PB89-151401

EPA/600/2-89/001b
January 1989

COMPARATIVE EVALUATION OF MESOPHILIC AND THERMOPHILIC ANAEROBIC DIGESTION

PHASE II - STEADY STATE STUDIES

by:

Irwin J. Kugelman
and
Vincent G. Guida

Environmental Studies Center
Lehigh University
Bethlehem, Pennsylvania 18015

Cooperative Agreement No. CR811022

Project Officer:

Harry E. Bostian
Water and Hazardous Waste Treatment Research Division
Risk Reduction Engineering Laboratory
Cincinnati, Ohio 45268

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement #CR811022 to Lehigh University. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing of research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

One of the major procedures for stabilization of municipal wastewater sludge is anaerobic digestion. In this report a comparison is provided between operation of the process at mesophilic vs. thermophilic conditions.

E. Timothy Oppelt, Acting Director
Risk Reduction Engineering Laboratory

CONTENTS

FIGURES

TABLES

SECTION 1

INTRODUCTION

The purpose of this study was to conduct a comparative evaluation of the performance of anaerobic digestion systems under different temperature regimes. The temperature regimes chosen were those most commonly used in field installations (i.e., mesophilic 35°C and thermophilic 50-55°C). Evaluation of performance is in terms of a number of parameters including: stability of operation, degree of waste stabilization, dewaterability of digested sludge and odor.

The work has been divided into two phases. The first phase was reported on separately and dealt with operation of anaerobic digestion systems under temperature transitions. The second phase which is reported on here, deals with long term steady-state performance under mesophilic and thermophilic conditions. The basic question to be answered by Phase II is whether or not thermophilic anaerobic digestion is superior to mesophilic anaerobic digestion.

The evaluation of system performance under the two temperature conditions was conducted in large laboratory scale reactors (50 liter liquid capacity) using municipal primary sludge from the Allentown, PA Waste Water Treatment Plant. The systems were monitored for the following parameters: total gas and methane production, pH, alkalinity, total volatile acids, speciated volatile acids, total and soluble COD, ammonia-nitrogen, organic nitrogen, carbohydrate, oil and grease, total and volatile solids, and sludge dewaterability. Data were collected at 25-day HRT and 15-day HRT.

SECTION 2

CONCLUSIONS

1) Steady state operation above 50°C was characterized by poor performance. Volatile acids, especially propionic acid, were above 1,000 mg/l. Breakdown of various sludge components was less than under mesophilic conditions.

2) Consequently, long-term steady state data collection was obtained at 49.5°C in the thermophilic region.

3) In terms of pH, alkalinity, volatile acids, and methane production the long-term steady state performance at 49.5°C and 35°C was satisfactory at 25-day and 15-day HRT.

4) Under all conditions the performance of the mesophilic system was slightly superior to the thermophilic system.

5) At both detention times significantly higher breakdown of carbohydrate and oil and grease were achieved in the mesophilic unit.

6) At both detention times significantly higher breakdown of organic nitrogen occurred under thermophilic conditions.

7) At both detention times slightly higher destruction of total and volatile solids and COD occurred under mesophilic conditions.

8) The soluble COD of the thermophilic sludge was always at least 1,000 mg/l higher than for the mesophilic sludge.

9) At both detention times sludge dewaterability was significantly better, as measured by the CST test, under mesophilic conditions.

10) Sludge dewaterability for both temperature systems could be significantly improved by conditioning with ferric chloride. Higher doses were required for the thermophilic sludge.

11) Lime, both alone and with ferric chloride, had little effect on sludge dewaterability.

12) Performance of both systems was better, in terms of breakdown of raw sludge components, at 25-day detention time.

13) Detention Time had little effect on sludge dewaterability.

14) Thermophilic sludge odor was more disagreeable than that from mesophilic sludge even when volatile acids were low.

15) These data indicate that operation of anaerobic digestion at thermophilic conditions has no advantage over operation at mesophilic conditions.

SECTION 3

RECOMMENDATIONS

1) The observation reported on here of high propionic acid at temperatures above 50°C should be investigated. Pasteurization can be achieved by operation of anaerobic systems at temperatures above 50°C. This will not be possible unless the systems can operate without high propionic acid levels. The reason for the high propionic acid levels should be ascertained so that a remedy can be applied.

2) These studies should be repeated with a sludge feed which is a mixture of primary and secondary sludge.

3) These studies should be repeated at lower detention times.

4) Studies of the operation of anaerobic digestion over the whole temperature range from 35°C to 55°C should be conducted to determine the true optimum temperature for operation of this process.

SECTION 4

EXPERIMENTAL PLAN

The basic purpose of this phase of the study was to compare the performance of anaerobic digestion processes at thermophilic and mesophilic conditions. Comparison was based on parallel steady-state operation over periods of several months using a feed of raw primary sludge from a municipal treatment plant. Evaluation of performance was based on measurement of total gas production, methane production, COD destruction, grease destruction, carbohydrate destruction, organic nitrogen destruction, total and volatile solids destruction and sludge dewaterability. Two periods of steady-state operation were intensively monitored. One period lasted almost six months during which the hydraulic detention time was maintained at 25 days. After a short transition period of two weeks at a 20-day detention time, a second period of steady-state operation at a 15-day hydraulic detention was carried out for a two and one-half month period.

SECTION 5

EXPERIMENTAL PROCEDURES

APPARATUS

The anaerobic reactors used in this study are illustrated in Figures 1 and 2. These were constructed of lucite and were rectangular in cross section. Interior bottom panels sloped from the vertical sides to the split pipe outlet which in turn was centered in the base of the unit. This insured that there were no dead spaces near the bottom of the unit. Total volume of each reactor was approximately 75 liters, with 50 liters of liquid maintained in the unit at a detention time of 25 days and 45 liters of liquid maintained during the period when the detention time was 15 days. Each unit was mixed by gas recirculation using a diaphram type gas pump rated at 9.5 liters per minute with a maximum pressure of 18 psi. The operation of the mixing pumps was not continuous but rather was controlled by a timer set to turn the pumps on 6 minutes each one-half hour.

An alternate mixing technique which could be used was a hand operated diaphram pump which could circulate the liquid sludge from the bottom of the unit to the top through an external pipe. Each stroke of this hand pump could displace approximately 300 ml of liquid sludge.

The inlet and outlet lines for the feed and digested sludge were 1" schedule 80 PVC pipe. Full flow ball values of the same material and size were used to control flow in and out of the unit.

Gas measurement was made with a Wet Tip Gas Meter (Wet Tip Meter Co., Wayne, PA.) which functions on the liquid displacement tipping bucket principle. These meters were calibrated against a Wet Test Meter at the gas flow rate anticipated in the anaerobic reactors (1-5 liters per hour). The wet tip type meter provides a water seal on the gas outlet line with a back pressure equal to the water depth in the meter (5 1/2 inches).

OPERATION

Raw primary sludge was periodically collected from the Allentown, PA. Sewage Treatment Plant. This is a typical municipal treatment plant serving a large metropolitan area. It has a reasonable mix of domestic and industrial wastes (plating, brewery, meat packing, food processing, truck assembly). The sludges at this plant are separated so that the primary sludge contains little or no secondary sludge. Sludge is digested at this

Figure 1. Operational diagram of anaerobic digestion unit.

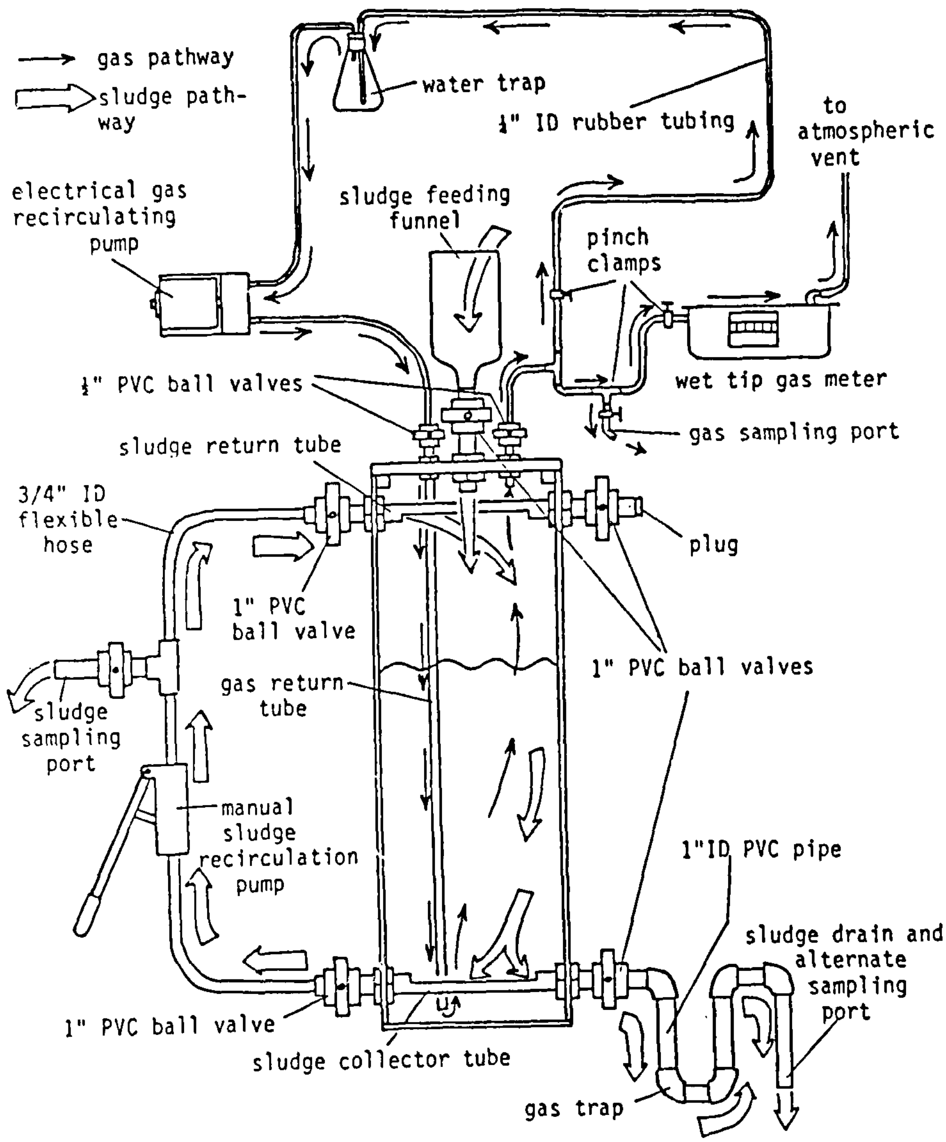
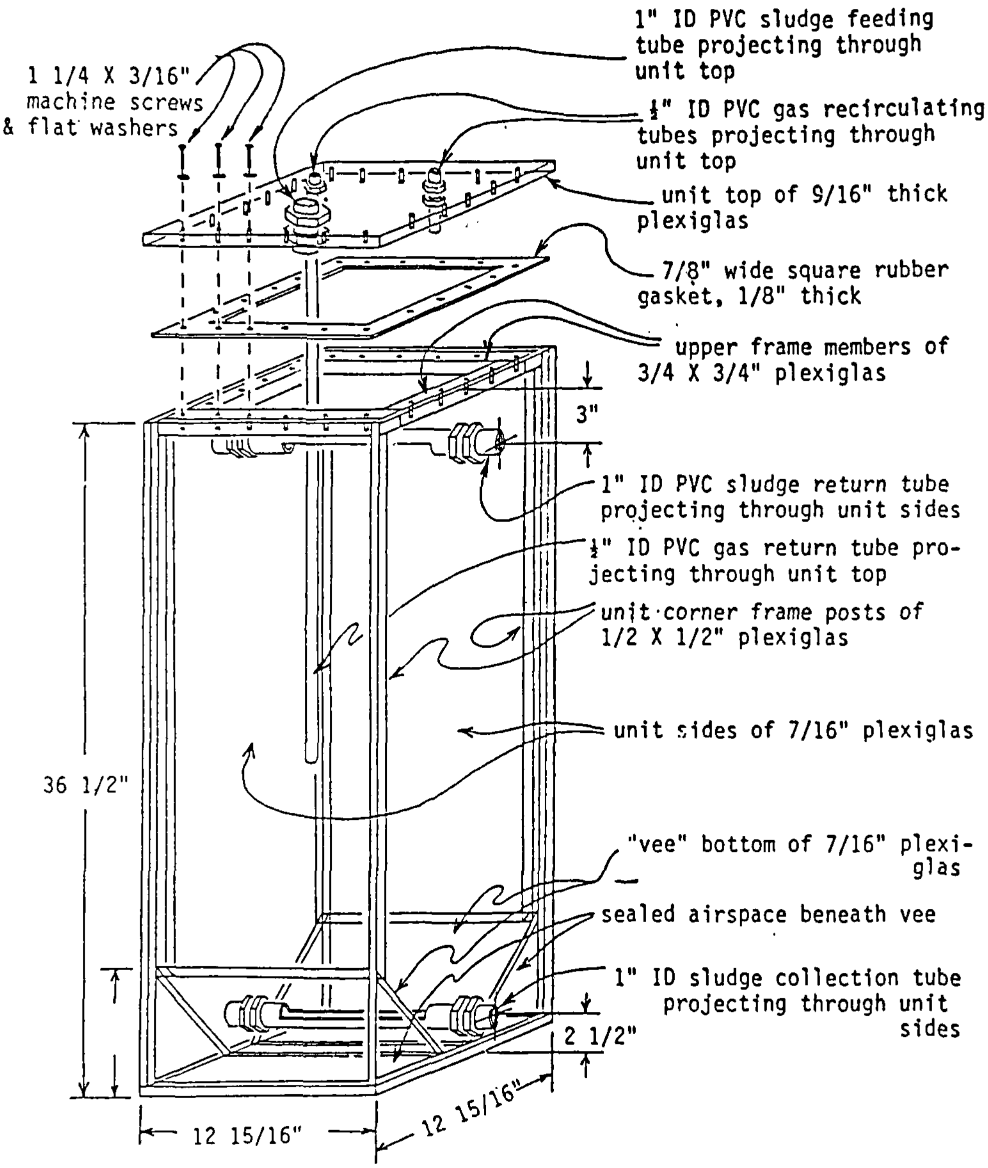


Figure 2. Details of construction of anaerobic digestion unit.



plant in a mesophilic digester which usually operates at a 20-day detention time. In order to control odors, raw primary sludge is rapidly pumped from the primary clarifiers, thus thickening does not usually occur in the primaries. Sludge was collected as it was being pumped from the primary to the sludge handling area.

The sludge collected was transported to Lehigh University Environmental Studies Center and kept under refrigeration at 4°C until used. Sludge was usually collected once per week. Upon being brought to the laboratory the sludge was sampled for total and volatile solids analysis. These data were used to determine if the sludge had to be diluted prior to use. Dilution was with Bethlehem, PA tap water. It was decided early in the study to maintain a constant total solids concentration in the feed. The original target was 4%, but after one month of sludge feed to the units this value was changed to 3.5%. The latter was chosen when experience indicated that sludge obtained from this plant often was in the range 3.5% to 4.0% solids. The sludge was relatively weak because as indicated above thickening was not conducted in the primary clarifier. Each sludge batch was kept in a 10-gallon plastic container under refrigeration.

Two anaerobic reactors described previously were used in this study. Each was kept in a walk-in temperature-controlled room. The gas meters were also housed in the respective rooms. Temperature control was achieved with the use of a thermostat and an electric space heater. A large air circulation fan was run continuously in each incubator to maintain uniform temperature distribution. Each thermostat could keep the air temperature at ±1°C from the set point. The temperature in each unit, however, was ± 0.1°C from the set point because the large mass of water in each reactor evened out the air temperature swings.

Each reactor received identical treatment except for the temperature. Feed of raw sludge and withdrawal of digested sludge was conducted once per day. The procedure was:

1) Several hours prior to the feeding time the proper quantity of sludge was taken from the 10-gallon reservoir in the refrigerator and placed in the incubation room to warm it prior to feeding: Dilution if necessary took place at this time using Bethlehem tapwater maintained in the incubator room.

2) At the appointed time the gas meter reading was recorded.

3) The valve from the reactor to the gas meter was closed.

4) The hand pump was used for a minute to circulate sludge. Simultaneously the gas recirculation pump was activated.

5) Sludge was withdrawn through the bottom outlet line into a bucket, and then was put back into the unit through the feed reservoir in the top.

6) This procedure in (5) was repeated several times until the layer of solids and foam at the top of the reactor was completely broken up.

The hand pumping and gas recirculation was not able to break up this layer even though the main body of sludge was, by visual observation, well mixed. Only the cascade of sludge from the inlet line was able to disperse, temporarily, this layer. The level of liquid in the reactor was checked against a calibrated scale on the reactor side. If the level was low (due to evaporation) make up Bethlehem tap water was added.

7) After the layer at the top of the liquid was dispersed and the water level adjusted, the daily sample was withdrawn.

8) The feed was then placed in the feed funnel at the top of the reactor, and entered the unit when the 1" feed valve was opened. In step 3 it had been indicated that the gas outlet valve was closed. This valve was kept closed throughout the procedure in steps 3 through 8. Thus when the daily withdrawal was made in step 7 the system was placed under a vacuum. This procedure facilitated the feeding of the raw sludge slurry in step 8, as the vacuum helped pull the sludge into the reactor.

9) After feeding, the valve in the gas outlet line was opened to restore gas flow to the gas meter.

ANALYSIS OF SLUDGE AND GAS

Periodically the raw sludge, digested sludge and gas produced were analysed for a variety of parameters. The procedures used are presented below:

Gas Measurement and Analysis

Gas volume production was measured with a "Wet Tip Gas Meter". In this type of meter the gas enters a submerged housing and displaces water. When sufficient water is displaced a counterweight causes the housing to tip and this event is recorded on an electronic counter. The housing is double sided and piped so that after tipping, gas is directed to the now submerged side and the process is repeated. Each count represents a standard volume which is a function of the adjustable counter weight position. The manufacturer claims accuracy at 97% to 99% up to 500 ml/minute. In this study the meters were calibrated periodically against a Wet Test Meter. A problem encountered was that the counterweight gradually changed due to accumulation of sediment in the water. This was generated by reaction between the digester gas and the water in the meter. Another was the need to periodically add make up water to the meter to counteract evaporation. Except for several periods when problems such as counterfailure and leakage in the inlet line were encountered the gas volume measurement was satisfactory.

Analysis of the gas for methane and carbon dioxide was conducted using a Fisher Gas Partitioner (1) which operates on the thermal conductivity principle. Gas samples were taken from the head space of the reactor through a gas sampling port using 100 ml capacity glass bulbs connected to a reservoir bottle filled with acid-salt solution. The partitioner was calibrated before each use with 100% methane, 100% carbon dioxide and 100% nitrogen. These produced peak heights on the apparatus recorder as a function of signal attenuation setting. The samples were run at the same attenuation setting as were used for the calibration. Volumetric percentage of each gas in the sample was determined by ratio of peak height of each component to that produced by the 100% standard. This procedure is considered accurate to about 1%.

pH

pH was determined using an electronic pH meter, Fisher Model 830 Acumet. Temperature compensation was used with a glass electrode. The procedures in "Standard Methods" (2) were followed.

Alkalinity

Alkalinity was determined by the titrametric procedure in "Standard Methods" (2). One hundred milliliter samples of sludge were titrated with 1N sulfuric acid to pH 4.2.

Volatile Acids

Total volatile acids were determined by the direct distillation method presented in "Standard Methods" (2). Volatile acids were speciated on a Dionex Ion Chromatograph using specific conductance as the detection technique. Separation of formic, acetic, propionic, butyric and lactic acids (non-volatile) was accomplished on a Dionex ASI anion column preceded by an anion guard column. A Model 14 Ion Chromatograph was modified to allow high pressure operation necessary to speciate volatile acids. Calibration was by standards of the pure acids at 10, 100 and 1000 mg/l. Sample analysis was by the peak height ratio method. Prior to injection in the Ion Chromatograph, the sludge sample was filtered through a 0.45 u membrane filter and the pH was adjusted to pH 4.3 with nitric acid.

Total and Volatile Solids

The procedures used were in accordance with "Standard Methods"(2). Raw sludge analyses were performed in triplicate; for digested sludge duplicates were used. Results were almost always ±2% of the average. The sludge was ground in a Waring blender prior to analysis.

Ammonia Nitrogen and TKN

Analysis was in accordance with the Kjeldahl (Macro) procedures in "Standard Methods"(2). Distillate was collected in boric acid and titrated with N/50 sulfuric acid. Duplicates were run on all samples and reported as the average. All sludge was ground in a Waring blender prior to analysis.

Grease and Oil

Determination was by the Soxhlet Extraction method given in "Standard Methods"(2). Only single samples were run.

Chemical Oxygen Demand

COD was determined by the Open Reflux Method given in "Standard Methods" (2). Soluble COD was run on sludge filtered through 0.45 u membrane filters. The sludge was ground in a Waring blender prior to analysis.

Carbohydrate

Total and soluble carbohydrate was determined by the method of Dubois et al. (3), as modified by Herbert et al.(4) and Kampmeier et al. (5). It is a colorimetric procedure in which phenol and hot sulfuric acid react with sugars to form an orange chromophore. The color is read in the range 480-450 nm. Standards are prepared using glucose. All sludges were ground prior to use in a Waring blender and soluble carbohydrate was determined on the filtrate from a 0.45 u membrane filter.

Capillary Suction Time (CST)

Sludge dewaterability was determined by the CST test using the apparatus produced by Triton Electronics LTD. of England. Unconditioned sludge was measured using the 3/4" diameter cup. Conditioned sludge was measured using the 3/8" diameter cup. The results reported are average of triplicates.

PRELIMINARY STUDIES

During the summer of 1986 the two reactor systems were constructed, leaks corrected, and seeded with digested sludge from the Allentown mesophilic digester. In addition, several gallons of the thermophilic sludge saved from Phase I (under refrigeration) was added to the thermophilic digester. Initially the digestors were fed the artificial substrate used in Phase I. The mesophilic unit was set at 35°C, the thermophilic unit in the range of 53 to 55°C. For several weeks biological action was satisfactory in both units but then gas production started dropping in the thermophilic unit and volatile acids increased. Addition of more sludge from the store saved from Phase I temporarily alleviated the problem, but as the seed was washed out by successive feedings poor performance returned. In September thermophilic digested sludge was obtained from the Rockaway Plant in New York City and added to the thermophilic unit. The feed was changed to a mixture of glucose and whole milk as it became difficult to obtain the original version of Carnation Instant Breakfast. The temperature was reduced to the range 50°C to 52°C as the New York City sludge digester was being operated at approximately 50°C. Again after several weeks poor performance set in. Near the end of October a dose of 25 mg/l of yeast extract was added to the thermophilic digester.

In less than two days gas production markedly increased and volatile acids returned to normal. It should be noted here that the high levels of volatile acids during this phase were almost completely propionic acid. Direct additions of acetic and butyric acid to the reactor resulted in rapid reduction of these acids in one day. Propionic acid on the other had never declined until yeast extract was added.

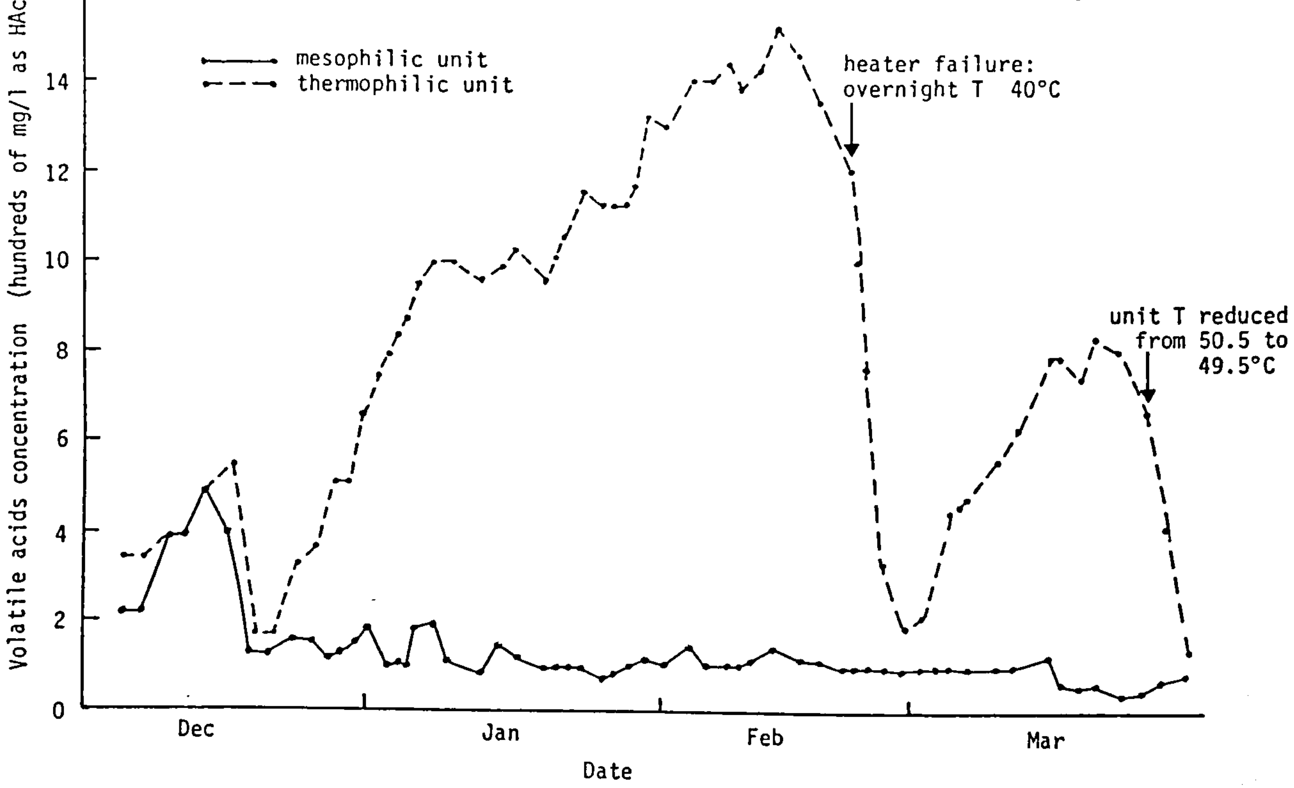
During this period of several months the mesophilic unit always exhibited good performance even without the addition of yeast extract. Eventually yeast extract was added to both units in order to keep their operation, except for temperature, identical. For a period of one month successful operation was achieved in both reactors using a feed of glucose and whole milk. Measurement of the methane production indicated that virtually all of the organics being fed were converted to methane. Consequently, at the end of November the feed was changed to raw primary sludge and the operation at a 25-day detention time begun. As indicated above, 25 mg/l of yeast extract (Difco) was added to the feed each day.

LONG RANGE OPERATION AND RESULTS

For a six-month period the reactors were operated at a 25-day detention time. No change in the operation of the mesophilic digester was necessary during that period. However, a significant change in the operation of the thermophilic digester was made after 3 1/2 months of operation. At that time the temperature was reduced from slightly above 50°C to slightly below 50°C. This was done in order to improve the operation of the thermophilic system. Figure 3 illustrates the volatile acids levels in both digestors starting in the beginning of December, 1986. It can be seen that the volatile acid level in the mesophilic digester was consistently low. However, the level in the thermophilic system gradually increased and reached a level of 1500 mg/l by the middle of February, 1987. Reference to Table A-5 which gives information on the volatile acid speciation indicates that approximately 90% of the volatile acids present in the thermophilic unit was propionic acid. Gas production and COD data were in accordance with the high levels of volatile acids in the thermophilic unit; that is gas production was lower and COD was higher in the thermophilic vs. the mesophilic unit (See Tables 6 and 8).

During the last week in February, the heater in the thermophilic room failed. Over night the temperature dropped to approximately 40°C. The heater was repaired and by the next day the temperature had returned to its usual value of 51°C. Surprisingly, during the day when the temperature was low, a much larger quantity of gas was evolved from the thermophilic unit than usual and volatile acids showed a significant drop. By the end of February, the volatile acids in the thermophilic unit were almost as low as those in the mesophilic unit. In addition, it was noted that the propionic acid comprised only 20% of the volatile acids in the thermophilic unit. The data for March indicates that a slow rise in volatile acids at about the same rate as had occurred in December and January. The propionic acid fraction of the total volatile acids rose to 70%. At this point the temperature set point of the thermophilic room was reduced to keep the

Figure 3. Volatile acids concentration in mesophilic and thermophilic digesters versus date. Mesophilic digester temperature was 35°C, thermophilic temperature exceeded 50°C except as noted. Hydraulic detention time in both cases was 25 days.



temperature in the unit between 49°C and 50°C. Volatile acids, especially the propionic acid, rapidly fell to levels which approximated those in the mesophilic unit. Based on this evidence, the temperature in the thermophilic unit was maintained at 49.5°C for the remainder of this study.

The operation at 25-day detention time was maintained through April and May. At the end of May the detention time was reduced to 20 days. Maintenance of operation at this detention time was intended for several more months. However, after two weeks the detention time was converted to 15 days which was maintained for the next 2 1/2 months. This latter change was made because it was felt that a 15-day detention time was more representative of field conditions.

Once the temperature in the thermophilic unit was reduced to 49.5°C essentially trouble free operation was maintained in both units. The data which are presented here are basically broken into 4 periods of operation:

Time Period	Detention Time	Temperature	
		Thermophilic	Mesophilic
December 1986 - March 1987	25 days	50.5	35.0
April May 1987	25 days	49.5	35.0
First-half June 1987	20 days	49.5	35.0
Last-half June August 1987	15 day	49.5	35.0

<u>Raw Sludge Characteristics</u>

The characteristics of the raw sludge fed to the digestors during this study are presented in Tables A-1, A-2, and A-3. Table A-1 presents the data on raw sludge solids (total and volatile). Also presented are the dates when the sludge was procured from the Allentown, PA. STP and the dates it was fed to the anaerobic reactors. Table A-2 presents the analyses of the full strength sludge for various parameters and Table A-3 gives the values of these parameters after dilution of the raw sludge. As indicated previously dilution was used to reduce the total solids in the actual feed to 3.5%. All analyses were conducted on the full strength feed rather than the diluted material. It was thought that more accurate results would be obtained using this technique, as the inaccuracy in making dilutions and sampling small volumes would be avoided. All samples of raw sludge used for analysis were ground in a Waring blender prior to the start of the analyses. It should be noted that batches of raw sludge obtained on a specific date were fed to the systems during different consecutive periods and that the sludge characteristics changed significantly from one period to another. For example, the sludge obtained on 4/27/87 was used for three consecutive periods 4/28-5/4, 5/5-5/11, and 5/12-5/18. These three periods represent separate fillings of the 10-gallon storage reservoir from individual 5-gallon buckets used to transport sludge from the treatment plant. It was found the the sludge although collected at the same time was occasionally significantly different in each of the 5-gal. buckets. Thus the differences between consecutive 10-gal. units of sludge were not mainly due to deterioration of the sludge in storage. The results given in Table A-1, A-

2, and A-3 indicate little difference in this sludge from that considered typical raw sludge. The major differences were a consistently high volatile fraction of solids (generally >80%), and high grease and oil content. The latter is probably responsible for the high volatile solids content.

pH, Alkalinity and Volatile Acids - Digested Sludge

Table A-4 presents pH, alkalinity, and total volatile acids data for the effluent from the two systems throughout the study. Except for the period of high volatile acids discussed previously volatile acids were usually quite low approximately 100-250 mg/l. For a few days after the change from a 20-day detention time to a 15-day detention time, the volatile acids in the thermophilic unit increased slightly, but soon they fell to the usual levels. With respect to volatile acid speciation as shown in Table A-5, there was no specific trend except for that discussed earlier when the temperature was above 50°C. Once the temperature was reduced to below 50°C the predominant volatile acid in the thermophilic unit was acetic acid. In the mesophilic unit sometimes acetic was dominant, sometimes propionic was dominant and at other times both were approximately equal.

The pH and alkalinity data indicate that both were consistently higher in the thermophilic unit, although the magnitude of the differences were small. These data reflect the higher breakdown of organic nitrogen observed in the thermophilic unit. Breakdown of organic nitrogen leads to the formation of ammonium bicarbonate which titrates as alkalinity. This compound serves as the main buffer in anaerobic treatment systems. Table A-9 which presents data on the ammonia-N concentration in these units and Table A-4 illustrate the correlation between these two parameters. The pH and alkalinity were both in the normal range of these parameters for anaerobic digestion systems.

Gas Production

Gas production data are presented in Table A-6. The methane fraction was similar in both units. It ranged from 57.5% to 64.5% with a mean close to 60%. Daily gas production was relatively constant; changing only in response to changes in strength of the feed. These data have been converted to volumes of gas at 0°C and 1 atmosphere pressure but have not been converted to a dry gas basis. Assuming the gas was saturated with water vapor at the temperature of the reactor and that the mixture of methane, carbon dioxide and water vapor acts as an ideal gas, the correction factor to be applied to the data in A-6 to convert to dry gas basis is 0.8813 at 49.5°C and 0.9445 at 35°C.

Total and Volatile Solids - Digested Sludge

Data on total and volatile solids are given in Table A-7 and are plotted along with the raw sludge data on solids in Figures 4 and 5. It can be seen that total and volatile solids were almost always higher in the thermophilic unit than the mesophilic unit. The differences were most pronounced during the period when the thermophilic unit was at a temperature above 50°C. But, during the latter part of May and August (the end of each steady-state period), solids levels in both units were almost the same. In July total solids levels in both units suddenly peaked at 2.2% to 2.35% and then dropped back to the usual levels near 2.0%. this coincided with increases in raw and digested sludge organic nitrogen, and oil and grease. Overall volatile solids destruction was higher in the mesophilic unit than the thermophilic unit.

COD

Chemical oxygen demand, total and soluble, in each reactor is presented in Table A-8. These data along with the raw sludge COD are presented in Figure 6. Prior to lowering the thermophilic temperature below 50°C the COD of the thermophilic unit was consistently higher than that of the mesophilic unit. During the April-May period (25-day detention time after thermophilic temperature was lowered) the COD of both units was similar. After reduction of the detention time the COD of the thermophilic sludge was initially higher than that of the mesophilic sludge. Much of this difference was eliminated by the end of the 15-day detention time operation.

The soluble COD data indicate that the thermophilic unit had a soluble COD about 1400 to 1700 mg/l higher than in the mesophilic unit. The difference was greater in the period when the thermophilic unit was operated at temperatures above 50°C. Indeed, the first period of lower temperature operation when the space heater failed can be seen on the soluble COD plot; as a significant drop in soluble COD in the latter part of February. However, even under the best of thermophilic operation a definite difference in soluble COD was observed.

Nitrogen

Nitrogen analyses of the reactor contents as well as the raw sludge feed are presented in Table A-9 and Figures 7 and 8. It can be seen that the ammonia-N was always higher and the organic nitrogen was always lower in the thermophilic unit. Since the TKN of both units was the same these data indicate superior organic nitrogen conversion to ammonia-N in the thermophilic unit. The difference was higher at 25-day detention time than at 15-day detention time. The quantitative differences will be discussed later in this report. As indicated previously because of the higher degree of conversion of organic nitrogen to ammonia-N the pH and alkalinity were always higher in the thermophilic than in the mesophilic unit.

Oil and Grease

Table A-10 and Figure 9 presents the oil and grease data collected during this study. It can be seen that the reduction of oil and grease was higher in the mesophilic unit than in the thermophilic unit. This difference was especially pronounced when the thermophilic unit was operated above 50°C because volatile acids are measured as grease and oil in this particular analytical test. There seems to be little change in the difference between the units which could be ascribed to the reduction of the detention time to 15 days. These data will be reviewed later in this report.

Figure 4. Total solids versus date for raw, thermophilic, and mesophilic sludges.

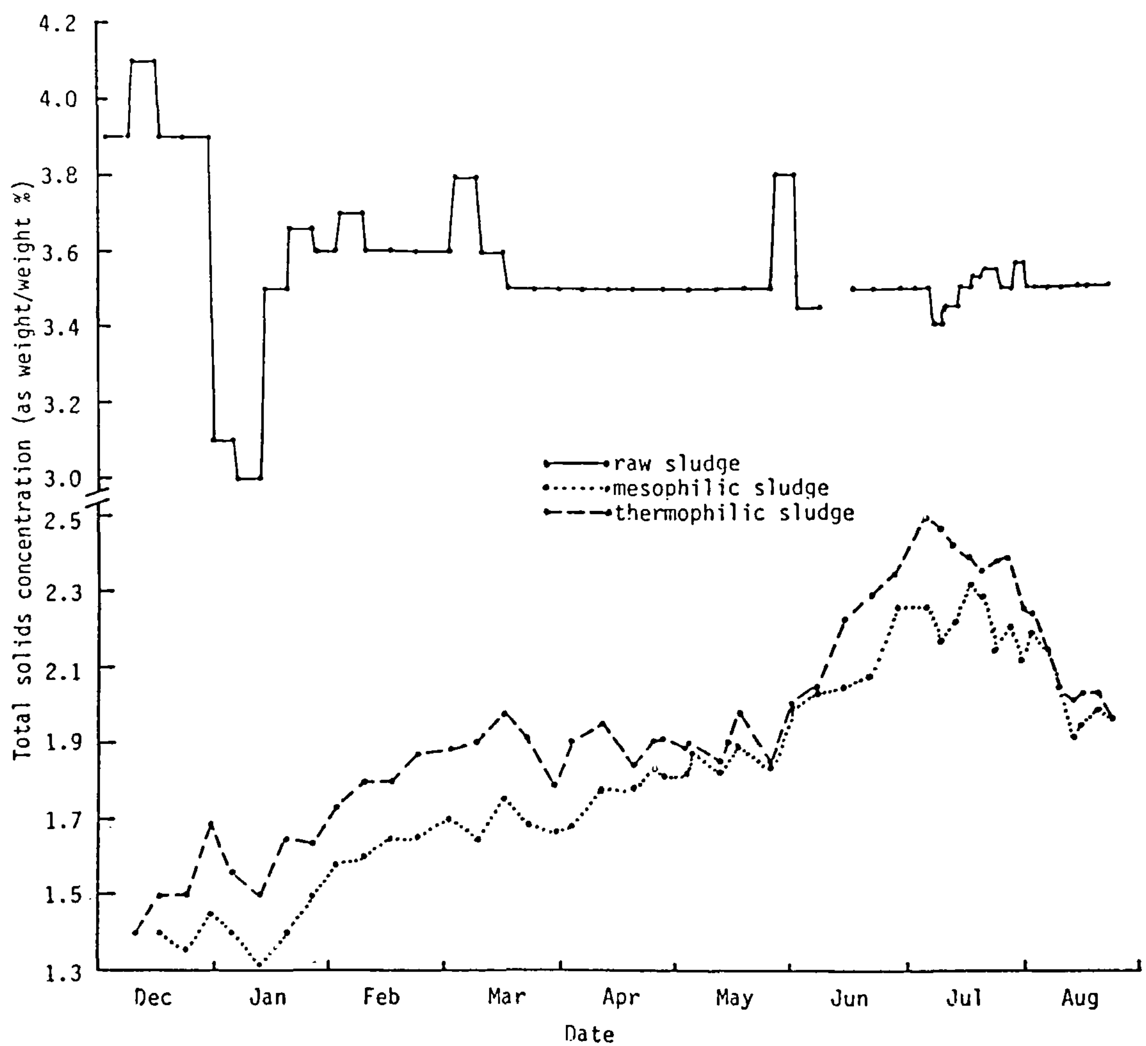


Figure 5. Volatile solids fraction for raw, mesophilic and thermophilic sludges versus date.

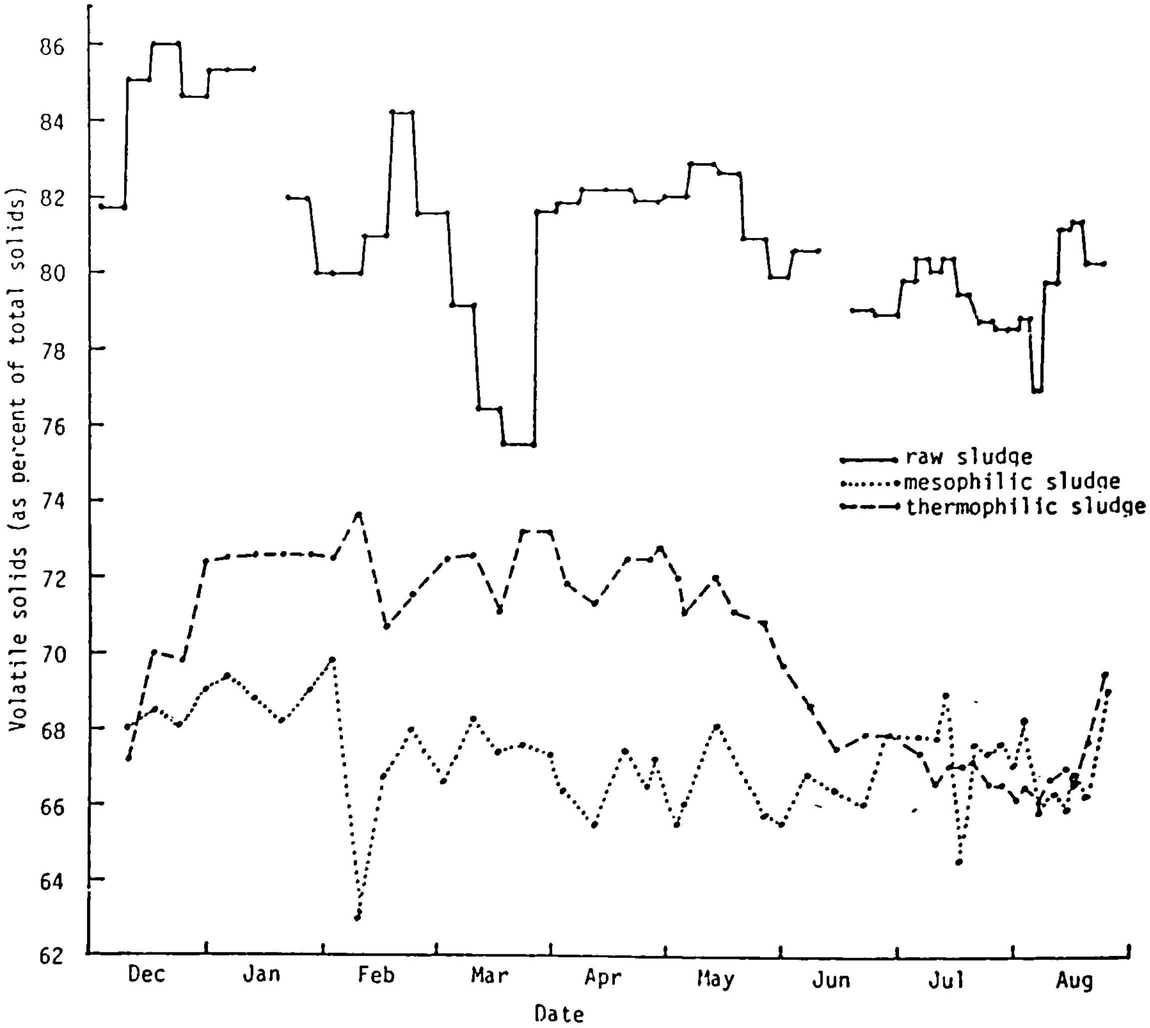
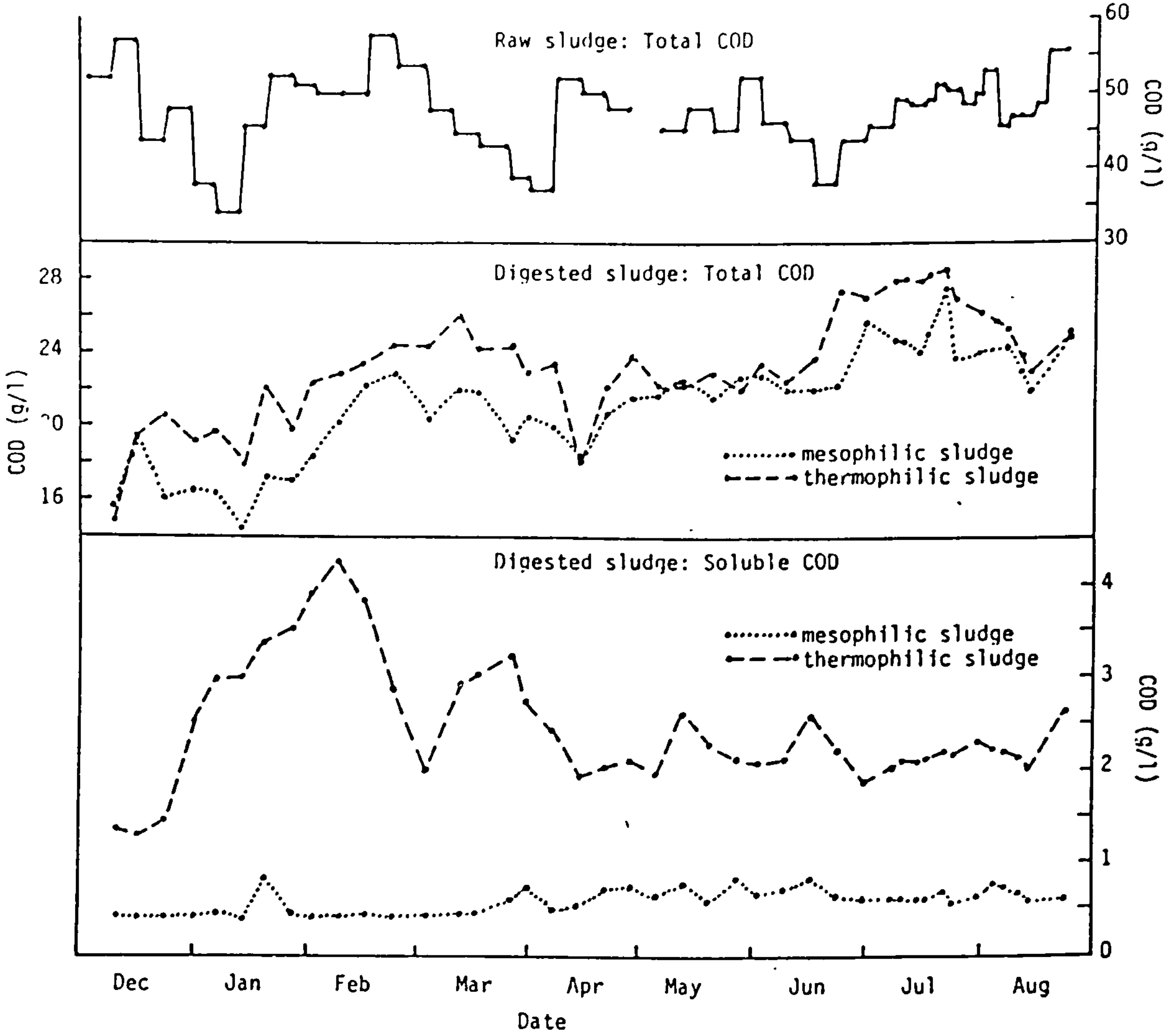


Figure 6. Total and soluble chemical oxygen demand (COD) in raw and digested sludges.



Carbohydrate

Sludge carbohydrate measurements were only conducted during the 15-day detention time operation because the method of analysis utilized was not found until late in the Spring, 1987. These data are presented in Table A-11 and Figure 10. Total carbohydrate reduction was higher in the mesophilic unit than in the thermophilic unit. The difference ranged from 500 mg/l to 1200 mg/l. Soluble COD was also lower in the mesophilic averaging about 50 mg/l less than in the thermophilic unit.

Sludge Dewaterability

Throughout most of the study measurements were made on the dewaterability of the effluent from each unit. Preliminary tests were performed using three methods of dewatering. One technique was the Capillary Suction Time Test (CST), another was the Buchner Funnel Filtration Test, the third was a batch centrifugation test developed by Vesiland (6). It was found that the latter two tests were very difficult to run unless the sludge was conditioned with a coagulant. The CST test, however, gave reasonable measurements with and without the addition of coagulants. Thus, the CST test was used to characterize the difference between both types of sludge. Table A-12 and Figure 11 present data on the CST measurement for the sludges throughout the steady-state portion of this test. The measurements in March were made at room temperature but the temperature was not recorded. Starting in the beginning of May, temperature was recorded and eventually the temperature at which the test was conducted was standardized at 25°C. The results substantially indicate that the thermophilic sludge was more difficult to dewater in an unconditioned state than the mesophilic sludge. Visual observation of the sludge clearly indicated better separation under gravity conditions for the mesophilic sludge. In addition, the sludge supernatant was visibly dirtier for the thermophilic sludge. This indicates that the size of digested sludge particles in the thermophilic sludge was smaller than in the mesophilic sludge. When the sludge was subjected to centrifugation without conditioners present, the thermophilic centrate was much dirtier than that from the mesophilic sludge, although the depth of the solids pool was almost the same for both sludges.

On July 5 CST measurements were made at 25°C, 49.5°C and 35°C. This was achieved by bringing the CST apparatus into the incubation rooms. As would be expected, the CST was lower at the higher temperatures. The ratio of CST at the higher temperature to the reference temperature (25°C) was 300/377 for the mesophilic and 415/534 for the thermophilic. The ratio for the mesophilic sludge is that expected based on the viscosity of water at 35°C and 25°C. However, the ratio for the thermophilic sludge is not in accordance with the viscosity ratio of water at 49°C vs. 25°C.

In addition to the unconditioned tests some tests were conducted in which sludge was conditioned with ferric chloride and/or lime. These data are presented in Table A-13. It can be seen that ferric chloride conditioning had a significant affect on the CST values of both sludges.

Figure 7. Ammonia concentration of raw, mesophilic, and thermophilic sludges versus date.

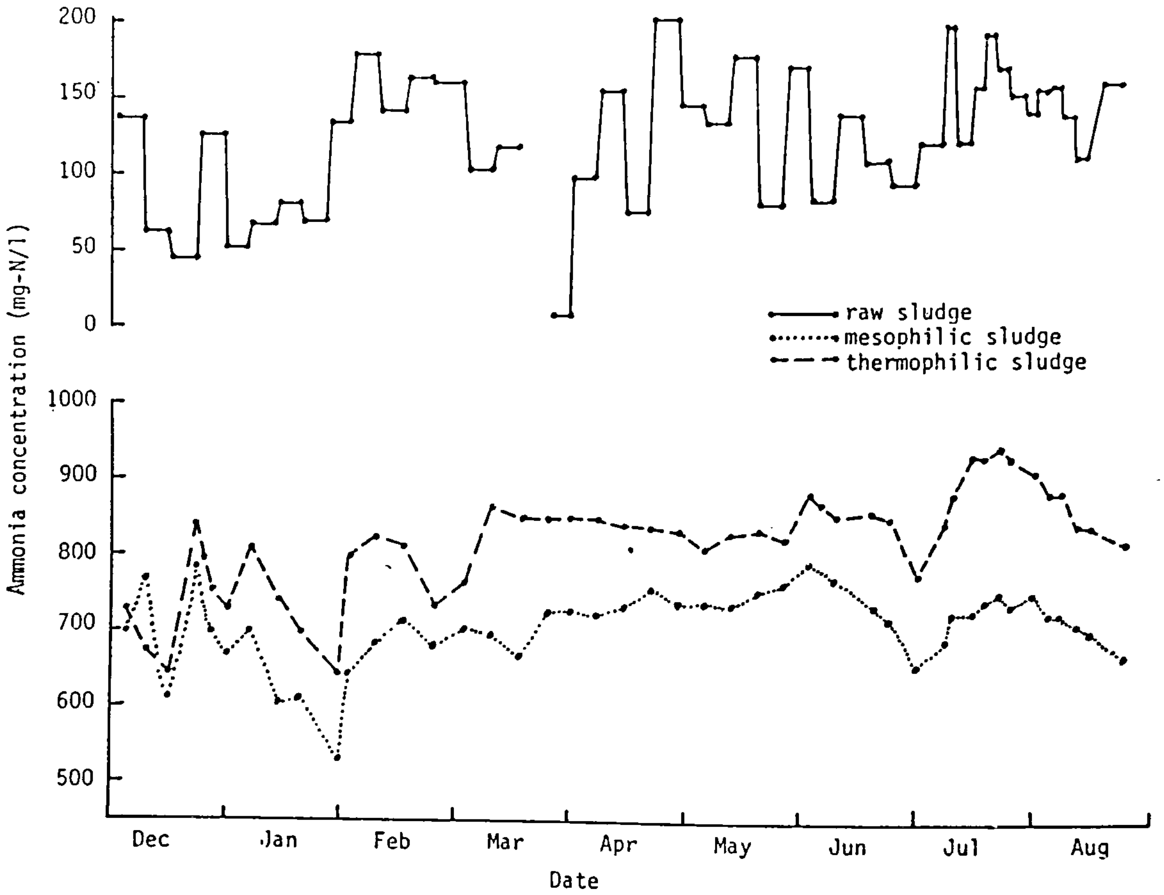


Figure 8. Organic nitrogen concentration of raw, mesophilic, and thermophilic sludges versus date.

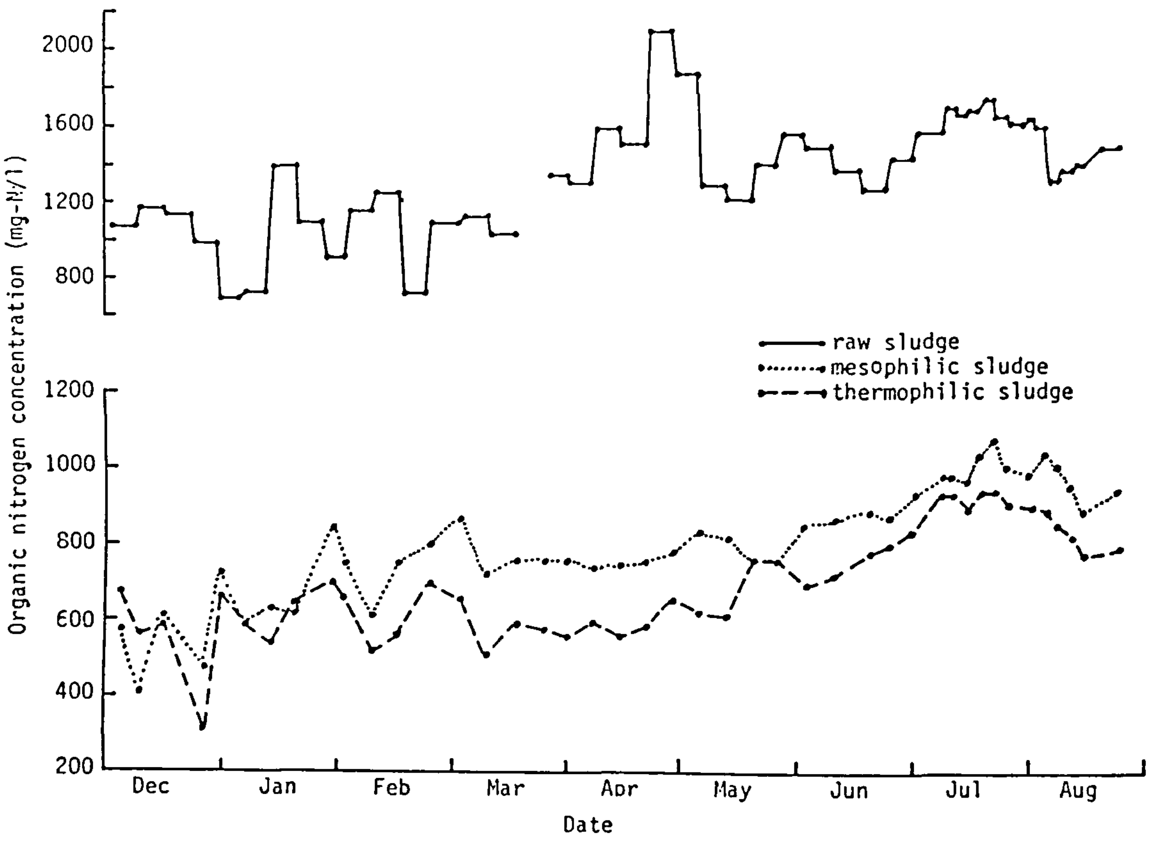


Figure 9. Oil and grease concentrations in raw, mesophilic, and thermophilic sludges versus date.

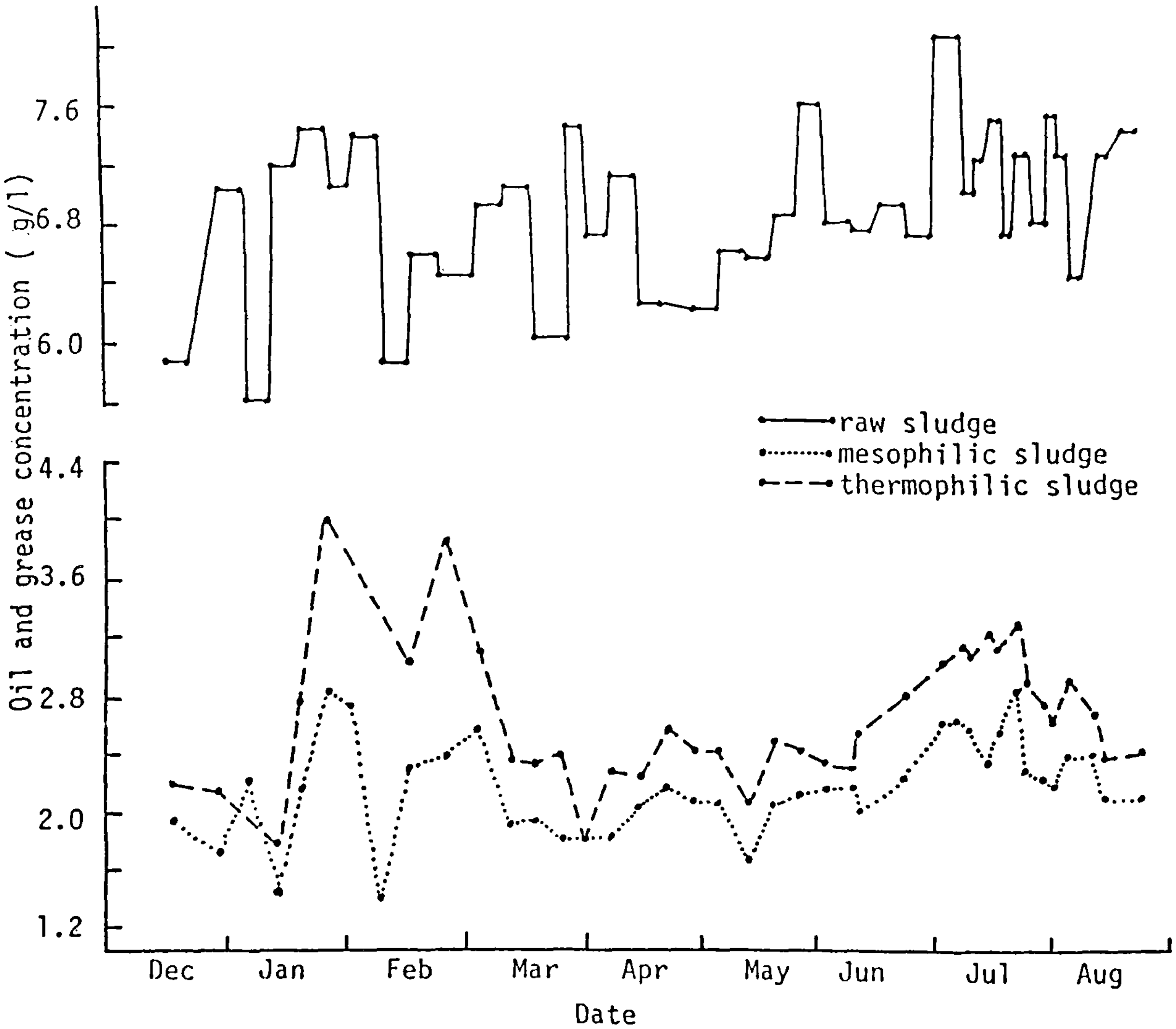
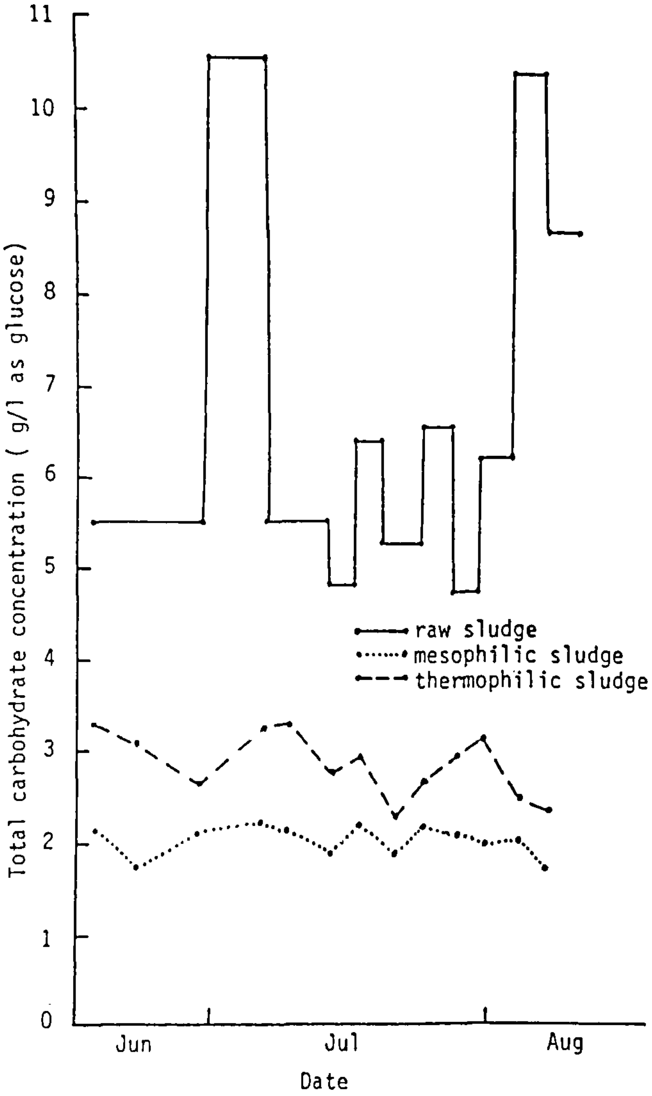
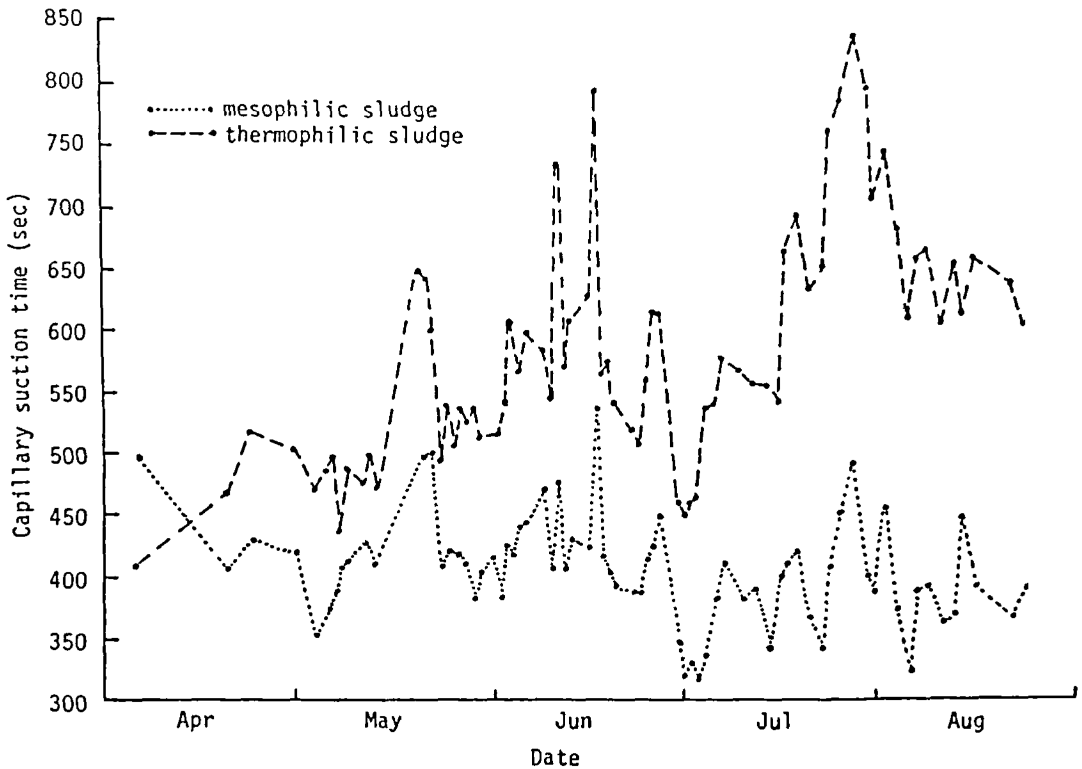


Figure 10. Total carbohydrate concentration in raw, mesophilic, and thermophilic sludges versus date.



The addition of lime to a sludge already conditioned with ferric chloride had little effect above that achieved with the ferric chloride alone. The use of lime alone had little or no effect on the sludge. The dose of ferric chloride required to achieve very low CST values was generally between 4 and 5 g/l, for the mesophilic sludge. A dose of >5 g/l ferric chloride was required to achieve good results with the thermophilic sludge. Although higher doses of ferric chloride, with produced better dewatering, also effected the greatest pH reduction, equivalent results between mesophilic and thermophilic conditioned sludge were not obtained until the pH was reduced to 4.3. The ferric chloride dose required to properly condition mesophilic sludge was always less than that required to condition thermophilic sludge.

Figure 11. Mean capillary suction time for mesophilic and thermophilic sludges versus date.



SECTION 6

DISCUSSION OF RESULTS

In this study two large anaerobic reactors were operated in parallel for several months at each detention time. The only difference between the two reactors was that one was maintained at 35°C while the other was maintained at temperatures both above and below 50°C. It was found that high volatile acids (primarily propionic acid) were present when the temperature was above 50°C. When the temperature was reduced to 49.5°C the propionic acid fell to low levels and the overall performance of the thermophilic system approximated that of the mesophilic system. Recent studies (7) (8) have indicated high volatile acids, especially propionic acid, under thermophilic anaerobic conditions. Thus the finding here concerning propionic acid is verified by others. However, no reference to this very sharp change at 50°C has been found in the literature. This phenomenon should be investigated because it may be a limiting step in the application of thermophilic digestion.

A comparison of the performance of both systems under steady state conditions is given below.

TABLE 1. SUMMARY OF PERFORMANCE OF MESOPHILIC AND THERMOPHILIC DIGESTERS

Detention Time	Unit	Volatile Solids	COD D.M.	COD Gas	Organic Nitrogen	Grease & Oil	Carbohydrate
25	T	51.7	52.6	53.2	59.4	65.0	-
25	M	57.2	52.9	63.1	50.2	71.2	-
15	T	44.7	44.2	53.3	44.9	59.3	56.2
15	M	47.0	49.9	56.8	27.2	67.4	68.8

The thermophilic system data are for the period when the temperature was 49.5°C. This Table 1 reviews the percent removal of volatile solids, COD, organic nitrogen, grease and oil, and carbohydrate. The COD removal was calculated on two bases; direct measurement of COD in the effluent and calculation of the COD equivalent of the methane gas produced during reactor operation. Carbohydrate data were only available at a 15-day detention time while the other data cover both 25-day detention time and 15-day detention time. It must be emphasized that by all normal parameters the operation of each reactor system was satisfactory. Alkalinity, pH, volatile acids, fraction of methane in the gas were all in the normal range. However, as indicated below the mesophilic unit consistently out performed the thermophilic unit except for organic nitrogen breakdown. In general the degree of advantage which the mesophilic unit had over the thermophilic unit was small, but quantifiable. As would be anticipated, the performance of either system was better at the 25-day detention time than the 15-day detention time. Several field-scale studies of thermophilic vs. mesophilic anaerobic digestion have been conducted in the U.S. (9) (10) (11). All of these have indicated essentially identical performance for both systems. The data obtained in this study could be interpreted to support the conclusions of these studies or to refute it; as the difference in performance between the two systems was modest.

Another factor which was investigated in this study was the dewaterability characteristics of the sludge produced under mesophilic and thermophilic conditions. This has been a point of controversy because the results have been conflicting. Some studies indicate superior dewaterability (10) for thermophilic sludge, others indicate the reverse situation (9). The studies here clearly demonstrate that mesophilic sludge is easier to dewater than thermophilic sludge irrespective of conditioning. The CST of mesophilic sludge was 2/3 to 1/2 that of thermophilic sludge and the dose of ferric chloride required to achieve equivalent CST was always higher for the thermophilic sludge.

Previous reports on the characteristics of thermophilic sludge have indicated that the supernatant was poor compared to mesophilic sludge. This finding was confirmed in this study. Not only was the thermophilic supernatant much higher in suspended solids but the soluble COD was always 1,000+ mg/l higher than the mesophilic supernatant. Measurements of soluble carbohydrate, grease and oil and organic nitrogen were run to determine the source of this extra COD. It was found that the COD of soluble organic fractions could not account for all of the extra soluble COD in the thermophilic sludge supernatant. For example, the difference between the soluble organic nitrogen in the two systems was only 2 mg/l; the difference in soluble oil and grease was only 150 mg/l and the difference in soluble carbohydrate was only at most 75 mg/l. Measurement of soluble sulfide in the units gave values in the range of 4-8 mg/l which again could not account for the COD difference. Another topic for future research is the nature of this extra soluble COD.

Finally, the question of odor must be addressed. It has been reported that thermophilic sludge is odorous compared to mesophilic sludge. This phenomenon was confirmed in this study; although quantitative odor measurements were not made. An odor panel made of the personnel in the Environmental Studies Center voted unanimously that thermophilic sludge had a more disagreeable odor than mesophilic sludge. Two votes were taken, once when the volatile acids were high and again when they were low. In both situations the thermophilic sludge was rated most disagreeable, although it was less so under low volatile acid conditions.

The bulk of the data generated in this study indicates that anaerobic digestion of municipal sewage sludge should be performed under mesophilic conditions rather than thermophilic conditions.

REFERENCES

1. Fisher Scientific Catalogue - 1986, p. 250.

2. Standard Methods for the Examination of Water and Wastewater APHA, AWWA, WPCF, 15th Ed. (1985).

3. Dubois, M., et al, "Colorimetric Method for Determination of Sugars and Related Substances", Analytical Chemistry 28, 350 (1956).

4. Herbert, D., et al., "Determination of Total Carbohydrate". In Methods in Microbiology 5B, Ed. Norris J. R. and, Robbins D. W., 265 Academic Press, New York.

5. Kampmeier, D. T., et al, "Carbohydrate as a Measure of Biomass in Expanded Bed Anaerobic Filters", Dept. of Civil Engineering, University of Illinois 208 N. Romine Urbana, IL, 61801.

6. Vesilind, P. A., Zhang, G., "Technique for Estimating Sludge Compactibility in Centrifugal Dewatering". Journal of the Water Pollution Control Federation, 56, 1231 (1984).

7. Lin, C. Y., "Temperature Characteristics of the Methanogenesis Process in Anaerobic Digestion", Water Science and Technology, 19, 299 (1987).

8. Gosh, S., "Improved Gasification by Two-Phase Anaerobic Digestion". Journal of the Environmental Engineering Division, ASCE, 113 1265 (1987).

9. Buhr, H. and Andrews, J. "Review Paper, The Thermophilic Anaerobic Digestion Process". Water Research, 11, 129 (1976).

10. Garber, W. F., "Operating Experience with Thermophilic Anaerobic Digestion". Journal of the Water Pollution Control Federation, 54, 1170 (1982).

11. Rimkus, R. R., et. al., "Full Scale Thermophilic Digestion at the West-Southwest Sewage Treatment Works, Chicago, Illinois". Journal of the Water Pollution Control Federation, 54, 1447 (1982).

Table A-1. RAW SLUDGE DATA SHEET ( ) - Indicates Dilution Correction Factor

Date Obtained	Date 1st Feed	Date End Feed	% Total Solids	% Volatile Solids
12/1/86	12/2/86	12/8/86	5.2(.75) = 3.9	81.7
12/8/86	12/9/86	12/15/86	4.1	85.1
12/15/86	12/16/86	12/22/86	3.9	86.0
12/22/86	12/23/86	12/29/86	3.9	84.6
12/29/86	12/30/86	1/5/87	3.1	85.4
1/5/87	1/6/87	1/12/87	3.0	85.4
1/12/87	1/13/87	1/19/87	3.5	-
1/19/87	1/20/87	1/26/87	6.1(.6) = 3.66	82.0
1/19/87	1/27/87	2/2/87	6.0(.6) = 3.6	80.0
1/19/87	2/3/87	2/9/87	5.3(.7) = 3.7	80.0
2/9/87	2/10/87	2/16/87	4.5(.8) = 3.6	81.0
2/16/87	2/17/87	2/23/87	6.5 (.55)= 3.6	84.2
2/23/87	2/24/87	3/2/87	5.96(.6) = 3.6	81.6
3/2/87	3/3/87	3/9/87	5.9(.65) = 3.8	79.1
3/9/87	3/10/87	3/16/87	4.5(.8) = 3.6	76.4
3/16/87	3/17/87	3/24/87	4.4(.8) = 3.5	75.5
3/23/87	3/25/87	3/30/87	5.13(.7) = 3.5	81.6
3/23/87	3/31/87	4/6/87	5.27(.66)= 3.5	81.8
3/23/87	4/7/87	4/13/87	4.35(.8) = 3.5	82.21
4/13/87	4/14/87	4/20/87	5.4(.65) = 3.5	82.22
4/13/87	4/21/87	4/27/87	5.5(.64) = 3.5	81.87
4/27/87	4/28/87	5/4/87	3.85(.9) = 3.5	81.97
4/27/87	5/5/87	5/11/87	4.9(.7) = 3.5	82.87
4/27/87	5/12/87	5/18/87	3.85(.9) = 3.5	82.59
5/18/87	5/19/87	5/25/87	5.1(.68) = 3.5	80.91
5/18/87	5/26/87	6/1/87	5.0(.76) = 3.8	79.9
6/1/87	6/2/87	6/8/87	5.4(.64) = 3.45	80.60
6/1/87	6/9/87		5.24(.67)= 3.5	79.57
6/15/87	6/16/87	6/22/87	5.42(.65)= 3.5	79.06
6/15/87	6/23/87	6/29/87	5.61(.63)= 3.5	78.93
6/29/87	6/30/87	7/2/87	3.79(.93)= 3.5	79.76
7/2/87	7/3/87	7/6/87	3.52(1.0)= 3.5	80.36
7/6/87	7/7/87	7/9/87	3.F2(1.0)= 3.4	80.10
7/9/87	7/10/87	7/13/87	3.71(.93)= 3.45	80.4
7/13/87	7/14/87	7/16/87	3.81(.92)= 3.5	79.4
7/16/87	7/17/87	7/19/87	3.53(1.0)= 3.53	-
7/17/87	7/20/87	7/23/87	3.86(.92)= 3.55	78.7
7/17/87	7/24/87	7/27/87	4.01(.87)= 3.5	78.48
7/27/87	7/28/87	7/30/87	3.57(1.0)= 3.57	78.52
7/27/87	7/31/87	8/3/87	3.84(.92)= 3.5	78.78
8/3/87	8/4/87	8/6/87	4.21(.83)= 3.5	76.88
8/3/87	8/7/87	8/10/87	4.60(.76)= 3.5	79.73
8/10/87	8/11/87	8/13/87	5.14(.68)= 3.5	81.07
8/10/87	8/14/87	8/16/87	5.00(.7) = 3.5	81.29
8/10/87	8/17/87	8/22/87	4.66(.75)= 3.5	80.2

Table A-2. FULL STRENGTH RAW SLUDGE - (All Units mg/l Except pH)

Date Obtained	pH	Vol. Acids	Alk.	Total COD	NH_3	TKN	Org. Nit.	Oil & Grease	Total CH_2O
12/1/86	5.6	2732	1900	69,555	183	1624	1441	-	
12/8/86	5.6	1297	2150	56,832	63	1232	1169	-	
12/15/86	5.6	1675	1700	43,593	45	1176	1130	5850	
12/22/86	5.2	1669	1250	47,923	128	1120	991	-	
12/29/86	5.5	941	900	37,407	52	728	695	7315	
1/5/87	6.0	1234	1300	33,703	67	784	716	5545	
1/12/87	5.5	1457	1500	45,550	83	1484	1400	7525	
1/19/87	5.6	2297	1350	87,339	117	1960	1842	13030	
1/19/87	5.4	3036	1600	85,064	224	1964	1540	12242	
1/19/87	5.3	3081	1550	71,420	259	1925	1666	11026	
2/9/87	5.8	2005	1150	62,680	178	1750	1571	7308	
2/16/87	5.7	2695	1300	104,976	301		1302	12251	
2/23/87	5.6	3400	1650	89,472	273	2128	1855	10945	
3/2/87	5.3	3081	1550	72,990	160	1920	1760	11026	
3/9/87	5.5	1858	1100	55,594	151	1456	1304	9143	
3/16/87	5.6	1978	1250	53,681		1389	-	7548	
3/23/87	5.8	1700	900	55,264	14	1946	1931	11216	
3/23/87	5.4	2950	1350	56,345	150	2134	1983	10416	
3/23/87	5.5	2651	1450	65,078	196	1788	1985	9279	
4/13/87	5.6	2024	1525	76,800	119	2467	2348	9709	
4/13/87	5.6	2904	1100	75,072	208				
4/27/87	5.5	2196	900	80,998	164	2251	2087	6977	
4/27/87	5.6	2965	1250	64,232	196	2066	1848	9651	
4/27/87	5.4	2267	1125	53,136	199	1557	1357	7446	
5/18/87	5.8	2509	1200	67,200	121	2198	2076	10413	
5/18/87	5.6	2904	1150	69,312	229	2310	2080	10528	
6/1/87	5.7	2419	950	71,064	131	2436	2305	10772	
6/1/87	5.6	3223	1550	65,739	211	2257	2046	10319	
6/15/87	5.8	2955	1300	58,784	224	2285	2061	11007	8,500
6/15/87	5.5	2884	1350	70,168	150	2285	2135	10938	8,500
6/29/87	5.5	1751	1500	49,138	132	1840	1707	9216	11,460
7/6/87	5.8	1812	1150	49,046	200	1904	1704	7253	5,510
7/9/87	5.6	1600	950	52,192	132	1946	1814	8086	5,920
7/13/87	5.4	1943	950	53,360	173	2022	1848	8549	5,220
7/16/87	-	-	-	50,986	191	1932	1741	7857	6,450
7/17/87	5.5	1680	950	54,880	187	1991	1804	8221	5,720
7/17/87		1484	1075	55,987	177	2041	1864	8257	7,550
7/27/87		1720	1050	49,935	141	1778	1637	7901	4,760
7/27/87		1609	1000	57,882	171	1915	1744	8231	6,790
8/3/87	5.65	2135	1500	54,802	191	1789	1598	7876	12,500
8/3/87	5.5	2934	1300	61,797	183	1988	1804	-	11,400
8/10/87	5.4	2368	1250	69,696	166	2240	2073	11103	-
8/10/87	5.4	2368	1250	69,215	-	-	-	-	-
8/10/87	5.54	NM	1750	74,131	215	2217	2003	10320	-

Table A-3. DILUTED RAW SLUDGE FEED (All Units mg/l Except for pH)

Period	Fed	Vol. Acids	Total Alk.	COD	NH_3	TKN	Org. Nit.	Oil & Grease	COD/ V.S.	Total CH_2O
12/2/86	12/8/86	2049	1425	52,166	137	1218	1081	-	1.637	
12/9/86	12/15/86	1297	2150	56,832	63	1232	1169	-	1.629	
12/16/86	12/22/86	1675	1700	43,593	45	1176	1130	5850	1.300	
12/23/86	12/29/86	1669	1250	47,923	128	1120	991	-	1.452	
12/30/86	1/5/87	941	900	37,407	52	728	695	7315	1.413	
1/6/87	1/12/87	1234	1300	33,703	67	784	716	5545	1.315	
1/13/87	1/19/87	1457	1500	45,550	83	1484	1400	7525	-	
1/20/87	1/26/87	1378	750	52,403	70	1176	1105	7818	1.746	
1/27/87	2/2/87	1821	960	51,038	134	1178	924	7345	1.772	
2/3/87	2/9/87	2157	1085	49,994	181	1347	1166	7718	1.689	
2/10/87	2/16/87	1604	920	50,144	142	1400	1257	5846	1.720	
2/17/87	2/23/87	1482	715	57,736	165		716	6738	1.905	
2/24/87	3/2/87	2040	990	53,683	163	1276	1113	6567	1.827	
3/3/87	3/9/87	2003	1007	47,443	104	1248	1144	7166	1.578	
3/10/87	3/16/87	1486	880	44,475	120	1164	1043	7314	1.617	
3/17/87	3/24/87	1582	1000	42,945		1111		6038	1.625	
3/25/87	3/30/87	1190	630	38,685	10	1362	1352	7851	1.355	
3/31/87	4/6/87	1953	891	37,188	99	1309	1309	6875	1.299	
4/7/87	4/13/87	2121	1160	52,061	157	1430	1588	7423	1.809	
4/14/87	4/20/87	1316	991	49,920	77	1603	1526	6311	1.735	
4/21/87	4/27/87	1858	704	48,046	133	1484	1350	6998	1.677	
4/28/87	5/4/87	1976	810	72,898	147	2025	1878	6279	2.541	
5/5/87	5/11/87	2076	875	44,962	137	1431	1294	6756	1.550	
5/12/87	5/18/87	2040	1013	47,822	179	1601	1221	6701	1.654	
5/19/87	5/25/87	1706	816	45,696	82	1495	1412	7081	1.614	
5/26/87	6/1/87	2207	874	52,677	174	1756	1581	8001	1.735	
6/2/87	6/8/87	1572	618	46,192	85	1583	1498	7002	1.633	
6/9/87	6/15/87	3126	1039	44,045	141	1512	1371	6914	1.577	
6/16/87	6/22/87	1921	845	38,210	146	1485	1340	7155	1.372	5525
6/23/87	6/29/87	1817	851	44,205	94	1440	1345	6891	1.585	5355
6/30/87	7/2/87	1628	1395	45,698	123	1711	1588	8571	1.626	10657
7/7/87	7/9/87	1812	1150	49,046	200	1904	1704	7253	1.790	5510
7/10/87	7/13/87	1488	884	48,539	122	1809	1687	7521	1.750	5505
7/14/87	7/16/87	1788	874	49,091	159	1859	1700	7866	1.764	4802
7/17/87	7/19/87	-	-	50,986	191	1932	1741	7857	-	6450
7/20/87	7/23/87	1546	874	50,490	172	1831	1659	7564	1.807	5262
7/24/87	7/27/87	1726	935	48,709	154	1775	1621	7184	1.779	6568
7/28/87	7/30/87	1720	1050	49,935	141	1778	1640	7902	1.781	4760
7/31/87	8/3/87	1480	920	53,251	157	1761	1604	7571	1.913	6246
8/4/87	8/6/87	1772	1245	45,485	159	1484	1326	6537	1.689	10375
8/7/87	8/10/87	2229	988	47,121	139	1510	1371	-	1.689	8664
8/11/87	8/13/87	1610	850	47,393	113	1523	1409	7550	1.679	-
8/14/87	8/16/87	1657	875	48,450	-	-	-	-	1.696	-
8/17/87	8/22/87	NM	1312	55,598	161	1662	1501	7740	-	-

Table A-4. pH-ALKALINITY -VOLATILE ACIDS (All Units mg/l Except pH)

Date	pH		Alkalinity		Volatile Acids	
	Thermophilic	Mesophilic	Thermophilic	Mesophilic	Thermophilic	Mesophilic
12/3/86	7.3	7.1	3850	3550	340.	220.8
12/5	-	-	-	-	340.	220.8
12/8	-	-	-	-	395.6	404.8
12/10	7.3	7.1	4100	3900	404.8	395.6
12/12	-	-	-	-	496.8	487.6
12/15	-	-	-	-	552.	414.
12/17	7.3	7.06	4000	3900	163.2	130.5
12/19	-	-	-	-	182.2	151.8
12/22	-	-	-	-	333.9	161.9
12/24	7.35	7.1	4050	3900	384.6	151.8
12/26	-	-	-	-	506.	111.
12/27	-	-	-	-	506.	132.
12/29	-	-	-	-	657.8	151.8
12/31	7.35	7.15	4250	4200	748.9	192.3
1/2/87	-	-	-	-	799.5	111.3
1/3	-	-	-	-	840.	101.
1/4	-	-	-	-	880.	101.
1/5	-	-	-	-	951.3	192.3
1/7	7.3	7.1	4450	3860	-	232.
1/9	-	-	-	-	1001.9	212.5
1/10	-	-	-	-	961.	101.
1/12	-	-	-	-	961.	91.
1/14	7.2	7.0	4150	3650	1001.9	151.8
1/16	-	-	-	-	1032.2	121.4
1/17	-	-	-	-	941.	101.
1/18	-	-	-	-	961.	101.
1/19	-	-	-	-	1012.	101.
1/21	7.2	7.1	4250	3950	1062.6	111.3
1/23	-	-	-	-	1163.8	111.3
1/25	-	-	-	-	1113.	81.
1/26	-	-	-	-	1133.4	91.1
1/28	7.3	7.1	4150	3750	1163.8	111.3
1/30	7.3	7.1	-	-	1335.8	121.4
2/1	-	-	-	-	1315.	101.
2/4	7.3	7.15	4250	4000	1415.	151.
2/6	7.3	7.1	-	-	1400.	101.
2/8	-	-	-	-	1425.	101.
2/9	7.3	7.1	-	-	1386	101.
2/11	7.3	7.1	4500	4250	1425.6	111.1
2/13	7.3	7.1	-	-	1534.5	131.3
2/16	7.2	7.1	-	-	1465.2	111.1
2/18	7.3	7.1	4500	4150	1346.4	111.1

Table A-4. pH-ALKALINITY -VOLATILE ACIDS (Continued)

Date	pH		Alkalinity		Volatile Acids	
	Thermo philic	Meso-philic	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic
2/20	7.3	7.1	-	-	-	-
2/21	-	-	-	-	1197.9	91.08
2/22	-	-	-	-	1009.8	101.
2/23	7.3	7.1			762.3	91.08
2/25	7.35	7.1	4850	4150	337.6	91.08
2/27	7.35	7.1	-	-	188.1	119.6
3/1	-	-	-	-	212.	112.
3/2	7.4	7.15	-	-	227.7	111.3
3/5	7.4	7.1	5100	4350	445.	101.2
3/6	7.35	7.1	-	-	426.	111.3
3/7	-	-	-	-	475.	111.
3/9	7.3	7.1	-	-	564.3	105.8
3/11	7.25	7.15	4750	4400	633.6	101.2
3/13	7.35	7.15	-	-		
3/15	-	-	-	-	800.	130.
3/16	7.35	7.25	-	-	796.9	87.4
3/18	7.35	7.25	4725	4150	739.2	73.6
3/20	7.3	7.15	-	-	841.5	73.6
3/23	7.3	7.15	-	-	811.8	50.6
3/25	7.4	7.15	[illegible]	3850	673.2	60.7
3/27	7.35	7.1		-	405.9	90.08
3/30	7.35	7.1	-	-	138.6	91.08
4/1	7.4	7.05	4350	4400	101.2	60.72
4/3	-	-	-	-	158.4	80.96
4/6	7.45	7.2	-	-	158.4	86.0
4/8	7.35	7.05	4450	4100	207.9	86.02
4/10	7.3	7.2	-	-	222.8	73.6
4/13	7.3	7.05	-	-	282.0	81.0
4/15	7.25	7.15	450	4250	396.0	132.0
4/17	7.65	7.1	-	-	243.0	81.0
4/20	7.45	7.05	-	-	124.0	86.0
4/22	7.45	7.05	4375	4000	134.0	81.0
4/24	-	-	-	-	153.5	116.4
4/27	7.35	7.1	-	-	109.0	73.6
4/29	7.35	7.2	4320	4100	351.5	131.56
5/1	7.35	7.1	-	-	158.4	80.96
5/4	7.55	7.2	-	-	148.5	111.32
5/6	7.4	7.2	4350	4125	252.5	111.32
5/8	7.5	7.25	-	-	-	101.2
5/11	7.45	7.2	-	-	273.6	96.14
5/13	7.5	7.1	4275	4225	207.9	86.02
5/15	7.55	7.3	-	-	158.4	96.14

Table A-4. pH-ALKALINITY -VOLATILE ACIDS (Continued)

Date	pH Thermo philic	pH Meso-philic	Alkalinity Thermo-philic	Alkalinity Meso-philic	Volatile Acids Thermo-philic	Volatile Acids Meso-philic
5/18	7.35	7.2	-	-	138.6	60.72
5/20	7.45	7.25	4425	4275	133.65	86.02
5/22	7.45	7.3	-	-	128.7	91.08
5/24	-	-	-	-	138.6	91.08
5/27	7.5	7.25	4350	4275	183.2	101.2
5/28	-	-	-	-	188.1	91.08
6/1	7.4	7.15	-	-	143.6	91.08
6/3	7.45	7.3	4525	4350	232.65	212.5
6/4	-	-	-	-	168.3	117.4
6/5	7.45	7.3	-	-	148.5	101.2
6/8	7.35	7.15	-	-	178.2	131.56
6/10	7.35	7.2	4800	4600	346.5	101.2
6/11	-	-	-	-	386.1	136.62
6/12	-	-	-	-	455.4	111.3
6/15	7.2	7.10	-	-	574.0	131.0
6/17	7.50	7.50	5200	4550	524.7	141.7
6/19	7.45	7.35	-	-	267.3	141.7
6/22	7.25	7.30	-	-	227.7	121.4
6/24	7.30	7.10	5050	4450	376.2	172.0
6/26	7.35	7.10	-	-	287.1	172.0
6/27	-	-	-	-	260.0	-
6/29	7.35	7.05	-	-	143.6	121.4
7/1	7.35	7.05	4750	4300	178.2	141.7
7/3	-	-	-	-	200.0	130.0
7/6	7.4	7.1	4800	4150	217.0	136.0
7/9	7.4	7.1	5000	4550	158.0	121.0
7/11	-	-	-	-	200.0	150.0
7/13	7.4	7.15	5375	4300	178.0	121.0
7/16	7.25	7.05	5500	4450	217.8	141.7
7/18	-	-	-	-	250.0	120.0
7/20	7.45	7.10	5000	4250	168.3	121.4
7/23	7.4	7.20	4900	4400	198.0	141.7
7/25	-	-	-	-	160.0	160.0
7/27	7.4	7.05	5050	4500	183.2	131.6
7/30	7.35	7.05	5100	4350	237.6	121.4
8/3	7.3	7.05	4950	4300	267.0	131.0
8/6	7.3	7.0	4925	4350	416.0	162.0
8/8	-	-	-	-	270.0	130.0
8/10	7.25	7.0	4775	4250	178.0	192.0
8/13	7.25	6.95	4700	4200	148.0	126.0
8/15	-	-	-	-	200.0	150.0
8/17	7.34	7.10	-	-	356.0	208.0
8/23			End 15 Day D.T.			

Table A-5. SPECIATED ACID
(Expressed as % Volatile Acid)

	Thermophilic					Mesophilic				
Date	F	L	A	P	B	F	L	A	P	B
12/5/86	6.3	19.1	35.0	39.6	-	5.2	17.8	11.7	65.2	-
12/8/86	7.2	25.3	39.9	27.6	-	-	29.8	8.4	61.8	-
12/10/86	9.2	25.0	37.1	28.7	-	15.5	46.6	20.2	17.7	-
12/12/86	6.7	22.8	35.6	34.9	-	9.4	26.8	14.6	49.2	-
12/15/86	3.6	15.8	29.1	51.5	-	7.1	-	13.5	79.4	-
12/17/86	-	-	7.8	92.2	-	-	-	25.8	74.2	-
12/19/86	17.9	8.2	35.8	38.2	-	2.7	7.4	14.9	68.9	-
12/22/86	40.0	12.5	22.2	61.4	-	7.8	21.2	13.1	57.9	-
12/24/86	1.9	8.3	15.3	74.5	-	12.4	35.1	17.4	35.1	-
12/26/86	2.8	9.4	12.2	72.0	-	10.8	36.7	15.4	37.1	-
12/29/86	0.3	4.6	13.0	82.1	-	-	30.7	19.0	50.3	-
12/31/86	2.3	7.7	9.4	80.4	-	12.1	49.7	16.1	22.1	-
1/2/87	1.3	5.4	6.5	86.6	-	-	-	21.6	78.4	-
1/5/87	1.7	7.1	7.2	84.0	-	5.7	22.4	9.9	62.0	-
1/7/87	1.3	4.9	7.7	79.8	-	5.4	28.2	17.5	48.8	-
1/9/87	1.3	7.7	6.1	84.9	-	9.1	36.5	17.2	37.2	-
1/12/87	0.9	4.1	4.5	90.5	-	9.1	40.1	19.8	31.0	-
1/14/87	1.4	4.9	10.3	83.4	-	11.2	38.8	19.5	30.5	-
1/16/87	1.4	6.2	6.1	86.2	-	10.5	42.3	18.8	28.5	-
1/21/87	0.0	0.0	8.9	91.1	-	0.0	46.8	15.4	37.8	-
1/23/87	0.4	2.6	7.8	89.2	-	9.1	43.6	22.7	24.6	-
1/28/87	1.4	5.6	7.2	86.0	-	10.2	40.0	22.3	27.6	-
2/2/87	9.6	6.4	5.3	87.3	-	11.6	34.1	17.1	37.2	-
2/6/87	0.7	9.5	5.2	89.7	-	5.5	35.4	9.8	49.3	-
2/9/87	0.7	4.7	7.4	87.2	-	6.8	50.4	11.6	31.1	-
2/11/87	0.8	3.8	0.7	90.6	-	5.4	37.7	19.7	37.2	-
2/13/87	0.3	2.0	4.8	92.9	-	6.4	36.7	10.2	46.7	-
2/16/87	0.7	4.6	4.3	90.4	-	6.7	33.7	9.2	50.3	-
2/18/87	1.6	7.6	8.5	82.4	-	11.7	58.3	11.7	18.3	-
2/20/87	.6	2.9	8.4	88.1	-	10.3	41.2	26.8	21.6	-
2/23/87	2.4	14.2	19.9	69.6	-	0	53.5	23.1	23.4	-
2/25/87	3.1	14.1	37.1	45.7	-	2.5	32.5	24.9	40.0	-
2/27/87	5.8	44.4	29.6	20.2	-	14.2	66.3	19.1	29.4	-
3/2/87	4.6	19.5	35.1	40.9	-	11.4	57.1	13.7	74.8	-
3/5/87	3.7	16.9	40.0	39.4	-	7.8	75.4	16.8	0	-
3/11/87	2.2	8.8	12.1	76.9	-	5.8	32.0	18.5	43.7	-
3/13/87	2.0	8.9	12.5	76.6	-	8.8	46.8	19.4	26.9	-
3/16/87	1.2	7.1	10.3	81.4	-	0	77.9	13.0	9.1	-
3/18/87	1.5	7.4	13.9	77.3	-	8.7	46.5	20.4	24.4	
3/20/87	2.0	8.3	10.1	79.7	-	11.1	47.4	19.2	22.4	-
3/25/87	1.1	0.4	19.0	77.3	-	6.6	20.8	24.3	48.3	-
3/27/87	0.7	3.5	23.6	72.2	-	4.7	11.2	12.2	71.9	-

Table A-5. SPECIATED ACID (Continued)
(Expressed as % Volatile Acid)

Date	Thermophilic F	Thermophilic L	Thermophilic A	Thermophilic P	Thermophilic B	Mesophilic F	Mesophilic L	Mesophilic A	Mesophilic P	Mesophilic B
3/30/87	1.1	7.0	46.8	45.1	-	1.5	12.5	5.7	80.3	-
4/1/87	2.8	14.0	56.2	27.0	-	2.2	7.3	43.7	46.8	-
4/3/87	0.9	5.5	47.4	46.2	-	1.4	6.7	11.1	80.8	-
4/6/87	1.0	8.7	49.8	40.5	-	2.2	14.1	11.6	72.2	-
4/8/87	0.9	4.0	28.7	66.4	-	1.1	7.4	6.1	85.4	-
4/10/87	0.8	4.9	30.9	63.4	-	1.7	11.1	9.1	78.1	-
4/13/87	0.6	3.7	18.4	77.4	-	0.0	17.0	26.7	58.2	-
4/15/87	0.9	2.7	41.1	55.3	-	3.8	12.3	20.3	63.6	-
4/17/87	1.6	4.3	44.1	49.9	-	0	17.0	24.7	58.2	-
4/20/87	1.2	6.0	36.1	56.7	-	0	11.6	8.5	79.9	-
4/22/87	1.5	7.2	54.6	36.8	-	0	9.7	15.8	74.5	-
4/24/87	0.0	3.7	49.1	47.2	-	2.5	5.3	10.2	82.0	-
4/29/87	1.2	0	58.5	40.3	-	11.7	9.2	7.6	71.4	-
5/1/87	1.4	4.6	70.59	23.5	-	12.8	4.0	17.4	65.7	-
5/4/87	1.8	0.9	40.2	56.9	-	6.9	2.1	11.3	79.6	-
5/6/87	1.7	-	41.4	56.9	-	2.9	-	25.3	71.7	-
5/8/87	0.5	1.7	29.1	68.7	-	1.9	9.1	10.1	78.8	-
5/11/87	0.9	2.8	58.0	38.4	-	1.9	5.9	16.1	76.1	-
5/13/87	2.4	5.7	72.4	19.5	-	2.0	6.4	42.0	49.5	-
5/15/87	-	3.4	52.4	44.1	-	1.0	6.2	13.5	79.3	-
5/18/87	-	1.3	36.6	62.1	-	1.7	5.3	17.5	75.5	-
5/20/87	1.2	5.9	62.41	30.4	-	-	6.9	22.5	70.6	-
5/22/87	1.4	5.9	67.0	25.7	-	2.1	5.9	14.8	77.2	-
5/27/87	4.5	4.8	75.2	15.5	-	3.1	4.3	11.1	77.5	-
5/29/87	4.9	6.9	54.4	33.8	-	7.6	3.8	13.4	75.2	-
6/1/87	3.3	5.5	49.4	41.8	-	9.7	4.5	27.0	58.8	-
6/5/87	2.4	-	69.9	27.4	-	5.8	-	35.7	58.5	-
6/8/87	-	-	32.4	67.5	-	5.7	-	20.0	74.2	-
6/10/87	2.7	-	42.6	54.7	-	9.5	-	49.6	40.9	-
6/12/87	2.2	2.9	29.7	65.2	-	8.9	18.7	49.4	22.9	-
6/15/87	1.0	1.3	16.0	82.0	-	6.7	9.6	39.7	44.1	-
6/17/87	0.3	1.0	18.5	80.2	-	1.5	17.3	56.3	24.8	-
6/19/87	1.0	3.5	38.7	56.8	-	2.0	16.6	45.0	36.2	-
6/22/87	2.2	7.8	45.1	45.0	-	0.8	7.7	28.6	62.9	-
6/25/87	0.4	1.7	23.7	74.2	-	0.6	11.1	45.7	42.6	-
6/26/87	0.3	3.1	30.4	66.2	-	-	10.6	39.0	50.5	-
6/29/87	1.0	12.2	76.1	10.7	-	0.5	9.9	36.5	53.0	-
7/1/87	2.2	7.1	76.6	14.0	-	3.9	8.5	50.0	27.5	-
7/6/87	1.1	8.7	83.7	6.4	-	9.9	9.1	39.8	41.2	-
7/9/87	1.1	8.8	84.6	5.5	-	0.9	11.6	40.5	46.9	-
7/13/87	1.0	8.0	87.0	3.9	-	2.1	19.9	44.1	33.7	-
7/16/87	1.9	7.2	78.7	12.2	-	-	9.7	42.9	47.4	-
7/20/87	2.0	6.3	83.5	8.3	-	1.0	13.0	32.7	53.2	-

Table A-5. SPECIATED ACID (Continued)
(Expressed as % Volatile Acid)

	Thermophilic					Mesophilic				
Date	F	L	A	P	B	F	L	A	P	B
7/24/87	2.3	6.3	77.4	4.0	-	-	3.8	8.1	15.5	-
7/27/87	0.9	4.8	79.1	15.1	-	-	7.2	80.7	12.1	-
7/30/87	1.0	3.4	78.5	17.1	-	-	10.2	36.7	53.1	-
8/3/87	2.5	0.3	41.0	56.2	-	-	3.3	66.7	30.0	-
8/6/87	1.3	0.7	26.7	71.3	-	-	3.9	26.4	69.7	-
8/10/87	6.0	0.3	85.7	8.0	-	-	-	33.3	66.6	-
8/13/87	6.0	1.0	86.9	6.0	-	3.0	-	30.4	66.6	-

F=Formic Acid
L=Lactic Acid
A=Acetic Acid
P=Propionic Acid
B=Butyric Acid

Table A-6. GAS PRODUCTION

Date	Gas Production - Liters		% of CH_4		Amount of CH_4 - Liters	
	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic	Thermo philic	Meso-philic
11/28/86	41.6	37.2	-	-	-	-
11/29	41.2	42.8	-	-	-	-
11/30	46.8	44.9	-	-	-	-
12/1	48.26	39.5	59.6	61.6	28.8	24.3
12/2	34.8	49.3	-	-	-	-
12/3	35.9	49.8	62.3	59.6	22.4	29.7
12/4	46.1	44.8	-	-	-	-
12/5	38.6	43.2	57.7	57.1	22.3	24.7
12/6	35.2	38.4	-	-	-	-
12/7	44.1	43.5	-	-	-	-
12/8	44.8	40.8	60.1	61.3	26.9	25.0
12/9	40.9	44.5	-	-	-	-
12/10	48.4	51.1	60.3	60.3	29.2	30.8
12/11	49.5	47.1	-	-	-	-
12/12	50.3	50.6	61.2	60.4	30.8	30.6
12/13	51.9	58.4	-	-	-	-
12/14	44.7	45.7	-	-	-	-
12/15	46.2	57.5	63.2	60.0	29.2	37.9
12/16	43.8	41.9	-	-	-	-
12/17	39.5	45.4	63.2	61.3	24.9	27.8
12/18	42.9	46.9	-	-	-	-
12/19	52.2	46.9	60.9	61.0	31.8	34.7
12/20	49.5	56.2	-	-	-	-
12/21	54.6	-*	-	-	-	-
12/22	50.1	54.3	61.1	60.1	30.6	32.6
12/23	50.4	50.4	-	-	-	-
12/24	44.1	44.6	61.8	59.8	27.3	26.3
12/25	43.2	51.8	-	-	-	-
12/26	45.5	53.8	58.5	55.1	26.6	29.6
12/27	42.8	52.1	-	-	-	-
12/28	*	*	-	-	-	-
12/29	*	*	-	-	-	-
12/30	47.1	37.96	59.2	60.9	27.9	23.1
12/31	41.5	38.4	58.5	60.2	24.3	23.1
1/1/87	42.7	38.7	-	-	-	-
1/2	44.6	38.6	57.5	59.7	25.6	23.0
1/3	40.7	41.8	-	-	-	-
1/4	41.1	42.6	-	-	-	-
1/5	36.96	39.02	58.6	58.9	21.7	23.0
1/6	36.7	36.9	-	-	-	-
1/7	37.5	38.1	59.2	60.1	22.2	22.9
1/8	35.8	38.0	-	-	-	-
1/9	34.8	41.1	61.6	59.4	21.4	24.4

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters Thermo-philic	Meso-philic	% of CH_4 Thermo-philic	Meso-philic	Amount of CH_4 - Liters Thermo philic	Meso-philic
1/10	33.7	38.8	-	-	-	-
1/11	38.5	40.3	-	-	-	-
1/12	36.7	40.6	60.7	59.3	22.3	24.0
1/13	31.7	36.98	-	-	-	-
1/14	38.2	38.2	59.7	59.8	22.8	22.8
1/15	49.7	38.6	-	-	-	-
1/16	46.5	38.9	59.2	61.1	27.5	23.8
1/17	36.4	38.7	-	-	-	-
1/18	36.5	39.0	-	-	-	-
1/19	39.5	38.4	60.1	60.5	23.7	23.2
1/20	41.7	45.4	-	-	-	-
1/21	34.3	32.8	59.0	58.3	20.2	19.1
1/22	42.3	41.7	-	-	-	-
1/23	47.8	46.4	58.7	58.8	28.1	26.6
1/24	42.9	49.1	-	-	-	-
1/25	42.1	37.9	-	-	-	-
1/26	41.5	40.6	57.7	58.4	23.9	23.7
1/27	37.4	38.8	-	-	-	-
1/28	38.0	39.6	59.3	60.4	22.5	23.9
1/29	39.1	38.8	-	-	-	-
1/30	39.2	41.9	57.0	57.0	22.3	23.9
1/31	39.9	43.1	-	-	-	-
2/1	37.5	40.5	-	-	-	-
2/2	39.6	44.5	58.5	57.7	23.2	25.7
2/3	37.0	42.9	-	-	-	-
2/4	35.7	43.4	60.0	60.1	21.4	26.1
2/5	34.0	42.0	-	-	-	-
2/6	36.5	43.1	60.1	60.0	21.9	25.9
2/7	36.9	42.9	-	-	-	-
2/8	39.6	43.7	-	-	-	-
2/9	38.5	40.7	60.0	61.1	23.1	24.9
2/10	36.8	38.2	-	-	-	-
2/11	37.8	37.6	59.7	60.6	22.6	22.8
2/12	38.9	40.3	-	-	-	-
2/13	40.6	41.9	58.8	60.0	23.9	25.1
2/14	40.86	39.8	-	-	-	-
2/15	42.1	43.9	-	-	-	-
2/16	39.3	39.9	60.2	57.3	23.7	22.9
2/17	37.5	37.8	-	-	-	-
2/18	37.1	37.6	60.4	62.8	22.4	23.6
2/19	34.3	37.7	-	-	-	-
2/20	40.7	37.8	61.9	60.3	25.2	22.8
2/21	*	39.5	-	-	-	-

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters		% of CH_4		Amount of CH_4 - Liters	
	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic	Thermo philic	Meso-philic
2/22	*	44.2	-	-	-	-
2/23	52.5	41.5	64.5	59.6	33.9	26.8
2/24	43.5	38.0	-	-	-	-
2/25	48.4	44.0	63.2	61.6	30.1	27.1
2/26	46.3	44.5	-	-	-	-
2/27	38.9	43.0	62.6	60.5	24.4	26.0
2/28	37.5	43.5	-	-	-	-
3/1	41.4	47.3	-	-	-	-
3/2	42.8	45.7	-	-	-	-
3/3	38.0	42.8	-	-	-	-
3/4	*	*	61.7	59.8	-	-
3/5	-	-	-	-	-	-
3/6	30.7	40.4	63.4	59.6	19.5	24.1
3/7	33.9	39.3	-	-	-	-
3/8	35.6	41.2	-	-	-	-
3/9	36.3	42.9	62.0	60.0	22.5	25.7
3/10	35.9	39.6	-	-	-	-
3/11	33.7	37.1	61.0	60.0	20.6	22.3
3/12	34.5	31.8	-	-	-	-
3/13	35.5	32.8	60.8	59.8	21.6	19.6
3/14	34.7	32.6	-	-	-	-
3/15	35.1	32.5	-	-	-	-
3/16	31.6	35.4	60.8	59.5	19.2	21.1
3/17	33.1	33.7	-	-	-	-
3/18	31.9	33.5	-	-	-	-
3/19	35.1	39.7	60.8	59.3	21.3	23.5
3/20	34.8	39.6	61.3	59.5	21.3	23.6
3/21	37.1	39.5	-	-	-	-
3/22	36.9	38.3	-	-	-	-
3/23	36.3	36.9	62.2	60.4	22.6	22.3
3/24	39.8	38.3	-	-	-	-
3/25	38.7	22.1(*)	63.7	60.1	24.6	*
3/26	40.9	37.6	-	-	-	-
3/27	47.1	39.1	63.2	-	-	-
3/28	47.9	41.8	-	-	-	-
3/29	40.7	40.8	-	-	-	-
3/30	44.6	40.7	61.8	58.9	27.6	24.0
3/31	44.3	41.4	-	-	-	-
4/1	39.4	40.5	62.5	62.4	24.6	25.3
4/2	43.6	41.3	-	-	-	-
4/3	43.4	41.7	62.8	60.5	27.2	25.2
4/4	47.4	44.0	-	-	-	-
4/5	40.7	40.7	-	-	-	-

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters		% of CH_4		Amount of CH_4 - Liters	
	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic	Thermo philic	Meso-philic
4/6	41.1	42.2	62.5	59.9	25.7	25.3
4/7	43.2	41.9	-	-	-	-
4/8	39.6	38.9	60.4	63.0	23.9	24.5
4/9	41.2	39.9	-	-	-	-
4/10	40.7	40.5	62.1	60.8	25.3	24.6
4/11	38.9	37.1	-	-	-	-
4/12	38.7	41.7	-	-	-	-
4/13	40.1	39.9	62.0	60.6	24.9	24.2
4/14	*	39.9	-	-	-	-
4/15	*	35.2	61.0	60.7	-	21.4
4/16	36.4	33.6	-	-	-	-
4/17	*	35.1	62.1	59.8	-	21.0
4/18	*	35.5	-	-	-	-
4/19	36.0	34.8	-	-	-	-
4/20	35.0	34.6	65.2	62.5	22.8	21.6
4/21	34.8	33.4	-	-	-	-
4/22	34.2	34.0	64.3	62.2	22.0	21.1
4/23	*	34.4	-	-	-	-
4/24	34.1	34.5	62.6	60.5	21.3	20.9
4/25	*	35.7	-	-	-	-
4/26	36.7	35.2	-	-	-	-
4/27	35.8	34.7	62.7	60.4	22.4	21.0
4/28	*	32.6	-	-	-	-
4/29	31.2	35.3	62.8	60.3	19.6	21.3
4/30	34.9	34.9	-	-	-	-
5/1	33.5	29.2	62.9	61.8	21.1	18.0
5/2	34.2	34.6	-	-	-	-
5/3	33.5	35.3	-	-	-	-
5/4	*	30.7	*	60.5	-	18.6
5/5	*	34.8	-	-	-	-
5/6	31.2	31.9	60.5	60.7	18.9	19.4
5/7	33.6	34.8	-	-	-	-
5/8	33.7	34.8	62.1	60.4	20.9	21.0
5/9	28.9	36.4	-	-	-	-
5/10	38.9	34.3	-	-	-	-
5/11	39.7	34.4	63.2	61.1	25.1	21.0
5/12	45.6	40.2	-	-	-	-
5/13	37.6	32.5	63.0	60.7	23.7	19.7
5/14	40.1	35.6	-	-	-	-
5/15	39.0	35.1	62.2	60.8	24.2	21.3
5/16	35.3	33.4	-	-	-	-
5/17	37.1	35.3	-	-	-	-
5/18	36.0	37.8	62.3	61.3	22.4	23.2

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters Thermo-philic	Gas Production - Liters Meso-philic	% of CH_4 Thermo-philic	% of CH_4 Meso-philic	Amount of CH_4 - Liters Thermo philic	Amount of CH_4 - Liters Meso-philic
5/19	34.3	37.3	-	-	-	-
5/20	31.9	35.2	62.8	61.1	20.0	21.5
5/21	31.9	34.9	-	-	-	-
5/22	32.9	36.8	62.5	61.1	20.6	22.5
5/23	32.4	34.9	-	-	-	-
5/24	34.8	34.6	62.2	61.1	21.6	21.1
5/25	33.1	33.6	-	-	-	-
5/26	33.5	33.5	-	-	-	-
5/27	39.4	39.1	61.2	61.3	24.1	23.9
5/28	43.5	36.6	-	-	-	-
5/29	44.2	46.8	62.6	60.8	27.7	28.5
5/30	47.3	47.4	-	-	-	-
5/31	43.4	43.7	-	-	-	-
6/1	44.4	42.6	62.5	61.7	27.7	26.3
6/2	42.5	42.5	-	-	-	-
6/3	40.4	38.4	63.7	63.1	25.7	24.2
6/4	38.9	35.4	-	-	-	-
6/5	40.4	37.6	64.0	63.2	25.8	23.8
6/6	39.2	38.0	-	-	-	-
6/7	36.8	39.8	-	-	-	-
6/8	37.1	39.3	63.7	62.7	23.6	24.6
6/9	35.0	36.9	-	-	-	-
6/10	35.8	39.1	63.9	63.4	22.9	24.8
6/11	39.1	42.4	-	-	-	-
6/12/87	39.1	42.4	-	-	-	-
6/13	44.7	44.0	-	-	-	-
6/14	46.1	50.6	-	-	-	-
6/15	44.2	45.5	63.6	63.6	28.1	28.9
6/16	45.6	48.7	-	-	-	-
6/17	44.4	43.4	64.4	63.5	28.6	27.6
6/18	45.3	41.6	-	-	-	-
6/19	48.4	42.5	63.6	61.9	30.8	26.3
6/20	48.3	44.9	-	-	-	-
6/21	45.4	44.0	-	-	-	-
6/22	40.6	43.1	62.1	62.2	25.2	26.8
6/23	*	42.4	-	-	-	-
6/24	*	41.6	61.6	61.8	17.1	25.7
6/25	*	40.0	-	-	-	-
6/26	*	40.5	62.1	62.1	17.3	25.2
6/27	*	40.8	-	-	-	-
6/28	*	42.2	-	-	-	-
6/29	*	39.8	62.5	62.6	20.5	24.9
6/30	39.8	39.8	-	-	-	-

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters		% of CH_4		Amount of CH_4 - Liters	
	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic	Thermo philic	Meso-philic
7/1	45.1	42.1	63.3	63.0	28.5	26.5
7/2	44.5	42.8	-	-	-	-
7/3	46.0	44.7	64.7	63.9	29.8	28.6
7/4	49.8	47.4	-	-	-	-
7/5	48.9	43.8	-	-	-	-
7/6	49.6	45.7	65.2	65.1	32.3	29.8
7/7	48.6	45.0	-	-	-	-
7/8	47.2	45.2	-	-	-	-
7/9	46.2	46.2	65.2	64.8	30.1	29.9
7/10	45.6	45.3	-	-	-	-
7/11	49.0	48.0	-	-	-	-
7/12	49.9	48.8	-	-	-	-
7/13	48.6	48.9	64.9	64.8	31.5	31.7
7/14	47.7	48.8	-	-	-	-
7/15	44.8	48.3	-	-	-	-
7/16	46.6	47.4	64.8	64.9	30.2	30.8
7/17	47.0	47.6	-	-	-	-
7/18	49.3	48.3	65.5	65.0	32.3	31.4
7/19	49.5	53.4	-	-	-	-
7/20	49.1	51.7	65.5	65.0	32.2	33.6
7/21	50.5	50.8	-	-	-	-
7/22	49.5	50.0	-	-	-	-
7/23	51.7	50.2	65.2	64.5	33.7	32.4
7/24	51.3	51.0	-	-	-	-
7/25	47.7	51.2	63.9	62.7	30.5	32.1
7/26	52.5	53.6	-	-	-	-
7/27	51.2	46.8	64.7	64.9	33.1	30.4
7/28	47.9	49.5	-	-	-	-
7/29	49.2	48.9	-	-	-	-
7/30	50.4	49.4	64.8	64.0	32.7	31.6
8/1/87	51.3	51.7	63.9	62.6	36.1	37.4
8/2	53.1	52.7	-	-	-	-
8/3	48.9	50.8	64.5	64.2	31.5	32.6
8/4	48.1	50.2	-	-	-	-
8/5	48.3	49.5	-	-	-	-
8/6	49.9	58.7	62.6	61.08	31.2	35.8
8/7	50.8	54.7	-	-	-	-
8/8	53.4	51.1	63.6	62.6	33.9	32.0
8/9	58.1	54.0	-	-	-	-
8/10	54.4	56.7	63.0	61.7	34.3	35.0
8/11	52.1	53.1	-	-	-	-
8/12	53.1	56.3	-	-	-	-
8/13	54.4	54.4	62.75	61.1	34.1	33.2

Table A-6. GAS PRODUCTION (Continued)

Date	Gas Production - Liters		% of CH_4		Amount of CH_4 - Liters	
	Thermo-philic	Meso-philic	Thermo-philic	Meso-philic	Thermo philic	Meso-philic
8/14	55.3	53.4	-	-	-	-
8/15	57.8	54.9	63.0	61.8	36.4	33.9
8/16	56.1	58.1	-	-	-	-
8/17	56.4	60.75	62.2	60.5	35.1	36.6
8/18	49.9	54.9	-	-	-	-
8/19	61.5	60.9	64.3	62.1	39.5	37.8
8/20	60.9	64.5	-	-	-	-
8/21	59.25	62.75	61.4	60.2	36.4	37.8
8/22	62.75	62.5	-	-	-	-
8/23	63.95	61.45	63.0	61.6	40.3	37.85

*Gas Meter Malfunction

Table A-7. DIGESTED SLUDGE SOLIDS - PERCENT

Date	Total Thermophilic	Total Mesophilic	Volatile Thermophilic	Volatile Mesophilic
12/9/86	1.39	1.4	67.2	68
12/16	1.5	1.4	70.0	68.5
12/23	1.5	1.35	69.8	68.
12/29	1.69	1.45	72.4	69.
1/5/87	1.56	1.4	72.5	69.4
1/12	1.5	1.3	72.6	68.8
1/19	1.65	1.4	72.6	68.2
1/26	1.63	1.5	72.6	69.0
2/2	1.73	1.58	72.5	69.9
2/9	1.8	1.60	73.7	63.0
2/16	1.8	1.65	70.7	66.7
2/23	1.88	1.65	71.53	68.0
3/2	1.89	1.71	72.5	66.6
3/9	1.91	1.65	72.6	68.3
3/16	1.98	1.76	71.12	67.4
3/22	1.92	1.69	73.3	67.6
3/29	1.79	1.67	73.2	67.3
4/3	1.91	1.68	71.78	66.36
4/11	1.96	1.78	71.27	65.35
4/19	1.84	1.78	72.45	67.49
4/25	1.91	1.84	72.45	66.45
4/27	1.92	1.82	72.8	67.3
5/3	1.89	1.82	71.95	65.47
5/4	1.91	1.89	71.13	66.03
5/12	1.85	1.82	72.04	68.12
5/17	1.99	1.89	71.16	67.50
5/25	1.86	1.84	70.85	65.80
5/31	2.01	2.02	69.71	65.54
6/7	2.05	2.02	68.65	66.84
6/14	2.23	2.05	67.47	66.41
6/21	2.29	2.08	67.96	66.05
6/27	2.35	2.26	67.85	67.87
7/5	2.5	2.26	67.43	67.82
7/9	2.47	2.17	66.59	67.77
7/12	2.42	2.21	67.10	68.98
7/16	2.39	2.32	67.05	64.55
7/19	2.35	2.29	67.18	67.66
7/23	2.38	2.14	66.59	67.38
7/26	2.39	2.21	66.60	67.68
7/30	2.25	2.11	66.20	67.07
8/2	2.24	2.19	66.52	68.31
8/6	2.L5	2.15	66.07	65.80
8/9	2.05	2.05	66.75	66.33
8/13	2.01	1.92	67.02	65.92

Table A-7. DIGESTED SLUDGE SOLIDS - PERCENT (Continued)

Date	Total		Volatile	
	Thermophilic	Mesophilic	Thermophilic	Mesophilic
8/15	2.03	1.95	66.54	66.96
8/19	2.03	1.99	67.76	66.24
8/23	1.96	1.96	69.56	69.13

Table A-8. DIGESTED SLUDGE COD - mg/l

Date	Total		Soluble	
	Thermophilic	Mesophilic	Thermophilic	Mesophilic
12/9/86	14,652.8	15,520.4	1311.	401.
12/15	19,311.2	19,215.6	1269.6	351.8
12/22	20,498.4	15,912.	1445.2	351.9
12/30	18,931.2	16,518.4	2500.	356.4
1/6/87	19,584.4	16,292.2	2962.9	422.2
1/13	17,766.7	14,318.4	2954.9	350.2
1/19	22,131.2	17,196.2	3359.2	814.1
1/26	19,698.	16,954.	3488.8	399.8
2/2	22,367.5	18,432.5	3878.0	368.6
2/9	22,750.	20,202.5	4267.0	377.6
2/16	23,522.4	22,161.6	3810.2	396.6
2/24	24,384.	22,848.	2841.6	376.32
3/3	24,140.2	20,338.6	1938.8	380.2
3/12	26,118.4	21,827.5	2873.0	402.9
3/17	24,083.0	21,693.0	3014.9	419.2
3/26	24,288.0	19,184.0	3238.4	563.2
3/31	22,816.0	20,435.2	2698.2	726.1
4/7	23,359.0	19,890.0	2386.8	469.2
4/14	17,856.0	18,240.0	1881.6	522.2
4/21	22,080.0	20,609.0	2024.0	699.2
4/28	23,865.6	21,515.2	2097.3	716.0
5/5	22,221.0	21,700.0	1946.3	624.96
5/12	22,041.6	22,435.2	2,597.8	755.71
5/19	22,848.0	21,504.0	2,265.6	568.32
5/26	21,888.0	22,656.0	2,112.0	837.12
6/2	23,312.0	22,748.0	2,068.0	624.16
6/9	22,337.0	21,973.6	2,106.6	709.61
6/16	23,584.0	21,824.0	2,604.8	823.68
6/23	27,244.0	22,148.0	2,195.2	595.8
6/30	26,864.0	25,716.0	1,816.4	608.0
7/7	25,834.0	24,710.0	2,003.0	599.0
7/9	27,980.0	24,605.0	2,087.7	589.0
7/14	27,784.0	24,012.0	2,079.2	596.2
7/16	28,205.0	24,860.0	2,097.3	578.6
7/21	28,518.0	27,440.0	2,195.2	678.2
7/23	26,827.0	23,620.0	2,138.4	544.3
7/30	26,085.0	23,990.0	2,284.8	624.5
8/4	25,723.0	25,723.0	2,199.0	768.0
8/7	25,280.0	24,531.0	2,172.0	734.0
8/11	23,813.0	23,038.0	2,090.0	658.0
8/13	22,943.0	21,979.0	2,005.0	559.0
8/23	24,898.0	25,085.0	2,621.0	607.0

Table A-9. DIGESTED SLUDGE NITROGEN - mg/l

Date	Ammonia Thermophilic	Ammonia Mesophilic	Organic Thermophilic	Organic Mesophilic
12/4/86	728	700	672	580
12/9	672	770	560	406
12/15	644	616	588	616
12/22	840	784	-	-
12/26	756	700	308	476
12/30	728	672	672	728
1/6/87	812	700	588	588
1/13	742	602	538	630
1/19	700	615	644	617
1/29	644	532	700	840
2/2	798	644	658	756
2/9	826	686	518	602
2/16	812	714	568.4	758
2/24	733.6	680.4	697.2	798.
3/2	764.4	702.8	658.	873.
3/9	865.2	697.2	511	716.8
3/17	851.2	668.0	591	757.4
3/24	849.8	728.0	572.6	758.8
3/31	851.2	728.0	558.6	754.6
4/7	849.8	725.2	595	736.4
4/14	843.0	734	554	741.0
4/21	840.0	758.8	582.4	753.2
4/28	834.4	736.4	652.4	779.8
5/5	812.0	739.2	621.6	828.8
5/12	831.0	737.8	610.8	817.6
5/19	834.4	756.0	760.2	764.4
5/26	824.6	763.0	760.2	756.0
6/2	884.8	795.2	690.2	851.2
6/9	854.0	772.8	719.6	868.1
6/18	861.0	737.8	778.7	887.6
6/23	851.2	716.8	796.6	870.8
6/30	777.0	658.0	833.0	928.2
7/7	844.2	690.2	929.6	978.6
7/9	882.0	728.0	938.0	971.6
7/14	935.2	728.0	886.2	966.0
7/17	931.0	741.8	933.8	1037.4
7/21	945.0	754.6	939.4	1085.0
7/24	929.6	735.0	904.4	1006.6
7/31	911.4	753.2	897.4	988.4

Table A-10. DIGESTED SLUDGE OIL & GREASE (mg/l)

Date		Thermophilic	Mesophilic
12/17/86		2255	1935
12/22		-	-
12/29		2200	1625
1/6/87		6035	2290
1/13		1726	1333
1/19		2955	2200
1/26		4505	3035
2/2		-	2911
2/9		-	1225
2/16		3259	2356
2/25		4311.5	2479
3/3		3368	2735
3/11		2434	1864.5
3/17		2403	1925.5
3/24		2483.5	1770.0
3/31		1770.3	1782.5
4/7		2359.5	1769.0
4/14		2290.7	2041.0
4/21		2712.2	2196.7
4/28		2518.3	2109.4
5/5		2525.9	2070.4
5/12		2059.4	1585.8
5/19		2627.3	2051.6
5/26		2531.7	2161.1
6/2		2430.5	2191.2
6/9		2383.9	2191.7
6/10		2683.0	2066.0
6/23		3002.9	2274.0
7/2		3283.0	2762.6
7/7		3396.0	2767.1
7/9		3333.3	2702.3
7/14		3537.7	2403.2
7/16		3385.1	2655.0
7/21		3589.0	3041.3
7/23		3093.0	2338.3
7/28		2918.6	2273.5
7/30		2761.8	2188.8
8/4		3125.1	2484.2
8/6	(Soluble)	178	38
8/11		2853.0	2482.0
8/13		2453.0	2095.0
8/23		2535.0	2130.0

Table A-11. DIGESTED SLUDGE CARBOHYDRATE

mg/l

Date	Total		Soluble	
	T	M	T	M
6/17/87	3150	2182	143	124
6/23/87	3068	1870	95	49
6/29/87	2650	2060	113	69
7/6/87	3240	2230	127	68
7/9/87	3360	2160	69	34
7/14/87	2770	1890	168	78
7/17/87	2950	2200	68	51
7/21/87	2300	1890	88	27
7/24/87	2710	2200	133	57
7/28/87	2950	2080	106	56
7/31/87	3140	1950	90	60
8/4/87	2520	2020	57	30
8/7/87	2360	1710	101	53

Table A-12. MEAN CAPILLARY SUCTION TIME (SEC)
(Unconditioned Sample)

Date	Temp. (°C)	Thermophilic	Mesophillic
3/14/87	-	611.8*	524.2*
3/15	-	466.3*	475.5*
3/21	-	417.3*	457.6*
3/22	-	463.2*	398.5*
3/29	-	423.2*	389.0*
4/5	-	405.5*	491.4*
4/19	-	463.2	402.7
4/23	21	512.1	425.0
4/30	-	496.7	416.9
5/3	25	464.7	351.8
5/5	23.5	480.7	372.9
5/6	23.5	490.6	387.9
5/7	25	432.8	405.5
5/8	21.5	482.2	411.6
5/11	24.5	467.3	426.7
5/12	25	495.37	409.4
5/13	23.5	465.7	469.2
5/20	25	638.7	493.0
5/21	24.5	632.5	593.2
5/22	24.5	589.9	494.6
5/23	24.5	485.0	405.5
5/24	24.5	534.9	417.8
5/25	24.0	496.8	414.2
5/26	24.0	533.2	402.8
5/27	24.5	516.3	405.1
5/28	24.5	527.1	377.1
5/29	25	504.9	399.9
5/31	26	506.6	411.4
6/1	26	506.3	376.9
6/2	25	533.6	419.1
6/3	24	596.8	414.9
6/4	23.5	557.5	434.5
6/5	23.5	587.2	439.8
6/8	25	574.4	464.1
6/9	26	535.0	403.3
6/10	24	722.6	472.2
6/11	26	561.9	403.3
6/12	24	597.0	423.9
6/15	25.5	618.0	421.2
6/16	24.5	781.5	522.3
6/17	23.5	553.5	415.6
6/18	25	566.6	398.4
6/19	25.5	533.8	386.0
6/22	26	510.4	384.1

Table A-12. MEAN CAPILLARY SUCTION TIME (SEC) (continued)
(Unconditioned Sample)

Date	Temp. (^oC)	Thermophilic	Mesophillic
6/23	27	501.5	381.5
6/24	26.5	549.5	410.0
6/25	26	606.6	420.3
6/26	25.5	604.8	443.1
6/29/87	26	453.4	344.8
6/30	26.5	444.4	318.1
7/1	26.5	454.4	327.4
7/2	26.5	458.4	316.3
7/3	25	527.6	333.5
7/5	49	415.2	-
7/5	35	-	300.8
7/5	25	533.9	377.9
7/6	25	571.2	407.3
7/9	22	562.4	379.1
7/11	25	548.0	387.0
7/13	22	548.2	339.4
7/15	25	535.2	395.7
7/16	25	653.7	404.7
7/18		684.0	417.0
7/20	25	623.5	362.6
7/22	25	642.2	338.4
7/23	25	742.7	405.1
7/25	25	771.0	448.0
7/27	25	814.7	485.0
7/29	25	782.0	397.2
7/30	25	694.2	383.2
8/1	25	732.0	451.0
8/3	25	672.3	369.3
8/5	25	600.6	321.4
8/6	25	647.0	385.4
8/8	25	655.0	388.0
8/10	25	595.3	358.0
8/12	25	644.7	366.4
8/13	25	600.2	444.6
8/15	25	648.0	385.0
8/21	25	627.0	362.0
8/23	25	595.0	387.0

* Temperature not measured

Table A-13. CAPILLARY SUCTION TIME TESTS WITH CONDITIONERS ADDED

Date	$FeCl_3 6H_2O$ Added (g/1)	$Ca(OH)_2$ Added (g/1)	Cup Size (cm)	Mesophillic pH	Mesophillic CST (sec)	Thermophilic pH	Thermophilic CST (sec)
3/15/87	0	0	1.8	7.15	475.5	7.4	466.3
	1	0	1.8	6.6	288.8	6.9	392.8
	2	0	1.8	6.5	74.4	6.5	135.9
	3	0	1.8	6.2	22.5	6.3	57.6
	4	0	1.8	6.1	15.7	6.1	16.2
3/21/87	0	0	1.8	7.35	398.5	7.6	463.2
	1	0	1.8	6.95	142.7	7.1	271.3
	1	0.5	1.8	7.45	155.4	7.45	223.2
	1	1.0	1.8	7.90	230.0	8.05	348.6
	1	1.5	1.8	8.50	166.4	8.40	317.4
	1	2.0	1.8	8.65	237.6	8.60	261.8
	0	0.5	1.8	8.15	429.6	8.40	431.1
	0	2.0	1.8	8.9	407.3	8.90	378.4
3/29/87	0	0	1.8	7.4	389.0	7.75	423.2
	3	0	1.0	6.4	90.1	6.3	342.3
	4	0	1.0	6.0	44.9	6.25	62.6
	5	0	1.0	5.65	30.8	5.9	30.3
	6	0	1.0	5.35	25.5	5.8	23.4
	7	0	1.0	5.30	22.6	5.3	19.3
4/5/87	0	0	1.0	7.5	491.4	8.0	405.5
	4	0	1.0	6.8	40.8	6.65	78.3
	4	0.5	1.0	7.1	42.2	7.1	91.9
	4	1.0	1.0	7.4	30.8	7.25	69.0
	4	1.5	1.0	7.55	33.8	7.40	85.2
	4	2.0	1.0	7.75	30.0	7.65	141.5
	4	3.0	1.0	8.5	78.7	8.3	203.2
7/8/87	3	0	1.0	6.6	335.9	6.9	1291.2
	4	0	1.0	6.75	110.3	7.05	685.4
	5	0	1.0	6.75	61.7	6.6	362.6
7/15/87	4	0	1.0	6.7	19.4	6.55	1020.4
	5	0	1.0	6.4	32.0	6.4	493.8
	6	0	1.0	6.15	19.4	6.15	79.6
	4	0	1.8	6.7	10.8	6.55	149.2
	10.4	0	1.0	-	-	4.3	17.5
	8.9	0	1.0	4.3	18.0	-	-

Table A-13. CAPILLARY SUCTION TIME TESTS WITH CONDITIONERS ADDED

(Continued)

Date	$FeCl_3 6H_2O$ Added (g/1)	$Ca(OH)_2$ Added (g/1)	Cup Size (cm)	Mesophillic pH	Mesophillic CST (sec)	Thermophilic pH	Thermophilic CST (sec)
7/22/87	4	0	1.0	6.3	99.3	6.5	933.5
	4	0	1.8	6.3	31.1	6.5	140.2
	5	0	1.0	6.1	34.7	6.3	594.3
	6	0	1.0	5.9	24.1	6.15	169.2
	9.05	0	1.0	4.3	18.8	-	-
	10.4	0	1.0	-	-	4.3	16.7
7/29/87	6	0	1.0	6.0	25.9	6.2	186.7
	5	0	1.0	6.15	40.2	6.35	663.3
	4	0	1.0	6.4	76.0	6.5	1039.8
	4	0	1.8	6.4	16.1	6.5	161.6
	9.0	0	1.0	4.3	17.5	-	-
	10.8	0	1.0	-	-	4.3	18.3
8/5/87	4	0	1.0	6.35	53.7	6.5	908.0
	4	0	1.8	6.35	11.1	6.5	154.0
	5	0	1.0	6.2	25.2	6.4	193.0
	6	0	1.0	6.0	18.0	6.2	49.6
	7	0	1.0	5.8	16.1	6.0	25.3
	8.95	0	1.0	4.3	16.6	-	-
	10.45	0	1.0	-	-	4.3	17.8
8/12/87	4	0	1.0	6.2	40.0	6.5	49.5
	5	0	1.0	6.0	21.0	6.3	119.5
	6	0	1.0	5.8	20.8	6.1	34.3
	7	0	1.0	5.6	16.3	5.9	15.8
	9.2	0	1.0	4.3	15.9	-	-
	10.0	0	1.0			4.3	16.4