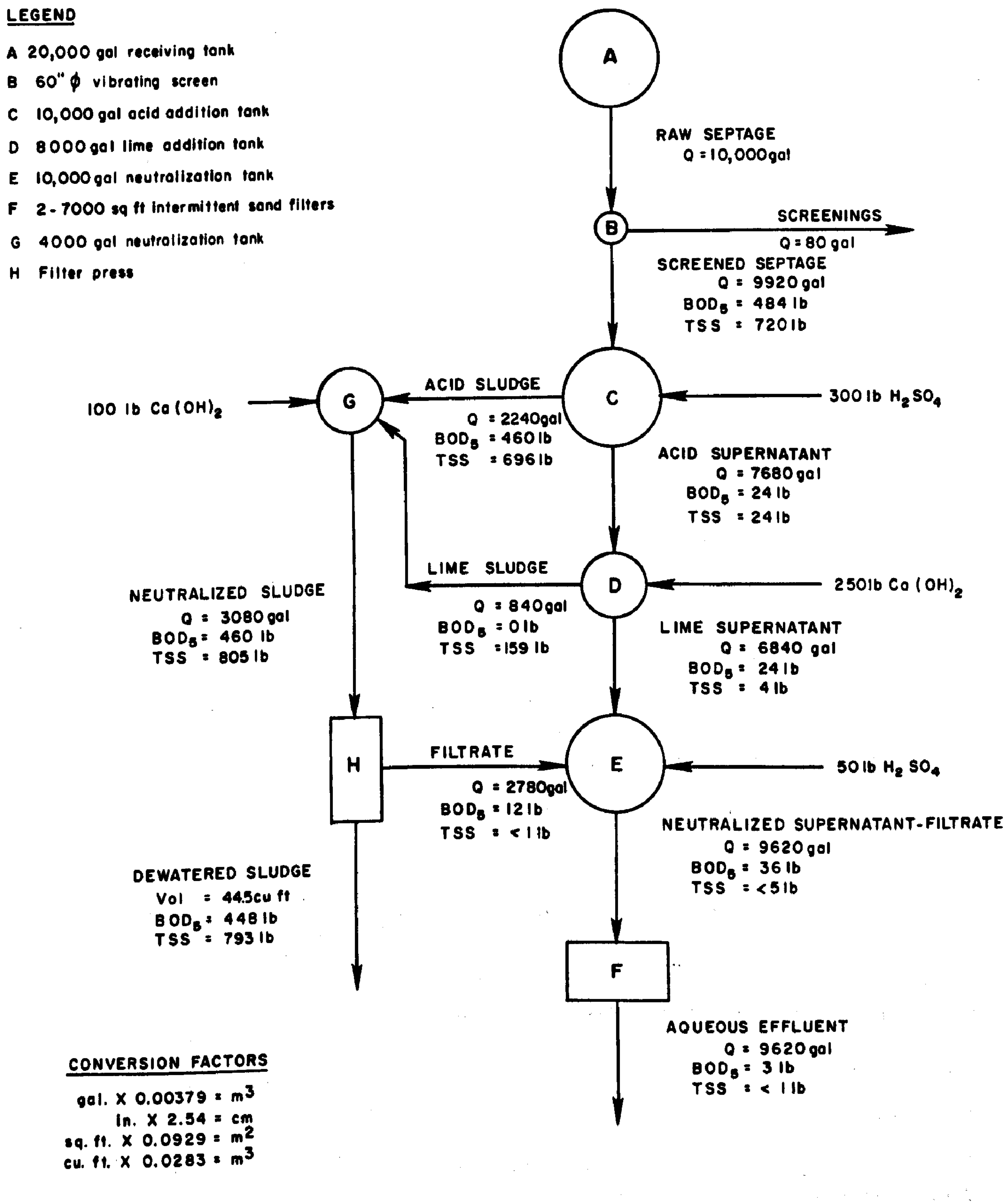


FIGURE 5. ALTERNATE 3 SYSTEM SCHEMATIC

TABLE 45. ALTERNATE 3 EQUIPMENT LIST

Component		Installed Cost, $
76 m^3 (20,000 gal) raw septage receiving tank*		$ 12,000
38 m^3 (10,000 gal) acid addition tank		7,750
30 m^3 (8,000 gal) lime addition tank		6,560
38 m^3 (10,000 gal) supernatant/filtrate neutralization tank*		6,300
15 m^3 (4,000 gal) sludge neutralization tank*		3,825
1.53 m (60 in) diameter 40-mesh vibrating screen		10,000
Two 38-380 l/min (10-100 gpm) positive displacement sludge transfer pump		13,000
Two 380 l/min (100 gpm) supernatant/filtrate transfer pump		1,400
0.17 m^3/min (25 cfm) air blower for mixing		950
1.9 m^3 (500 gal) sulfuric acid storage tank		1,000
3.8 l/min (4 gpm) sulfuric acid metering pump		1,730
1.9 m^3 (500 gal) lime slurry tank		1,000
227 l/min (60 gpm) lime slurry pump		230
Filter press		220,500
Two 650 m^2 (7,000 ft^2) intermittent sand filters		48,000
Piping and valving		4,640
178 m^2 (1,920 ft^2) building for housing equipment		40,320
Pickup truck		5,000
Electrical		9,375
	Subtotal	$393,580
Contingency (15 percent)		59,035
	Total	$452,615

*Installed below grade

Table 46 gives a tentative scheduling of events at this 37.9 m^3 (10,000 gal.) capacity septage facility. It has been estimated that approximately 0.75 person-hours would be required to process 3.79 m^3 (1,000 gal.) of raw septage and perform required maintenance at this facility.

Assuming a maximum of 190 m^3 (50,000 gal.) of raw septage is processed per week and facility life is ten years, minimum estimated treatment costs have been calculated and are presented in Table 47.

TABLE 47. ALTERNATE 3 CAPITAL AND OPERATING COSTS

Category	Cost $/m^3$	Cost $/1,000 Gal.
Amortization of Capital	6.54	24.79
Maintenance	0.46	1.74
Chemicals	0.41	1.57
Electricity and Water	0.18	0.69
Labor	1.43	5.41
Total	$9.02	$34.20

ALTERNATE 4: TREATMENT OF 37.9 M^3/DAY (10,000 GPD) OF SEPTAGE AT A MUNICIPAL WASTEWATER FACILITY

Processes selected for the treatment of 37.9 m^3/day (10,000 gpd) of septage at a municipal wastewater facility include: (1) screening and equalization, (2) ferric chloride and lime conditioning, (3) aqueous fraction treatment by controlled rate addition to the treatment plant influent, and (4) sludge fraction dewatering using the plant's existing equipment. An example of such equipment is a vacuum filter. Figure 6 presents a schematic of this system as well as the associated flow, BOD_5 and TSS balances.

A list of the required equipment and installed cost estimates is presented in Table 48. Estimated total cost is $110,705.

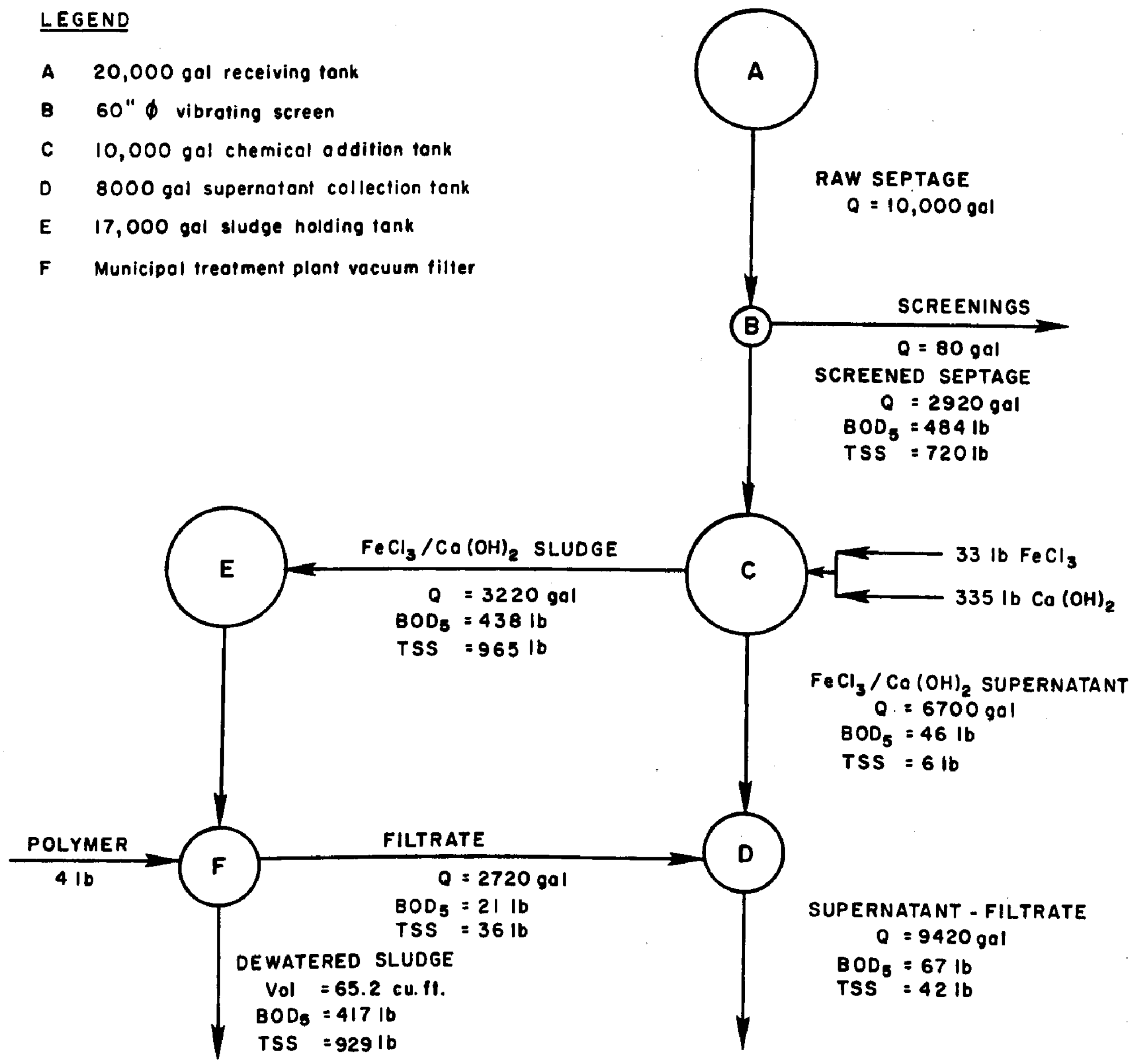
Table 49 gives a tentative scheduling of events at this facility. It has been estimated that approximately 0.75 person-hours would be required to process 3.79 m^3 (1,000 gal.) of raw septage and perform required maintenance at this facility.

Assuming a maximum of 190 m^3 (50,000 gal.) of raw septage is processed per week and facility life is ten years, minimum treatment costs have been calculated and are presented in Table 50.

TABLE 46. ALTERNATE 3 ACTIVITY SCHEDULE

Time	Activity
6:45 - 8:00*	Transfer lime supernatant to supernatant filtrate tank using centrifugal pump
8:00 - 8:15	Drain lime sludge to sludge neutralization tank
8:15 - 9:30	Transfer acid supernatant to lime addition tank using centrifugal pump
9:30 - 9:45	Drain acid sludge to sludge neutralization tank and make up lime slurry
9:45 - 12:15	Screen 10,000 gal of raw septage using positive displacement pump
10:00 - 10:15	Adjust pH of supernatant-filtrate to 6.5 to 8.5
10:15 - 10:30	Adjust pH of acid supernatant to 11.0±
10:30 - 10:45	Adjust pH of sludge to 9 to 10
10:45 - 11:00	Adjust pH of screened septage to 2.0±
11:00 - 1:00	Transfer neutralized supernatant-filtrate to intermittent sand filter using centrifugal pump
1:00 - 3:00	Perform required maintenance and/or dispose of dewatered solids and screenings
7 1/2 hrs/day	Filter press operation

*Initiated with automatic timer.



CONVERSION FACTORS

gal. X 0.00379 = m^3
in. X 2.54 = cm
sq. ft. X 0.0929 = m^2
cu. ft. X 0.0283 = m^3

FIGURE 6. ALTERNATE 4 SYSTEM SCHEMATIC

TABLE 48. ALTERNATE 4 EQUIPMENT LIST

Component		Installed Cost, $
76 m^3 (20,000 gal) raw septage receiving tank*		$ 12,000
38 m^3 (10,000 gal) chemical addition tank		7,750
30 m^3 (8,000 gal) supernatant holding tank*		6,560
64 m^3 (17,000 gal) sludge holding tank*		8,300
1.53 m (60 in) diameter 40-mesh vibrating screen		10,000
Two 38-380 l/min (10-100 gpm) positive displacement sludge transfer pumps		13,000
Two 380 l/min (100 gpm) supernatant transfer pumps		1,400
0.71 m^3/min (25 cfm) air blower for mixing		950
0.57 m^3 (150 gal) ferric chloride storage tank		910
3.8 l/min (1 gpm) ferric chloride metering pump		1,730
1.9 m^3 (500 gal) lime slurry tank		230
227 l/min (60 gpm) lime slurry pump		1,000
Piping and valving		3,990
117 m^2 (1,260 ft^2) building for housing equipment		26,460
Electrical		1,985
	Subtotal	$ 96,265
Contingency (15 percent)		14,440
	Total	$110,705

*Installed below grade

TABLE 49. ALTERNATE 4 ACTIVITY SCHEDULE

Time	Activity
7:00 - 8:30	Transfer $FeCl_3/Ca(OH)_2$ supernatant to supernatant-filtrate tank using centrifugal pump.
7:30 - 8:00	Mix polymer for dewatering
8:30 - 9:30	Transfer $FeCl_3/Ca(OH)_2$ sludge to sludge holding tank using positive displacement pump.
*9:45 - 1:45	Dewater $FeCl_3/Ca(OH)_2$ sludge using municipal treatment plant gravity dewatering device
10:00 - 1:00	Screen 10,000 gal of raw septage using positive displacement pump
10:15 - 11:15	Make up $FeCl_3$ solution and lime slurry
2:00 - 3:00	Clean up dewatering equipment and perform maintenance

*Time required to dewater 929 lbs of sludge (not necessarily done every day).

TABLE 50. ALTERNATE 4 CAPITAL AND OPERATING COSTS

Category	Cost $/m^3$	Cost $/1,000 Gal.
Amortization of Capital	1.60	6.06
Maintenance	0.11	0.43
Chemicals*	0.42	1.59
Electricity and Water	0.06	0.24
Labor	1.43	5.41
Total	$3.62	$13.73

*Includes 5 kg/t (10 lb/ton) of polymer for dewatering on municipal equipment at a cost of $4.41/kg ($2.00/lb).

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APPENDIX

SUPPLEMENTAL PILOT PLANT DATA

TABLE A-1. RAW SCREENED SEPTAGE CHARACTERISTICS

Parameter	Batch 001	002	003	004	005	006
TS, mg/l	3,000	5,560	5,090	2,560	29,700	13,100
TVS, mg/l	2,380	3,670	4,040	1,830	26,400	10,900
TSS, mg/l	2,250	5,060	4,370	2,140	22,600	11,600
VSS, mg/l	1,940	4,440	3,810	1,820	22,200	10,000
pH, S.U.	6.7	6.2	6.0	7.0	5.3	5.9
BOD_5 (total), mg/l	1,360	3,550	2,280	1,380	24,000	4,700
BOD_5 (soluble), mg/l	315	780	700	560	5,450	775
COD, mg/l	3,270	20,500	10,200	4,120	37,000	12,400
NH_3-N, mg/l as N	62	98	75	92	82	44
Organic-N, mg/l as N	71	91	75	108	558	226
PO_4 (total), mg/l as P	50	135	70	25	54	40
PO_4 (ortho), mg/l as P	27	100	20	25	8	28
Alkalinity, mg/l as $CaCO_3$	390	440	320	475	500	910
Fe, mg/l	18	39	35	47	85	57
Ni, mg/l	-	-	-	0.05	0.42	-
Cd, mg/l	0.04	0.06	0.03	<0.02	0.2	-
Cu, mg/l	2.0	3.5	2.4	2.8	30.0	14
Mn, mg/l	0.20	0.52	0.40	0.60	1.4	0.2
Zn, mg/l	3.7	3.4	2.9	3.7	18.0	9.3
Grease and Oil, mg/l	-	-	-	-	-	-

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 007	008	009	010	011	012
TS, mg/l	5,320	9,400	7,900	12,950	14,200	14,200
TVS, mg/l	4,200	7,500	6,300	10,750	11,000	11,000
TSS, mg/l	4,470	9,300	10,700	8,592	13,800	13,800
VSS, mg/l	3,900	7,700	8,900	6,935	11,000	11,000
pH, S.U.	6.0	5.0	4.8	4.8	6.0	6.0
BOD_5 (total), mg/l	3,480	>5,000	>5,000	>5,000	6,600	6,600
BOD_5 (soluble), mg/l	1,140	1,200	1,360	1,440	780	780
COD, mg/l	9,200	14,400	14,100	12,500	18,600	18,600
NH_3-N, mg/l as N	76	70	70	68	69	69
Organic-N, mg/l as N	64	170	258	177	191	191
PO_4 (total), mg/l as P	42.5	42	27	50	54	53.5
PO_4 (ortho), mg/l as P	19	11	21	36	54	53.5
Alkalinity, mg/l as $CaCO_3$	410	430	410	550	340	340
Fe, mg/l	26	120	51	62	-	19.7
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	7.2	16	11.6	12	-	8.6
Mn, mg/l	0.6	1.0	0.6	1.2	-	0.42
Zn, mg/l	4.2	11	7.2	9.2	-	13.2
Grease and Oil, mg/l	-	-	-	-	-	-

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 013	014	015	016	017	018
TS, mg/l	26,400	9,950	27,740	2,720	25,860	5,760
TVS, mg/l	20,010	6,540	15,730	1,920	24,900	4,670
TSS, mg/l	20,190	6,420	18,940	2,510	18,850	5,180
VSS, mg/l	14,970	4,320	11,500	2,090	17,560	4,540
pH, S.U.	9.8	6.1	6.1	7.0	6.3	5.4
BOD_5 (total), mg/l	4,395	50,000	7,500	990	3,900	2,690
BOD_5 (soluble), mg/l	555	4,650	750	390	435	495
COD, mg/l	15,500	132,000	34,900	18,430	28,400	10,600
NH_3-N, mg/l as N	3	73	76	37	80	74
Organic-N, mg/l as N	242	549	454	165	470	316
PO_4 (total), mg/l as P	40.5	60	44	20	60	46
PO_4 (ortho), mg/l as P	22	42	35	20	27	35
Alkalinity, mg/l as $CaCO_3$	370	520	420	110	280	70
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease & Oil, mg/l	-	-	-	-	11,600	1,660

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 019	020	021	022	023	024
TS, mg/l	5,970	3,300	9,240	6,845	4,050	4,050
TVS, mg/l	5,130	2,480	7,190	5,340	3,180	3,180
TSS, mg/l	5,570	2,750	8,870	6,440	3,950	3,920
VSS, mg/l	3,990	2,430	6,870	5,260	3,280	3,280
pH, S.U.	5.4	5.3	6.5	6.6	6.9	6.9
BOD_5 (total), mg/l	10,900	10,000	4,900	2,560	2,380	2,380
BOD_5 (soluble), mg/l	900	780	720	630	1,330	1,830
COD, mg/l	28,500	12,120	28,400	4,525	7,750	7,750
NH_3-N, mg/l as N	74	73	54	37	67	67
Organic-N, mg/l as N	111	112	98	113	113	113
PO_4 (total), mg/l as P	60	66	72	35	30	30
PO_4 (ortho), mg/l as P	35	8	30	28	24	24
Alkalinity, mg/l as $CaCO_3$	250	190	240	212	290	290
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease and Oil, mg/l	7,600	4,350	1,710	1,192	1,140	1,140

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 025	026	027	028	029	030
TS, mg/l	9,850	42,100	17,290	4,680	9,140	-
TVS, mg/l	7,920	32,600	14,315	3,890	8,080	-
TSS, mg/l	5,860	40,200	16,630	3,440	6,300	4,880
VSS, mg/l	4,900	30,700	13,330	3,000	3,975	3,820
pH, S.U.	6.3	6.8	6.6	2.8	7.6	6.3
BOD_5 (total), mg/l	3,030	11,700	8,550	2,175	3,840	3,820
BOD_5 (soluble), mg/l	1,860	1,175	1,200	390	1,200	750
COD, mg/l	9,050	35,100	10,700	4,850	6,700	-
NH_3-N, mg/l as N	71	102	50	26	47	95
Organic-N, mg/l as N	154	253	261	80	120	-
PO_4 (total), mg/l as P	64	130	65	50	18	-
PO_4 (ortho), mg/l as P	35	25	33	14	17	-
Alkalinity, mg/l as $CaCO_3$	300	640	240	0	375	330
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease and Oil, mg/l	208	-	2,350	1,420	1,312	-

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 031	032	033	034	035	036
TS, mg/l	-	-	-	-	-	-
TVS, mg/l	-	-	-	-	-	-
TSS, mg/l	3,150	3,690	4,140	3,810	2,400	2,400
VSS, mg/l	2,480	3,190	3,650	3,270	2,070	2,070
pH, S.U.	5.8	7.2	6.8	7.0	6.7	6.5
BOD_5 (total), mg/l	2,610	1,410	2,430	3,420	2,280	1,740
BOD_5 (soluble), mg/l	500	340	600	500	540	420
COD, mg/l	-	-	-	-	-	-
NH_3-N, mg/l as N	52	51	60	62	52	54
Organic-N, mg/l as N	-	-	-	-	-	-
PO_4 (total), mg/l as P	-	-	-	-	-	-
PO_4 (ortho), mg/l as P	-	-	-	-	-	-
Alkalinity, mg/l as $CaCO_3$	360	280	290	330	285	310
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease and Oil, mg/l	-	-	-	-	-	-

(Continued)

TABLE A-1. (Continued)

Parameter	Batch 037	Batch 038	Batch 039
TS, mg/l	-	-	9,850
TVS, mg/l	-	-	7,920
TSS, mg/l	2,400	3,840	5,860
VSS, mg/l	2,070	2,600	4,900
pH, S.U.	6.5	6.9	6.3
BOD_5 (total), mg/l	4,200	1,035	3,030
BOD_5 (soluble), mg/l	360	400	1,860
COD, mg/l	-	-	9,050
NH_3-N, mg/l as N	54	44	71
Organic-N, mg/l as N	-	-	225
PO_4 (total), mg/l as P	-	-	64
PO_4 (ortho), mg/l as P	-	-	35
Alkalinity, mg/l as $CaCO_3$	310	340	300
Fe, mg/l	-	-	-
Ni, mg/l	-	-	-
Cd, mg/l	-	-	-
Cu, mg/l	-	-	-
Mn, mg/l	-	-	-
Grease and Oil, mg/l	-	-	208

TABLE A-2. PLAIN SEDIMENTATION OF RAW SCREENED SEPTAGE

Run Number 1
Corresponding Feed Material - 016

Parameter	Supernatant Quality Following Sedimentation For 0 Hr	24 Hr	48 Hr
TS, mg/l	2,720	2,370	2,220
TVS, mg/l	1,920	1,720	1,720
SS, mg/l	2,510	1,720	1,410
VSS, mg/l	2,090	1,510	1,210
BOD_5 (total), mg/l	990	990	830
NH_3-N, mg/l as N	37	36	37
Organic-N, mg/l as N	128	126	113
PO_4 (total), mg/l as P	20	9	11

Run Number 2
Corresponding Feed Material - 021

Parameter	0 Hr	24 Hr	48 Hr
TS, mg/l	9,240	8,780	8,620
TVS, mg/l	7,190	6,820	6,740
SS, mg/l	8,870	7,230	6,920
VSS, mg/l	6,870	5,520	5,350
BOD_5 (total), mg/l	4,900	4,700	4,600
NH_3-N, mg/l as N	54	54	52
Organic-N, mg/l as N	98	96	87
PO_4 (total), mg/l as P	72	42	40

(Continued)

TABLE A-2. (Continued)

Run Number 3
Corresponding Feed Material - 027

Parameter	Supernatant Quality Following Sedimentation For 0 Hr	24 Hr	48 Hr
TS, mg/l	17,290	13,700	13,520
TVS, mg/l	14,315	11,330	11,100
SS, mg/l	16,630	12,650	12,500
VSS, mg/l	13,330	10,050	9,840
BOD_5 (total), mg/l	8,550	8,240	8,030
NH_3-N, mg/l as N	50	50	50
Organic-N, mg/l as N	261	230	230
PO_4 (total), mg/l as P	65	57	53

Run Number 4
Corresponding Feed Material - 039

TS, mg/l	9,850	7,230	6,840
TVS, mg/l	7,920	5,740	5,330
SS, mg/l	5,860	5,220	5,130
VSS, mg/l	4,900	4,240	4,120
BOD_5 (total), mg/l	3,030	2,980	2,640
NH_3-N, mg/l as N	71	70	68
Organic-N, mg/l as N	225	195	190
PO_4 (total), mg/l as P	64	58	52

TABLE A-3. SUPERNATANT CHARACTERISTICS FOLLOWING AERATION AND TWO HOURS SETTLING

Parameter	Treatment Number 101	102	103	104
Corresponding Feed Material*	001	002	004	017
Aeration Period, Hours	16	16	16	16
Supernatant Volume, m^3	0.57	0.30	0.76	0.76
, gal	150	80	200	200
TS, mg/l	2,460	4,400	9,320	18,570
TVS, mg/l	1,960	3,560	8,410	15,600
TSS, mg/l	1,910	3,930	7,570	12,300
VSS, mg/l	1,700	3,410	6,900	10,600
pH, S.U.	5.9	6.4	6.1	6.7
BOD_5 (total), mg/l	1,190	2,920	3,660	2,540
BOD_5 (soluble), mg/l	240	510	1,020	390
COD, mg/l	2,460	10,400	12,600	16,200
NH_3-N, mg/l as N	4.3	19	32	58
Organic-N, mg/l as N	67	123	438	332
PO_4 (total), mg/l as P	10	30	31	56
PO_4 (ortho) mg/l as P	<5	15	1	19
Alkalinity, mg/l as $CaCO_3$	106	100	460	258
Fe, mg/l	15	38	-	-
Ni, mg/l	-	-	-	-
Cd, mg/l	0.04	0.04	-	-
Cu, mg/l	2.0	2.9	-	-
Mn, mg/l	0.20	0.45	-	-
Zn, mg/l	3.0	2.9	-	-
Grease & Oil, mg/l	-	-	4,140	6,970

(Continued)

TABLE A-3. (Continued)

Parameter	Treatment Number 105	106	107	108
Corresponding Feed Material*	001	011	021	002
Aeration Period, Hours	20	24	24	96
Supernatant Volume, m^3	0.53	0.76	0.76	0.42
, gal	140	200	200	110
TS, mg/l	1,540	13,100	15,800	1,800
TVS, mg/l	1,150	11,000	11,175	1,150
TSS, mg/l	810	10,800	10,200	875
VSS, mg/l	760	9,540	7,850	790
pH, S.U.	5.5	6.6	6.3	6.4
BOD_5 (total), mg/l	710	5,910	3,840	180
BOD_5 (soluble), mg/l	280	262	780	150
COD, mg/l	820	17,300	29,500	2,390
NH_3-N, mg/l as N	17	58	36	10
Organic-N, mg/l as N	34	212	229	15
PO_4 (total), mg/l as P	<10	25	66	<10
PO_4 (ortho) mg/l as P	<5	18	30	<5
Alkalinity, mg/l as $CaCO_3$	98	340	240	47
Fe, mg/l	4.3	-	-	26
Ni, mg/l	-	-	-	-
Cd, mg/l	0.04	-	-	0.04
Cu, mg/l	0.47	-	-	1.8
Mn, mg/l	0.07	-	-	0.32
Zn, mg/l	0.90	-	-	2.1
Grease and Oil, mg/l	-	-	1,710	-

*Initial Volume 0.76 m^3 (200 gal)

TABLE A-4. SUPERNATANT CHARACTERISTICS FOLLOWING FERRIC CHLORIDE ADDITION TO RAW SCREENED SEPTAGE

Parameter	Treatment Number 109	110	111	112	113	114
Corresponding Feed Material*	007	008	009	011	012	013
$FeCl_3$ Dose, mg/l as $FeCl_3$	400	400	600	500	450	500
Supernatant Volume, m^3	0.45	0.49	0.45	0.45	0.42	0.45
, gal	120	130	120	120	110	120
TS, mg/l	960	1,400	1,430	1,230	2,080	1,610
TVS, mg/l	360	630	510	680	1,520	720
TSS, mg/l	64	88	68	190	840	65
VSS, mg/l	58	74	52	170	770	63
pH, S.U.	5.0	4.8	3.3	5.7	6.2	6.2
BOD_5 (total), mg/l	700	1,380	1,200	525	1,125	190
BOD_5 (soluble), mg/l	680	1,140	1,080	-	-	-
COD, mg/l	670	1,320	1,050	1,175	2,830	590
NH_3-N, mg/l as N	72	60	62	60	65	2
Organic-N, mg/l as N	31	40	24	190	175	238
PO_4 (total), mg/l as P	<2	10.5	<1	6.5	20.5	4
PO_4 (ortho) mg/l as P	<2	5.5	<1	-	-	<2
Alkalinity, mg/l as $CaCO_3$	16	220	-	120	180	70
Fe, mg/l	18	10	45	-	-	0.4
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	0.05	0.13	0.14	0.21	0.28	0.35
Mn, mg/l	0.60	0.50	1.1	0.05	0.09	0.90
Zn, mg/l	0.8	0.43	2.8	1.2	0.83	0.87
Grease and Oil, mg/l	-	-	-	-	-	-

(Continued)

TABLE A-4. (Continued)

Parameter	Treatment Number 115	116	117	118	119	120
Corresponding Feed Material*	014	016	017	018	028	021
$FeCl_3$ Dose mg/l as $FeCl_3$	400	400	400	400	600	500
Supernatant Volume, m^3	0.53	0.42	0.38	0.42	0.42	0.57
, gal	140	110	100	110	110	150
TS, mg/l	2,920	1,060	2,340	2,150	1,560	2,275
TVS, mg/l	1,680	580	1,790	1,650	765	1,120
TSS, mg/l	200	20	800	780	90	45
VSS, mg/l	150	20	730	670	85	40
pH, S.U.	5.8	6.2	6.1	6.2	4.2	4.3
BOD_5 (total), mg/l	1,165	175	480	810	100	120
BOD_5 (soluble), mg/l	1,055	-	190	-	84	84
COD, mg/l	1,495	350	2,530	3,200	200	235
NH_3-N, mg/l as N	78	28	59	91	24	33
Organic-N, mg/l as N	29	10	81	139	8	4
PO_4 (total), mg/l as P	2	<2	3.5	14	<2	<2
PO_4 (ortho) mg/l as P	<2	<2	<2	14	<2	<2
Alkalinity, mg/l as $CaCO_3$	320	50	50	190	-	-
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease and Oil, mg/l	-	204	328	440	-	232

*Initial Volume - 0.76 m^3 (200 gal)

TABLE A-5. SUPERNATANT CHARACTERISTICS FOLLOWING LIME TREATMENT OF FERRIC CHLORIDE FORMED SUPERNATANT

Parameter	Treatment Number				
	121	122	123	124	125
Corresponding Feed Material*	109	110	111	112	113
Lime Dose, mg/l as $Ca(OH)_2$	4,000	4,000	4,000	4,000	4,000
Supernatant Volume, m^3	0.42	0.44	0.40	0.42	0.38
, gal	110	115	105	110	100
TS, mg/l	33,160	5,130	2,500	7,900	3,720
TVS, mg/l	29,210	1,720	600	2,585	1,285
TSS, mg/l	<1	370	70	15	34
VSS, mg/l	<1	25	5	10	24
pH, S.U.	12.6	11.5	11.3	11.8	11.7
BOD_5 (total), mg/l	750	1,200	990	250	465
BOD_5 (soluble), mg/l	730	1,200	900	245	450
COD, mg/l	750	860	1,120	550	700
NH_3-N, mg/l as N	54	52	56	51	56
Organic-N, mg/l as N	<1	68	29	229	214
PO_4 (total), mg/l as P	<2	<1	<1	5	1
PO_4 (ortho) mg/l as P	<2	<1	<1	1	<1
Alkalinity, mg/l as $CaCO_3$	-	1,380	1,070	1,800	1,460
Fe, mg/l	0.10	0.30	0.50	-	-
Ni, mg/l	-	-	-	-	-
Cd, mg/l	-	-	-	-	-
Cu, mg/l	0.04	0.09	0.11	-	-
Mn, mg/l	<0.10	<0.10	<0.10	-	-
Zn, mg/l	0.01	0.22	0.14	-	-
Grease and Oil, mg/l	-	-	-	-	-

(Continued)

TABLE A-5. (Continued)

Parameter	Treatment Number 126	127	128	129	130
Corresponding Feed Material*	114	115	116	117	118
Lime Dose, mg/l as $Ca(OH)_2$	3,000	2,000	2,500	2,000	2,500
Supernatant Volume, m^3	0.38	0.38	0.47	0.44	0.42
, gal	100	100	125	115	110
TS, mg/l	5,710	4,140	12,770	5,750	7,260
TVS, mg/l	1,980	1,600	4,225	1,230	2,150
TSS, mg/l	52	50	20	130	65
VSS, mg/l	48	48	10	68	41
pH, S.U.	11.4	11.3	11.7	12.2	12.1
BOD_5 (total), mg/l	50	25	325	650	46
BOD_5 (soluble), mg/l	20	20	310	410	31
COD, mg/l	220	280	1,200	1,275	200
NH_3-N, mg/l as N	2	1	64	56	21
Organic-N, mg/l as N	238	249	15	64	7
PO_4 (total), mg/l as P	2	1	<2	<2	<2
PO_4 (ortho) mg/l as P	<2	<1	<2	<2	<2
Alkalinity, mg/l as $CaCO_3$	1,200	1,000	2,420	130	2,850
Fe, mg/l	0.02	-	-	-	-
Ni, mg/l	-	-	-	-	-
Cd, mg/l	-	-	-	-	-
Cu, mg/l	<0.1	-	-	-	-
Mn, mg/l	<0.1	-	-	-	-
Zn, mg/l	<0.1	-	-	-	-
Grease and Oil, mg/l	-	-	-	190	204

*Initial volumes equal to those presented as supernatant volumes in Table A-4.

TABLE A-6. SUPERNATANT CHARACTERISTICS FOLLOWING FERRIC CHLORIDE AND LIME TREATMENT OF RAW SCREENED SEPTAGE

Parameter	Treatment Number		
	131	132	133
Corresponding Feed Material*	006	006	007
$FeCl_3$ Dose, mg/l as $FeCl_3$	400	400	400
Lime Dose, mg/l as $Ca(OH)_2$	4,000	4,000	4,000
Supernatant Volume, m^3	0.53	0.53	0.49
, gal	140	140	130
TS, mg/l	5,000	6,700	7,400
TVS, mg/l	2,160	2,710	2,500
TSS, mg/l	168	125	31
VSS, mg/l	136	110	19
pH, S.U.	12.2	12.1	12.2
BOD_5 (total), mg/l	740	190	900
BOD_5 (soluble), mg/l	585	50	850
COD, mg/l	12,400	3,200	850
NH_3-N, mg/l as N	44	38	72
Organic-N, mg/l as N	226	9	21
PO_4 (total), mg/l as P	40	<1	<1
PO_4 (ortho) mg/l as P	28	<1	<1
Alkalinity, mg/l as $CaCO_3$	910	1,900	2,540
Fe, mg/l	57	0.6	1.0
Ni, mg/l	-	-	-
Cd, mg/l	-	-	-
Cu, mg/l	14	<0.1	0.7
Mn, mg/l	0.2	<0.1	<0.1
Zn, mg/l	9.3	0.1	0.1
Grease and Oil, mg/l	-	-	-

*Initial Volume - 0.76 m^3 (200 gal)

TABLE A-7. SUPERNATANT CHARACTERISTICS FOLLOWING ALUM CONDITIONING OF RAW SCREENED SEPTAGE

Parameter	Treatment Number					
	134	135	136	137	138	139
Corresponding Feed Material*	021	022	022	022	023	024
Alum Dose, mg/l as $Al_2(SO_4)_3$	4,000	3,800	4,700	5,700	2,250	3,750
Supernatant Volume, m^3	0.57	0.53	0.38	0.44	0.42	0.44
, gal	150	140	100	115	110	115
TS, mg/l	5,900	5,815	6,560	6,850	2,540	4,480
TVS, mg/l	3,000	2,630	3,140	2,330	1,340	1,850
TSS, mg/l	200	85	250	208	60	150
VSS, mg/l	160	70	195	172	50	115
pH, S.U.	4.1	4.0	3.9	3.9	4.2	4.0
BOD_5 (total), mg/l	78	300	300	310	380	260
BOD_5 (soluble), mg/l	60	230	240	280	100	160
COD, mg/l	630	362	400	424	242	222
NH_3-N, mg/l as N	32	38	38	38	61	60
Organic-N, mg/l as N	14	17	16	33	5	22
PO_4 (total), mg/l as P	8	7	10	9	3.5	9
PO_4 (ortho) mg/l as P	6	5	7	7	4	6
Alkalinity, mg/l as $CaCO_3$	-	-	-	-	-	-
Fe, mg/l	32	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	.28	-	-	-	-	-
Mn, mg/l	.05	-	-	-	-	-
Zn, mg/l	.47	-	-	-	-	-
Grease and Oil, mg/l	176	236	-	-	-	280

(Continued)

TABLE A-7. (Continued)

Parameter	Treatment Number 140	141	142	143	144	145
Corresponding Feed Material*	024	025	025	025	026	026
Alum Dose, mg/l as $Al_2(SO_4)_3$	6,000	2,250	3,750	6,000	3,750	6,000
Supernatant Volume, m^3	0.44	0.42	0.40	0.38	0.45	0.44
, gal	115	110	105	100	120	115
TS, mg/l	5,850	2,500	3,380	3,740	2,810	2,690
TVS, mg/l	2,350	690	720	550	1,060	1,965
TSS, mg/l	100	300	200	70	120	510
VSS, mg/l	90	70	145	40	90	375
pH, S.U.	4.0	6.6	6.6	6.6	4.2	4.0
BOD_5 (total), mg/l	315	465	400	280	315	400
BOD_5 (soluble), mg/l	180	405	370	275	315	295
COD, mg/l	283	582	606	364	510	1,415
NH_3-N, mg/l as N	61	62	62	100	29	31
Organic-N, mg/l as N	<1	12	10	77	32	34
PO_4 (total), mg/l as P	11	<2	<2	<2	8.5	9
PO_4 (ortho) mg/l as P	9	<2	<2	<2	2	7
Alkalinity, mg/l as $CaCO_3$	-	156	186	142	-	-
Fe, mg/l	-	-	-	-	-	-
Ni, mg/l	-	-	-	-	-	-
Cd, mg/l	-	-	-	-	-	-
Cu, mg/l	-	-	-	-	-	-
Mn, mg/l	-	-	-	-	-	-
Zn, mg/l	-	-	-	-	-	-
Grease and Oil, mg/l	-	-	-	228	-	-

(Continued)

TABLE A-7. (Continued)

Parameter	Treatment Number 146	147	148	149	150	151
Corresponding Feed Material*	026	027	027	027	028	029
Alum Dose, mg/1 as $Al_2(SO_4)_3$	8,250	4,700	5,700	5,200	3,000	4,000
Supernatant Volume, m^3	0.49	0.63	0.66	0.57	0.40	0.51
, gal	130	165	175	150	105	135
TS, mg/1	5,760	2,260	3,530	1,850	4,740	7,100
TVS, mg/1	2,500	940	1,390	710	2,515	3,610
TSS, mg/1	240	130	180	150	150	195
VSS, mg/1	240	130	150	130	130	150
pH, S.U.	4.0	4.2	4.1	4.2	4.0	3.9
BOD_5 (total), mg/1	375	330	340	310	65	64
BOD_5 (soluble), mg/1	340	280	280	290	57	43
COD, mg/1	860	410	570	715	444	182
NH_3-N, mg/1 as N	39	45	46	47	23	32
Organic-N, mg/1 as N	23	<1	9	10	46	39
PO_4 (total), mg/1 as P	17	3	6.5	3	5	5
PO_4 (ortho) mg/1 as P	10	3	<1	2	2.5	2
Alkalinity, mg/1 as $CaCO_3$	-	-	-	-	-	-
Fe, mg/1	-	-	-	-	-	-
Ni, mg/1	-	-	-	-	-	-
Cd, mg/1	-	-	-	-	-	-
Cu, mg/1	-	-	-	-	-	-
Mn, mg/1	-	-	-	-	-	-
Zn, mg/1	-	-	-	-	-	-
Grease and Oil, mg/1	248	172	-	-	-	-

*Initial Volume - 0.76 m^3 (200 gal)

TABLE A-8. SUPERNATANT CHARACTERISTICS FOLLOWING ACID CONDITIONING OF RAW SCREENED SEPTAGE

Parameter	Treatment Number 153	154	155	156
Corresponding Feed Material*	004	004	005	017
Supernatant Volume, m^3	0.61	0.64	0.45	0.45
, gal	160	170	120	120
TS, mg/l	3,145	3,850	7,800	4,370
TVS, mg/l	625	550	4,200	1,510
TSS, mg/l	345	410	1,900	250
VSS, mg/l	170	220	1,400	20
pH, S.U.	<2	<2	<2	2.3
BOD_5 (total), mg/l	350	420	1,400	200
BOD_5 (soluble), mg/l	320	-	1,100	130
COD, mg/l	600	485	3,000	1,150
NH_3-N, mg/l as N	92	38	82	58
Organic-N, mg/l as N	108	52	58	30
PO_4 (total), mg/l as P	25	25	52	9
PO_4 (ortho) mg/l as P	25	23	50	2
Alkalinity, mg/l as $CaCO_3$	-	-	-	
Fe, mg/l	10.1	34.0	19.0	-
Ni, mg/l	-	0.07	0.05	-
Cd, mg/l	<0.02	<0.02	0.16	-
Cu, mg/l	0.90	0.70	1.5	-
Mn, mg/l	0.15	0.48	0.70	-
Zn, mg/l	1.1	2.8	8.5	-
Grease and Oil, mg/l	-	-	-	340

(Continued)

TABLE A-8. (Continued)

Parameter	Treatment Number 157	158	159	160
Corresponding Feed Material*	018	021	028	029
Supernatant Volume, m^3	0.61	0.57	0.70	0.66
, gal	160	150	185	175
TS, mg/l	4,970	3,520	4,105	4,320
TVS, mg/l	1,620	800	2,230	2,170
TSS, mg/l	83	175	120	250
VSS, mg/l	74	150	115	210
pH, S.U.	2.8	2.4	2.0	2.2
BOD_5 (total), mg/l	560	200	92	60
BOD_5 (soluble), mg/l	400	140	72	53
COD, mg/l	800	630	303	404
NH_3-N, mg/l as N	94	38	25	40
Organic-N, mg/l as N	51	10	40	62
PO_4 (total), mg/l as P	60	58	21	29
PO_4 (ortho) mg/l as P	59	14	9	23
Alkalinity, mg/l as $CaCO_3$	-	-	-	-
Fe, mg/l	-	-	-	-
Ni, mg/l	-	-	-	-
Cd, mg/l	-	-	-	-
Cu, mg/l	-	-	-	-
Mn, mg/l	-	-	-	-
Zn, mg/l	-	-	-	-
Grease and Oil, mg/l	160	196	-	238

*Initial Volume - 0.76 m^3 (200 gal)

TABLE A-9. SUPERNATANT CHARACTERISTICS FOLLOWING LIME TREATMENT OF ACID FORMED SUPERNATANT

Parameter	Treatment Number			
	161	162	163	164
Corresponding Feed Material*	153	154	155	156
Supernatant Volume, m^3	0.57	0.57	0.38	0.53
, gal	150	150	100	140
TS, mg/l	3,300	3,150	9,050	6,200
TVS, mg/l	445	230	1,420	1,140
TSS, mg/l	nil	nil	200	103
VSS, mg/l	nil	nil	140	60
pH, S.U.	11.2	>11	>11.5	12.0
BOD_5 (total), mg/l	120	88	1,400	350
BOD_5 (soluble), mg/l	120	88	1,050	330
COD, mg/l	120	89	1,310	1,330
Organic-N, mg/l as N	62	38	58	38
PO_4 (total), mg/l as P	37	27	20	45
PO_4 (ortho) mg/l as P	2	2	2	10
$O-PO_4$, mg/l as P	<1	2	<1	1
Alkalinity, mg/l as $CaCO_3$	-	-	930	1,820
Fe, mg/l	0.30	0.36	0.36	-
Ni, mg/l	0.03	<0.02	0.03	-
Cd, mg/l	<0.02	<0.02	<0.01	-
Cu, mg/l	0.02	0.15	0.52	-
Mn, mg/l	0.01	0.46	<0.01	-
Zn, mg/l	0.06	0.15	0.57	-
Grease and Oil, mg/l	-	-	-	260

(Continued)

TABLE A-9. (Continued)

Parameter	Treatment Number 165	166	167
Corresponding Feed Material*	158	159	160
Supernatant Volume, m^3	0.42	0.57	0.63
, gal	110	150	165
TS, mg/l	5,160	5,200	6,820
TVS, mg/l	1,170	1,230	1,470
TSS, mg/l	23	130	60
VSS, mg/l	10	68	25
pH, S.U.	12.2	12.2	12.0
BOD_5 (total), mg/l	240	650	83
BOD_5 (soluble), mg/l	75	410	45
COD, mg/l	400	1,275	200
Organic-N mg/l as N	40	59	37
PO_4 (total), mg/l as P	0	61	14
PO_4 (ortho) mg/l as P	<2	<2	<2
O-PO_4, mg/l as P	<2	<2	<2
Alkalinity, mg/l as $CaCO_3$	1,410	1,130	2,420
Fe, mg/l	-	-	-
Ni, mg/l	-	-	-
Cd, mg/l	-	-	-
Cu, mg/l	-	-	-
Mn, mg/l	-	-	-
Zn, mg/l	-	-	-
Grease and Oil, mg/l	208	190	-

*Initial volumes indicated as supernatant volumes in Table A-8.

TABLE A-10. SAND DRYING BED TREATMENT OF RAW SCREENED SEPTAGE

	Parameter	Raw Septage	Filtrate On Day 1	Filtrate On Day 2
Trial No. 1	Volume, m^3	0.18	0.09	0.05
	, gal	48.0	24.0	12.0
	TS, mg/l	10,340	1,790	1,080
	TVS, mg/l	7,700	1,280	750
	TSS, mg/l	7,240	310	70
	VSS, mg/l	5,800	300	70
	pH, S.U.	6.2	6.6	6.9
	BOD_5, (total), mg/l	5,650	755	650
	BOD_5, (soluble), mg/l	1,100	662	615
Trial No. 2	Volume, m^3	0.18	0.14	-
	, gal	48.0	36.0	-
	TS, mg/l	10,060	1,880	-
	TVS, mg/l	7,270	1,390	-
	TSS, mg/l	8,150	490	-
	VSS, mg/l	6,680	425	-
	pH, S.U.	5.3	6.2	-
	BOD_5 (total), mg/l	5,690	1,630	-
	BOD_5 (soluble), mg/l	2,320	1,230	-

(Continued)

TABLE A-10. (Continued)

	Parameter	Raw Septage	Filtrate On Day 1	Filtrate On Day 2
Trial No. 3	Volume, m^3	0.18	0.10	-
	, gal	48.0	27.0	-
	TS, mg/l	16,280	1,400	-
	TVS, mg/l	12,350	950	-
	TSS, mg/l	14,560	200	-
	VSS, mg/l	7,280	180	-
	pH, S.U.	6.3	6.7	-
	BOD_5 (total), mg/l	7,450	750	-
	BOD_5 (soluble), mg/l	2,580	640	-
Trial No. 4	Volume, m^3	0.18	0.13	-
	, gal	48.0	33.0	-
	TS, mg/l	14,320	1,450	-
	TVS, mg/l	10,130	1,080	-
	TSS, mg/l	8,550	240	-
	VSS, mg/l	5,200	220	-
	pH, S.U.	5.4	6.8	-
	BOD_5 (total), mg/l	9,560	1,090	-
	BOD_5 (soluble), mg/l	2,550	895	-

TABLE A-11. SAND DRYING BED TREATMENT OF THE COMBINED SLUDGE FRACTIONS FROM $FeCl_3$ ADDITION FOLLOWED BY LIME ADDITION

	Parameter	Ferric Chloride/ Lime Sludge	Filtrate On Day 1	Filtrate On Day 2
Trial No. 1	Volume, m^3	0.18	0.10	0.04
	, gal	48.0	25.2	9.6
	TS, mg/l	-	-	-
	TVS, mg/l	-	-	-
	TSS, mg/l	11,220	9	66
	VSS, mg/l	3,903	4	33
	pH, S.U.	11.9	12.1	12.1
	BOD_5 (total) mg/l	7,350	1,020	1,230
	BOD_5 (soluble) mg/l	2,180	1,000	920
Trial No. 2	Volume, m^3	0.18	0.10	-
	, gal	48.0	25.2	-
	TS, mg/l	-	-	-
	TVS, mg/l	-	-	-
	TSS, mg/l	29,250	9	-
	VSS, mg/l	17,500	4	-
	pH, S.U.	12.2	12.1	-
	BOD_5 (total) mg/l	10,200	1,020	-
	BOD_5 (soluble) mg/l	2,530	1,000	-

(Continued)

TABLE A-11. (Continued)

	Parameter	Ferric Chloride/ Lime Sludge	Filtrate On	
			Day 1	Day 2
Trial No. 3	Volume, m^3	0.18	0.11	-
	, gal	48.0	30.0	-
	TS, mg/1	-	-	-
	TVS, mg/1	-	-	-
	TSS, mg/1	14,460	49	-
	VSS, mg/1	5,040	14	-
	pH, S.U.	11.3	11.4	-
	BOD_5, (total) mg/1	-	860	-
	BOD_5 (soluble) mg/1	-	-	-
Trial No. 4	Volume, m^3	0.18	0.14	-
	, gal	48.0	36.0	-
	TS, mg/1	-	-	-
	TVS, mg/1	-	-	-
	TSS, mg/1	29,250	66	-
	VSS, mg/1	17,520	33	-
	pH, S.U.	12.2	12.1	-
	BOD_5 (total) mg/1	10,200	1,020	-
	BOD_5 (soluble) mg/1	2,530	890	-

TABLE A-12. SAND DRYING BED TREATMENT OF ALUM CONDITIONING SLUDGE

	Parameter	Alum Sludge	Filtrate On Day 1	Filtrate On Day 2
Trial No. 1	Volume, m^3	0.18	0.15	-
	, gal	48	38.4	-
	TS, mg/l	41,180	1,130	-
	TVS, mg/l	32,560	950	-
	TSS, mg/l	30,600	79	-
	VSS, mg/l	25,500	29	-
	pH, S.U.	4.0	5.1	-
	BOD_5 (total) mg/l	10,240	240	-
	BOD_5 (soluble) mg/l	1,180	220	-
Trial No. 2	Volume, m^3	0.18	0.14	-
	, gal	48.0	38.2	
	TSS, mg/l	26,470	81	-
	VSS, mg/l	22,060	46	-
	pH, S.U.	4.1	5.0	-
	BOD_5 (total) mg/l	8,850	320	-
	BOD_5 (soluble) mg/l	1,190	320	-
Trial No. 3	Volume, m^3	.18	0.15	-
	, gal	48	38.6	-
	TSS, mg/l	34,730	77	-
	VSS, mg/l	28,940	12	-
	pH, S.U.	3.9	5.2	-
	BOD_5 (total) mg/l	11,630	160	-
	BOD_5 (soluble) mg/l	1,170	120	-

TABLE A-13. SAND DRYING BED TREATMENT OF COMBINED SLUDGES FROM THE ACID/LIME CONDITIONING PROCESS

	Parameter	Acid/Lime Sludge	Filtrate On	
			Day 1	Day 2
Trial No. 1	Volume, m^3	0.18	0.11	0.05
	, gal	48.0	28.8	13.2
	TS, mg/l	-	-	-
	TVS, mg/l	-	-	-
	TSS, mg/l	15,170	140	58
	VSS, mg/l	6,023	140	16
	pH, S.U.	8.9	6.8	7.3
	BOD_5 (total) mg/l	10,350	360	360
	BOD_5 (soluble) mg/l	1,660	330	330
Trial No. 2	Volume, m^3	0.18	0.09	0.05
	, gal	48.0	24.0	14.3
	TS, mg/l	34,387	3,720	3,520
	TVS, mg/l	13,900	1,290	1,130
	TSS, mg/l	22,140	96	72
	VSS, mg/l	12,920	96	38
	pH, S.U.	10.4	7.5	7.0
	BOD_5 (total) mg/l	11,700	420	340
	BOD_5 (soluble) mg/l	2,110	360	330

(Continued)

TABLE A-13. (Continued)

	Parameter	Acid/Lime Sludge	Filtrate On Day 1	Filtrate On Day 2
Trial No. 3	Volume, m^3	0.18	0.11	0.05
	, gal	48.0	28.8	12.0
	TS, mg/1	31,500	3,560	3,635
	TVS, mg/1	27,000	1,050	1,150
	TSS, mg/1	30,700	11	15
	VSS, mg/1	24,300	8	11
	pH, S.U.	3.0	6.9	6.2
	BOD_5 (total) mg/1	36,400	840	930
	BOD_5 (soluble) mg/1	1,125	840	880
Trial No. 4	Volume, m^3	0.18	0.14	0.04
	, gal	48.0	36.0	10.8
	TS, mg/1	31,500	2,050	1,270
	TVS, mg/1	27,000	570	378
	TSS, mg/1	30,700	45	35
	VSS, mg/1	24,300	40	35
	pH, S.U.	3.0	6.0	6.1
	BOD_5 (total) mg/1	36,400	585	460
	BOD_5 (soluble) mg/1	1,125	600	410

TABLE A-14. SLUDGE DEWATERING BY SOLID BOWL CENTRIFUGE

Run Number	Sludge Type	Influent TSS, mg/l	Centrate TSS, mg/l	Cake, % Solids	% Capture Of TSS
2	$FeCl_3$/Lime	31,000	3,695	16.5	90.5
3	$FeCl_3$/Lime	42,140	6,928	16.0	87.3
4	$FeCl_3$/Lime	28,560	4,754	14.3	85.1
6	$FeCl_3$/Lime	26,510	3,720	15.8	88.2
12	$FeCl_3$/Lime	22,580	3,280	15.9	87.3
13	$FeCl_3$/Lime	30,930	3,686	16.3	89.5
15	Alum	33,000	13,973	20.6	62.4
16	Alum	28,400	13,120	20.1	56.6
18	Alum	36,800	18,260	18.4	55.0
20	Alum	22,450	10,140	17.6	58.7
24	Alum	31,900	18,500	17.2	48.5
27	Acid/Lime	29,400	18,800	19.1	39.9
29	Acid/Lime	24,580	15,490	20.0	40.6
31	Acid/Lime	30,700	17,550	20.0	40.6
42	Acid/Lime	32,600	20,120	19.8	42.6
46	Acid/Lime	38,500	24,000	21.9	42.2
50	90/10*	31,590	25,100	16.4	24.2
53	90/10*	23,350	18,420	20.0	25.7
54	90/10*	18,420	14,580	18.2	22.6
56	90/10*	23,790	18,920	19.1	22.7
58	90/10*	29,470	23,540	16.4	23.5

*90% aerobically digested secondary sludge + 10% acid/lime sludge (v/v)

TABLE A-15. SLUDGE DEWATERING BY FILTER PRESS

Run Number	Sludge Type	TSS, mg/l		Cake	
		Influent	Filtrate	% Solids	Thickness mm (in)
1	$FeCl_3$/Lime	29,600	42	50.0	6.35 (0.25)
2	$FeCl_3$/Lime	31,000	38	50.1	3.18 (0.13)
12	$FeCl_3$/Lime	22,580	34	47.2	6.35 (0.25)
15	Alum	33,000	14	55.0	12.70 (0.50)
16	Alum	28,400	16	51.3	12.70 (0.50)
18	Alum	36,800	21	49.8	6.35 (0.25)
27	Acid/Lime	29,400	2	24.9	6.35 (0.25)
28	Acid/Lime	24,650	6	25.3	9.53 (0.38)
30	Acid/Lime	32,940	4	24.8	12.70 (0.50)
31	Acid/Lime	30,700	3	26.0	12.70 (0.50)
50	90/10*	31,590	12	44.6	6.35 (0.25)
53	90/10*	23,350	9	42.8	6.35 (0.25)
55	90/10*	27,000	6	45.7	6.35 (0.25)

*90% aerobically digested secondary sludge + 10% acid/lime sludge (v/v)

TABLE A-16. SLUDGE DEWATERING BY CLOTH BELT VACUUM FILTRATION

Sludge Run #	Sludge Type	TSS, mg/l Influent	TSS, mg/l Filtrate	Cake % Solids	Cake Thickness, mm (in)	Cake Yield $kg/m^2/hr$ ($lb/ft^2/hr$)
1	$FeCl_3$/Lime	29,600	67	29.3	1.59 (0.06)	2.0 (0.4)
2	$FeCl_3$/Lime	31,000	87	24.5	3.18 (0.13)	3.4 (0.7)
5	$FeCl_3$/Lime	20,170	117	35.0	1.59 (0.06)	2.4 (0.5)
7	$FeCl_3$/Lime	20,170	97	22.8	1.59 (0.06)	1.5 (0.3)
9	$FeCl_3$/Lime	24,128	121	26.7	1.59 (0.06)	2.0 (0.4)
14	Alum*	33,000	56	27.0	6.35 (0.25)	7.3 (1.5)
15	Alum	33,000	80	28.0	1.59 (0.06)	2.0 (0.4)
16	Alum	28,400	62	26.5	1.59 (0.06)	2.0 (0.4)
19	Alum	26,400	97	24.8	1.59 (0.06)	1.5 (0.3)
22	Alum	29,280	103	26.4	3.18 (0.13)	2.0 (0.4)
25	Acid/Lime	31,580	52	25.4	3.18 (0.13)	3.4 0.7
27	Acid/Lime	24,900	64	26.9	3.18 (0.13)	3.4 (0.7)
28	Acid/Lime	24,650	23	28.3	3.18 (0.13)	3.9 (0.8)
36	Acid/Lime	30,700	44	27.0	3.18 (0.13)	3.9 (0.8)
41	Acid/Lime	33,280	37	23.2	3.18 (0.13)	2.9 (0.6)

*Conditioned with lime at 2,000 mg/l and anionic polymer 25 mg/l.

TABLE A-17. VACUUM FILTRATION OF A MIXTURE OF 10% ACID/LIME SLUDGE AND 90% AEROBICALLY DIGESTED SECONDARY SLUDGE (v/v%)

Run #	Feed Sludge % TSS	Conditioner Type	Conditioner Dose, mg/l	CST, Sec.	Cake % Solids	Cake Thickness, mm (in)	Filtrate TSS, mg/l	Cake Yield $kg/m^2/hr$ ($lbs/ft^2/hr$)
A	2.2	None	-	121	20.4	1.59 (0.06)	64	1.5 (0.3)
B	2.6	None	-	132	5.2	3.18 (0.13)	74	0.5 (0.1)
C	4.6	Anionic	15	29	24.0	1.59 (0.06)	20	1.5 (0.3)
D	4.9	None	-	57	23.0	3.18 (0.13)	20	2.9 (0.6)
E	2.4	$FeCl_3$ Lime Anionic	800 4,000 10	20	17.8	3.18 (0.13)	87	2.4 (0.5)
F	3.7	$FeCl_3$ Lime Anionic	600 4,000 30	29	18.4	1.59 (0.06)	52	2.4 (0.5)
G	2.6	$FeCl_3$ Lime Cationic	500 4,000 160	38	12.6	1.59 (0.06)	59	1.0 (0.2)

(Continued)

TABLE A-17. (Continued)

Run #	Feed Sludge % TSS	Conditioner Type	Conditioner Dose, mg/l	CST, Sec.	Cake % Solids	Cake Thickness, mm (in)	Filtrate TSS, mg/l	Cake Yield $kg/m^2/hr$ $(lbs/ft^2/hr)$
H	2.6	$FeCl_3$	2,000					
		Lime	8,000					
		Cationic	160	16	13.0	3.18 (0.13)	200	1.0 (0.2)
I	1.7	Alum	2,000	21	9.3	3.18 (0.13)	190	1.0 (0.2)
		Lime	to pH 6.3					
J	1.7	Alum	2,000	29	8.4	1.59 (0.06)	210	0.5 (0.1)
		Lime	-					
K	1.9	Alum	2,000					
		Cationic	160	20	7.2	1.59 (0.06)	1,200	0.5 (0.1)
L	3.4	Alum	2,000					
		Anionic	200	39	15.0	1.59 (0.06)	3,120	1.0 (0.2)
M		Alum	2,000					
		Anionic	15	34	16.0	3.18 (0.13)	84	2.0 (0.4)

TABLE A-18. VACUUM FILTRATION OF A MIXTURE OF 10% RAW SCREENED SEPTAGE AND 90% AEROBICALLY DIGESTED SECONDARY SLUDGE (v/v%)

		Conditioners			Cake			Cake Yield	
Run #	Feed Sludge % Solids	Type	Dose, mg/l	CST, Sec.	% Solids	Thickness, mm (in)	Filtrate TSS, mg/l	$kg/m^2/hr$ ($lbs/ft^2/hr$)	Cake Release
N	3.7	None	–	128	18.2	<1.59 (<0.06)	290	1.0 (0.2)	Did not release
O	2.9	None	–	187	–	<1.59 (<0.06)	210	–	Did not release
P	3.1	$FeCl_3$ Lime	200 6,000	42	7.8	<1.59 (<0.06)	110	0.5 (0.1)	Did not release
Q	2.8	$FeCl_3$ Lime Anionic	2,000 6,000 25	28	11.5	3.58 (0.13)	87	1.5 (0.3)	Poor release
R	3.7	Alum Lime	5,000 to pH 6.5	39	8.7	1.59 (0.06)	76	0.5 (0.1)	Poor release
S	3.7	Anionic	160	47	9.2	1.59 (0.06)	120	0.5 (0.1)	Poor release

TABLE A-19. SEPTAGE INTRODUCED TO CONTACT ZONE OF UNIT # 1

Screened Septage Characteristics

Date	BOD_5 (Total), mg/l	BOD_5 (Soluble), mg/l	pH, S.U.	NH_3-N, mg/l as N	Alkalinity, mg/l as $CaCO_3$	TSS, mg/l	VSS, mg/l
11-18-77	3,820	750	6.3	95	330	4,880	3,820
11-19-77	2,610	500	5.8	52	360	3,150	2,480
11-20-77	1,410	340	7.2	51	280	3,690	3,190
11-21-77	2,430	600	6.8	60	290	4,140	3,650
Average	2,657	547	6.5	64.5	315	3,965	3,285

Parameters Measured in Contact Zone

Date/Unit	pH, S.U.		NH_3-N, mg/l as N		Alkalinity, mg/l as $CaCO_3$		TSS, mg/l		VSS, mg/l		O_2 Uptake, mg/l/hr	
	1	2	1	2	1	2	1	2	1	2	1	2
11-18-77	-	-	-	-	-	-	-	-	-	-	15.0	18.0
11-19-77	6.2	6.3	6.4	4.4	70	70	5,220	4,270	-	-	15.6	12.0
11-20-77	6.2	6.3	6.2	4.8	82	68	5,550	4,000	4,230	2,900	18.6	15.6
11-21-77	6.2	6.2	1.6	1.4	81	69	4,060	3,120	3,180	2,450	16.2	19.0
11-22-77	6.3	6.3	1.7	1.4	71	69	4,189	3,640	3,690	2,940	18.0	15.6
Average	6.2	6.3	4.0	3.0	76	69	4,754	3,757	3,700	2,763	16.7	16.0

(Continued)

TABLE A-19. (Continued)

Parameters Measured in Re-Aeration Zone												
	pH, S.U.		NH_3-N, mg/l as N		Alkalinity, mg/l as $CaCO_3$		TSS, mg/l		VSS, mg/l		O_2 Uptake, mg/l/hr	
Date/Unit	1	2	1	2	1	2	1	2	1	2	1	2
11-18-77	-	-	-	-	-	-	-	-	-	-	15.0	21
11-19-77	6.3	6.3	5.6	4.2	68	60	4,270	2,525	-	-	14.4	10.8
11-20-77	6.3	6.3	6.4	5.8	58	68	5,050	3,950	4,230	2,920	18.6	12.6
11-21-77	5.8	6.3	3.0	2.6	78	68	2,980	2,300	-	-	17.4	10.8
11-22-77	6.2	6.3	3.0	2.6	83	67	1,200	2,300	1,000	1,740	15.6	25.8
Average	6.2	6.3	4.5	3.8	72	66	3,375	2,768			16.2	16.2

Secondary Clarifier Effluent												
	BOD_5, mg/l		pH, S.U.		NH_3-N, mg/l as N		Alkalinity, mg/l as $CaCO_3$		TSS, mg/l		TOC, mg/l	
Date/Unit	1	2	1	2	1	2	1	2	1	2	1	2
11-18-77	6	13	6.9	6.5	3.3	1.9	56	39	13	15	12	-
11-19-77	8	10	7.0	6.5	3.1	1.2	54	40	14	17	12	7
11-20-77	7	10	7.0	6.8	2.2	1.5	52	38	10	10	11	8
11-21-77	7	9	6.9	6.8	2.3	1.9	54	44	-	6	14	6
11-22-77	7	9	6.9	-	2.4	1.5	54	46	8	5	11	6
Average	7	8.2	6.9	6.6	2.7	1.6	54	41	11.2	10.6	12	6.8

(Continued)

TABLE A-19. (Continued)

Falmouth Treatment Plant - Operational Parameters

Date	Flow, m^3/Day (mgd)	Plant Influent*		Plant Effluent	
		BOD_5, mg/l	TSS, mg/l	BOD_5, mg/l	TSS, mg/l
11-18-77	2,480 (0.655)	48	52.3	8	14
11-19-77	3,180 (0.839)	61	34.8	9	15
11-20-77	3,490 (0.920)	39	51.9	9	10
11-21-77	2,780 (0.734)	52	47.2	9	7

*Does not include contributions from screened septage added to plant.

TABLE A-20. SCREENED SEPTAGE INTRODUCED IN RE-AERATION ZONE OF UNIT #1

Influent Septage Material

Date	BOD_5 (Total), mg/l	BOD_5 (Soluble), mg/l	pH, S.U.	NH_3-N mg/l as N	Alkalinity mg/l as $CaCO_3$	TSS, mg/l	VSS, mg/l
12-5-77	2,280	540	7.0	62	330	3,810	3,270
12-6-77	1,740	420	6.7	52	285	3,800	3,270
12-7-77	4,200	360	6.5	54	310	2,400	2,070
12-8-77	4,200	360	6.5	54	310	2,400	2,070
12-9-77	1,035	400	6.9	44	340	3,840	2,600
Average	2,810	430	6.7	53.2	255	3,252	2,656

Contact Zone Values

Date/Unit	pH, S.U.		NH_3-N mg/l as N		Alkalinity mg/l as $CaCO_3$		TSS, mg/l		VSS, mg/l		O_2 Uptake mg/l/hr	
	1	2	1	2	1	2	1	2	1	2	1	2
12-5-77	6.6	6.5	3.2	3.0	82	68	3,310	2,320	2,410	1,694	11.4	11.4
12-6-77	6.7	6.7	3.3	3.1	78	68	3,110	2,460	2,170	1,700	12.0	11.2
12-7-77	6.5	6.8	3.6	3.1	84	70	3,670	3,030	2,650	2,160	15.0	9.0
12-8-77	6.4	6.5	2.8	2.9	78	74	3,712	2,880	2,590	2,080	-	-
12-9-77	6.5	6.6	2.4	2.1	76	74	3,300	3,170	2,238	1,902	11.4	10.8
Average	6.5	6.6	2.5	2.8	79.6	70.8	3,420	2,772	2,412	1,907	12.4	10.6

(Continued)

TABLE A-20. (Continued)

Re-Aeration Zone Values

Date/Unit	pH, S.U. 1	pH, S.U. 2	NH_3-N, mg/l as N 1	NH_3-N, mg/l as N 2	Alkalinity, mg/l as $CaCO_3$ 1	Alkalinity, mg/l as $CaCO_3$ 2	TSS, mg/l 1	TSS, mg/l 2	VSS, mg/l 1	VSS, mg/l 2	O_2 Uptake mg/l/hr 1	O_2 Uptake mg/l/hr 2
12-5-77	6.5	6.3	2.0	1.0	66	64	4,280	3,800	3,100	2,710	9.0	10.2
12-6-77	6.5	6.4	4.3	3.2	70	86	3,800	4,100	2,760	2,400	9.6	8.4
12-7-77	6.5	6.5	2.5	2.3	86	76	5,200	4,100	3,800	2,900	14.0	9.6
12-8-77	6.4	6.5	2.0	2.0	88	78	5,550	4,600	3,860	3,260	-	-
12-9-77	6.7	6.5	1.1	1.0	94	70	4,000	3,220	2,760	2,390	13.8	9.0
Average	6.5	6.4	2.4	1.9	81	75	4,566	3,964	3,256	2,732	11.6	9.3

Secondary Clarifier Effluent Values

Date/Unit	BOD_5 mg/l 1	BOD_5 mg/l 2	pH, S.U. 1	pH, S.U. 2	NH_3-N, mg/l as N 1	NH_3-N, mg/l as N 2	Alkalinity, as $CaCO_3$ 1	Alkalinity, as $CaCO_3$ 2	TSS, mg/l 1	TSS, mg/l 2	TOC, mg/l 1	TOC, mg/l 2
12-5-77	10.5	5.4	6.9	6.8	2.8	2.6	52	50	5.1	3.7	13	9
12-6-77	8.6	3.5	7.8	7.2	2.2	2.2	56	58	46	22	9	7
12-7-77	-	-	-	-	-	-	-	-	-	-	-	-
12-8-77	11	7.5	7.1	6.9	3.1	3.5	56	62	56	34	18	12
12-9-77	12.3	4.8	6.8	6.7	2.5	3.0	62	62	27	19	12	9
Average	10.6	5.3	7.1	6.9	2.6	2.8	56	57	33.5	19.7	13	9

(Continued)

TABLE A-20. (Continued)

Falmouth Treatment Plant - Operational Parameters

Date	Flow m^3/day mgd	Total Plant Influent* BOD$_5$ mg/l	Total Plant Influent* TSS, mg/l	Total Plant Effluent BOD$_5$ mg/l	Total Plant Effluent TSS, mg/l
12-5-77	3,440 (0.907)	39	54.3	8	4.2
12-6-77	3,140 (0.828)	48	39.7	6	12.1
12-7-77	3,140 (0.829)	51	52.8	-	-
12-8-77	2,670 (0.704)	37	47.8	9	9.2
12-9-77	5,190 (1.37)	42	65.6	8	11.8

*Does not include contributions from screened septage added to plant

TABLE A-21. SETTLING RATE DATA FOR SEPTAGE CONDITIONED WITH ACID

Depth, Inches	mg/l, TSS Time, Hours 0	1	2	3	4	5	6	22
0	4,340	250	82	80	80	80	67	45
7	4,500	520	86	80	80	76	62	65
15	5,050	7,040	200	130	148	123	76	62
22	4,600	7,100	8,400	210	157	100	74	62
30	5,970	11,800	15,400	16,500	18,200	17,600	20,900	310
36	6,120	12,580	16,290	18,340	21,280	22,940	23,750	26,280

Final pH - 2.0
Total Tank Depth - 106.7 cm (42 in)

TABLE A-22. SETTLING RATE DATA FOR LIMED ACID SUPERNATANT

Sampling Depth, cm (in)		mg/l, TSS Settling Time, Hours			
		0	1	1.5	2.0
0.0	(0)	640	30	30	30
17.8	(7)	640	52	30	30
38.1	(15)	750	46	30	30
55.9	(22)	750	45	30	30
76.2	(30)	750	950	30	30
91.4	(36)	750	2,210	4,010	5,260

Final pH - 11.5
Total Tank Depth - 106.7 cm (42 in)

TABLE A-23. SETTLING RATE DATA FOR FERRIC CHLORIDE AND LIME CONDITIONED SLUDGE

Depth, Inches	mg/l, TSS Time, Hours							
	0	1	2	3	4	5	6	22
0	6,800	75	40	40	40	30	30	30
7	6,800	75	50	40	40	30	30	30
15	7,200	5,800	75	50	42	33	33	30
22	6,700	13,600	14,200	6,400	75	40	40	40
30	6,800	11,570	16,900	19,390	25,900	18,600	23,120	750
36	6,950	12,200	16,900	21,290	26,480	19,230	24,280	26,590

$FeCl_3$ - 400 mg/l
$Ca(OH)_2$ - 4,000 mg/l
Total Tank Depth - 106.7 cm (42 in)

TABLE A-24. SETTLING RATE DATA FOR ALUM CONDITIONED SEPTAGE

Depth, Inches	mg/1, TSS Time, Hours 0	1	2	3	4	5	6	22
0	6,400	138	72	74	70	68	70	60
7	6,410	194	74	70	68	70	70	64
15	6,600	6,590	185	80	74	80	75	72
22	6,800	8,920	11,400	2,350	170	80	80	72
30	6,790	10,600	17,700	23,700	16,600	20,500	26,300	278
36	7,240	11,200	18,400	25,280	26,570	27,290	29,380	29,560

Alum - 4,000 mg/1
No pH adjustment
Total Tank Depth - 106.7 cm (42 in)

TABLE A-25. COLIFORM KILL BY ACID ADDITION

Contact Time, Hr	Coliform Colonies/100 ml Trial 1	Trial 2	Trial 3
0	4.5×10^6	5.8×10^6	6.3×10^6
4	1,200	910	1,100
8	<20	200	<20
16	<20	<20	<20
pH, S.U.	1.6	1.9	2.0
TSS, mg/l	13,280	9,840	6,840
T, °C	20	20	20

TABLE A-26. LIME AND HEAT TREATMENT OF RAW SCREENED SEPTAGE

Trial #1

pH	Coliform Count, 10^6 Colonies/100 ml Temperature, °C 20	35	50	62
5	2.1	2.1	--	x
7	4.2	110	--	x
9	10.6	110	0.75	x
10	--	--	0.058	x
11	0.036	x	x	x

Trial #2

pH	20	35	50	62
5	1.3	1.3	--	x
7	4.1	95	--	x
9	11.5	95	0.83	x
10	--	--	0.036	x
11	0.058	x	x	x

Trial #3

pH	20	35	50	62
5	1.7	1.4	--	x
7	3.4	95	--	x
9	8.8	95	0.83	x
10	--	--	0.056	x
11	0.056	x	x	x

x = less than 20/100 ml

(Continued)

TABLE A-26. (Continued)

Trial #1

pH	Sludge Volume, % of Total Temperature °C 20	35	50	62
5	100	100	--	100
7	95	95	--	65
9	80	80	65	50
10	--	--	50	--
11	80	60	30	30

Trial #2

5	100	100	--	100
7	95	95	--	65
9	80	80	65	50
10	--	--	50	--
11	80	65	30	30

Trial #3

5	100	100	--	100
7	95	95	--	65
9	80	80	65	50
10	--	--	50	--
11	80	70	30	30

TABLE A-27. PILOT SCALE EQUIPMENT IN U.S. EPA SLUDGE DEATERING TRAILER

Description	Manufacturer
Solid Bowl Centrifuge	Sharples, Model P-600E
Basket Centrifuge	DeLaval, Model 12
Cloth Belt Vacuum Filter	Eimco, 0.92 m (3 ft) drum diameter by 0.46 m (1.5 ft) drum length
Filter Press	Dart-Hoesch, Model MP-300

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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Project Officer: Robert P. B. Bowker (513) 684-7620

16. ABSTRACT

Pilot scale studies at a 3.79 m^3/day (1,000 gpd) facility on septage treatment have indicated a number of alternatives exist. Screening with a 40-mesh (0.42 mm opening) vibrating screen yielded approximately 75 percent TSS removal as well as a resulting liquid that could be conditioned with conventional chemicals. Conditioning of screened septage with lime, ferric chloride, and/or alum yielded positive results but required extensive jar testing to optimize chemical dose(s). A two-stage acid/lime process was developed for conditioning which yielded consistent positive results with no jar testing required. The sludge fraction from various conditioning studies was dewatered by centrifugation, vacuum filtration, filter pressing and sand bed drying with the latter two techniques affording more positive results. The aqueous fraction from various conditioning studies was subjected to chlorination, activated carbon adsorption, intermittent sand filtration and conventional biological treatment at a municipal treatment plant with the latter two techniques yielding more positive results. Studies on leachate from dewatered septage solids buried in soil indicated soil type had a pronounced impact on leachate quality. Treatment of screened septage in a municipal secondary treatment plant was also investigated. Selected system designs and associated capital and operating costs for septage treatment are presented and discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sludges Septic tanks Screenings Treatment Settling Dewatering Disposal	Septic tank sludge (septage) treatment Septage treatment system design	13B
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