# Class A Biosolids

## Terminal Island Treatment Plant


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**Environmental Engineering Division**

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# EXECUTIVE SUMMARY

The City of Los Angeles, Bureau of Sanitation has applied its biosolids to agricultural fields in compliance with U. S. EPA regulations since 1988. The biosolids are produced by mesophilic digestion of the sewage sludge at its wastewater treatment plants. Mesophilically digested sewage sludge meets U.S. EPA Class B standards for pathogens and can be safely recycled. However, adverse public perception of this practice has influenced many local jurisdictions into enacting ordinances to phase out or ban the practice. Kern County passed such an ordinance in late 1999 to phase out Class B biosolids after December 31, 2002. It is for this reason that the Bureau decided to investigate the possibility of producing Class A biosolids at its treatment plants.

The highest quality of biosolids is called Exceptional Quality (EQ). In order to qualify for this classification, biosolids must comply with three criteria: low metal concentration limits (Table 3 of 40 CFR 503.13), a vector attraction reduction requirement (40 CFR 503.33) and the Class A pathogen density reduction requirement (40 CFR 503.32). The City already meets the first two requirements. Thus, the main challenge to produce EQ biosolids is to ensure that the Class A pathogen density reduction requirement is met. The biosolids regulations are briefly discussed in Appendix 7.1.

In an effort to produce Class A biosolids at Terminal Island Treatment Plant (TITP), we have been testing different full-scale thermophilic anaerobic digestion processes. The three processes tested and their general objectives were:

1) Single stage thermophilic digestion (Phase I, February 1999 to June 2000):
   - Conversion from mesophilic to thermophilic digestion.
   - Establishment of a stable thermophilic culture.
   - Determination of digestion performance.
   - Determination of compliance with Class A biosolids production, Alternative 3 of 40 CFR Part 503.
2) Two-stage thermophilic digestion, using two digesters in series (Phase II, July 2000 to April 2001):
   - Determination of digestion performance.
   - Determination of compliance with Class A biosolids production, Alternative 3 of 40 CFR Part 503.
3) Single-stage thermophilic batch digestion, using 3 digesters in parallel (Phase III, July 2001 to present).
   - Determination of compliance with Class A biosolids production, Alternative 1 of 40 CFR Part 503.

Whereas Phases I and II generally focused on the conversion to and the performance of thermophilic digestion, compliance with 40 CFR Part 503 through Alternative 1 was the main purpose of Phase III. The specific objectives for Phase III, as defined by the Department of Public Works Class A Biosolids Task Force, were:

A. Implementation of protocols to work with strict attention to Quality Assurance/Quality Control (QA/QC) methods (Section 2) during:
   1. Sampling procedures for digested sludge and wet cake throughout the post-digestion train for microbial studies.
   2. Microbial analysis procedures of samples.
B. Preparation of a report presenting the results, conclusions, and recommendations for the studies on *Salmonella* (pathogen), fecal coliform (indicator), helminth ova, and enteric viruses densities (Sections 3, 4, 5).
C. Additional studies to define the biosolids temperature profile along the post-digestion train, and to evaluate contamination/regrowth issues throughout the post-digestion train (Section 6).

## RESULTS

### Phase I

*Process implementation:* Digester 1 was selected for conversion to thermophilic treatment. The conversion included rapid heating and a program for slowly increasing the sludge feeding rate to the digester. After conversion, the digester was operated at a target temperature of 131 $^0$F and an average solids retention time of 12 days with a semi-continuous feed sludge (Alternative 3 of 40 CFR Part 503).

*Digestion performance:* A thermophilic culture with stable digester performance was obtained in about two weeks. Solids destruction and gas production were similar or better than observed during mesophilic digestion.

*Pathogen/indicator densities: Salmonella* sp. densities in digested sludge were always less than the limit of 3 MPN/4 g dry wt. Fecal coliform densities in digested sludge occasionally exceeded the limit of 100 MPN/g dry wt.

*Other requirements of 40 CFR Part 503:* All heavy metal concentrations in digested sludge were less than their limit concentrations specified in 40 CFR Part 503 for EQ biosolids. The volatile solids destruction was significantly higher than the minimum of 38% required for the vector attraction reduction as specified in 40 CFR Part 503.

### Phase II

*Process implementation*: Digesters 1 and 2 were operated in series to increase the average solids retention time to 24 days (12 days each). The target temperature in the first digester was 131 $^0$F and digested sludge from this digester was transported to the second digester by gravity flow. Sludge feeding was semi-continuous (Alternative 3 of 40 CFR Part 503).

*Digestion performance*: Using two digesters in series, solids destruction and gas production slightly improved over those observed during Phase I using a single digester.

*Pathogen/indicator densities*: Densities of fecal coliform in digested sludge from the second stage were consistently below the limit of 1000 MPN/g dry wt. Untreated sludge did not contain helminth ova, neither was helminth ova observed in digested sludge. Enteric viruses present in untreated sludge were effectively reduced in digested sludge to less than the limit of 1 PFU/4 g dry wt.

### Phase III

*Process implementation:* Three digesters were operated in parallel for single-stage thermophilic batch digestion. The time-temperature goal (Alternative 1) is to ensure a detention time of 24 hours at 131°F. There are three phases in the batch digestion cycle (feed, hold, and withdraw) that each of the three digesters go through once every three days.

*Pathogen/indicator densities:* Densities of *Salmonella* in the mixture of digester inflow were generally in the range between 5.8 to >16 MPN/4 g dry wt and in few occasions <2.2 MPN/4 g dry wt. *Salmonella* densities at all post-digestion sampling locations were <2.2 MPN/4 g dry wt. High densities of fecal coliform (approximately $10^6$ MPN/g dry wt) were observed in the mixture of digester inflow. During the four months of testing, most of the samples from Location 2 (Digester outflow) showed fecal coliform densities lower than the limit of 1000 MPN/g dry wt. Only 12 out of 86 samples (14%) exceeded this limit. Location 3 (Centrifuge) also showed several incidences where the exceedances were observed. Five out of 17 samples (29.4%) from Location 3 exceeded the limit. A high density of fecal coliform (approximately $10^5$ MPN/g dry wt) was observed at Location 4 (Truck).

The helminth ova density throughout the post digestion train was below 1 ovum/4 g dry wt. Similarly, the density of enteric viruses was also below 1 PFU/4 g dry wt although high densities (ranging from 41 to 201 PFU/4 g dry wt) were detected in the digester inflow.

*Contamination, regrowth and temperature profile studies:* Fecal coliform densities were very low in digested sludge samples (approximately 50 MPN/g dry wt) and there was a small increase in counts (approximately 100 MPN/g dry wt) after 48 hours at room temperature. Relatively low densities of fecal coliform were measured in wetcake samples obtained at the centrifuge and at the conveyer belt (10 to 250 MPN/g dry wt). However, a significant increase in the density occurred in both types of samples ($8 \times 10^5$ to $2.5 \times 10^6$ MPN/g dry wt) after 48 hours at room temperature. Wetcake samples from the truck loading location initially showed high levels of fecal coliform ($8 \times 10^6$ MPN/g dry wt). A further increase to approximately $10^8$ MPN/g dry wt was observed after 48 hours.
Very low fecal coliform densities ($<10^1$ MPN/g dry wt) were measured in laboratory-centrifuged digested sludge samples and they increased to approximately <250 MPN/g dry wt at 25, 37, or 44.5 °C after approximately 72 - 96 hrs. A similar trend was observed in the fecal coliform density in laboratory-centrifuged digested sludge amended with high-pressure effluent (HPE), polymer-type coagulant, or both. At 55 °C, fecal coliform counts ($<10^1$ MPN/g dry wt) did not increase in laboratory-centrifuged digested sludge with all combinations of HPE and polymer.
The sludge temperature continually decreased throughout the post-digestion process. A significant drop was observed between the centrifuge and silo through the conveyer belt, where wetcake is exposed to ambient air.

## CONCLUSIONS

### Phase I

1 Rapid heating and slowly increasing the sludge feed rate facilitated a rapid conversion from mesophilic to thermophilic digestion and prevented excessive acid accumulation in the digester.

2 Analysis of chemical parameters demonstrated the development of a balanced thermophilic culture, capable of achieving a relatively constant digester performance despite sometimes highly fluctuating sludge feed rates.

3 The digestion performance was improved by conversion from mesophilic to thermophilic operation. As summarized in Table 12, total and volatile solids destruction were respectively 17 and 12 % higher at during thermophilic digestion. The expected increase in gas production is 20%. The significance of these findings would be subject to further research, in particular because of uncertainties in analytical procedures.

4 Semi-continuous operation at an average sludge retention time of approximately 12 days and an average temperature of 128.1 $^0$F significantly reduced the fecal coliform density, but exceedance of the EPA limit of 1000 MPN/g dry wt was sometimes observed.

5 Semi-continuous operation at an average sludge retention time of approximately 12 days and an average temperature of 128.1 $^0$F consistently reduced the *Salmonella* sp. density to below the EPA limit of 3 MPN/4 g dry wt.

6 Class A qualification according to Alternative 3 of 40 CFR Part 503 could not be demonstrated because densities of helminth ova and enteric viruses were not determined.

7 Heavy metals concentrations in thermophilically digested sludge satisfied the highest standards (EQ) standards in 40 CFR Part 503.

8 Volatile solids destruction during thermophilic digestion satisfied the standards set in 40 CFR Part 503 for vector attraction reduction.

### Phase II

1 Doubling the sludge retention time to 24 days by employing two digesters in series only slightly improved digester performance in terms of solids destruction and predicted gas production.

2 Fecal coliform densities in sludge from the first digester were sometimes above the limit of 1000 MPN/g dry wt, which agrees with results obtained during Phase I. Consistent reduction of fecal coliform to well below the limit for Class A biosolids was achieved by putting a second digester in series so that the average retention time was doubled.

3 *Salmonella* sp. densities were not determined during Phase II, but disinfection to below the limit for Class A biosolids can reasonably be assumed to have occurred. Phase I research demonstrated that single stage treatment was already sufficient to reduce *Salmonella* sp. densities to an undetectable level.

4 De density of enteric viruses in raw sludge varied greatly, but effective disinfection to less than the EPA limit of 1 PFU/4 g dry wt was observed at all times.

5 Both untreated and digested sludge did not contain helminth ova.

6 Alternative 3 of 40 CFR Part 503 requires demonstration of the process to effectively reduce helminth ova and enteric viruses to below their limits (respectively $<1$ ovum/4 g dry wt and $<1$ PFU/4 g dry wt). It is also generally required to demonstrate that the density of fecal coliform or the density of *Salmonella* sp. in digested sludge is less than their limits (respectively, 1000 MPN/g dry wt and $<3$ MPN/4 g dry wt). Demonstration of pathogen reduction by any process requires in the first place the presence of the particular pathogen in untreated sludge. Since this was not the case for helminth ova, its reduction could not be demonstrated. TITP can therefore not use Alternative 3 to demonstrate qualification of its digestion process for Class A biosolids production.

**Phase III**

1 The *Salmonella* densities observed in the digester inflow were significantly reduced by single-stage thermophilic batch digestion to below the limit established in 40 CFR Part 503.32 (<3 MPN/4 g dry wt) for Class A biosolids by using Alternative 1, time-temperature regime defined in Part 503 Rule.

2 Fecal coliform densities observed in the digester inflow were also significantly reduced after digestion. In general, the fecal coliform density in digested sludge was below the Class A limit of <1000 MPN/g dry wt. However, on several occasions, the densities exceeded this limit. This is attributed to the fact that the required thermophilic temperatures were not reached in the digesters due to insufficient heat supply by outdated boilers.

3 *Salmonella* densities were below the Class A limit throughout additional locations in the post-digestion train.

4 Fecal coliform densities exceeded the Class A limit several times after the centrifuge and at all times at the truck loading facility. One possible cause could be external contamination. The conveyer belt that transports wetcake from the centrifuge to the silo is exposed to an open environment leaving the wetcake vulnerable to external contamination sources such as bird droppings, etc.

5 Although not explicitly required for Alternative 1, densities of helminth ova and enteric viruses were determined and found to meet the EPA Class A limit (<1 ovum/4 g dry wt and <1 PFU/4 g dry wt, resp.) after digestion (as specified in Alternative 3).

6 A preliminary profile of the biosolids temperature throughout the post-digestion train showed a major drop between the centrifuge and the truck loading location. Temperatures at the truck loading facility were low enough to allow for growth of fecal coliform.

7 Based on preliminary tests, HPE and polymer were not found to be significant sources of contamination.

**RECOMMENDATIONS**

TITP is currently fully converted to thermophilic digestion using three digesters in parallel. As in Phase III, the target temperature is 131 $^0$F at a batch holding of 24 hours according to Alternative 1 of 40 CFR Part 503. Several modifications to the TITP digesters and post-digestion train are recommended (Section 5):

- Addition of new sludge mixing systems, sludge heating systems, recirculation pumps, and steam injectors to the digesters.
- Heat tracing and insulation of transfer lines.
- Modifications to the belt conveyers for biosolids transport from the centrifuge to the storage building.

Once these modifications have been implemented, it is recommended to proceed with Phase IV testing.

# 1. INTRODUCTION

It has been one of the main goals of the City of Los Angeles Bureau of Sanitation to produce biosolids of Exceptional Quality (EQ). In order to qualify for such classification, biosolids must comply with three regulations: low metal concentration limits (Table 3 of 40 CFR 503.13), a vector attraction reduction requirement (40 CFR 503.33) and a pathogen density reduction requirement (40 CFR 503.32). The biosolids regulations are discussed briefly in Appendix 7.1. Historical data indicate that the metal concentrations in the biosolids are below the required limits in Table 3 of 40 CFR 503.13. The vector attraction requirement is satisfied when volatile solid (VS) reduction is at least 38%. Routine performance of the Terminal Island Treatment Plant's (TITP) digester process (mesophilic and thermophilic) has consistently demonstrated a 50% or greater VS reduction. Since the City meets these two requirements, the primary challenge to get EQ biosolids is to ensure that pathogen density reduction requirement is met. Thus, the Bureau of Sanitation's management has directed the Bureau's staff to perform full-scale studies to meet the last requirement and to produce Exceptional Quality (EQ) Biosolids.

40 CFR Part 503.32 lists six alternatives for treating biosolids in order to achieve the Class A qualification. Thermophilic digestion is the selected process for disinfection of the City's biosolids. Full-scale studies at TITP investigated two treatment alternatives for Class A biosolids production:

1. Alternative 1: This alternative requires batch processing of biosolids according to a specific time-temperature relation.
2. Alternative 3: This alternative does not specify a process for disinfection, but it requires demonstration of the selected process to reduce enteric viruses to equal or less than one Plaque-Forming Unit per 4 g dry weight and viable helminth ova to equal or less than one per 4 gram dry weight.

Additional information on both alternatives can be found in Appendix 7.1. In addition to process or treatment requirements, each alternative must also satisfy the following general requirement:

1. The density of *Salmonella* sp. bacteria in the biosolids must be less than 3 MPN/4 g dry wt, or
2. The density of fecal coliform in the biosolids must be less than 1000 MPN/g dry wt.

A task force was formed to oversee the effort to produce Class A biosolids at TITP. The task force is composed of personnel from various divisions within the Bureau of Sanitation (TITP staff, Applied Research of Wastewater Engineering Services Division, Environmental Monitoring Division, Regulatory Affairs Division), Bureau of Engineering (Environmental Engineering Division), and consultants. Task force members have participated in on site analysis at TITP and weekly meetings to discuss progress in producing Class A biosolids. Activities of the task force are being monitored by the Bureau of Sanitation's Biosolids Management and discussed at monthly biosolids meetings (REBOC).

An investigation program at TITP has been testing different full-scale thermophilic anaerobic digestion processes. This was to find the process that provides the best combination of operational costs, gas production, disinfection effectiveness and compliance with 40 CFR Part 503. The three processes tested were:

1. Phase I (February to June 2000): Single stage CSTR (continuously stirred tank reactor) thermophilic digestion, Alternative 3.
2. Phase II (July 2000 to April 2001): Two-stage thermophilic digestion, Alternative 3.
3. Phase III (July 2001 to present): Single-stage thermophilic batch digestion with three digesters in parallel, Alternative 1.

This report focuses on the conversion to thermophilic operation, the digestion performance under thermophilic operation, the pathogen disinfection and compliance with 40 CFR Part 503. With respect to Class A biosolids, densities of pathogenic subgroups (i.e., helminth ova, enteric viruses, *Salmonella* sp., and/or fecal coliform) were analyzed in the digester inflow and compared to post-digestion densities in order to evaluate the effectiveness of pathogen removal of the selected digestion process. In Phase III, microbial indicators were also analyzed throughout the post-digestion process at four different locations up to the truck loading facility. Supporting studies were conducted in order to address regrowth/contamination issues (Section 6 Supporting Studies). All studies were conducted with attention to Quality Assurance/Quality Control (QA/QC) procedures in all aspects of the field-testing, laboratory procedures, data collection, and analysis.

The general objectives of each phase were as follows.

**Phase 1**
The main objective was to convert the digesters from mesophilic to thermophilic operation and to establish a stable thermophilic culture. Phase I studies focused on optimization of start-up procedures and determination of the process performance with respect to solids destruction, gas production, and process and/or culture stability. Disinfection efficiency was evaluated by the density reduction of fecal coliform and *Salmonella* sp.

**Phase II**
The general objective of this phase was to improve digester performance with respect to digestion and disinfection. This was done by implementation of a digestion process using two digesters in series, instead of one digester as in Phase 1. The solids retention time during Phase II was therefore twice of that during Phase I. Phase II also included the analysis of helminth ova and enteric viruses as required in Alternative 3 for Class A biosolids.

**Phase III**
The general objective was to produce Class A biosolids in a single stage batch process according to the time-temperature requirement of Alternative 1. This could result in compliance with 40 CFR Part 503 without the need for frequent analysis of helminth ova and enteric viruses (as required under Alternative 3).

Whereas Phases I and II can best be described as research phases for optimization of digestion and disinfection, the specific purpose of Phase III was to demonstrate Class A biosolids production at TITP. The specific objectives of Phase III were:

1. Establish a single-stage thermophilic batch process at TITP that satisfies the requirements for Class A Biosolids as indicated by USEPA 40 CFR Part 503, Subsection 32 Alternative 1, time-temperature regimen.
   - 1.1. Conduct field inspections at TITP to identify potential sources of contamination and define procedures that help prevent them.
   - 1.2. Implement a single stage thermophilic process with three digesters operated in parallel under thermophilic digestion conditions at a target temperature of 131 $^{0}$F.
   - 1.3. Determine the pathogen/indicator densities in the biosolids to evaluate the effectiveness of pathogen destruction.
     - 1.3.1. Sample biosolids at the following locations:
       - 1.3.1.1. Inflow and outflow of digesters to evaluate the efficiency of the pathogen/indicator removal during the thermophilic digestion process.
       - 1.3.1.2. Throughout the post-digestion train, that is, after dewatering, at storage, and at the truck to define how *Salmonella* (pathogen) densities vary with respect to fecal coliform (indicator) densities.
       - 1.3.1.3. Follow EPA approved methods (Section 2) in all analysis and sampling operations (collection of samples, sampling schedule, sampling containers, etc.).

1.3.2. Analyze *Salmonella* (pathogen) densities in biosolids samples to evaluate compliance with EPA standards for pathogen removal.
1.3.3. Analyze fecal coliform (indicator) densities in biosolids samples to define if both criteria, that is, pathogen and indicator are in good agreement.
1.3.4. Analyze helminth ova and enteric viruses densities in biosolids samples to evaluate compliance with EPA standards for pathogen removal.

2. Perform supporting studies as discussed in Section 6, addressing bacterial contamination or regrowth problems in order to investigate potential solutions.
3. Propose additional studies as discussed in Section 5 to address problems that arise from the activities previously described.
4. Compile all data to support EPA requirements for Class A biosolids.

# 2. MATERIAL AND METHODS

## 2.1 Operational procedures

### 2.1.1 General process description

TITP has four egg-shaped digesters grouped into two pairs, and each with a volume of 1.34 MG (e.g., Figures 1, 2, and 3). The digesters were originally designed for continuous feed and withdrawal operations. The total sludge production at TITP is approximately 150,000 gpd and consists of a mixture of primary sludge and thickened waste activated sludge. The digesters are fed by pumping the sludge mixture from the blender to the re-circulating sludge line. In addition, scum, which comes from the scum concentrator, can only be pumped directly to either Digester 3 or Digester 4.

Mixing within the digesters is achieved by a combination of two methods. One method is pumping of the digester content from the bottom of the digester to the top. Each pair of digesters shares a common mixing pump. Therefore, when the pump is mixing one of the digesters, the other is mixed by the second method. The second method is a gas mixing system and, unlike the pump-mixing, each digester can be gas-mixed independently.

There are two ways of heating the digesters and both methods require the recirculation of the digester content, as shown in Figure 4. The first method is heating of the re-circulating sludge using heat exchangers. Hot water from the cogeneration process circulates through the heat exchangers to deliver heat. The second method is steam injection into the recirculating sludge. Low-pressure steam (under 15 psi) is produced by an onsite boiler and injected into the recirculation line for heating. During the thermophilic digestion process testing at TITP, steam injection was the main source of the heat.

Digester temperatures are measured in the recirculation pipe by a resistance temperature detector. Since the temperature measurement requires the digester content to be recirculated, only one digester out of each pair can be measured at a time. As described above, since the recirculation is achieved by pumping of the digester content from its bottom to the top, the measurements reflect the sludge temperature in the lower portion of the digester. The in-line temperature sensor measures the temperature continuously. Daily temperatures in this report represent the average temperature for that day.

### 2.1.2 Start-up conversion to thermophilic digestion (Phase I)

Rapid heating while slowly increasing the sludge feed rate to the digester is critical for rapid establishment of a stable thermophilic microbial culture. For Phase I, digester 1 was selected for thermophilic operation while mesophilic operation was continued in digester 3 for back-up purposes in case of failure of thermophilic operation (Figure 1). Digesters 2 and 4 were out of service. Heating of digester 1 started on February 15, 2000, at rate of approximately 3 $^{0}$C per day and was completed on February 21, 2000, reaching the target temperature of 131 $^{0}$F. Sludge feeding started on February 21, 2000, by the addition of 1600 gallon. Between February 23 and March 14, 2000, the sludge feed rate was low (0 – 36,000 gpd) and highly fluctuating. After March 14, 2000, the sludge feed rate was gradually increased in five steps from initially 36,000 gpd to 100,800 gpd after May 9, 2000. Sludge feeding and withdrawal cycles during each step are presented in Figure 5, whereas actual daily feeding rates are shown in Figure 6. From the latter figure it can be seen that the sludge feeding rate on a daily basis considerably fluctuated.

### 2.1.3 Single stage thermophilic digestion (Phase I)

Single stage operation was investigated during startup of digester 1 as described in section 2.1.2 and for an additional 6 weeks after completing the start-up. Figure 1 presents an overview of the process configuration. Assuming complete mixing, the hydraulic and solids retention times are

the same and the average solids retention time can be calculated by dividing the digester volume by the sludge feed rate. Thus, the average solids retention time in digester 1 was 11.9 days at 100,800 gpd, but longer during startup with lower feed rates.

The target digestion temperature during Phase 1 was 131 $^0$F. As shown in Table 1, the daily average temperature in digester 1 fluctuated between 123.2 and 139.8 $^0$F with an average value of 128.1 $^0$F. It should in this respect be emphasized that Alternative 3 does not specify requirements to the time or temperature during digestion. Not meeting the (self-imposed) target temperature has therefore no consequences with respect 40 CFR Part 503 requirements, as long as the limits for fecal coliform, *Salmonella* sp., enteric viruses and helminth ova are being met.

### 2.1.4 Two-stage thermophilic digestion (Phase II)

Two-stage digestion was investigated with the purpose of improving digestion and disinfection efficiencies by increasing the sludge retention time. Phase II was from July 2000 to April 2001, however, this report presents Phase II results obtained over October 2000 to March 2001. This period can be considered representative for entire Phase II. The process configuration, shown in Figure 2, consisted of digester 1 as the primary digester and digester 2 as the secondary digester. Digester 3 was in mesophilic operation whereas digester 4 was out of service. Feed from digester 1 to digester 2 was by gravity flow. By using two digesters in series, the average, overall sludge retention time was 25.6 days at an average sludge feed rate of 93750 gpd. Mixing in digester 1 was achieved by sludge recirculation while digester 2 received mixing by gas. The target temperature in digester 1 was 131 $^0$F, but actual temperatures ranged between 116.6 and 134.2 $^0$F with a daily average of 127.6 $^0$F (Table 2). Digester 2 was not heated. The temperature in digester 2 over October and November 2000 was highly fluctuating and frequently below 115$^0$F, but a relative constant temperature at an average value of 126.1 $^0$F was observed thereafter (Table 2).

### 2.1.5 Single stage thermophilic batch digestion (Phase III)

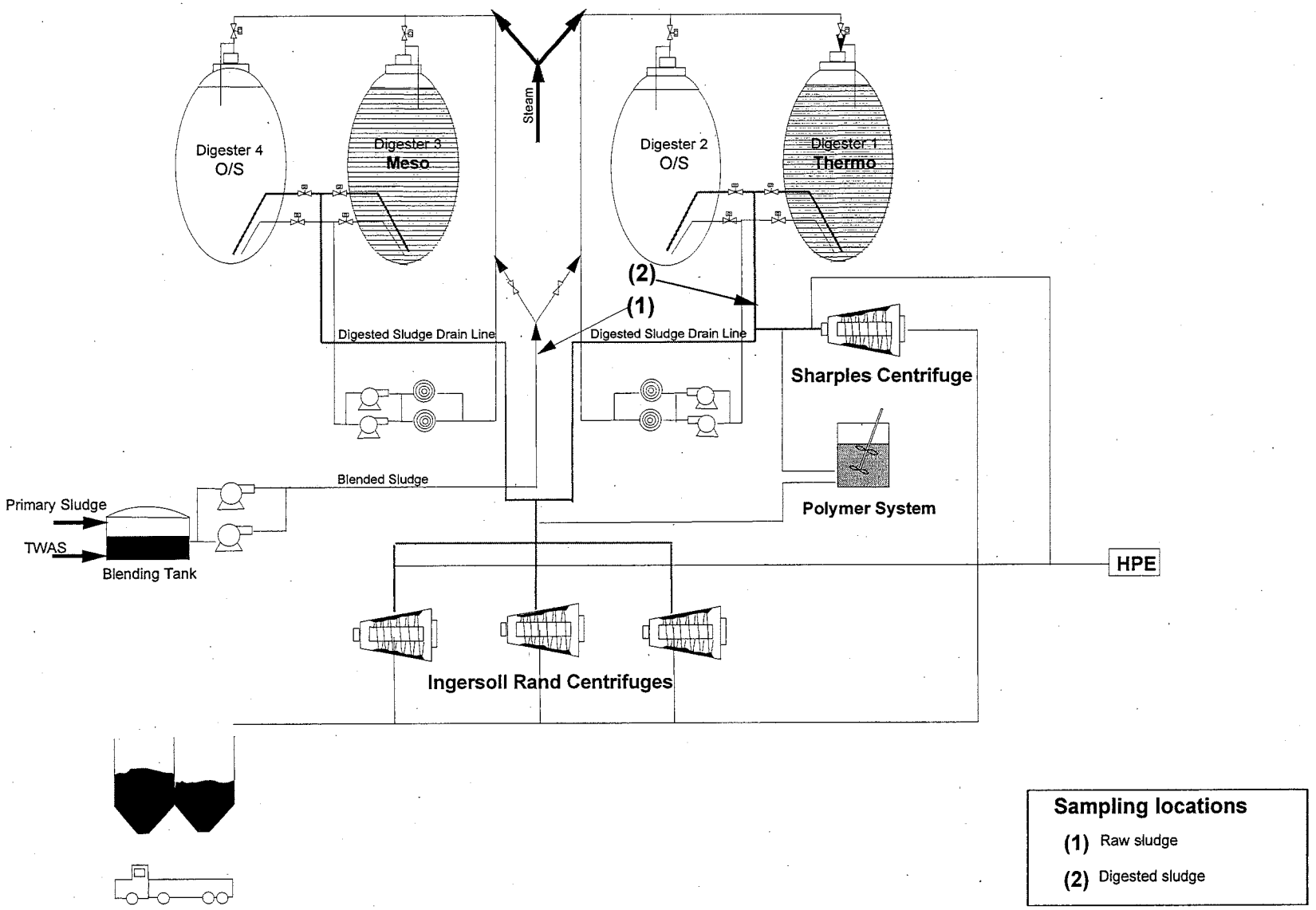
TITP changed its continuous-feed-and-withdrawal type of operation (as in Phase I and II) to a semi-batch process in order to meet the time-and-temperature requirement in Alternative 1 for Class A biosolids. This change was possible because of the relatively large capacity of the digesters and the capability of the digesters to handle a varying sludge level. Phase III was over July and November, 2001, during which period the parallel batch operation of digesters 1, 2 and 3 was investigated (Figure 3). At end of August 2001, digester 3 was taken out of service and replaced by digester 4. The time-and-temperature goal of alternative 1 during Phase III was to ensure a detention (or holding) time of 24 hours at 131°F. Each digester was operated on a 3-day cycle of sludge feeding, holding, and withdrawal, as shown in Figure 7. With each cycle complementary to one another, parallel operation of the digesters therefore ensured continuous feed to and withdrawal from the digester battery. The average solids retention time in the digesters was estimated to be approximately 27 days, with a guaranteed (=batch) holding time of 24 hours.

Table 3 shows that the target disinfection temperature of 131 °F was not fully achieved. Digesters 1 and 2 were very frequently below the target temperature, especially at the beginning of the test. Temperatures in Digesters 3 and 4 were more frequently near to the target. Temperatures lower than the target were due to the fact that the boiler was old, somewhat inefficient and close to its maximum heat generating capacity.

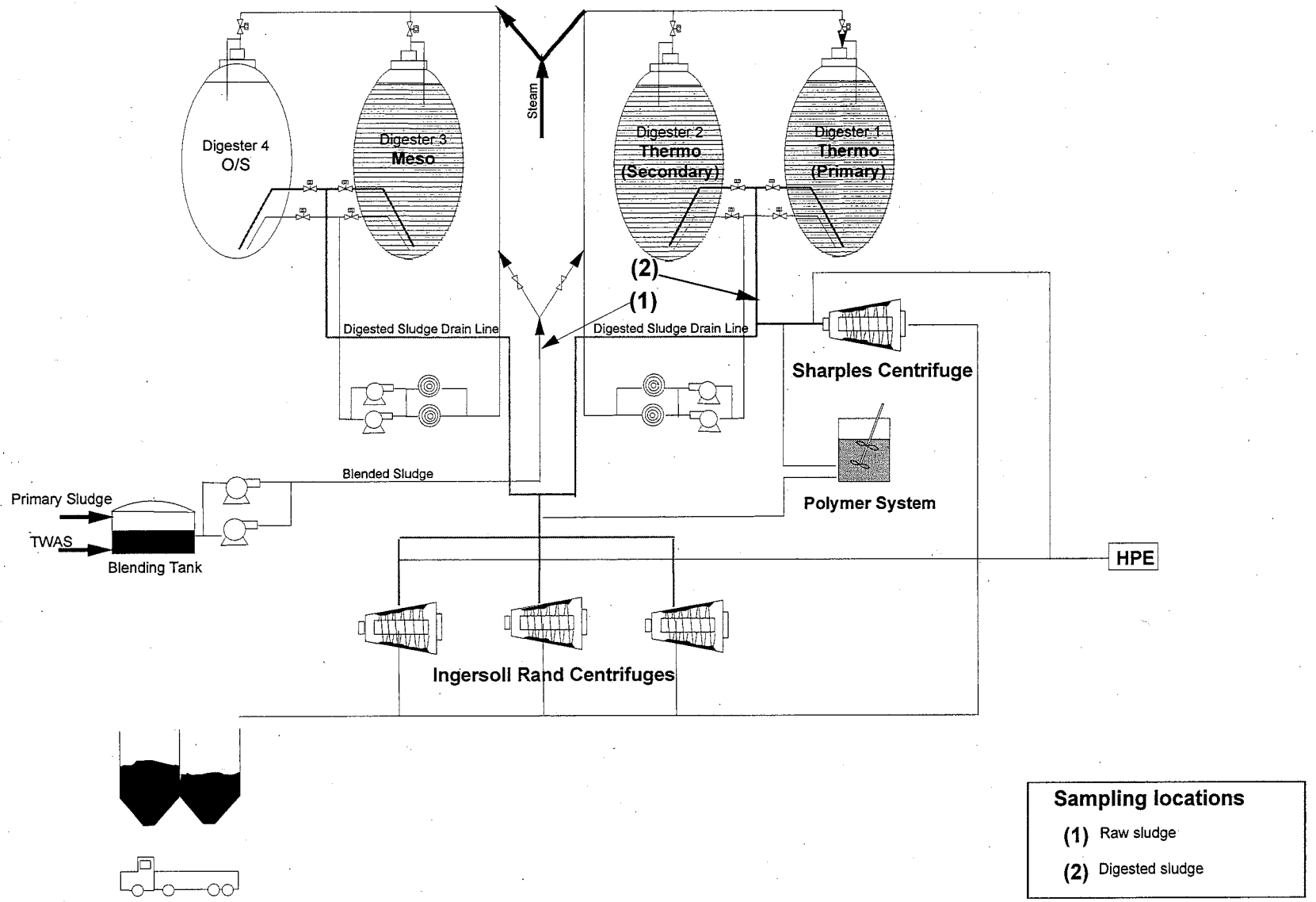
### 2.1.6 Operational instructions

Appendix 7.2 includes by detail the instructions to the operators for the digester operation during Phase III.

## Figure 1. Phase I - Process overview of single stage thermophilic digestion



## Figure 2. Phase II - Process overview of two stage thermophilic digestion



## Figure 3. Phase III - Process overview of single stage batch thermophilicdigestion

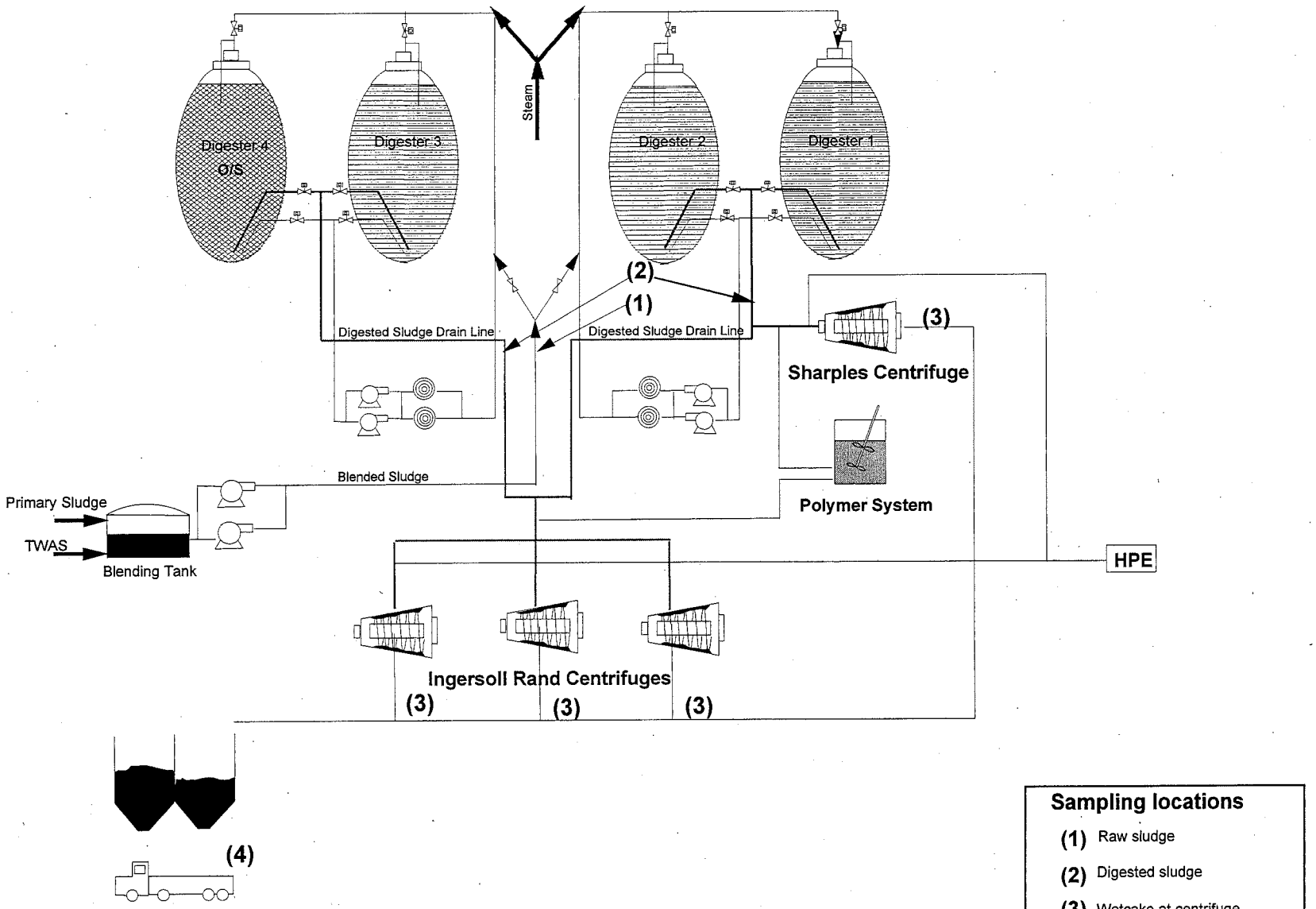
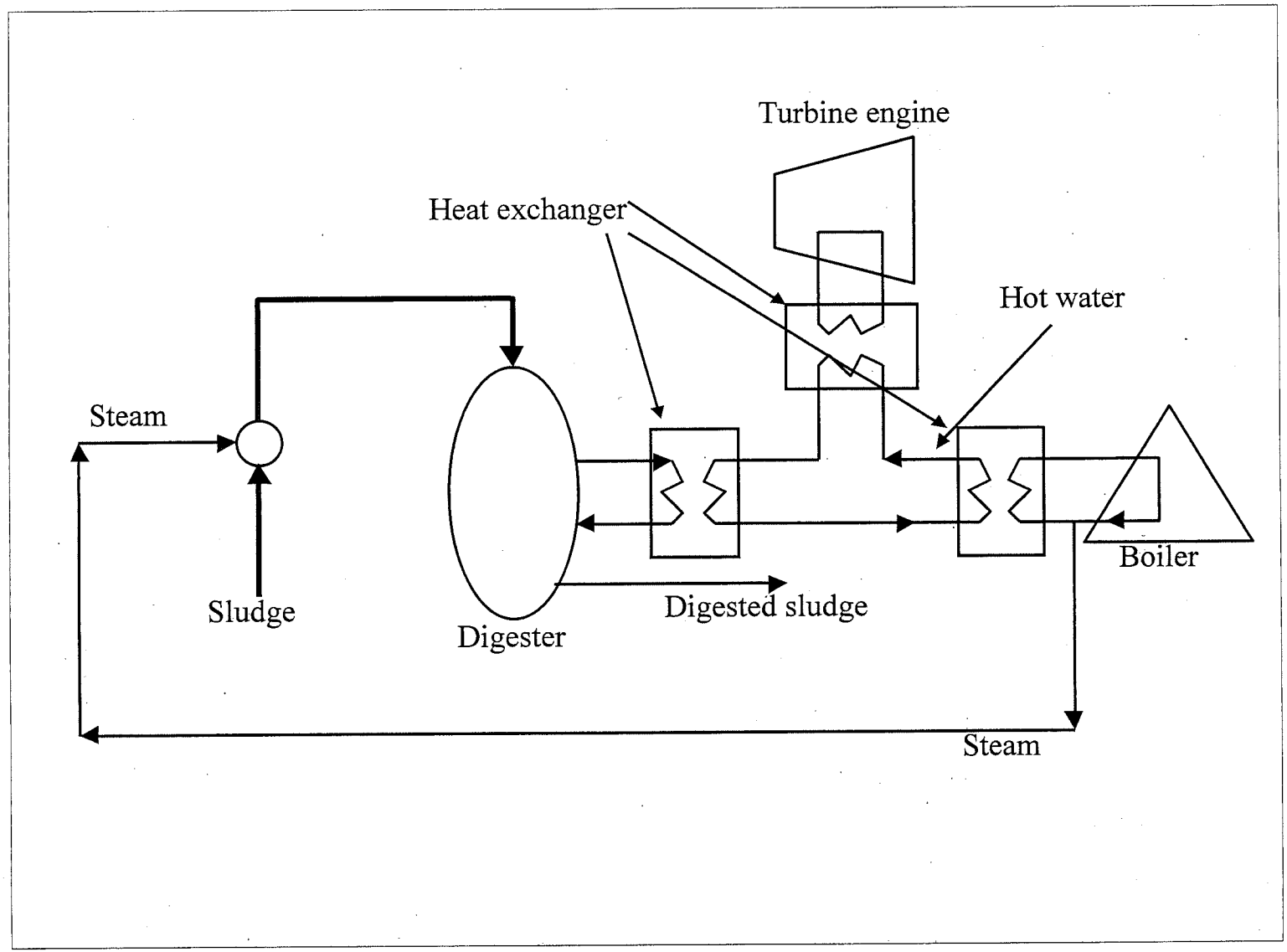


**Figure 4. Schematic of digester heating**



# Figure 5. Phase I - Sludge feeding and withdrawal cycles during start-up of digester 1

| Time | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | Feed | | No feed & no withdraw | | | | | | Feed | | No feed & no withdraw | | | | | | **Withdraw**<br>**Mon to Thurs:** Lower digester level to 17.4m<br>**Fri:** Lower digester level to 15.8 m for weekend feed<br>**Sat & Sun:**<br>No withdraw | | | | | | | | |
| Flow rate | 0.57 m³/min | | | | | | | | 0.57 m³/min | | | | | | | | Depends on centrifuge status | | | | | | | |

(a) 136 m³/day (36,000 gpd), 3/14 - 19

| Time | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | Feed | | | | | | | | Feed | | | | | | | | **Withdraw**<br>**Mon to Thurs:** Lower digester level to 17.4 m<br>**Fri:** Lower digester level to 15.8m for weekend feed<br>**Sat & Sun:**<br>No withdraw | | | | | | | | |
| Flow rate | 0.49 m³/min | | | | | | | | 0.49 m³/min | | | | | | | | 0.49 m³/min | | | | | | | |

(b) 177 m³/day (46800 gpd), 3/20 - 27

| Time | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | Feed | | | | | | | | Feed | | | | | | | | **Withdraw**<br>**Mon to Thurs:** Lower digester level to 17.1 m<br>**Fri:** Lower digester level to 15.8m for weekend feed<br>**Sat & Sun:**<br>no withdraw | | | | | | | | |
| Flow rate | 0.45 m³/min | | | | | | | | 0.45 m³/min | | | | | | | | 0.45 m³/min | | | | | | | |

(c) 245 m³/day (64,800 gpd), 3/28 - 4/25

| Time | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | Feed | | | | | | | | Feed | | | | | | | | **Withdraw**<br>**Mon to Thurs:** Lower digester level to 17.4 m<br>**Fri:** Lower digester level to 15.8m for weekend feed<br>**Sat & Sun:**<br>No withdraw | | | | | | | | |
| Flow rate | 0.49 m³/min | | | | | | | | 0.49 m³/min | | | | | | | | 0.49 m³/min | | | | | | | |

(d) 307 m³/day (81,000 gpd), 4/26 - 5/9

| Time | 0700 | 0800 | 0900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 0000 | 0100 | 0200 | 0300 | 0400 | 0500 | 0600 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | Feed | | | | | | | | Feed | | | | | | | | **Withdraw**<br>**Mon to Thurs:** Lower digester level to 17.1 m<br>**Fri:** Lower digester level to 15.8 m for weekend feed<br>**Sat & Sun:**<br>no withdraw | | | | | | | | |
| Flow rate | 0.53 m³/min | | | | | | | | 0.53 m³/min | | | | | | | | 0.53 m³/min | | | | | | | |

(e) 382 m³/day (100,800 gpd), 5/9 - present

**Figure 6. Phase I - Measured sludge feeding rates during start-up of digester 1**

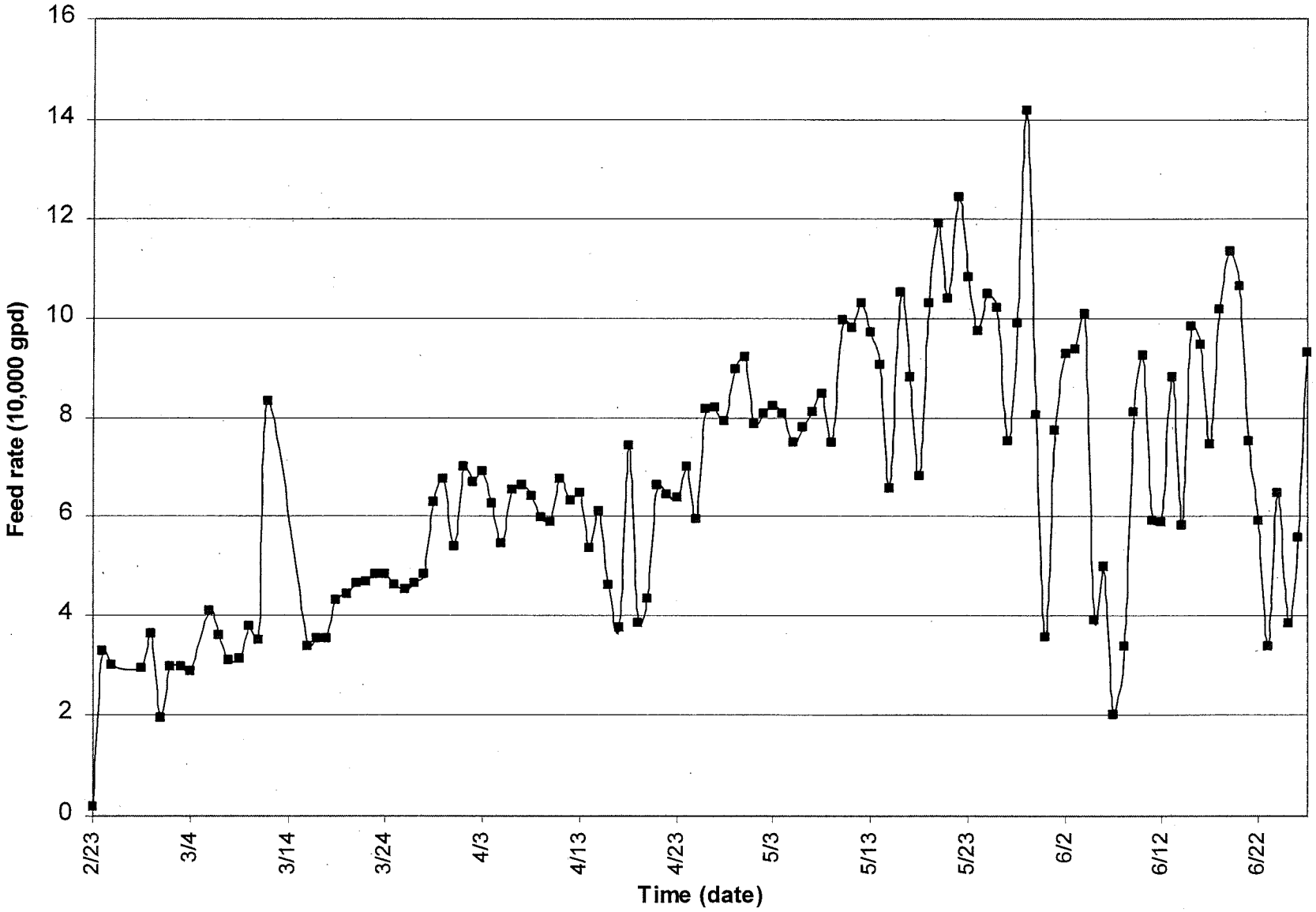


**Figure 7. Phase III - Digester cycles for batch operation**

| Day | Day 1 | | Day 2 | | Day 3 | | Day 4 | |
|---|---|---|---|---|---|---|---|---|
| Hours | 0 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 |
| Digester 1 | Feed (104 gpm) | | Hold | | Withdraw (104 gpm) | | Feed (104 gpm) | |
| Digester 2 | Withdraw (104 gpm) | | Feed (104 gpm) | | Hold | | Withdraw (104 gpm) | |
| Digester 3 | Hold | | Withdraw (104 gpm) | | Feed (104 gpm) | | Hold | |

## Table 1. Phase I - Digester temperatures

| Date | Temp (°F) Digester 1 |
|---|---|
| 2/23/00 | 129.7 |
| 2/23/00 | 129.8 |
| 2/25/00 | 129.0 |
| 2/26/00 | 129.1 |
| 2/27/00 | 129.1 |
| 2/28/00 | 129.0 |
| 2/29/00 | 128.2 |
| 3/1/00 | 127.9 |
| 3/2/00 | 128.8 |
| 3/3/00 | 127.6 |
| 3/5/00 | 126.4 |
| 3/5/00 | 125.5 |
| 3/6/00 | 126.2 |
| 3/7/00 | 126.2 |
| 3/8/00 | 127.2 |
| 3/9/00 | 126.6 |
| 3/11/00 | 126.6 |
| 3/11/00 | 127.6 |
| 3/11/00 | 127.6 |
| 3/13/00 | 126.1 |
| 3/14/00 | 127.5 |
| 3/15/00 | 126.5 |
| 3/16/00 | 126.5 |
| 3/17/00 | 127.0 |
| 3/18/00 | 127.1 |
| 3/18/00 | 126.1 |
| 3/20/00 | 126.1 |
| 3/21/00 | 128.0 |
| 3/22/00 | 128.9 |
| 3/23/00 | 131.1 |
| 3/24/00 | 131.3 |
| 3/25/00 | 130.8 |
| 3/26/00 | 130.7 |
| 3/27/00 | 130.2 |
| 3/28/00 | 129.6 |
| 3/29/00 | 129.2 |
| 3/30/00 | 127.7 |
| 3/31/00 | 128.0 |
| 4/2/00 | 125.2 |
| 4/2/00 | 126.7 |
| 4/3/00 | 126.5 |
| 4/4/00 | 127.7 |
| 4/5/00 | 127.6 |
| 4/6/00 | 128.8 |
| 4/7/00 | 127.4 |
| 4/8/00 | 127.5 |

| Date | Temp (°F) Digester 1 |
|---|---|
| 4/9/00 | 126.5 |
| 4/10/00 | 127.5 |
| 4/11/00 | 127.7 |
| 4/12/00 | 127.6 |
| 4/13/00 | 127.5 |
| 4/14/00 | 127.5 |
| 4/15/00 | 126.3 |
| 4/16/00 | 125.1 |
| 4/17/00 | 124.2 |
| 4/18/00 | 123.2 |
| 4/19/00 | 123.5 |
| 4/20/00 | 126.6 |
| 4/21/00 | 125.9 |
| 4/22/00 | 125.5 |
| 4/23/00 | 125.3 |
| 4/24/00 | 126.2 |
| 4/25/00 | 130.8 |
| 4/26/00 | 130.0 |
| 4/27/00 | 127.3 |
| 4/28/00 | 129.1 |
| 4/29/00 | 129.4 |
| 4/30/00 | 129.9 |
| 5/1/00 | 128.7 |
| 5/2/00 | 128.0 |
| 5/3/00 | 127.2 |
| 5/4/00 | 128.5 |
| 5/5/00 | 127.6 |
| 5/6/00 | 128.1 |
| 5/7/00 | 125.0 |
| 5/8/00 | 125.2 |
| 5/9/00 | 126.8 |
| 5/10/00 | 129.1 |
| 5/11/00 | 129.8 |
| 5/12/00 | 128.6 |
| 5/13/00 | 128.9 |
| 5/14/00 | 125.9 |
| 5/15/00 | 123.9 |
| 5/16/00 | 126.0 |
| 5/17/00 | 129.6 |
| 5/18/00 | 129.6 |
| 5/19/00 | 130.6 |
| 5/20/00 | 130.9 |
| 5/21/00 | 139.8 |
| 5/22/00 | 126.2 |
| 5/23/00 | 124.8 |
| 5/24/00 | 127.4 |

| Date | Temp (°F) Digester 1 |
|---|---|
| 5/25/00 | 129.1 |
| 5/26/00 | 128.8 |
| 5/27/00 | 128.5 |
| 5/28/00 | 127.7 |
| 5/29/00 | 127.8 |
| 5/30/00 | 129.7 |
| 5/31/00 | 130.8 |
| 6/1/00 | 130.2 |
| 6/2/00 | 129.2 |
| 6/3/00 | 128.2 |
| 6/4/00 | 126.5 |
| 6/5/00 | 125.9 |
| 6/6/00 | 127.3 |
| 6/7/00 | 131.2 |
| 6/8/00 | 131.3 |
| 6/9/00 | 129.8 |
| 6/10/00 | 126.6 |
| 6/11/00 | 125.8 |
| 6/12/00 | 127.4 |
| 6/13/00 | 129.5 |
| 6/14/00 | 130.1 |
| 6/15/00 | 130.3 |
| 6/16/00 | 130.4 |
| 6/17/00 | 129.0 |
| 6/18/00 | 127.8 |
| 6/19/00 | 129.5 |
| 6/20/00 | 131.0 |
| 6/21/00 | 130.4 |
| 6/22/00 | 129.8 |
| 6/23/00 | 130.0 |
| 6/24/00 | 129.0 |
| 6/25/00 | 128.4 |
| 6/26/00 | 127.9 |
| 6/27/00 | 126.8 |
| **Min.(°F)** | **123.2** |
| **Min.(°C)** | **50.7** |
| **Max.(°F)** | **139.8** |
| **Max.(°C)** | **59.9** |
| **Average(°F)** | **128.1** |
| **Average(°C)** | **53.4** |

# Table 2. Phase II - Digester temperatures

| Date | Temp (°F) | |
|---|---|---|
| | Digester 1 | Digester 2 |
| 10/11/00 | 127.1 | 113.3 |
| 10/12/00 | 129.1 | 111.4 |
| 10/13/00 | 132.0 | 114.5 |
| 10/14/00 | 131.1 | 108.1 |
| 10/15/00 | 130.2 | 97.9 |
| 10/16/00 | 130.2 | 81.3 |
| 10/17/00 | 131.3 | 84.4 |
| 10/18/00 | 132.9 | 92.3 |
| 10/19/00 | 131.5 | 97.9 |
| 10/20/00 | 131.3 | 102.1 |
| 10/21/00 | 129.7 | 104.3 |
| 10/22/00 | 126.6 | 105.2 |
| 10/23/00 | 123.9 | 104.7 |
| 10/24/00 | 125.5 | 104.1 |
| 10/25/00 | 126.7 | 111.8 |
| 10/26/00 | 130.3 | 111.8 |
| 10/27/00 | 132.7 | 108.1 |
| 10/28/00 | 134.2 | 91.4 |
| 10/29/00 | 129.6 | 106.0 |
| 10/30/00 | 129.2 | 107.8 |
| 10/31/00 | 131.9 | 112.1 |
| 11/1/00 | 132.2 | 114.3 |
| 11/2/00 | 131.5 | 113.0 |
| 11/3/00 | 130.3 | 115.0 |
| 11/4/00 | 128.1 | 95.5 |
| 11/5/00 | 128.4 | 79.5 |
| 11/6/00 | 128.4 | 107.6 |
| 11/7/00 | 128.7 | 117.5 |
| 11/8/00 | 131.4 | 117.1 |
| 11/9/00 | 132.9 | 113.7 |
| 11/10/00 | 130.2 | 91.6 |
| 11/11/00 | 128.2 | 78.7 |
| 11/12/00 | 127.0 | 84.5 |
| 11/13/00 | 127.7 | 87.1 |
| 11/14/00 | 131.0 | |
| 11/15/00 | 130.9 | |
| 11/16/00 | 128.5 | |
| 11/17/00 | 125.4 | 107.4 |
| 11/18/00 | 126.1 | 96.9 |
| 11/19/00 | 127.4 | 87.2 |
| 11/20/00 | 127.2 | 109.1 |
| 11/21/00 | 128.0 | |
| 11/22/00 | 130.3 | 89.9 |
| 11/23/00 | 131.0 | 76.4 |
| 11/24/00 | 130.4 | 76.9 |
| 11/25/00 | 130.0 | 82.6 |
| 11/26/00 | 130.4 | 88.8 |
| 11/27/00 | 131.1 | 110.8 |
| 11/28/00 | 132.6 | 114.8 |
| 11/29/00 | 129.8 | 116.5 |
| 11/30/00 | 129.1 | 113.9 |
| 12/1/00 | 128.7 | 112.4 |
| 12/2/00 | 128.6 | |
| 12/3/00 | 128.0 | |
| 12/4/00 | 128.6 | 124.2 |
| 12/5/00 | 131.6 | |
| 12/6/00 | 128.9 | 129.1 |
| 12/7/00 | 128.5 | 128.7 |

| Date | Temp (°F) | |
|---|---|---|
| | Digester 1 | Digester 2 |
| 12/8/00 | 127.1 | 128.6 |
| 12/9/00 | 124.2 | |
| 12/10/00 | 121.4 | |
| 12/11/00 | 121.8 | 123.2 |
| 12/12/00 | 122.5 | 124.3 |
| 12/13/00 | 124.4 | 125.0 |
| 12/14/00 | 126.9 | 126.3 |
| 12/15/00 | 129.3 | 127.4 |
| 12/16/00 | 129.8 | |
| 12/17/00 | 130.2 | |
| 12/18/00 | 131.3 | 126.6 |
| 12/19/00 | 131.9 | 128.3 |
| 12/20/00 | 131.7 | 128.4 |
| 12/21/00 | 129.5 | 130.4 |
| 12/22/00 | 128.4 | |
| 12/23/00 | 126.5 | |
| 12/24/00 | 124.4 | |
| 12/25/00 | 125.2 | |
| 12/26/00 | 127.5 | 125.3 |
| 12/27/00 | 130.6 | 127.5 |
| 12/28/00 | 130.2 | 128.1 |
| 12/29/00 | 131.0 | 130.7 |
| 12/30/00 | 130.4 | |
| 12/31/00 | 130.1 | |
| 1/1/01 | 129.6 | |
| 1/2/01 | 131.4 | 124.6 |
| 1/3/01 | 133.0 | 129.3 |
| 1/4/01 | 132.5 | 129.4 |
| 1/5/01 | 130.9 | |
| 1/6/01 | 130.3 | |
| 1/7/01 | 132.3 | |
| 1/8/01 | 130.0 | |
| 1/9/01 | 127.5 | |
| 1/10/01 | 129.9 | 129.1 |
| 1/11/01 | 128.9 | 129.3 |
| 1/12/01 | 127.0 | 126.3 |
| 1/13/01 | 124.5 | |
| 1/14/01 | 124.5 | |
| 1/15/01 | 125.9 | |
| 1/16/01 | 128.1 | 126.2 |
| 1/17/01 | 130.9 | 126.8 |
| 1/18/01 | 130.6 | |
| 1/19/01 | 130.5 | 128.9 |
| 1/20/01 | 124.6 | |
| 1/21/01 | 126.3 | |
| 1/22/01 | 127.9 | 125.3 |
| 1/23/01 | 128.8 | |
| 1/24/01 | 129.0 | 126.9 |
| 1/25/01 | 129.7 | |
| 1/26/01 | 131.5 | 128.9 |
| 1/27/01 | 131.0 | |
| 1/28/01 | 124.2 | |
| 1/29/01 | 122.7 | 125.4 |
| 1/30/01 | 124.5 | |
| 1/31/01 | 124.3 | 125.3 |
| 2/1/01 | 125.4 | |
| 2/2/01 | 125.3 | 126.9 |
| 2/3/01 | 124.8 | |

| Date | Temp (°F) | |
|---|---|---|
| | Digester 1 | Digester 2 |
| 2/4/01 | 124.3 | |
| 2/5/01 | 124.5 | 123.6 |
| 2/6/01 | 127.1 | |
| 2/7/01 | 129.2 | 127.0 |
| 2/8/01 | 132.0 | |
| 2/9/01 | 130.9 | 127.3 |
| 2/10/01 | 127.6 | |
| 2/11/01 | 124.4 | |
| 2/12/01 | 122.4 | 124.1 |
| 2/13/01 | 124.4 | |
| 2/14/01 | 127.9 | 125.3 |
| 2/15/01 | 129.8 | |
| 2/16/01 | 129.4 | 127.1 |
| 2/17/01 | 127.3 | |
| 2/18/01 | 123.5 | |
| 2/19/01 | 121.3 | |
| 2/20/01 | 122.1 | |
| 2/21/01 | 121.9 | 123.5 |
| 2/22/01 | 123.5 | |
| 2/23/01 | 123.5 | |
| 2/24/01 | 122.8 | |
| 2/25/01 | 121.2 | |
| 2/26/01 | 120.7 | 122.4 |
| 2/27/01 | 119.7 | |
| 2/28/01 | 121.1 | 124.4 |
| 3/1/01 | 121.8 | |
| 3/2/01 | 123.3 | 123.4 |
| 3/3/01 | 126.8 | |
| 3/4/01 | 124.8 | |
| 3/5/01 | 124.3 | |
| 3/6/01 | 126.8 | |
| 3/7/01 | 131.2 | |
| 3/8/01 | 130.5 | |
| 3/9/01 | 129.9 | |
| 3/10/01 | 128.4 | |
| 3/11/01 | 123.2 | |
| 3/12/01 | 122.8 | |
| 3/13/01 | 125.9 | |
| 3/14/01 | 125.1 | |
| 3/15/01 | 124.1 | |
| 3/16/01 | 123.4 | 124.2 |
| 3/17/01 | 122.0 | |
| 3/18/01 | 118.5 | |
| 3/19/01 | 118.8 | |
| 3/20/01 | 116.6 | |
| 3/21/01 | 116.9 | |
| 3/22/01 | 121.0 | |
| 3/23/01 | 126.3 | 124.4 |
| 3/24/01 | 129.6 | |
| 3/25/01 | 127.0 | |
| 3/26/01 | 126.6 | |
| 3/27/01 | 129.3 | |
| 3/28/01 | 129.8 | |
| 3/29/01 | 131.4 | |
| 3/30/01 | 129.5 | 121.0 |
| 3/31/01 | 127.7 | |
| **Average (°F)** | **127.6** | **126.1** |
| **Average (°C)** | **53.1** | **52.3** |

**Note:** Average temperature in digester 1 was calculated over 10/11/00 to 3/30/01 whereas the average temperature in digester 2 was calculated over 12/01/00 to 3/30/01

# Table 3. Phase III - Digester temperatures

| Date | Temperature (°F) | | | | Sampling Digester |
|---|---|---|---|---|---|
| | Digester 1 | Digester 2 | Digester 3 | Digester 4 | |
| 7/2/01 | 125.2 | 125.7 | 131.9 | | 1 |
| 7/2/01 | 125.2 | 125.7 | 131.9 | | 2 |
| 7/10/01 | 127.3 | 128.9 | 129.5 | | 1 |
| 7/11/01 | 127.5 | | 129.7 | | 2 |
| 7/12/01 | 128.9 | 130.5 | 130.2 | | 3 |
| 7/13/01 | 128.2 | 132.1 | 128.8 | | 1 |
| 7/17/01 | 126.7 | | 130.6 | | 2 |
| 7/18/01 | 126.5 | 130.0 | 130.4 | | 3 |
| 7/19/01 | 123.0 | 130.5 | 129.6 | | 1 |
| 7/20/01 | 124.8 | 130.1 | 130 | | 2 |
| 7/23/01 | 123.9 | | 130.8 | | 2 |
| 7/23/01 | 123.9 | | 130.8 | | 2 |
| 7/24/01 | 124.8 | 130.9 | 130.7 | | 3 |
| 7/25/01 | 124.7 | 132.4 | 130.4 | | 1 |
| 7/25/01 | 124.7 | 132.4 | 130.4 | | 1 |
| 7/26/01 | 124 | 132 | 130.7 | | 2 |
| 7/27/01 | 124 | 131.8 | 130.7 | | 3 |
| 7/27/01 | 124.0 | 131.8 | 130.7 | | 3 |
| 7/30/01 | 124.9 | 132 | 132.2 | | 3 |
| 7/30/01 | 124.9 | 132.0 | 132.2 | | 3 |
| 7/31/01 | 126.5 | 131.3 | 131.8 | | 1 |
| 8/1/01 | 127.7 | | 132.1 | | 2 |
| 8/1/01 | 127.7 | | 132.1 | | 2 |
| 8/2/01 | 127.5 | 131.3 | 132 | | 3 |
| 8/3/01 | 127.6 | 132.1 | 131.7 | | 1 |
| 8/3/01 | 127.6 | 132.1 | 131.7 | | 1 |
| 8/6/01 | 130.8 | 132.1 | 132.7 | | 1 |
| 8/6/01 | 130.8 | 132.1 | 132.7 | | 1 |
| 8/7/01 | 130.6 | | 134.2 | | 2 |
| 8/8/01 | 131.5 | 130.6 | 134.1 | | 3 |
| 8/9/01 | 132 | 132 | 132.7 | | 1 |
| 8/10/01 | 132 | | 132.8 | | 2 |
| 8/10/01 | 132.0 | | 132.8 | | 2 |
| 8/13/01 | 131.4 | | 132.8 | | 2 |
| 8/14/01 | | 130.1 | 133 | | 3 |
| 8/16/01 | 129.4 | 130.6 | | | 2 |
| 8/17/01 | 129.4 | 129.7 | 132.1 | | 3 |
| 8/17/01 | 129.4 | 129.7 | 132.1 | | 3 |
| 8/20/01 | 128.5 | 129.5 | 130.8 | | 3 |
| 8/21/01 | 128.7 | 130.7 | 128.2 | | 1 |
| 8/27/01 | 128.5 | 129.8 | 128.3 | | 1 |
| 8/30/01 | 124.8 | 130.9 | | 124.3 | 1 |
| 8/31/01 | 124.5 | 131.5 | | 123.7 | 2 |
| 9/4/01 | 127.6 | 133.0 | | 121.6 | 4 |
| 9/7/01 | | 129.4 | | | 4 |
| 9/10/01 | 128.4 | 132.8 | | 117.5 | 4 |
| 9/11/01 | 128.3 | 132.4 | | 117.3 | 1 |
| 9/12/01 | 130.2 | | | 116.9 | 2 |
| 9/13/01 | | 131.7 | | 118.4 | 4 |
| 9/14/01 | 133.1 | 129.9 | | 121.5 | 1 |
| 9/17/01 | | 127 | | 124.3 | 1 |
| 9/18/01 | 129.5 | | | 127.2 | 2 |
| 9/19/01 | 129.8 | 129.2 | | 129.1 | 4 |
| 9/20/01 | 129.4 | 129.9 | | 131.4 | 1 |
| 9/21/01 | 129.7 | | | 133.1 | 2 |
| 9/24/01 | 130.7 | | | 133.1 | 2 |
| 9/25/01 | | | | 132.3 | 4 |
| 9/27/01 | 131.2 | | | 133.1 | 2 |
| 9/28/01 | 132.6 | 129.5 | | 133.3 | 4 |
| 10/1/01 | 133.2 | 131.1 | | 133.9 | 4 |
| 10/2/01 | 132.5 | 131.9 | | 133.4 | 1 |
| 10/5/01 | 133.2 | 132.7 | | 134 | 1 |
| 10/10/01 | | 133.3 | | 134.6 | 4 |
| 10/10/01 | | 133.3 | | 134.6 | 4 |
| 10/11/01 | 132.1 | 134.1 | | 134.9 | 1 |
| 10/11/01 | 132.1 | 134.1 | | 134.9 | 1 |
| 10/12/01 | 131.6 | | | 134.9 | 2 |
| 10/15/01 | 132.8 | | | 136.7 | 2 |
| 10/16/01 | 133.6 | 134.1 | | 136.4 | 4 |
| 10/16/01 | 133.6 | 134.1 | | 136.4 | 4 |
| 10/17/01 | | 135.0 | | 135.6 | 1 |
| 10/17/01 | | 135 | | 135.6 | 1 |
| 10/18/01 | 134.3 | | | 134 | 2 |
| 10/19/01 | 136 | 133.5 | | 133.9 | 4 |
| 10/22/01 | 135.8 | 132.8 | | 133.7 | 4 |
| 10/23/01 | 135.9 | 133.3 | | 133.5 | 1 |
| 10/24/01 | 134.5 | | | 134.2 | 2 |
| 10/25/01 | | 131.9 | | 135.1 | 4 |
| 10/26/01 | 131.5 | 132.2 | | 136.2 | 1 |
| 10/29/01 | | 130.9 | | 134.4 | 1 |
| 10/30/01 | | | | 133.4 | 2 |
| 10/31/01 | | | | 129.1 | 4 |
| 11/1/01 | 134.9 | 126.8 | | 125.4 | 1 |
| 11/2/01 | 131.6 | | | 125.4 | 2 |
| 11/5/01 | 129.4 | 129.5 | | 128.6 | 2 |
| 11/6/01 | 127.1 | 124.3 | | 134 | 4 |
| **Avg. (°F)** | **129.2** | **131.2** | **131.3** | **130.6** | |
| **Avg. (°C)** | **54.0** | **55.1** | **55.2** | **54.8** | |

## 2.2 Sampling procedures

### 2.2.1 Digester inflow sampling protocols

Raw sludge samples were collected from between the blending tank and the digester (Location 1 in Figures 1, 2 and 3) according to the following procedure:

Location 1. Raw sludge samples **(influent sludge)**:

a. Open sampling port for 2 minutes to flush residual sludge from previous sampling event.
b. Collect 100 ml of sample in 2-liter bottle every 2 minutes until this composite grab sampling fills the bottle.
c. Cap the bottle and rinse outside of the bottle with effluent water.
d. Wipe the bottle with clean cloth and immediately store in cold box provided by the laboratory for preservation purpose.

### 2.2.2 Post-digestion sampling protocols

Digester effluent samples were taken at location 2 in Figures 1, 2 and 3. Additional sampling locations along the post-digestion train (Phase III) include (Figure 8):

- Location 3a (centrifuge wetcake from centrifuge outlet).
- Location 3b (centrifuge wetcake from conveyer belt).
- Location 4 (wet cake at hopper discharge).

Centrifuge wetcake was alternatively sampled at Locations 3a and 3b. At all locations, samples were collected in clean and sterilized containers and QA/QC procedures were followed in all sampling activities. Specific activities at each sample location were as follows:

Location 2. Sludge samples from digested sludge line **(digested sludge)**:

a. Open sampling port for 2 minutes to flush residual from previous sampling event.
b. Collect 100 ml of sample in 2-liter bottle every 2 minutes until this composite grab sampling fills the bottle.
c. Cap the bottle and rinse outside of the bottle with effluent water.
d. Wipe the bottle with clean cloth and immediately store in cold box provided by lab for preservation purpose.

Location 3a. Wetcake sample from centrifuge discharge location **(centrifuge wetcake)**:

a. Clean sampler with isopropyl alcohol and towel to prevent any contamination from previous sampling event.
b. Open sampling port at the bottom of centrifuge then insert sampler to catch cake from the centrifuge outlet. Collect approximately 200 grams of wetcake into a sterilized bottle or plastic bag.
c. Repeat step b until enough sample is collected.
d. Wipe the bottle with clean cloth and immediately store in cold box provided by lab for preservation purpose.

Location 3b. Wetcake sample from conveyer belt **(centrifuge wetcake)**:

a. Clean scrapper with isopropyl alcohol and towel to prevent any contamination from previous sampling event.
b. Collect approximately 100 grams of wetcake from the conveyer belt with scrapper into a sterilized bottle or plastic bag.
c. Repeat step b until 2 pounds of sample is collected.

d. Wipe the bottle with clean cloth and immediately store in cold box provided by lab for preservation purpose.

Location 4. Wetcake sample from silo before falling into truck **(hopper wetcake)**:

a. Clean scrapper with isopropyl alcohol and towel to prevent any contamination from previous sampling event.
b. Start catching wetcake from the hopper into sampler. As soon as the sampler is filled with wetcake, collect 400 grams of sample from sampler into a sterilized bottle of a plastic bag and discard the rest of the sample back into the hopper.
c. Repeat step b when truck is 30%, 60% and 90% full until enough sample is collected.
d. Wipe the bottle with clean cloth and immediately store in cold box provided by lab for preservation purpose.

### 2.2.3 Quality Assurance/Quality Control (QA/QC)

2.2.3.1 Sample collection

All of the following equipment should be thoroughly washed with soap and water prior to disinfection by 70% ethanol solution, allowed to air dry, and rinsed with sterile water before use:

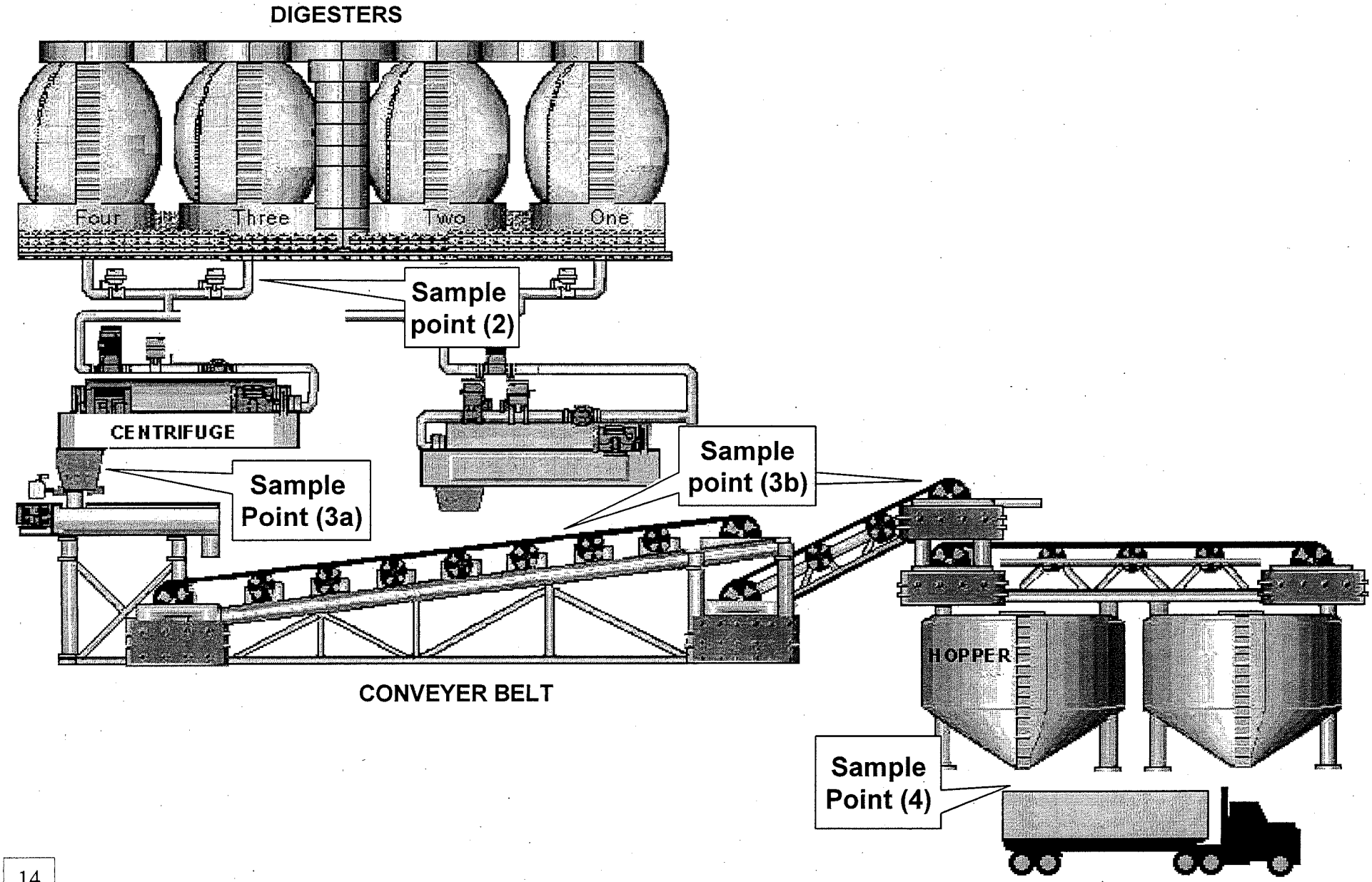
a. Scoops
b. Shovels
c. Augers
d. Sterile, plastic sample bottles
e. Sterile, whirl-pak bags

2.2.3.2 Sample preservation

Sample preservation prior to analysis was as follows:

a. If sample analysis is to begin within 1 hour following collection, no refrigeration is needed.
b. If sample analysis is to begin within 1 to 6 hours following collection, sample should be brought to the laboratory in an ice chest cooled to at least 10 $^{0}$C or lower.
c. If sample analysis is to begin within 6 to 24 hours following collection, sample should be brought to the laboratory as soon as possible, cooled to 10 $^{0}$C or lower and then immediately refrigerated in laboratory at 1 to 4 $^{0}$C.

**Figure 8. Phase III - Sampling locations in thermophilic post-digestion train**



## 2.3 Analytical methods

Digestion and disinfection performance during Phase I through III was evaluated by analysis of 14 parameters. These are summarized in Table 4, which also specifies the laboratories that performed the analyses and the methods they used. Digestion performance was evaluated by analysis of gas production ($CH_4$, $CO_2$), total solids, volatile solids, pH, alkalinity, $H_2S$, and volatile fatty acids (total and individual). These parameters were determined by using established procedures.

The efficiency of disinfection of fecal coliform, *Salmonella* sp., enteric viruses and helminth ova was determined by methods (Table 4) as required by 40 CFR Part 503. Details of the procedures are summarized in sections 2.3.1 through 2.3.4. Section 2.3.5 describes QA/QC protocols.

During Phase 1 a comparison was made of the heavy metal concentrations in biosolids from mesophilic and thermophilic treatment. Heavy metals were determined according to METHOD, and the resulting concentrations were compared to limit and ceiling concentrations specified in 40 CFR Part 503, as summarized in Appendix 7.1.

### 2.3.1 *Salmonella* sp.

2.3.1.1 Liquid samples (percent solids <4 %; TWAS, primary sludge & digested sludge)

a. Shake sample to mix.
b. Using a sterile 100 mL graduated cylinder dispense 100 mL of sample into each of 5 flasks containing 100 mL of double-strength Sulfa enriched Selenite Brilliant Green broth (2X SBG) for samples with suspected low concentrations of *Salmonella*.
c. Using a sterile 10 mL pipette dispense 10 mL of sample into each of 5 tubes containing 10 mL of 2X SBG medium.
d. Using a sterile 1 mL pipette dispense 1 mL of sample into each of 5 tubes containing 1X SBG and 1 mL of sample into a sterile 9 mL buffer dilution tube. (Do a serial dilution to desired concentration).
e. Using a sterile 10 mL pipet, dispense 1 mL of each dilution into each of 5 tubes of media.
f. Incubate at 37+ 0.5 $^0$C. Read tubes at 20 - 24 hrs.
g. Using a sterile cotton-tipped swab, transfer presumed positive tubes to XLT4 and mLIA plates. Incubate at 37+ 0.5 $^0$C for 20 – 24 hrs.
h. XLT4 and mLIA plates showing typical *Salmonella* colonies. Transfer colonies to BioMerieux' Vitek for confirmation.
i. Calculate *Salmonella* concentration using MPN table.

2.3.1.2 Solid samples (percent solids >5 %; wet cake from centrifuge, silo, truck and farm)

a. In sterile blender, add 270 mL of sterile Tween 80/buffer to 30 gram of sample.
b. Mix/blend for one minute.
c. Repeat Steps a –h for liquid samples given above.

### 2.3.2 Fecal coliform

2.3.2.1 Liquid samples (percent solids <4 %; TWAS, primary sludge & digested sludge)

a. Shake sample to mix.
b. Using a sterile 1 mL pipet, dispense 1 mL of sample into each of 5 tubes of A1 medium.
c. Using a sterile 10 mL pipet, dispense 1 mL of sample into 9 mL buffer dilution tube (Do a serial dilution to desired concentration).
d. Using a sterile 10 mL pipet, dispense 1 mL of each dilution into each of 5 tubes of A1 medium.
e. Incubate at 35 $^0$C for 3 hrs, then transfer to 44.5 $^0$C water bath for continued incubation.

f. Read tubes at 24± 2 hrs.

2.3.2.2 Solid samples (Percent solids >5 %; wet cake from centrifuge, silo, truck and farm)

a. In blender, add 270 mL of Tween/buffer to 30 gram of sample.
b. Mix for one minute.
c. Repeat Steps b – e for liquid samples given above.

### 2.3.3 Helminth ova

The densities of viable helminth ova were determined during Phase II (sampled after the first stage once every eight hours) and during Phase III (sampled once every day).

Summary of the procedure: This procedure identifies, quantifies and determines the viability of several types of ova from intestinal parasites. Solids samples are processed by blending with buffered water containing a surfactant. The blend is screened to remove large particles. The solids in the screened portion are allowed to settle out and the supernatant is decanted. The sediment is subjected to density gradient centrifugation using zinc sulfate (specific gravity 1.20). This flotation procedure yields a layer most likely to contain *Ascaris* and some other parasitic ova. Proteinaceous material is removed using an acid-alcohol/ether extraction step and the resulting concentrate is incubated at 26°C until control ova of *Ascaris lumbricoides* var. suum are fully embrionated. The concentrate is then microscopically examined for parasite ova using a Sedgwick-Rafter counting chamber.

### 2.3.4 Enteric viruses

The procedure for analysis of enteric viruses is long and complex. A complete protocol is available from BioVir Laboratories, Benicia, CA. Briefly, the method consists of an initial virus elution from the solids followed by concentration of viral particles by organic flocculation using beef extract. Then, enteric viruses are assayed using a BGM cell line and the plaque assay technique

### 2.3.5 Quality Assurance/Quality Control (QA/QC)

QA/QC was according to Part 9020 of Standard Methods (APHA, 1992)

2.3.5.1 Water

a. Daily test – pH, conductivity, and Chlorine
b. Monthly Test - Heterotrophic Plate Count
c. Annual Test - Water Suitability

2.3.5.2 Media: QA performed for each batch

a. pH
b. Sterility check
c. Positive and negative control cultures

2.3.5.3 Duplicate analysis

5% of the total number of samples analyzed

2.3.5.4 Equipment

a. Incubators/Waterbaths. - Temperatures are monitored and recorded twice a day; once in the morning and once in the afternoon
b. Incubator thermometers are calibrated semi-annually.

## Table 4. Phase I - Analytical parameters and methods

| Parameter | Method | Instrumentation | Sampling frequency (Phase III) |
|---|---|---|---|
| **Environmental Monitoring Division - Hyperion Treatment Plant, Playa Del Rey, CA** | | | |
| 1. Fecal coliforms | Multiple tube fermentation technique, [1]SM 9221 E.2 | | 4 to 5 days / week |
| 2. $CH_4$ | [2]EPA Method 18 | Gas chromatography | 4 to 5 days / week |
| 3. $CO_2$ | EPA Method 18 | Gas chromatography | 4 to 5 days / week |
| **Environmental Monitoring Division - Terminal Island Treatment Plant, Long Beach, CA** | | | |
| 4. Alkalinity | Titration, SM 2320 B | pH meter | 4 to 7 days / week |
| 5. VFA (total), Fig. 2 | Distillation and titration, SM 5560 C | Centrifuge, distillation assembly | 4 to 7 days / week |
| 6. Total solids | Gravimetric, 1003-105 C, SM 2540 B | Balance, oven | 4 to 7 days / week |
| 7. Volatile solids | Gravimetric, 550 C, SM 2540 E | Balance, furnace | 4 to 7 days / week |
| 8. pH | Electrometric, SM 4500-$H^+$ B | pH meter | 4 to 7 days / week |
| 9. $H_2S$ | Colorimetric tube[3] | Drager Analyzer (SCAQMD - approved) | 4 to 7 days / week |
| **Environmental Laboratory - University of California Los Angeles, Los Angeles, CA** | | | |
| 10. VFA (individual) | VFA levels as free acid | Gas chromatograph with flame ionization detector | Three times / week |
| **BioVir Laboratory, Benicia, CA** | | | |
| 11. *Salmonella* | Multiple tube enrichment technique, SM 9260 D.1 | | 3 times |
| 12. Helminth Ova | [4]EPA 600 (samples composited in lab) | | Every 8 hours for 4 weeks |
| 13. Enteric Virus | [5]ASTM D 4994-89 (samples composited in lab) | | Every 8 hours for 2 weeks |

[1]SM : Standard Methods for the Examination of Water and Wastewater, 18th Ed. (1992) American Public Health Association, Washington, DC.

[2]EPA Method 18: Standard Operating Procedure for Analysis of Fixed Gases in Air and Gaseous Samples by Gas Chromatography (SOP-AIR-010-4). Environmental Monitoring Division. Hyperion Treatment Pant. This is a procedure based on EPA Method 18 (40 CFR Pt. 60, App. A, Meth 18)

[3] Standard Operating Procedure for Determination of Hydrogen Sulfide in Digester Gas by Drager CMS Analyzer. Environmental Monitoring Division. Terminal Island Treatment Plant.

[4]EPA 600 . Yanko, W.A. Occurrence of Pathogens in Distribution and Marketing Municipal Sludges, EPA 600/1-87-014, 1987.

[5]ASTM D 4994-89, Standard Practice for Recovery of Viruses from Wastewater Sludges, Annual Book of ASTM Standards: Section 11 - Water and and Environmental Technology, ASTM, Philadelphia, PA, 1992.

# 3. RESULTS

All laboratory results of Phase III are included in Appendix 7.3.

## 3.1 Single stage thermophilic digestion (Phase I)

### 3.1.1 Start-up and process performance

3.1.1.1 VFA production, pH and alkalinity

Conversion from mesophilic to thermophilic digestion was initially accompanied with a sharp rise of the total volatile fatty acid (VFA) concentration (Figure 9), which indicates to a rapid and initial development of thermophilic acidogens that convert macromolecules to VFAs (first step in digestion). However, after two weeks of operation at thermophilic temperatures, the total VFA concentration decreased and became relatively constant at approximately 0.4 g/L. This indicates to subsequent development of acetogens and methanogens that convert VFAs to $CH_4$ and $CO_2$. Similar patterns of total VFA concentrations have been observed at other plants, however, culture stability at TITP was obtained relatively fast and after only two weeks of thermophilic operation. Tentatively, the schedule with slowly increasing sludge feeding rates prevented excessive VFA production that would otherwise cause the digester turning sour and a reduction of the gas production. This was confirmed by analysis of the pH and alkalinity, as depicted in Figure 10. The pH remained relatively constant between 7.0 and 7.5, and only small changes in the alkalinity were observed. The VFA to alkalinity ratio (Figure 11) remained well below one throughout the start-up, indicating that the sludge alkalinity and VFA consumption by methanogens were sufficiently high to prevent high VFA concentrations and souring of the digester.

3.1.1.2Solids destruction

Total and volatile solids contents are routinely and on a daily basis determined by the TITP laboratory (Figure 12). The digester influent was a mixture of 30% primary and 70% secondary sludges, containing 3.6 % total solids of which 76% were volatile solids. The total solids content in digested sludge was 2.1% of which 59% were volatile solids. From these data, average destructions of 42% total solids and 59% volatile solids were calculated.

3.1.1.3Gas production

The produced gas contained 60-65% $CH_4$ and 35-40% $CO_2$ with little variation over time during Phase I (Figure 13). A relatively high $CO_2$ concentration was shortly observed early in Phase I, which can possibly be related to relatively high VFA concentrations observed at the same time. $H_2S$ concentrations in the produced gas were initially up to 800 ppm, but they rapidly stabilized at 300 to 400 ppm (Figure 14).

3.1.1.4Heavy metal concentrations

Table 5 presents the monthly average heavy metal concentrations in mesophilically and thermophilically digested sludge during Phase I at TITP, as well as the monthly average limit concentrations of the metals that are regulated in 40 CFR Part 503. The results in Table 5 demonstrate that heavy metal concentrations in mesophilically and thermophically digested sludge were nearly identical. It can also be seen that all metal concentrations were well below the monthly average limit concentrations for EQ biosolids.

### 3.1.2 Disinfection performance

3.1.2.1Fecal coliform

Fecal coliform densities in the digester inflow were not determined during Phase I, but it can reasonably be assumed that they were comparable to the density of $10^6$ MPN/g dry wt as observed during Phase III (see section 3.3.2.1). The fecal coliform density in the digester outflow during Phase I was on average 100 MPN/g dry wt, although occasionally an exceedance of the EPA limit of 1000 MPN/g dry wt was observed, in particular during the first two months of Phase I (Figure 15).

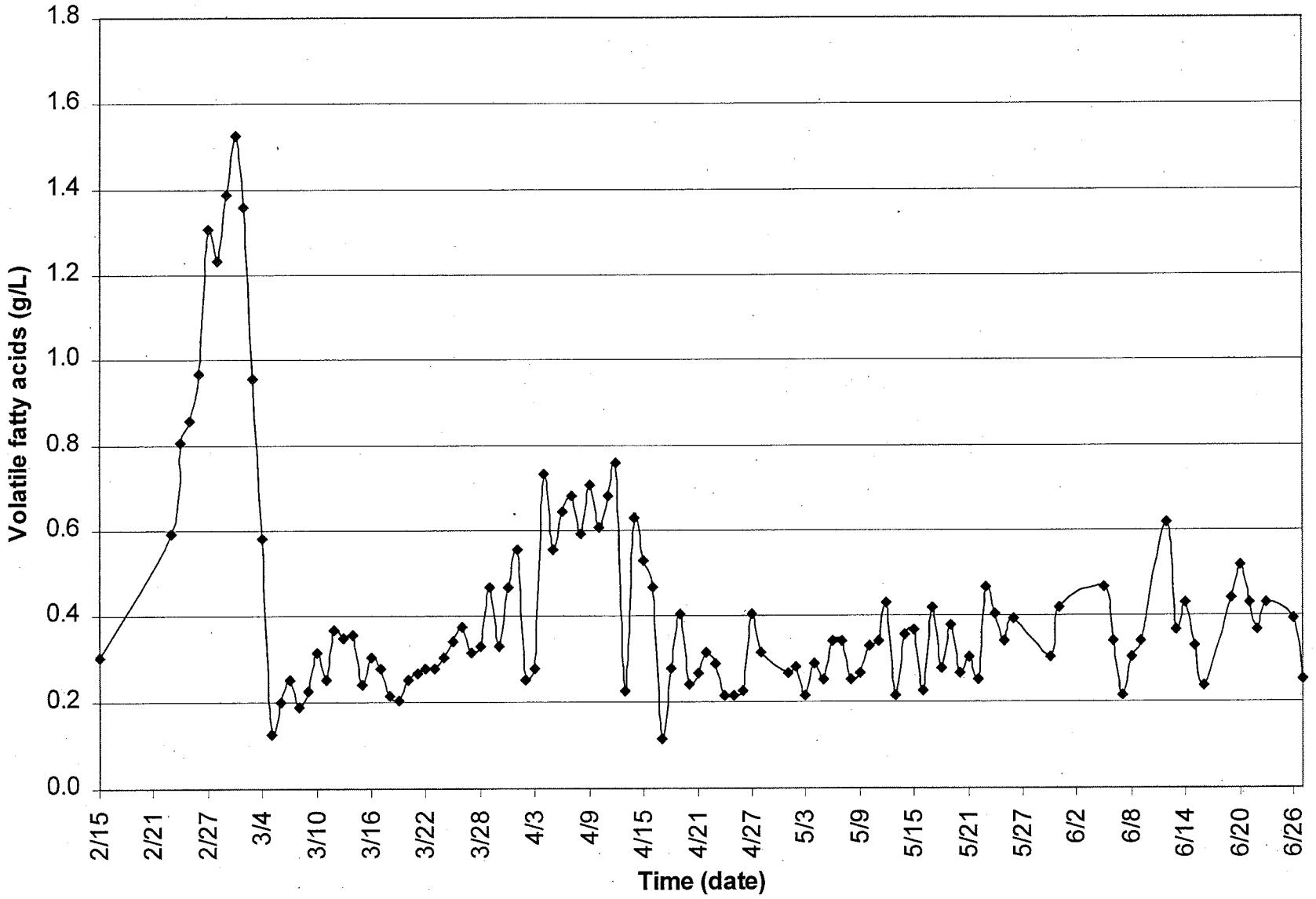
3.1.2.2 *Salmonella* sp.

Salmonella densities were determined on three occasions during Phase I in the digester outflow. At each time, they were found to be well below the EPA limit of 3 MPN/4 g dry wt (Table 6: Confusion about date of analyses).

3.1.2.3 Helminth ova and enteric viruses

Densities of helminth ova and enteric viruses were not determined during Phase I.

**Figure 9. Phase I - Total volatile fatty acids concentration in digester outflow**



## Figure 10. Phase I - Alkalinity and pH in digester outflow

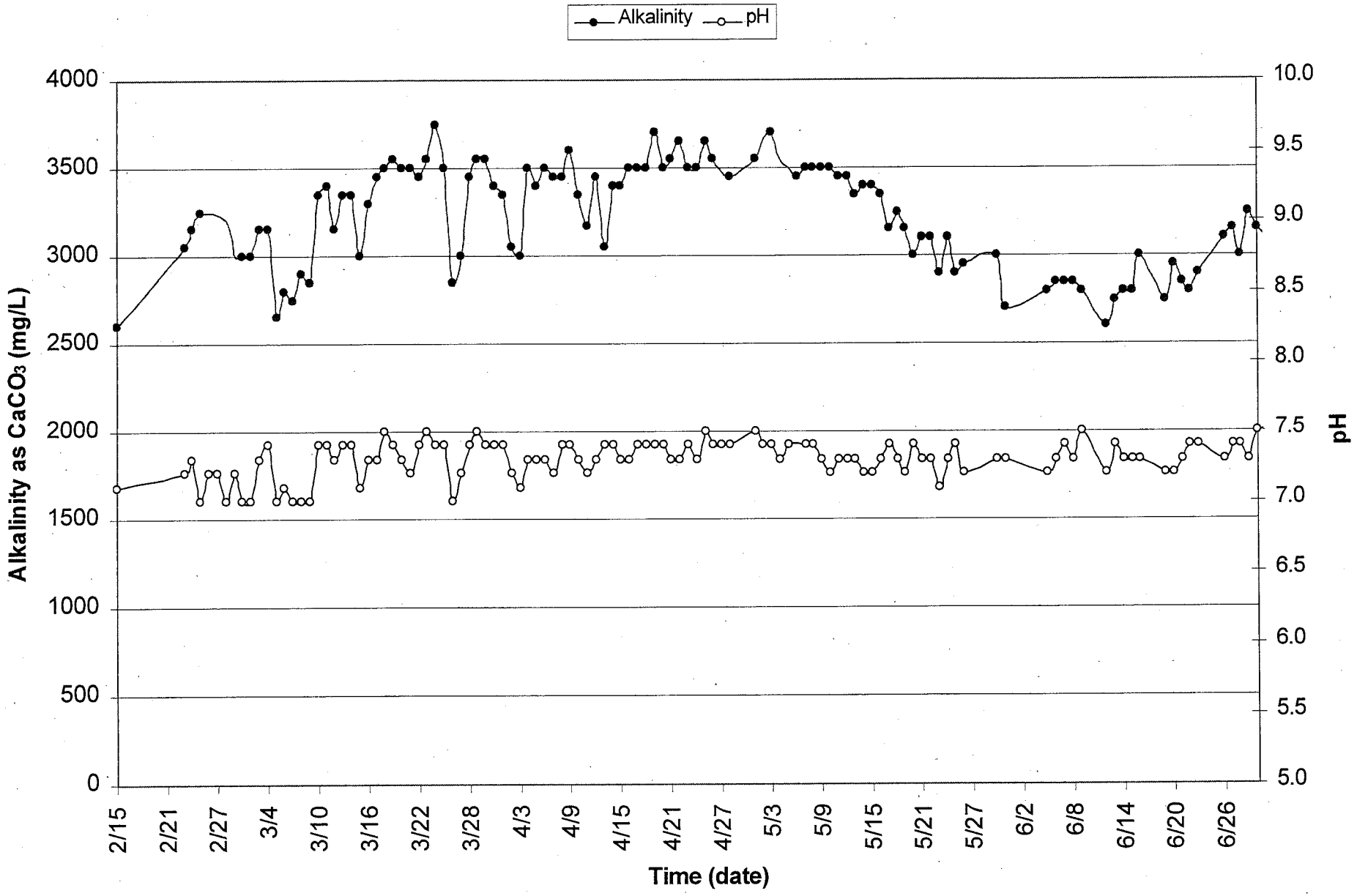


**Figure 11. Phase I - volatile fatty acid to alkalinity ratio in digester outflow**

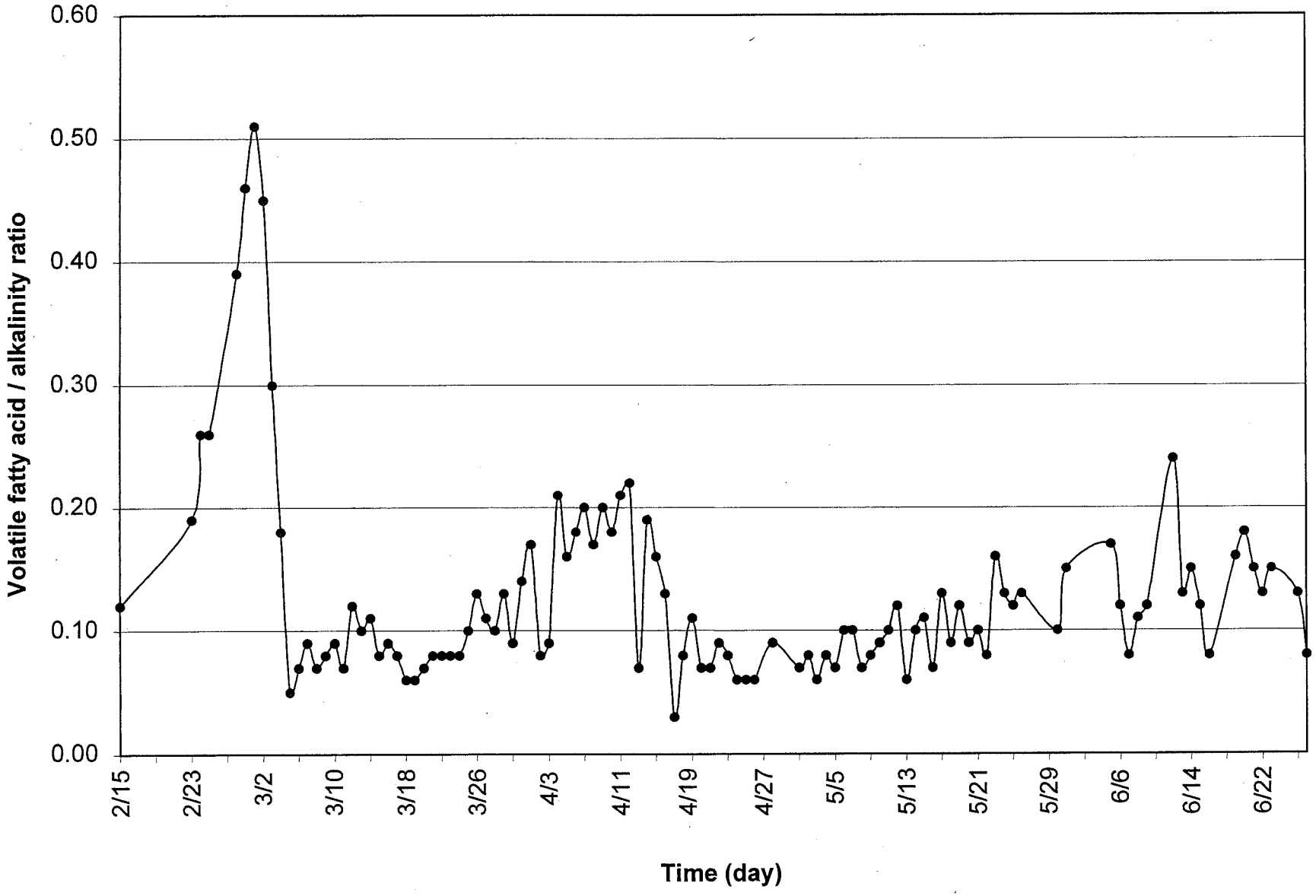
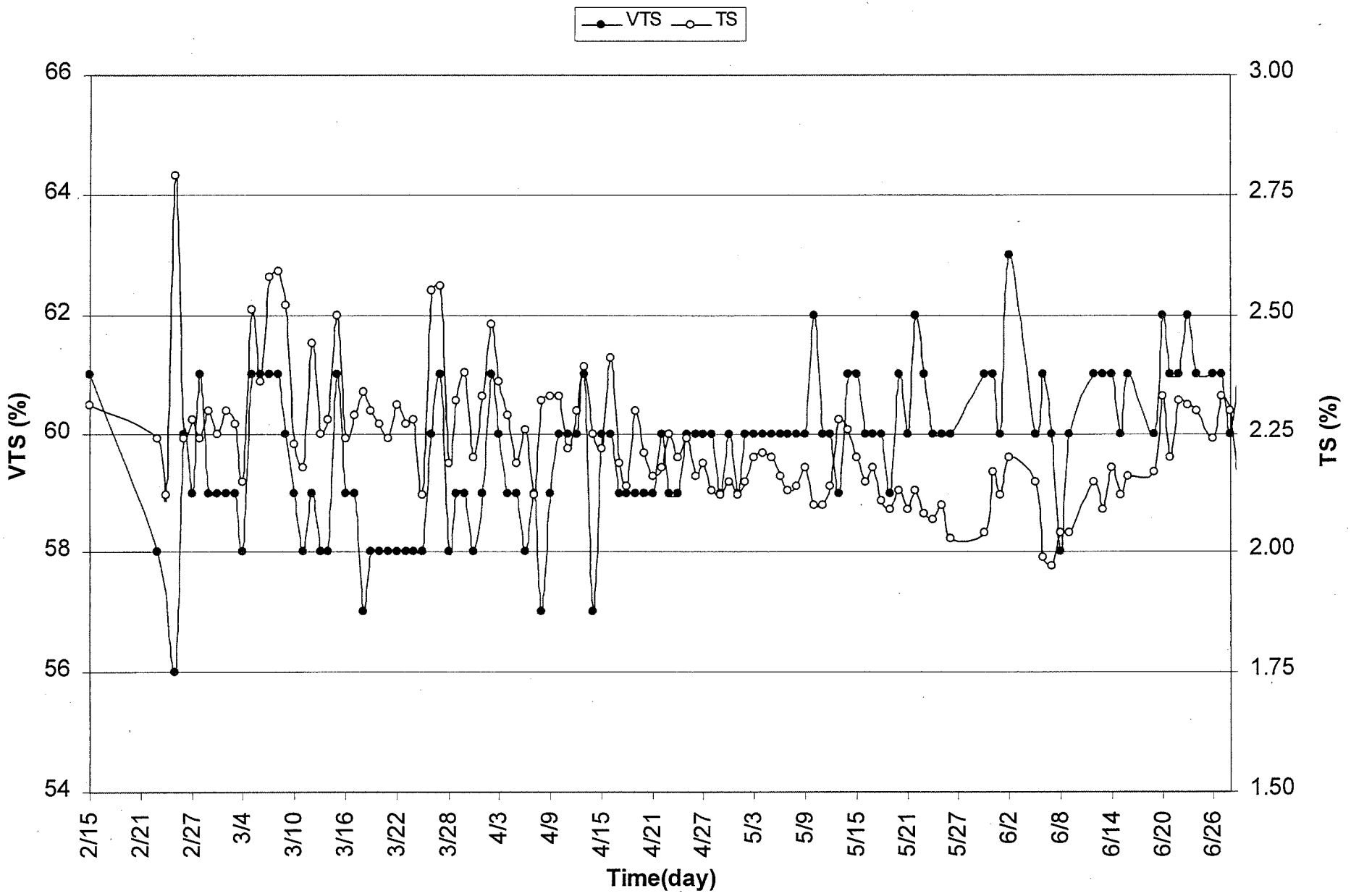


**Figure 12. Phase I - Total solids and volatile solids in digester outflow**



## Figure 13. Phase I - Composition of digester gas

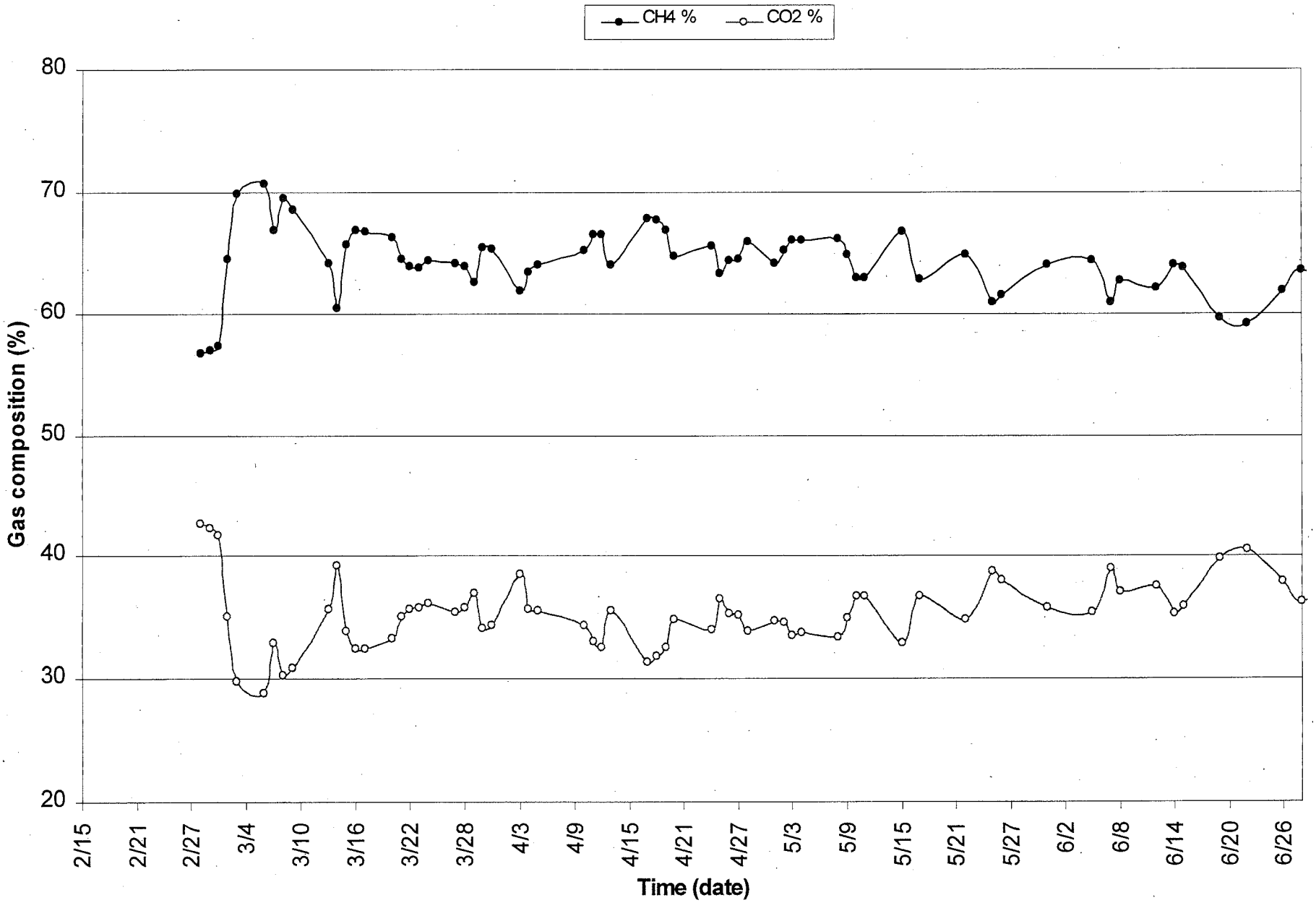


**Figure 14. Phase I - H2S concentrations in digester gas**

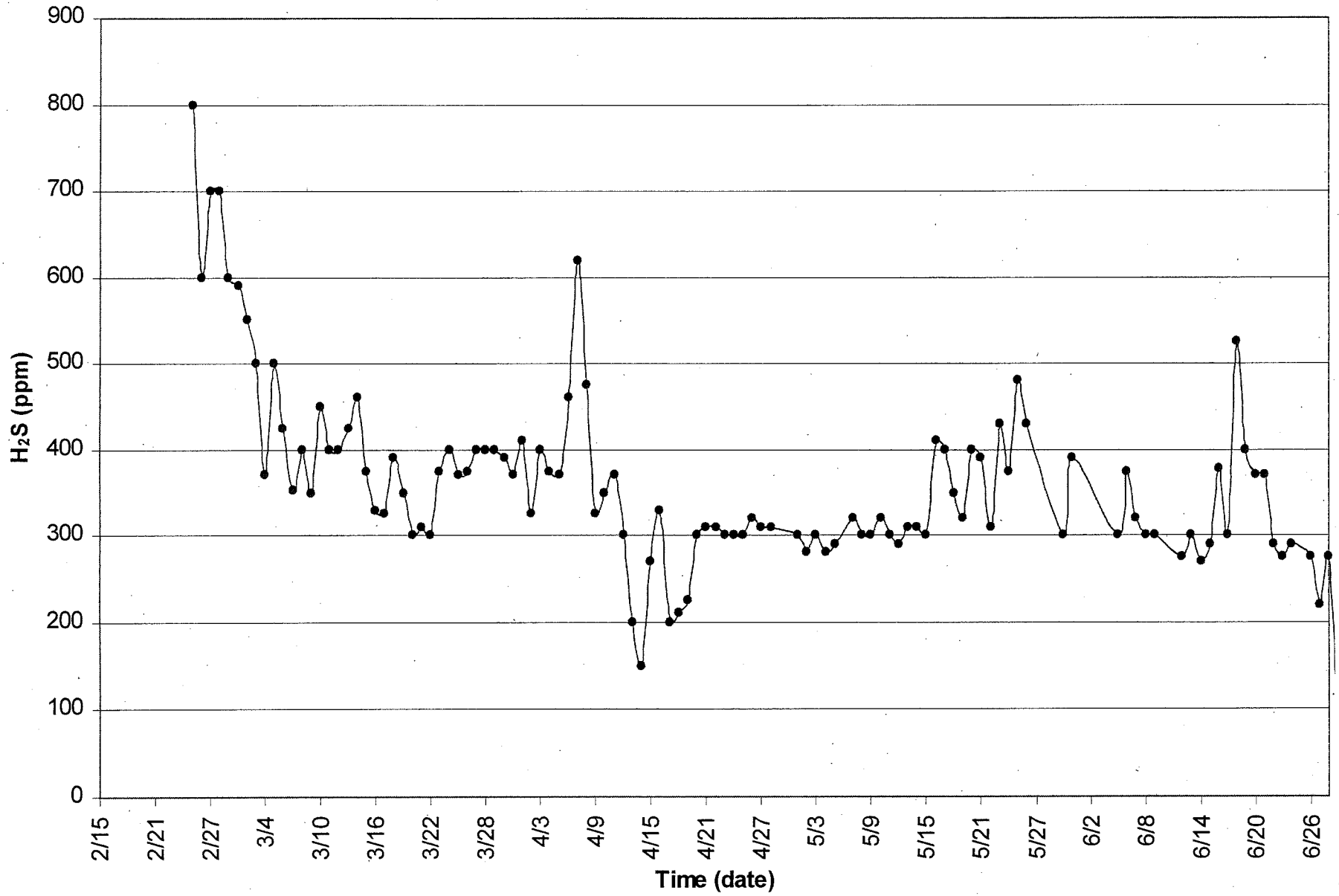
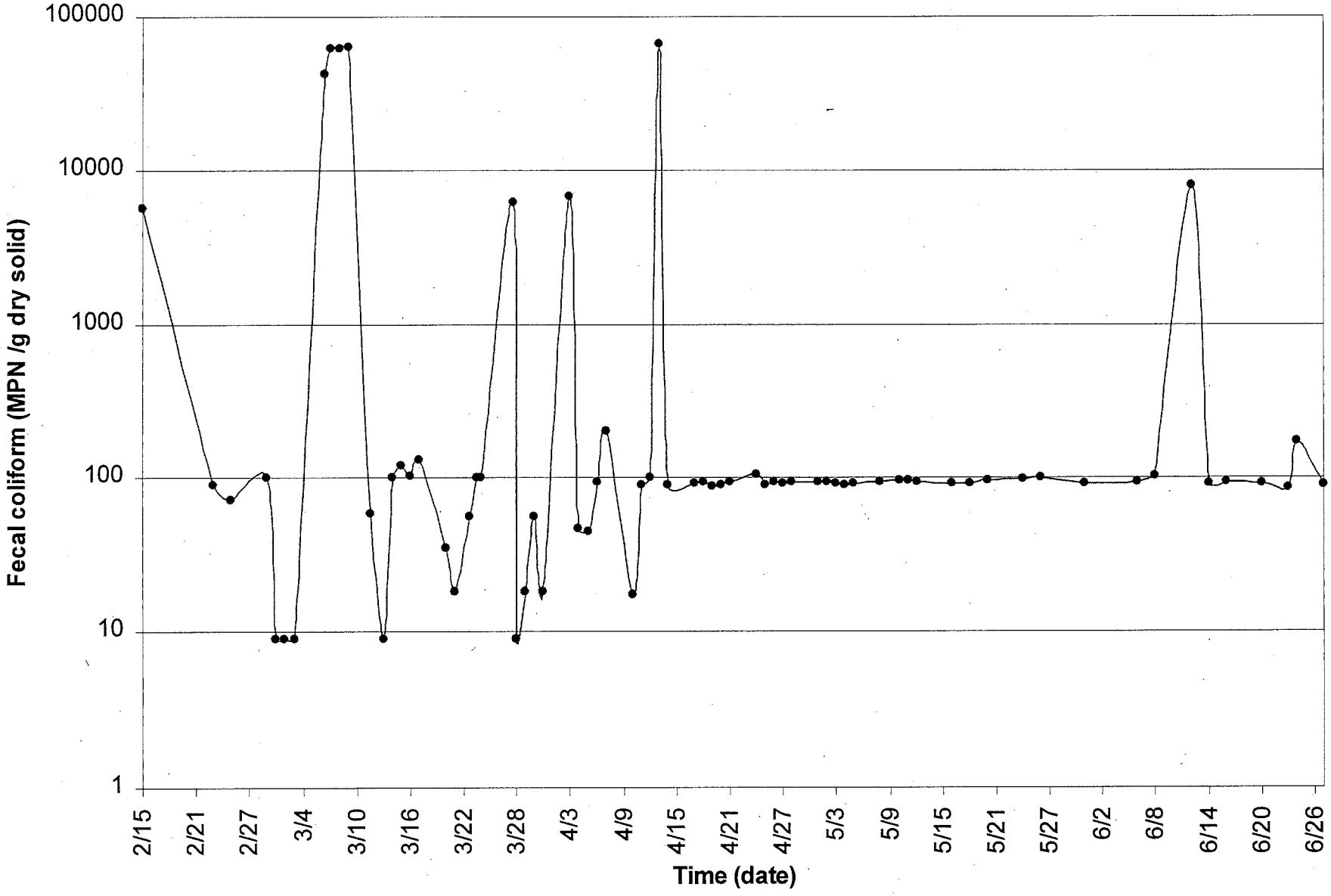


**Figure 15. Phase I - Fecal coliform in digester outflow**



## Table 5. Phase I - Heavy metal concentrations in digester outflows

| Metal | USEPA 40 CFR Part 503.13 | | TITP thermophilic | TITP mesophilic |
|---|---|---|---|---|
| | Ceiling values [a] (mg/kg dry wt) | Monthly averages [b] (mg/kg dry wt) | Monthly averages (mg/kg dry wt) | Monthly averages (mg/kg dry wt) |
| As | 75 | 41 | 11.5 | 9.1 |
| Cd | 85 | 39 | 3.2 | 4.23 |
| Cu | 4300 | 1500 | 265 | 264 |
| Pb | 840 | 300 | 59 | 55.6 |
| Hg | 57 | 17 | 3 | 2.16 |
| Mo | 75 | not applicable | 25 | 25.1 |
| Ni | 420 | 420 | 46.5 | 36.2 |
| Se | 100 | 100 | 58 | 62.9 |
| Zn | 7500 | 2800 | 964 | 844 |

[a] Maximum allowable concentration for biosolids land application, Table 1 in §503.13

[b] Limit concentration for EQ biosolids, Table 3 in §503.13

## Table 6. Phase I - *Salmonella* sp. densities in digester outflow

| Test Date | Density (MPN/4g dry wt) |
|---|---|
| 4/10/01 | <0.3 |
| 4/12/01 | <0.3 |
| 6/12/01 | <0.1 |

Verify

## 3.2 Two-stage thermophilic digestion (Phase II)

### 3.2.1 Process performance

3.2.1.1 VFA production, alkalinity and pH

Total VFA concentration, alkalinity and the pH in the first and second stage digester during Phase II are presented in Figures 16, 17, and 18, respectively. The total volatile fatty acids concentration was almost allways higher in the first stage digester than in the second stage digester (Figure 16). This is likely to occur when considering the sequence of reactions occurring during digestion. The first step is production of VFA by acidogens. Subsequently, VFAs are consumed by acetogens and methanogens for the production of $CH_4$ and $CO_2$. Apart from three excursions exceeding 0.8 g/L VFAs, the total VFA concentration was relatively constant and remained well below 0.5 g/L. As a result of higher VFA concentrations in the first digester, the sludge alkalinity in this digester was always less than that in the second digester (Figure 17). Similarly, the pH in the first stage digester was on average slightly lower than in the second stage digester, although the differences were minimal (Figure 18). No signs of excessive VFA production and digester souring, or low pH, were observed in either digester during Phase II.

3.2.1.2 Solids destruction

Figure 19 shows that the average total solids content was reduced to 2.1% in the first stage and further reduced to 1.9% in the second stage. The average contents of volatile solids as fractions of total solids were 59.5 and 57.9% in the first and second stage, respectively (Figure 20).

3.2.1.3 Gas production

The digester gases from the first and second stage both contained 60-70% $CH_4$ and 30-40% $CO_2$ (Figures 21 and 22, respectively), which is a typical composition for anaerobic digester gas. The $H_2S$ concentration was on average ~400 ppm with little difference in the contents in first and second stage digester gas (Figure 23).

### 3.2.2 Disinfection performance

3.2.2.1 Fecal coliform

Figure 24 demonstrates that fecal coliform densities in the first digester outflow regularly exceeded the EPA limit of 1000 MPN/g dry wt. However, subsequent storage in the second digester caused a further reduction of fecal coliform densities, and exceedence of the limit was only observed on two occasions over a 4-month period. The average fecal coliform density in the second digester outflow was 203 MPN/g dry wt.

3.2.2.2 *Salmonella* sp.

*Salmonella* sp. densities were not determined during Phase II. However, complete destruction/inactivation of Salmonella during Phase II can be reasonably expected as single stage digestion at half the retention time (Phase I) has already been proven to be sufficient.

3.2.2.3 Helminth ova and enteric viruses

Helminth ova and enteric viruses were extensively sampled over periods of one month and two weeks, respectively (Table 7). Digester inflow did not contain helminth ova at a detectable level. Enteric viruses were present in digester inflow at an average density of 8 PFU/4 g dry wt (41 samples), but were destroyed to below detection (< 1 PFU/4 g dry wt) after the first stage.

## 3.3 Single stage thermophilic batch digestion (Phase III)

### 3.3.1 Process performance

Digestion performance during Phase III was very comparable to the performance observed during earlier phases (sections 3.1.1 and 3.2.1, and therefore not included herein.

### 3.3.2 Disinfection performance

3.3.2.1 Fecal coliform

The fecal coliform density in the digester inflow was approximately $5x10^5$ - $10^6$ MPN/g dry wt (Table 8 and Figure 25). During four months of testing, most samples from the digester outflow showed fecal coliform densities lower than the limit of 1000 MPN/g dry wt. Out of 86 samples, 12 samples (14 %) exceeded the limit.

3.3.2.2 *Salmonella* sp.

Table 9 shows the results of digester inflow analysis. Densities of *Salmonella* sp. in the PS and TWAS mixture were in the range of 5.8 to >16 MPN/4 g dry wt and two occasions <2.2 MPN/4 g dry wt. Digestion reduced the *Salmonella* sp. density to less than 2.2 MPN/4 g dry wt (Table 9).

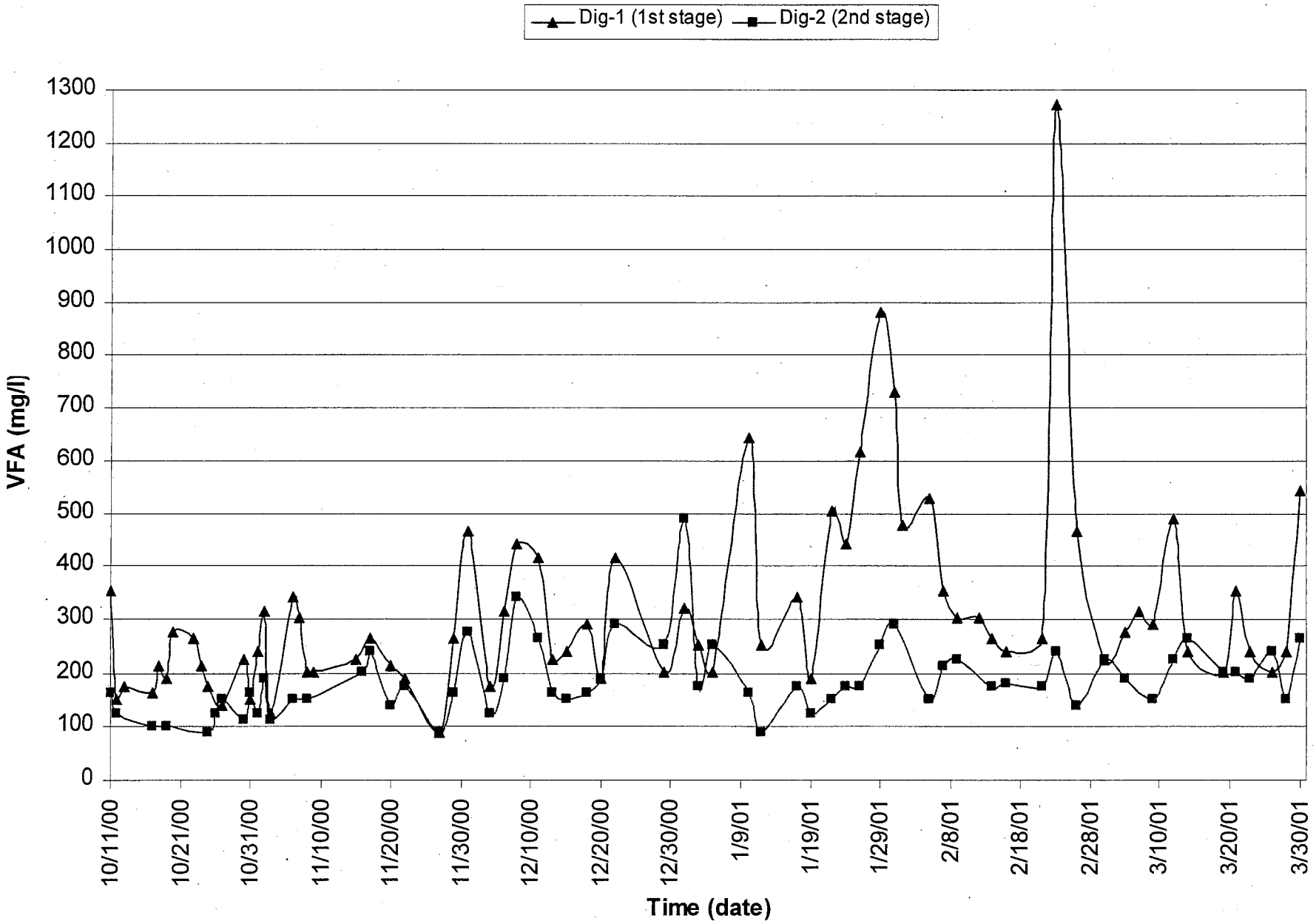
3.3.2.3 Helminth ova and enteric viruses

Results the analysis of helminth ova and enteric viruses densities are shown in Table 10 and Table 11, respectively. Analyses were performed on composite samples that had been taken over the designated periods. Helminth ova was not detected in any of the samples examined. The average density of enteric viruses in the digester inflow varied considerably with the sampling period (Table 11, see for comparison also Table 7 for sampling results during Phase II). The density of enteric viruses in the digester outflow was however below the detection limit, which is the EPA limit, of 1 PFU/4 g dry wt.

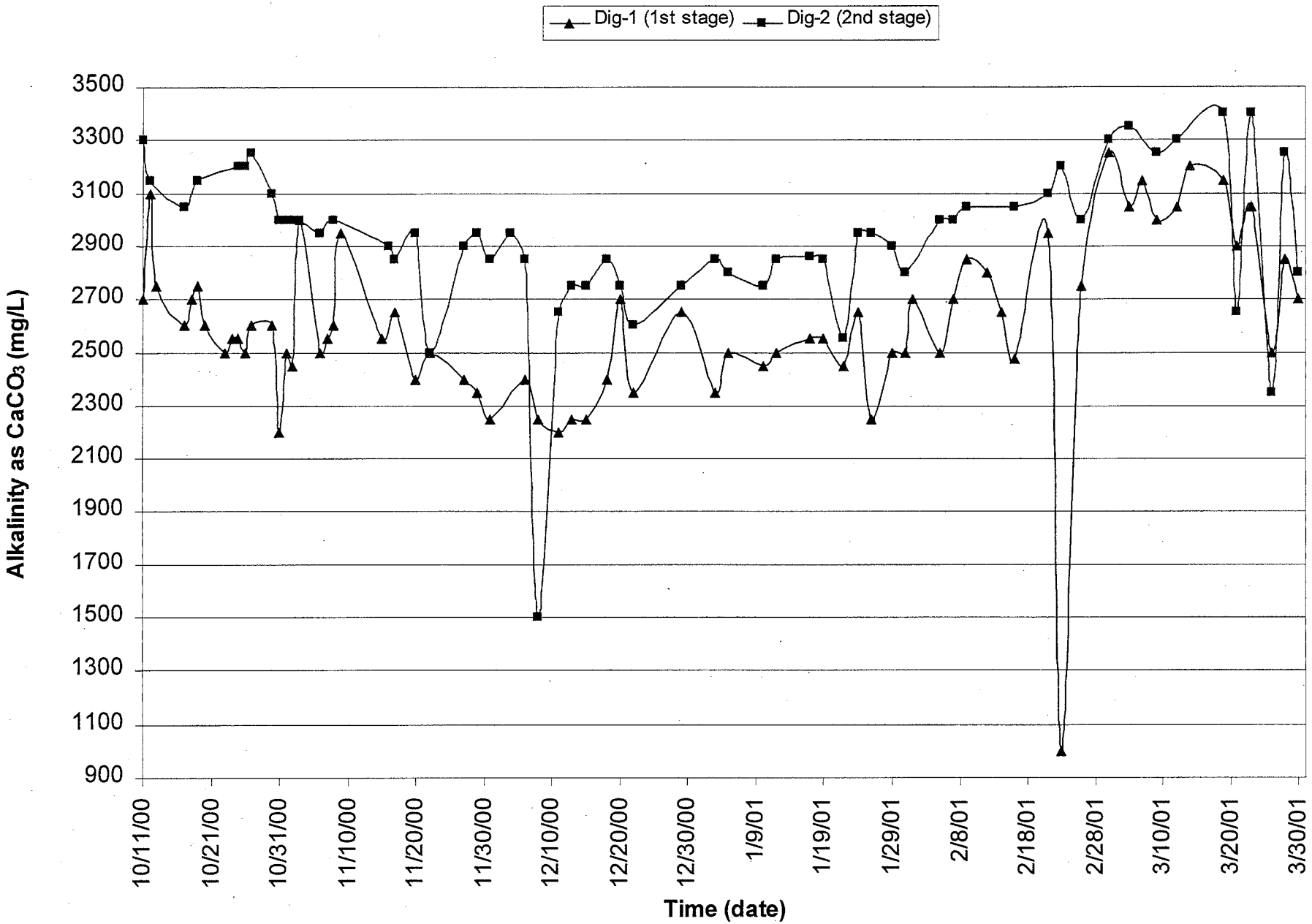
### 3.3.3 Post-digestion train

In order to evaluate the biosolids quality during post-digestion processing, samples were taken at the centrifuge outlet and from the hopper outlet when the biosolids were loaded into the truck. The densities of *Salmonella* sp., helminth ova and enteric viruses were all below the detection limit in samples along the post-digestion train (e.g., Tables 9, 10 and 11, respectively). The fecal coliform density in centrifuge wetcake slightly increased compared to the density in the digester outflow and exceedance of the EPA limit was observed in 29% of the samples (Table 8 and Figure 26). A sharp increase of the fecal coliform density was however observed in wetcake sampled at the truck loading facility. Densities ranged from $4.4 \times 10^4$ to $> 10^6$ MPN/g dry wt and were without exception well above the EPA limit of 1000 MPN/g dry wt (Table 8 and Figure 26).

**Figure 16. Phase II - Total volatile fatty acids concentrations in first and second stage digester outflows**



## Figure 17. Phase II - Alkalinity in first and second stage digester outflows



## Figure 18. Phase II - pH in first and second stage digester outflows

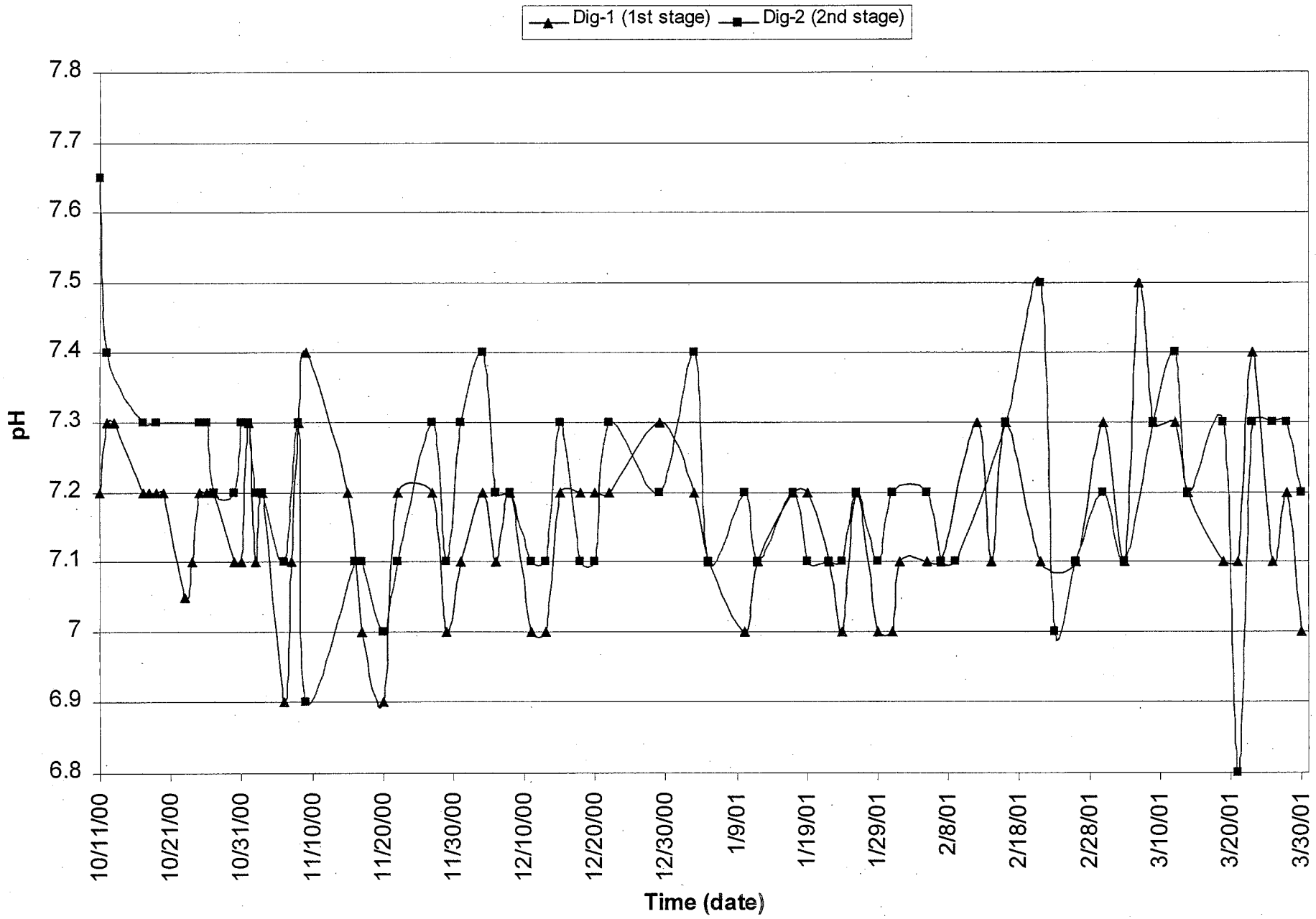


**Figure 19. Phase II - Total solids contents in first and second stage digester outflows**

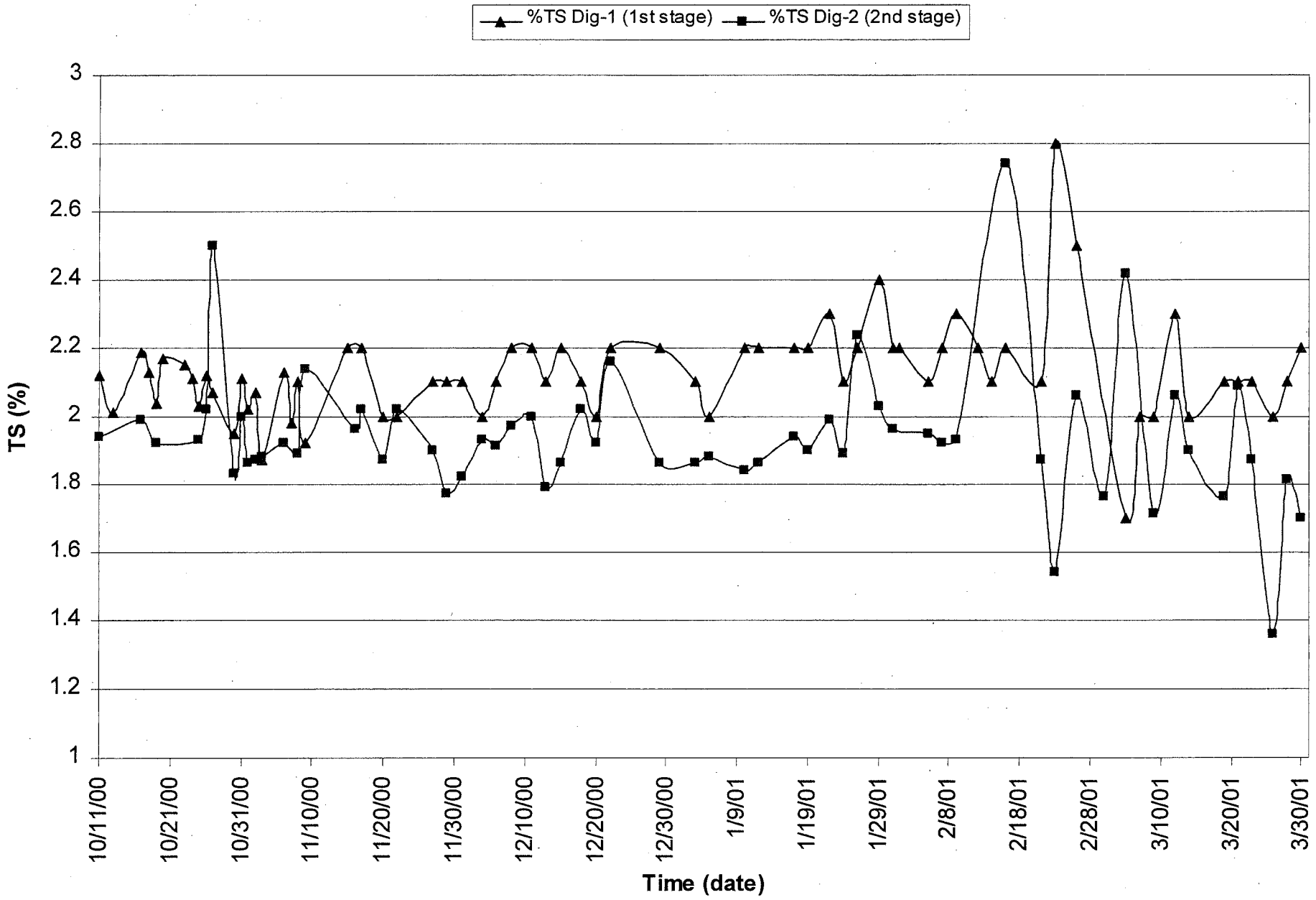


**Figure 20. Phase II - Volatile total solids contents in first and second stage digester outflows**

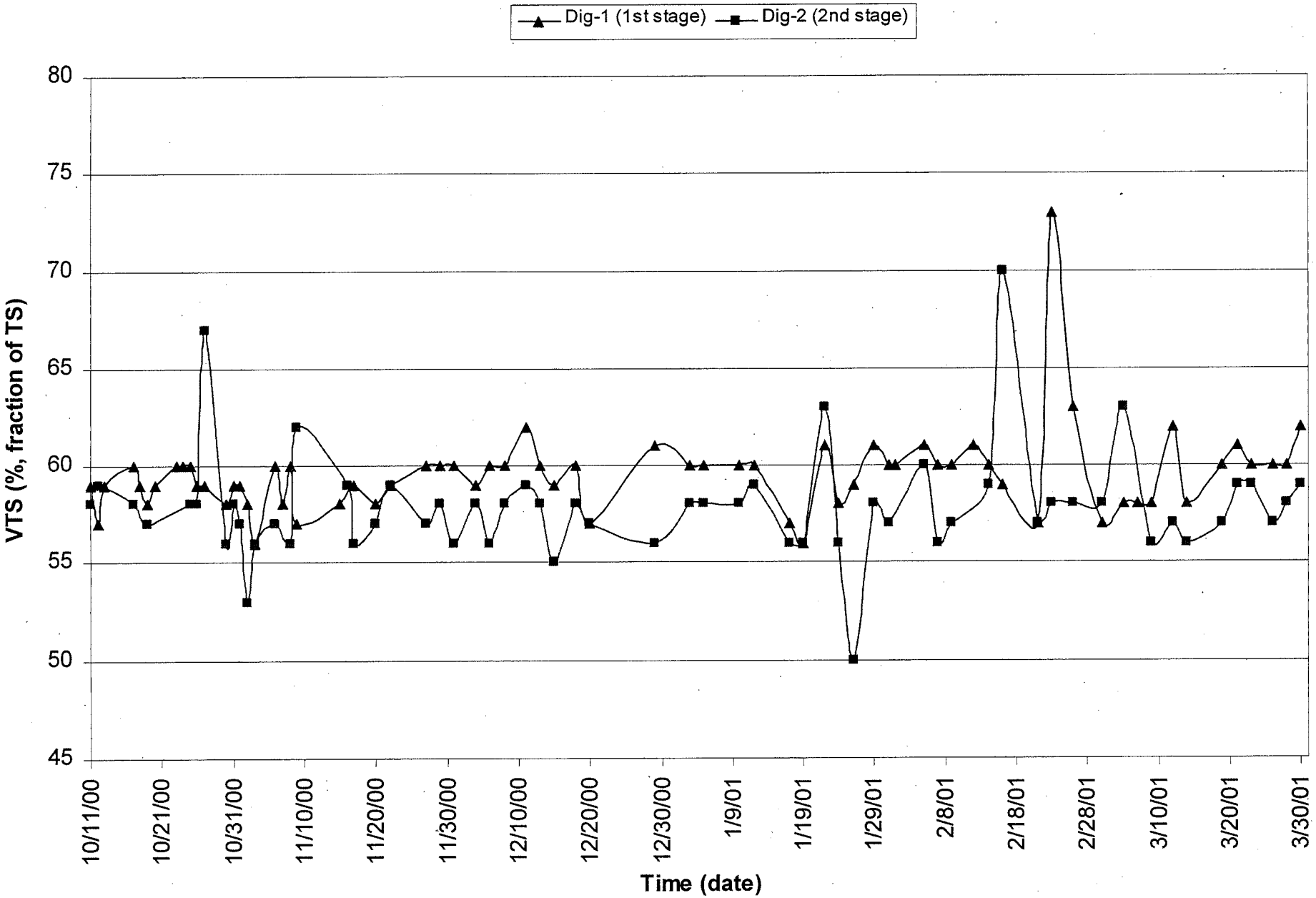


**Figure 21. Phase II - $CH_4$ contents in first and second stage digester outflows**

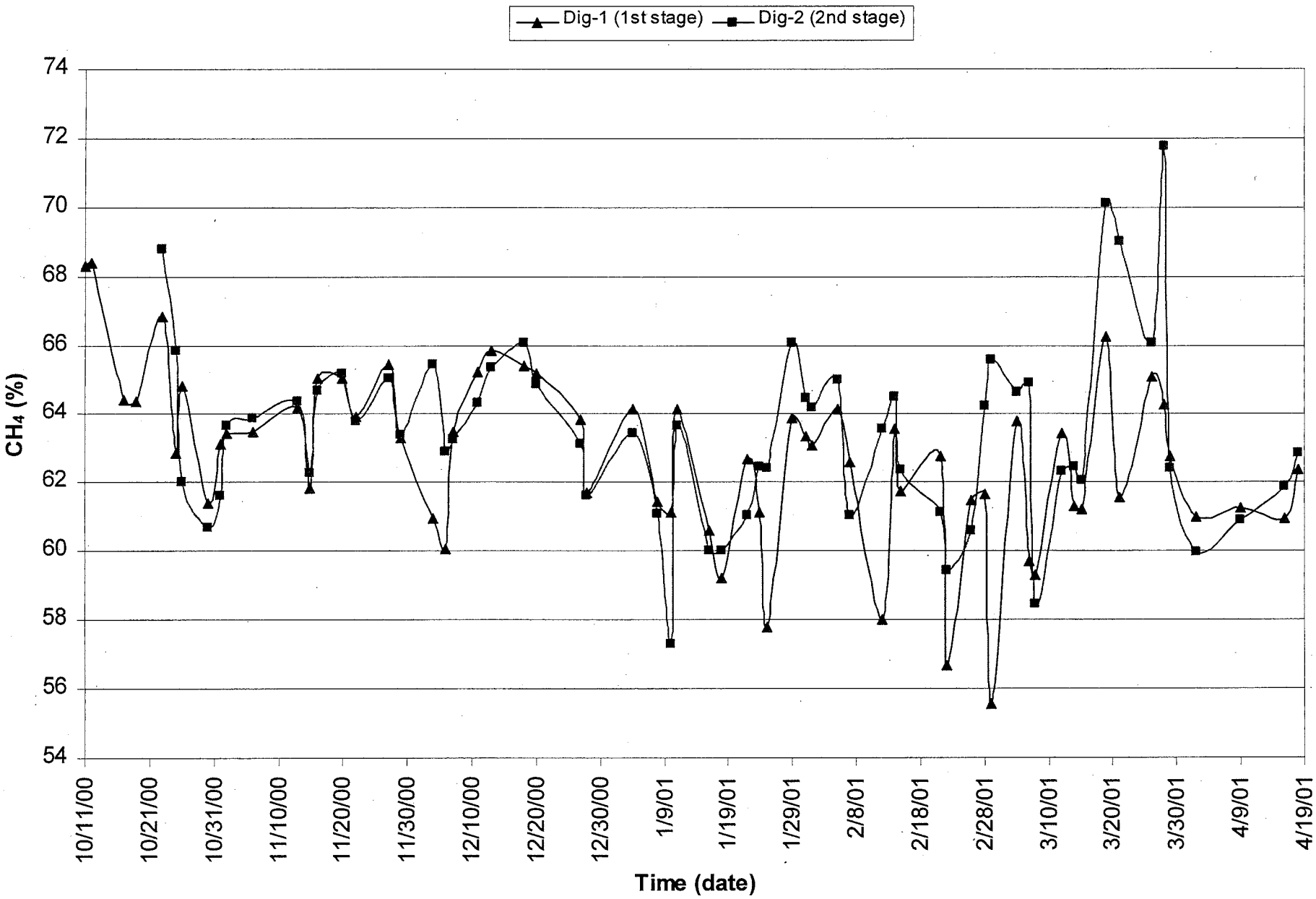


**Figure 22. Phase II - $CO_2$ contents in first and second stage digester outflows**

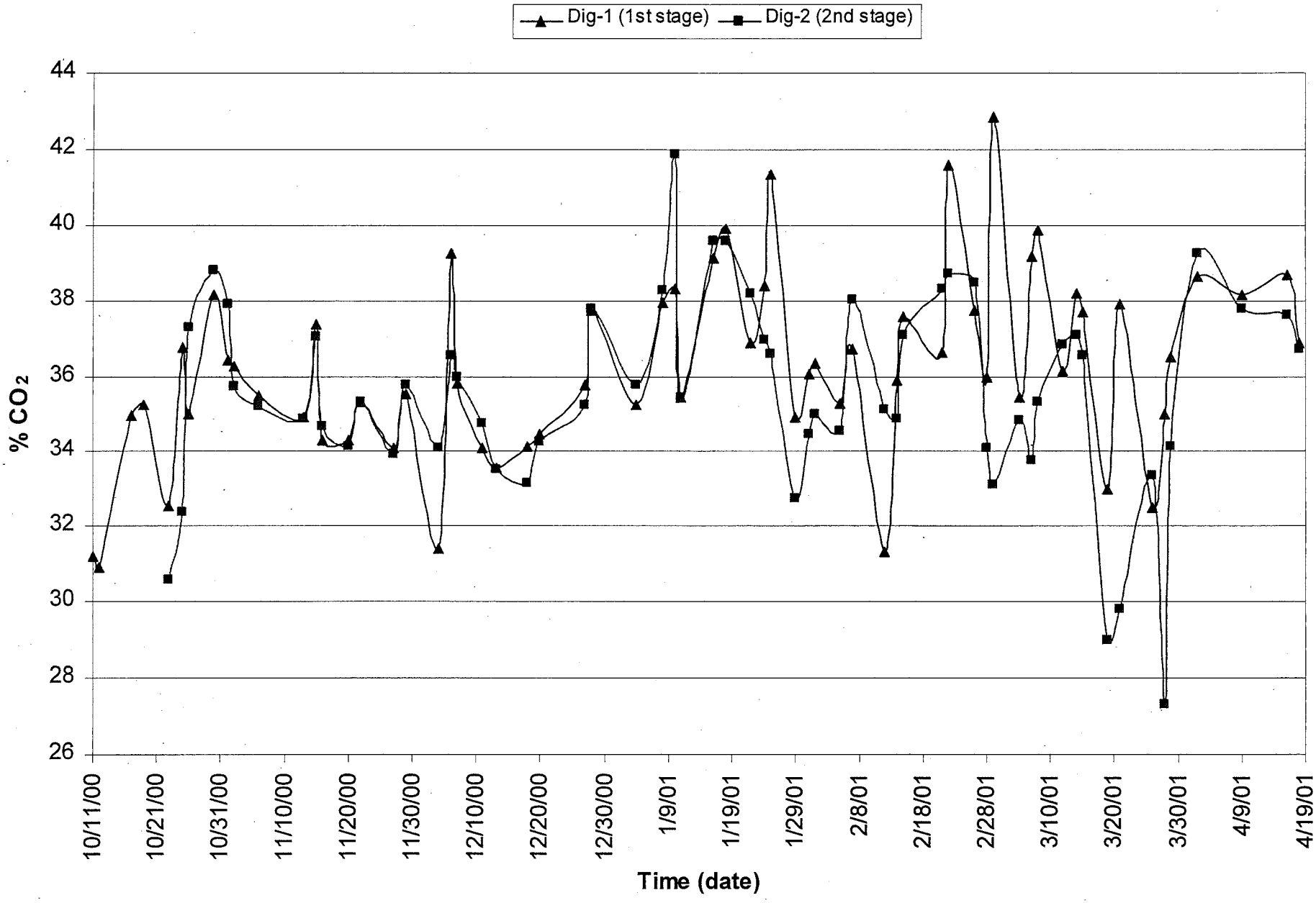


**Figure 23. Phase II - $H_2S$ concentrations in first and second stage digester outflows**

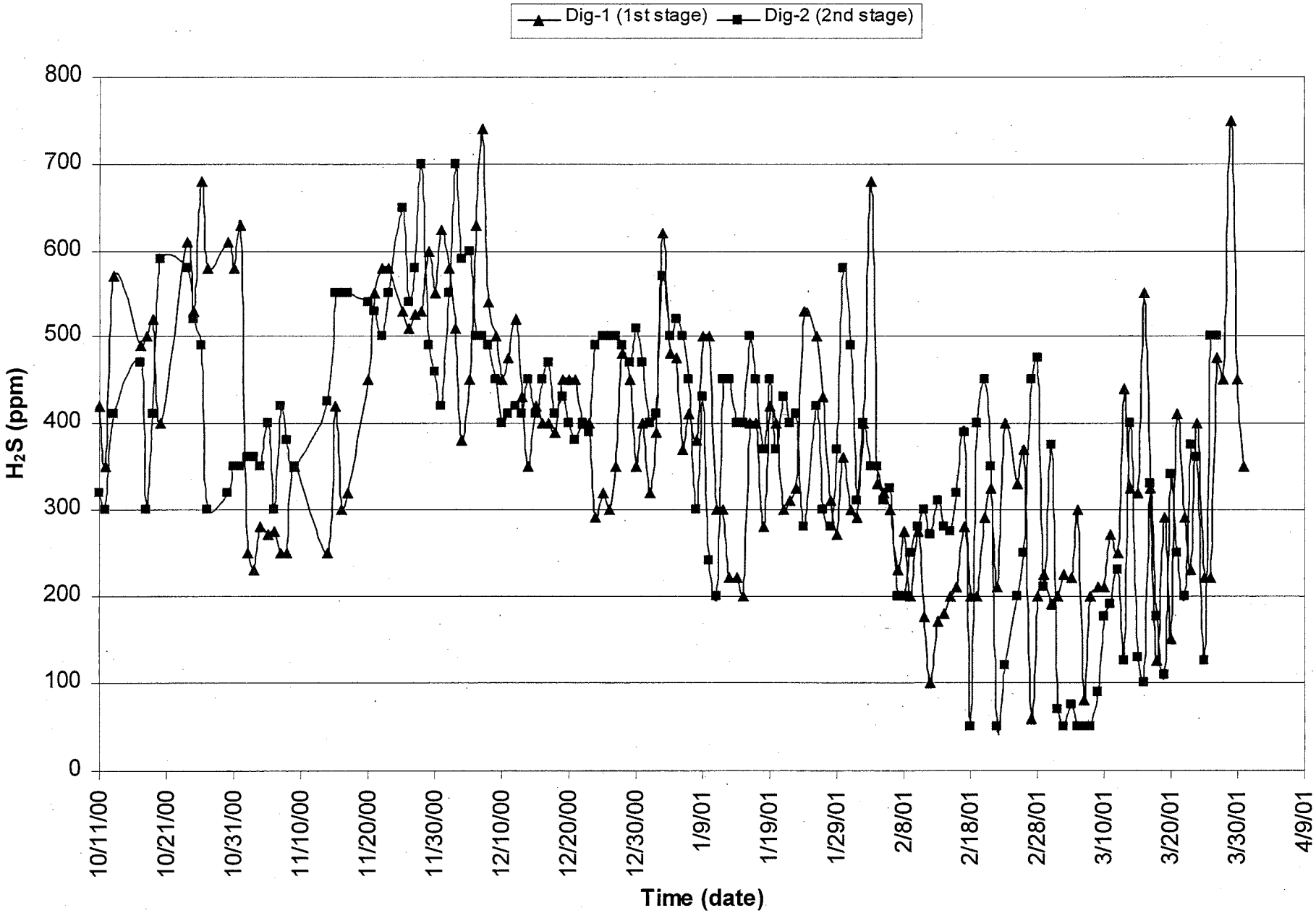
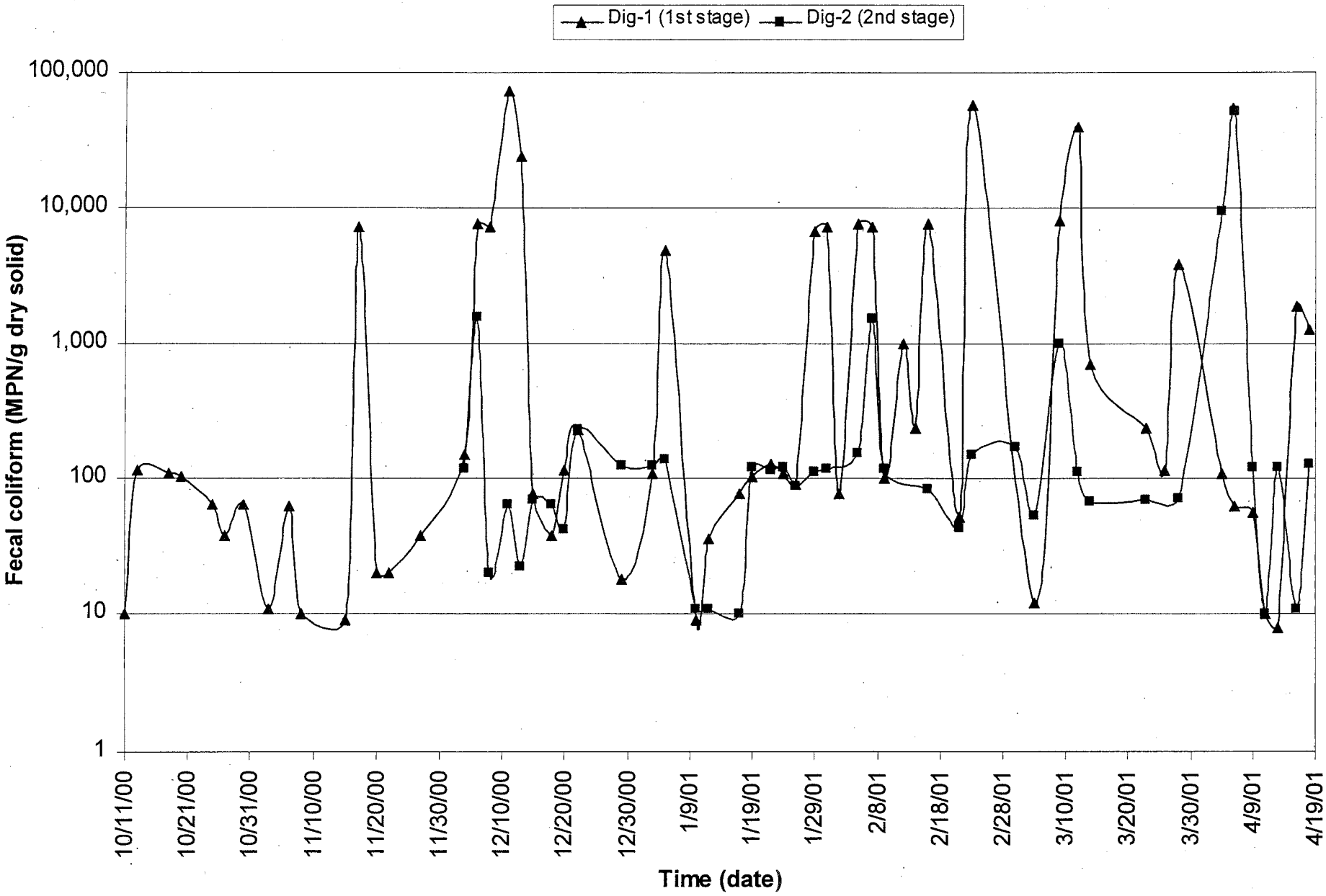


**Figure 24. Phase II - fecal coliform densities in first and second stage digester outflows**



## Table 7. Phase II - Helminth ova and enteric viruses densities

| Parameters | Sampling dates | Sample location | Number of samples | Density |
|---|---|---|---|---|
| Helminth ova (ova/4g dry wt) | 1/10/01-2/8/01 | inflow | 79 | <1 |
| | | outflow | 83 | <1 |
| Enteric virus (PFU/4g dry wt) | 1/24/01-2/8/01 | inflow | 41 | 8 |
| | | outflow | 43 | <1 |

**Figure 25. Phase III - fecal coliform densities in digester inflow and outflow**

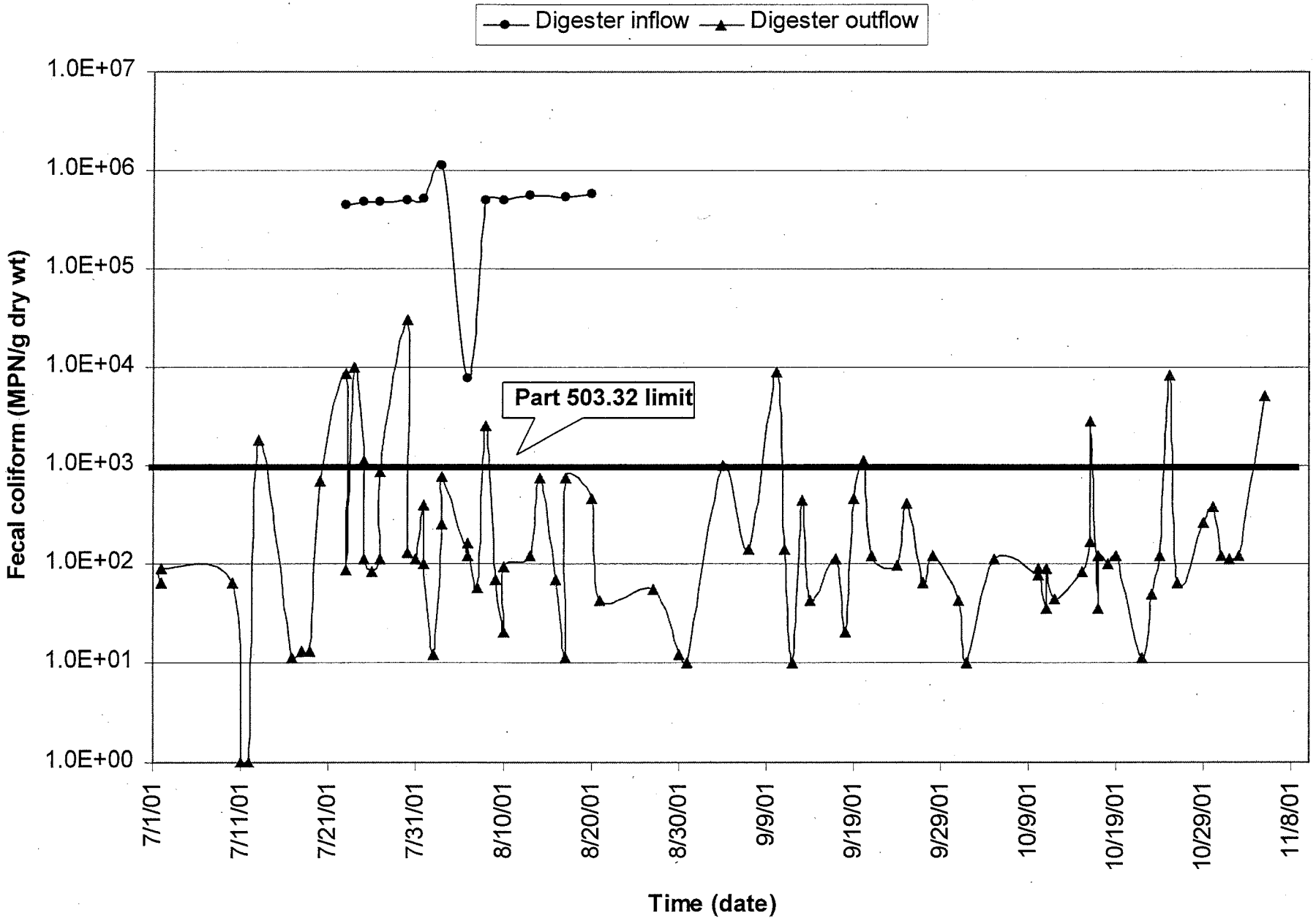
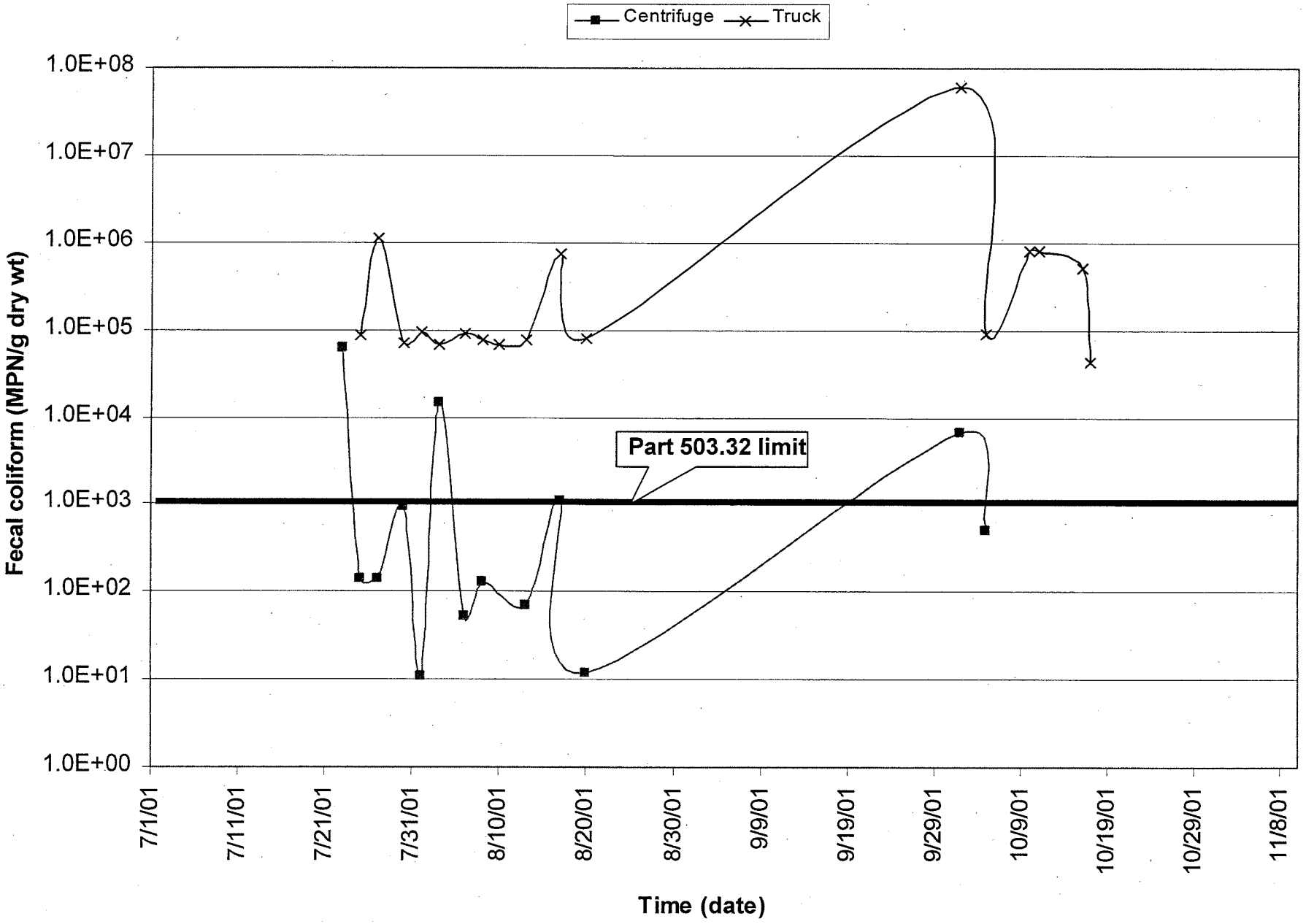


**Figure Y. Phase III - fecal coliform densities in post digestion train**



## Table [illegible] Phase III - Fecal coliform densities (MPN/g d[illegible] wt)

| Date | Digester | Temp. | Digester | | Wet Cake | |
|---|---|---|---|---|---|---|
| | | | Inflow | Outflow | Centrifuge | Truck |
| 7/2/01 | 1 | 125.2 | | < 6.4E+01 | | |
| 7/2/01 | 2 | 125.7 | | < 9.1E+01 | | |
| 7/10/01 | 3 | 129.5 | | 6.3E+01 | | |
| 7/11/01 | 2 | | | 1.0E+00 | | |
| 7/12/01 | 3 | 130.2 | | < 1.0E+00 | | |
| 7/13/01 | 1 | 128.2 | | 1.8E+03 | | |
| 7/17/01 | 2 | | | < 1.1E+01 | | |
| 7/18/01 | 3 | 130.4 | | < 1.3E+01 | | |
| 7/19/01 | 1 | 123 | | 1.3E+01 | | |
| 7/20/01 | 2 | 130.1 | | 6.8E+02 | | |
| 7/23/01 | 2 | | >= 4.4E+05 | 8.5E+03 | >= 6.2E+04 | |
| 7/23/01 | 2 | | | < 8.7E+01 | | |
| 7/24/01 | 3 | 130.7 | | >= 1.0E+04 | | |
| 7/25/01 | 1 | 124.7 | >= 4.7E+05 | 1.1E+03 | 1.4E+02 | >= 8.8E+04 |
| 7/25/01 | 1 | 124.7 | | < 1.1E+02 | | |
| 7/26/01 | 2 | 132 | | 8.2E+01 | | |
| 7/27/01 | 3 | 130.7 | >= 4.8E+05 | 1.1E+02 | < 1.4E+02 | >= 1.1E+06 |
| 7/27/01 | 3 | 130.7 | | 8.6E+02 | | |
| 7/30/01 | 3 | 132.2 | >= 5.0E+05 | 3.0E+04 | 9.2E+02 | >= 7.0E+04 |
| 7/30/01 | 3 | 132.2 | | < 1.3E+02 | | |
| 7/31/01 | 1 | 131.8 | | 1.1E+02 | | |
| 8/1/01 | 2 | | 5.2E+05 | 3.9E+02 | < 1.1E+01 | >= 9.5E+04 |
| 8/1/01 | 2 | | | < 1.0E+02 | | |
| 8/2/01 | 3 | 132 | | 1.2E+01 | | |
| 8/3/01 | 1 | 127.6 | 1.1E+06 | 2.5E+02 | 1.5E+04 | >= 6.9E+04 |
| 8/3/01 | 1 | 127.6 | | 7.7E+02 | | |
| 8/6/01 | 1 | 130.8 | >= 7.8E+03 | 1.2E+02 | 5.3E+01 | >= 8.9E+04 |
| 8/6/01 | 1 | 130.8 | | 1.6E+02 | | |
| 8/7/01 | 2 | | | 5.7E+01 | | |
| 8/8/01 | 3 | 134.1 | >= 5.0E+05 | 2.5E+03 | 1.3E+02 | >= 7.7E+04 |
| 8/9/01 | 1 | 132 | | 6.8E+01 | | |
| 8/10/01 | 2 | | >= 4.9E+05 | 2.0E+01 | AE | 6.9E+04 |
| 8/10/01 | 2 | | | < 9.3E+01 | | |
| 8/13/01 | 2 | | 5.5E+05 | 1.2E+02 | 6.9E+01 | 7.6E+04 |
| 8/14/01 | 3 | 133 | | 7.3E+02 | | |
| 8/16/01 | 2 | 130.6 | | 6.8E+01 | | |
| 8/17/01 | 3 | 132.1 | 5.3E+05 | 1.1E+01 | 1.1E+03 | 7.4E+05 |
| 8/17/01 | 3 | 132.1 | | 7.3E+02 | | |
| 8/20/01 | 3 | 130.8 | 5.7E+05 | 4.6E+02 | 1.2E+01 | 8.1E+04 |
| 8/21/01 | 1 | 128.7 | | 4.2E+01 | | |
| 8/27/01 | 1 | 128.5 | | 5.5E+01 | | |
| 8/30/01 | 1 | 124.8 | | 1.2E+01 | | |
| 8/31/01 | 2 | 131.5 | | 1.0E+01 | | |

| Date | Digester | Temp. | Digester | | Wet Cake | |
|---|---|---|---|---|---|---|
| | | | Inflow | Outflow | Centrifuge | Truck |
| 9/4/01 | 4 | 121.6 | | 1.0E+03 | | |
| 9/7/01 | 4 | | | 1.4E+02 | | |
| 9/10/01 | 4 | 117.5 | | 9.1E+03 | | |
| 9/11/01 | 1 | 128.3 | | 1.4E+02 | | |
| 9/12/01 | 2 | | | < 1.0E+01 | | |
| 9/13/01 | 4 | 118.4 | | 4.5E+02 | | |
| 9/14/01 | 1 | 133.1 | | 4.2E+01 | | |
| 9/17/01 | 1 | | | 1.1E+02 | | |
| 9/18/01 | 2 | | | 2.0E+01 | | |
| 9/19/01 | 4 | 129.1 | | 4.6E+02 | | |
| 9/20/01 | 1 | 129.4 | | 1.1E+03 | | |
| 9/21/01 | 2 | | | 1.2E+02 | | |
| 9/24/01 | 2 | | | 9.6E+01 | | |
| 9/25/01 | 4 | | | 4.1E+02 | | |
| 9/27/01 | 2 | | | 6.4E+01 | | |
| 9/28/01 | 4 | 133.3 | | 1.2E+02 | | |
| 10/1/01 | 4 | 133.9 | | 4.3E+01 | | |
| 10/2/01 | 1 | 132.5 | | < 1.0E+01 | < 6.8E+03 | 6.2E+07 |
| 10/5/01 | 1 | 133.2 | | 1.1E+02 | 5.0E+02 | 8.9E+04 |
| 10/10/01 | 4 | 134.6 | | 7.7E+01 | < 1.0E+02 | >= 8.0E+05 |
| 10/10/01 | 4 | 134.6 | | 9.1E+01 | | |
| 10/11/01 | 1 | 132.1 | | < 3.6E+01 | 1.3E+03 | >= 8.0E+05 |
| 10/11/01 | 1 | 132.1 | | < 9.1E+01 | | |
| 10/12/01 | 2 | | | < 4.5E+01 | | |
| 10/15/01 | 2 | | | 8.2E+01 | | |
| 10/16/01 | 4 | 136.4 | | 1.7E+02 | < 1.2E+02 | 5.1E+05 |
| 10/16/01 | 4 | 136.4 | | 2.8E+03 | | |
| 10/17/01 | 1 | | | 3.5E+01 | 4.7E+02 | 4.4E+04 |
| 10/17/01 | 1 | | | 1.2E+02 | | |
| 10/18/01 | 2 | | | 1.0E+02 | | |
| 10/19/01 | 4 | 133.9 | | 1.2E+02 | | |
| 10/22/01 | 4 | 133.7 | | 1.1E+01 | | |
| 10/23/01 | 1 | 135.9 | | 5.0E+01 | | |
| 10/24/01 | 2 | | | 1.2E+02 | | |
| 10/25/01 | 4 | 135.1 | | AE | | |
| 10/26/01 | 1 | 131.5 | | 8.3E+03 | | |
| 10/29/01 | 1 | | | 6.5E+01 | | |
| 10/30/01 | 2 | | | 2.6E+02 | | |
| 10/31/01 | 4 | 129.1 | | 3.8E+02 | | |
| 11/1/01 | 1 | 134.9 | | 1.2E+02 | | |
| 11/2/01 | 2 | | | 1.1E+02 | | |
| 11/5/01 | 2 | 129.5 | | 1.2E+02 | | |
| 11/6/01 | 4 | 134 | | 5.1E+03 | | |

## Table 9. Phase III - S*almonella* sp. densities (MPN/4g dry wt)

| Date | Digester Number | Digester | | Wet Cake | |
|---|---|---|---|---|---|
| | | Inflow | Outflow | Centrifuge | Truck |
| 7/10/01 | 1 | | < 2.2 | | |
| 7/12/01 | 3 | | < 1.5 | | |
| 7/17/01 | 2 | | < 2.2 | | |
| 7/19/01 | 1 | | < 2.2 | | |
| 7/27/01 | 3 | < 2.2 | | | |
| 7/30/01 | 3 | > 16 | < 2.2 | < 2.2 | < 2.2 |
| 8/2/01 | 1 | > 16 | < 2.2 | < 2.2 | |
| 8/8/01 | 3 | 5.8 | < 2.2 | < 1.6 | < 1.8 |
| 8/14/01 | 3 | < 2.2 | < 2.2 | < 2.2 | |
| 8/15/01 | 1 | 7.8 | < 2.2 | < 2.2 | < 2.2 |
| 8/16/01 | 2 | > 16 | < 2.2 | < 2.2 | < 2.2 |
| 10/16/01 | 4 | | < 2 | | |
| 10/17/01 | 1 | | < 1.8 | | < 1.9 |

## Table 10. Phase III - Helminth ova densities (ova/4g dry wt)

| Period | Digester | | Wet Cake | |
|---|---|---|---|---|
| | Inflow | Outflow | Centrifuge | Truck |
| 7/25/01 - 8/4/01 | NA | <1 | <1 | <1 |
| 8/6/01 - 8/17/01 | NA | NA | <1 | <1 |

## Table 11. Phase III - Enteric viruses densities (PFU/4g dry wt)

| Period | Digester | | Wet Cake | |
|---|---|---|---|---|
| | Inflow | Outflow | Centrifuge | Truck |
| 7/25/01 - 8/4/01 | 201.0 | <0.93 | <1 | <.97 |
| 8/6/01 - 8/17/01 | 41 | <1 | <1 | <1 |

# 4. CONCLUSIONS

## 4.1 Single stage thermophilic digestion (Phase I)

The main conclusions are:

1. Rapid heating and slowly increasing the sludge feed rate facilitated a rapid conversion from mesophilic to thermophilic digestion and prevented excessive acid accumulation in the digester.
2. Analysis of chemical parameters demonstrated the development of a balanced thermophilic culture, capable of achieving a relatively constant digester performance despite sometimes highly fluctuating sludge feed rates.
3. The digestion performance was improved by conversion from mesophilic to thermophilic operation. As summarized in Table 12, total and volatile solids destruction were respectively 17 and 12 % higher at during thermophilic digestion. The expected increase in gas production is 20%. The significance of these findings would be subject to further research, in particular because of uncertainties in analytical procedures.
4. Semi-continuous operation at an average sludge retention time of approximately 12 days and an average temperature of 128.1 $^0$F significantly reduced the fecal coliform density, but exceedance of the EPA limit of 1000 MPN/g dry wt was sometimes observed.
5. Semi-continuous operation at an average sludge retention time of approximately 12 days and an average temperature of 128.1 $^0$F consistently reduced the *Salmonella* sp. density to below the EPA limit of 3 MPN/4 g dry wt.
6. Class A qualification according to Alternative 3 of 40 CFR Part 503 could not be demonstrated because densities of helminth ova and enteric viruses were not determined.
7. Heavy metals concentrations in thermophilically digested sludge satisfied the highest standards (EQ) standards in 40 CFR Part 503.
8. Volatile solids destruction during thermophilic digestion satisfied the standards set in 40 CFR Part 503 for vector attraction reduction.

## 4.2 Two-stage thermophilic digestion (Phase II)

The main conclusions are:

1. Doubling the sludge retention time to 24 days by employing two digesters in series only slightly improved digester performance in terms of solids destruction and predicted gas production.
2. Fecal coliform densities in sludge from the first digester were sometimes above the limit of 1000 MPN/g dry wt, which agrees with results obtained during Phase I. Consistent reduction of fecal coliform to well below the limit for Class A biosolids was achieved by putting a second digester in series so that the average retention time was doubled.
3. *Salmonella* sp. densities were not determined during Phase II, but disinfection to below the limit for Class A biosolids can reasonably be assumed to have occurred. Phase I research demonstrated that single stage treatment was already sufficient to reduce *Salmonella* sp. densities to an undetectable level.
4. De density of enteric viruses in raw sludge varied greatly, but effective disinfection to less than the EPA limit of 1 PFU/4 g dry wt was observed at all times.
5. Both untreated and digested sludge did not contain helminth ova.
6. Alternative 3 of 40 CFR Part 503 requires demonstration of the process to effectively reduce helminth ova and enteric viruses to below their limits (respectively <1 ovum/4 g dry wt and <1 PFU/4 g dry wt). It is also generally required to demonstrate that the density of fecal coliform or the density of *Salmonella* sp. in digested sludge is less than their limits (respectively, 1000 MPN/g dry wt and <3 MPN/4 g dry wt). Demonstration of pathogen reduction by any process requires in the first place the presence of the particular pathogen in untreated sludge. Since this was not the case for helminth ova, its reduction could not be demonstrated. TITP can therefore not use Alternative 3 to demonstrate qualification of its digestion process for Class A biosolids production.

### 4.3 Single stage thermophilic batch digestion (Phase III)

The main conclusions are:

1. *Salmonella* sp. densities observed in the digester inflow were significantly reduced by the single-stage thermophilic batch digestion to below the limit established in 40 CFR Part 503.32 (<3 MPN/4 g dry wt) for Class A biosolids by using Alternative 1, time-temperature regime defined in 40 CFR Part 503.
2. Fecal coliform densities observed in the digester inflow were also significantly reduced after digestion. In general, fecal coliform density was below the Class A limit of 1000 MPN/g dry wt. However, in several occasions, the values exceeded this limit. This can tentatively be attributed to the fact that the required thermophilic temperatures were not reached in the digesters due to insufficient heat supply by outdated boilers.
3. *Salmonella* sp. densities were below the Class A limit throughout additional locations in the post-digestion train.
4. Fecal coliform densities exceeded the Class A limit several times after the centrifuge and at all times at the truck loading facility. The conveyer belt that transports wetcake from the centrifuge to the silo is exposed to an open environment leaving the wetcake vulnerable to external contamination sources such as bird droppings, etc.
5. Although not explicitly required for Alternative 1, densities of both helminth ova and enteric viruses were determined and found to meet the EPA Class A limit (<1 PFU/4 g dry wt) after digestion (as specified in Alternatives 3 and 4).
6. A preliminary profile of the biosolids temperature throughout the post-digestion train showed a major drop between the centrifuge and the truck loading location (Section 6).
7. Based on preliminary tests, HPE and polymer were not found to be significant sources of contamination (Section 6).

## Table 12. Phase I - Comparison of solids destruction by mesophilic and thermophilic digestion

| Parameters | Digester inflow (average ± standard deviations) | Digested sludge (average ± standard deviations) | |
|---|---|---|---|
| | | Mesophilic | Thermophilic |
| TS (%) | 3.6±0.3 | 2.3±0.16 | 2.1±0.14 |
| VS (% of TS) | 76±2.4 | 61±0.9 | 59±1.1 |
| TS destruction (%) | NA | 36±9 | 42±9 |
| VS destruction (%) | NA | 49±9 | 55±10 |
| Increase in TS destruction (%) | NA | NA | 17±25 |
| Increase in VS destruction (%) | NA | NA | 12±20 |
| Expected increase in gas production (%) | NA | NA | 20±32 |

NA: not applicable

## 5. RECOMMENDATIONS

**Phase 1**
Based on the results and conclusions of the Phase I study, it was recommended to proceed with the Phase II study and to include the following:

1. Two stage sequential treatment with a sludge retention time twice as long as in Phase I, with the objective to improve the disinfection efficiency, in particular that of fecal coliform.
2. Determination of the densities of helminth ova and enteric viruses in digester inflow and outflow, with the objective to demonstrate complete disinfection of both pathogens by two stage sequential treatment, and thus compliance with Alternative 3 of 40 CFR Part 503.

**Phase 2**
Based on the results and conclusions of the Phase II study, it was recommended to proceed with the Phase III study containing the following elements:

1. Demonstrate compliance with Alternative 1 of 40 CFR Part 503, the time-temperature relationship for batch digestion, rather than compliance with Alternative 3 as in Phase I and II.
2. Implement a batch digestion process with 3 digesters operated in parallel and that satisfies the time-temperature relationship of Alternative 1 by employing a batch holding time of 24 hours and a digestion temperature of 131 $^0$F.
3. Perform additional sampling along the post-digestion train to identify the extend of re-occurrence of pathogens in biosolids during post-digestion processing.
4. Perform additional studies to identify possible causes for re-occurrence of pathogens in processed biosolids.

Current recommendations, specified below, are based on the results and conclusions of the Phase III study. As noted, the temperature in the digesters during Phase III was often below the target disinfection temperature for batch processing at an holding time of 24 hours (131°F). Therefore, additional efforts are needed in order to fully comply with the time-temperature requirement of Alternative 1. These improvements will not only guarantee compliance with the *Salmonella* criterion but it will also help to eliminate the few exceedances of fecal coliform densities observed in this study. The following modifications for implementation are recommended by the Task Force:

1. **5145 – TITP Class A Biosolids conversion**
   TITP treatment process must be modified in order to achieve class A biosolids. Addition of new sludge mixing systems as well as new sludge heating systems to each of the existing digesters are parts of this project.

   Two new recirculation pumps will be added to each digester (one active, one standby). The new recirculation lines will travel up new 85-foot towers on the sides of digesters 1 and 4. Four new steam injectors will be part of these recirculation lines to heat the sludge being mixed in the digester.

   All transfer lines between the digesters and centrifuges as well as the truck silos will be heat traced, and insulated to maintain a temperature of around 131°F. Partially open covers will also be added to the truck loading silos to help maintain the temperature of the biosolids.

   These modifications will tentatively be completed by the end of 2002.

2. **5142 – TITP interim solids conveyance improvement**
   As part of the original design and construction of the TITP, a series of three belt conveyors were installed to transport dewatered solids from the solids dewatering building to the sludge storage building. This TITP interim solids conveyance improvement project would add reliability and flexibility to the current Class A Biosolids handling system by installing two

wet cake pumps and associated piping in conjunction with the existing conveying system. The two wet cake pumps could later be incorporated in the design for long-term improvements. Further, modifications to be included in this project would be to rehabilitate digester no. 4 to gain additional storage capacity in the liquid side and comply with the Best Practice Study (BPS) at a lesser cost and less disruptive method to plant operations than the recommended option in the BPS.

Once these modifications have been implemented, it is recommended to proceed with Phase IV testing to demonstrate full compliance with Alternative 1 of 40 CFR Part 503.

# 6. SUPPORTING STUDIES

The Phase III study demonstrated the re-occurrence of fecal coliform during post-digestion processing. The high density of fecal coliform observed at the truck loading facility can tentatively be attributed to regrowth of organisms that survived digestion and/or to growth of organisms subsequently introduced by contamination between the centrifuge outlet and the silo at the truck loading facility. Additional studies to test these hypotheses are discussed in this section.

Post-digestion processing at TITP consists of several steps: in-plant transfer (pipelines), water removal (diluted polymer addition and centrifugation), and storage. These steps are potential sources of contamination. The long pipeline to the centrifuge, the centrifuge itself, the post-centrifuge transport, and the storage facilities were examined for possible sources of contamination and conditions that would favor bacterial growth. In particular, the use of secondary effluent (HPE) to resuspend the polymer was suspected to be a potential source of contamination.

The temperature drop in the post-digestion train is also another factor that favors bacterial growth. Conveyer belts that transport the sludge between the centrifuge outlet and the silo are located outside the building without enclosure. As a result, the temperature of the sludge decreases and this drop in temperature may establish conditions for bacterial growth.

The following experiments were performed in order to evaluate the extent of regrowth in wet cake obtained from the thermophilic digestion process and to define the effect of temperature and contamination sources for the growth of fecal coliform:

1. Temperature profile study at TITP post-digestion thermophilic train
2. Fecal coliform regrowth at ambient temperature
3. Fecal coliform regrowth in digested sludge under centrifuge simulated conditions

## 6.1 Temperature profile study for post-digestion thermophilic train

*Salmonella* and fecal coliform regrowth requires a drop in the biosolids temperature along the post-digestion train in order to attain a permissible temperature for bacterial growth. Thus, the biosolids temperatures along the post-digestion thermophilic train were measured in order to identify the most probable sections of the train where bacterial growth may occur due to a drop in temperature.

Biosolids temperatures were measured on November 20, 2001, at the same locations where samples were collected for *Salmonella* and fecal coliform analysis. The temperature of diluted polymer was also measured in order to evaluate its effect on temperature of biosolids. The temperature was measured using three types of thermometers, conventional mercury, dial, and digital.

Table 13 shows the temperature profile obtained on November 20, 2001, along the thermophilic post-digestion train. Several measurements were taken with each device and the values were averaged. As expected, the temperatures continually decreased throughout the post-digestion process. A significant drop was observed between the centrifuge and silo through the conveyer belt, where wetcake is exposed to ambient air. Thus, it is probable that the drop in temperature between these two locations may allow bacterial growth. Enclosing and insulating the exposed conveyer system can decrease the temperature drop significantly.

## 6.2 Fecal coliform regrowth at ambient temperature

An evaluation of fecal coliform regrowth was performed in biosolids samples obtained at four different locations (digested sludge, and wetcake from centrifuge, conveyer belt, and truck). Individual samples were incubated at ambient temperature. At defined times, samples were analyzed for fecal coliform density. The results are presented in Table 14 and Figure 27. The fecal coliform densities in digested sludge samples were initially very low (approximately 50 MPN/g dry wt). There was only a very small increase of the density (approximately 100 MPN/g dry wt) after 48 hours at room temperature, after which no further growth was observed.

Wetcake samples obtained at the centrifuge and the conveyer belt contained fecal coliform in densities ranging from 10 to 250 MPN/g dry wt. A significant increase of the density occurred in both samples after 48 hours of incubation ($8 \times 10^5$ to $2.5 \times 10^6$ MPN/g dry wt). Table 14 provides the results obtained with two separate samples taken from centrifuge at two different dates (8/28/01 and 10/24/01). Fecal coliform rapidly grew in both centrifuge wetcake samples during the first 24 hours and they continued to grow over the next 24 hours but at a slower pace. Fecal coliform densities started to decrease over a longer period of time, as shown by the centrifuge wetcake sample taken on 10/24/01. Conveyer belt wetcake displayed similar characteristics as centrifuge wetcake but at a more rapid pace. Wetcake samples from the truck loading location initially contained high levels of fecal coliform ($8 \times 10^6$ MPN/g dry wt) and an increase of the density ($8 \times 10^8$ MPN/g dry wt) was observed after 98 hours of incubation. After 144 hours of incubation, the fecal colifom density slowly decreased and eventually stabilized at around $1 \times 10^8$ MPN/g dry wt. These results confirmed that either regrowth or contamination with an external microbial source occurred between the centrifuge and the silo.

## Table 13. Phase III - Temperature profiles along post-digestion train of Digester 2

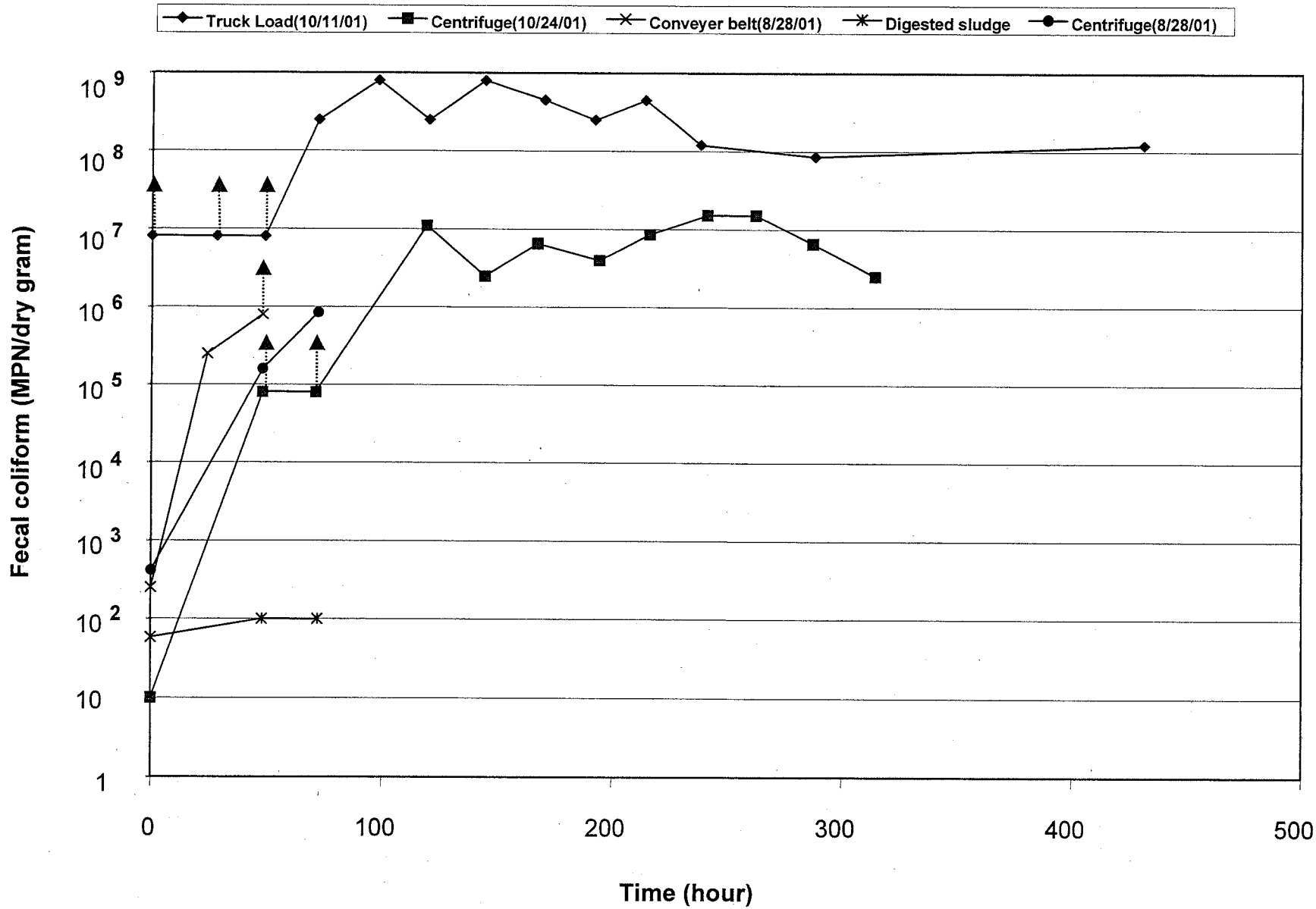
| Locations | Temperature (°F)* | | |
|---|---|---|---|
| | Digital thermometer | Dial thermometer | Mercury thermometer |
| Digested sludge | 128.3 | 131 | 126.5 |
| Centrate from Centrifuge | 123.7 | 127 | 123.8 |
| Diluted polymer | 68.8 | 71 | 73.4 |
| Centrifuge cake from the middle of conveyor belt | 119.2 | 118.7 | 117.8 |
| Centrifuge cake from the top of silo (end of the conveyor belt) | 109.6 | 111.2 | 112.5 |

**Notes**
Testing on 11/20/2001
*Temperatures shown are average values of several measurements

## Table 14. Phase III - Regrowth of fecal coliform in samples from post-digestion train

| Sample Date | Location | Regrowth Hr | MPN/g dry wt |
|---|---|---|---|
| 10/11/01 | Truck load | 0 | >= 8.0E+06 |
| 10/11/01 | Truck load | 28 | >= 8.0E+06 |
| 10/11/01 | Truck load | 49 | >= 8.0E+06 |
| 10/11/01 | Truck load | 72 | 2.5E+08 |
| 10/11/01 | Truck load | 98 | 8.0E+08 |
| 10/11/01 | Truck load | 120 | 2.5E+08 |
| 10/11/01 | Truck load | 144 | 8.0E+08 |
| 10/11/01 | Truck load | 170 | 4.5E+08 |
| 10/11/01 | Truck load | 192 | 2.5E+08 |
| 10/11/01 | Truck load | 214 | 4.5E+08 |
| 10/11/01 | Truck load | 238 | 1.2E+08 |
| 10/11/01 | Truck load | 288 | 8.5E+07 |
| 10/11/01 | Truck load | 337 | |
| 10/11/01 | Truck load | 431 | 1.2E+08 |
| | | | |
| 10/24/01 | Centrifuge | 0 | < 1.0E+01 |
| 10/24/01 | Centrifuge | 21 | |
| 10/24/01 | Centrifuge | 48 | >= 8.0E+04 |
| 10/24/01 | Centrifuge | 71 | >= 8.0E+04 |
| 10/24/01 | Centrifuge | 96 | |
| 10/24/01 | Centrifuge | 119 | 1.1E+07 |
| 10/24/01 | Centrifuge | 144 | 2.5E+06 |
| 10/24/01 | Centrifuge | 167 | 6.5E+06 |
| 10/24/01 | Centrifuge | 194 | 4.0E+06 |
| 10/24/01 | Centrifuge | 216 | 8.5E+06 |
| 10/24/01 | Centrifuge | 241 | 1.5E+07 |
| 10/24/01 | Centrifuge | 262 | 1.5E+07 |
| 10/24/01 | Centrifuge | 287 | 6.5E+06 |
| 10/24/01 | Centrifuge | 314 | 2.5E+06 |
| | | | |
| 8/28/01 | Digested sludge | 0 | 5.8E+01 |
| 8/28/01 | Digested sludge | 48 | 1.0E+02 |
| 8/28/01 | Digested sludge | 72 | 1.0E+02 |
| | | | |
| 8/28/01 | Centrifuge | 0 | 4.2E+02 |
| 8/28/01 | Centrifuge | 48 | 1.6E+05 |
| 8/28/01 | Centrifuge | 72 | 8.5E+05 |
| | | | |
| 8/28/01 | Conveyer belt | 0 | 2.5E+02 |
| 8/28/01 | Conveyer belt | 24 | 2.5E+05 |
| 8/28/01 | Conveyer belt | 48 | >= 8.0E+05 |

## Figure 27. Phase III - Regrowth of fecal coliform in samples from post-digestion train



### 6.3 Fecal coliform regrowth in digested sludge under centrifuge simulated conditions

Recontamination by fecal coliform may originate from additions used during dewatering process. Thus the objective of this study was to evaluate fecal coliform regrowth in digested sludge centrifuged in the laboratory under conditions that simulate the field dewatering system. Possible sources of bacterial contamination tested included the polymer, and the high pressure effluent (HPE).

Digested sludge samples were collected from Terminal Island Treatment Plant (TITP) on November 15, 2001. HPE, concentrated polymer, and field diluted polymer samples were collected from Hyperion Treatment Plant (HTP) on the same day. Sludge and various combinations of HPE and polymer were mixed to prepare four batches:

| | |
|---|---|
| Batch 1 (Blank): | digested sludge |
| Batch 2 (Blank + HPE): | digested sludge + HPE |
| Batch 3 (Blank + polymer): | digested sludge + lab diluted polymer (with fresh sterile water) |
| Batch 4 (Blank + HPE + polymer): | digested sludge + field diluted polymer (with HPE) |

The batches were centrifuged to a density of approximately 10% total solids in laboratory centrifuges. After centrifugation, the relatively concentrated solids were transferred to sample bottles that were incubated for selected times at four temperatures, 25, 37, 44.5, and 55°C (78, 99, 115, 131°F). All sample preparation operations were performed following strict QA/QC procedures to avoid bacterial contamination.

Very small increases of the fecal coliform density, all well below the legal limit, were observed after 96 hours of incubation at 25, 37 and 44.5 °C in all four batches (Figures 28, 29, and 30). At the highest temperature tested 55°C (131°F), densities were at or below the threshold and no increase was observed (Figure 31).

It should be mentioned that the total solid content of the dewatered sludge obtained by centrifugation in the laboratory was only about 10%, which is 1/3 of the content present in dewatered sludge from the plant centrifuge. Therefore, regrowth results from this study should be interpreted with some caution.

This study showed that very small regrowth was observed in digested sludge dewatered in the laboratory. The increase in fecal coliform densities was well below the legal limit, indicating that the number of fecal coliform that may have survived digestion was not enough to produce increases of the density similar as the one observed in the wet cake samples at the truck. It also indicates that the HPE and the polymer are not a significant source of fecal coliform contamination.

**Figure 28. Centrifuge simulation; fedal regrowth results at 78 °F (25 °C)**

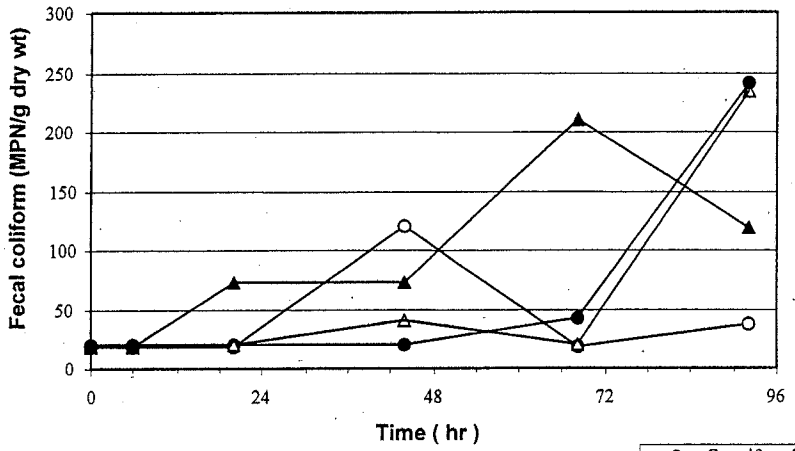
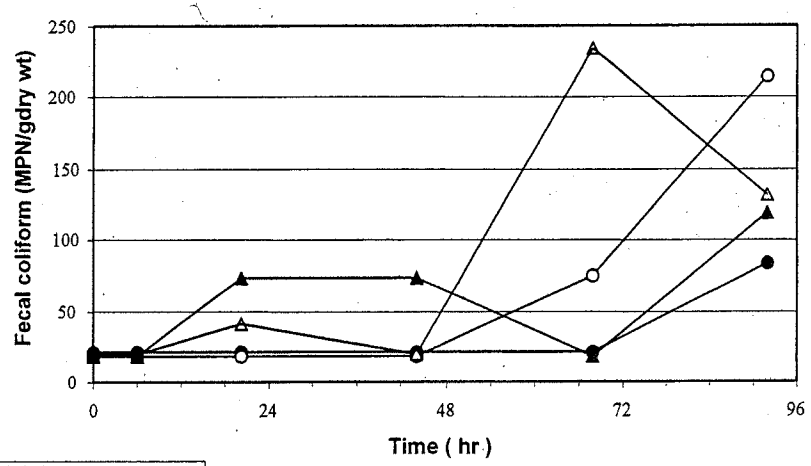



**Figure 29. Centrifuge simulation; fedal regrowth results at 99 °F (37 °C)**



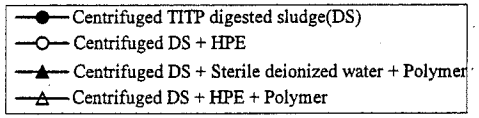




**Figure 30. Centrifuge simulation; fedal regrowth results at 115 °F (44.5 °C)**

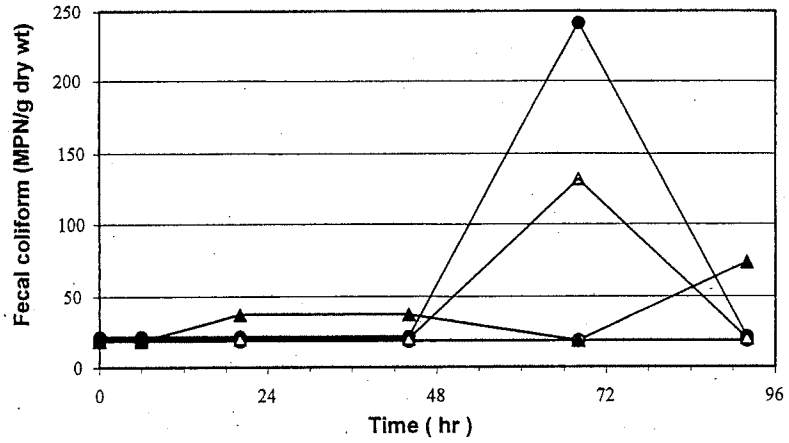
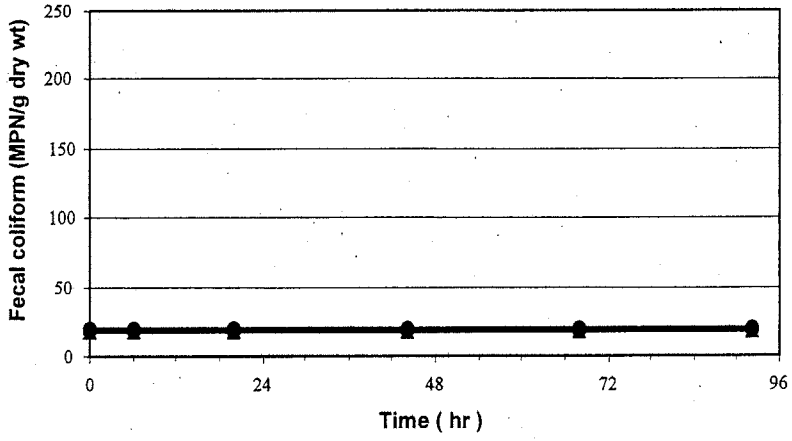



**Figure 31. Centrifuge simulation; fedal regrowth results at 131 °F (55 °C)**



# 7. APPENDICES

## Appendix 7.1 Legal aspects of the 40 CFR Part 503 Rule

### The Part 503 Biosolids Rule for POTWs

This appendix provides a short summary of the regulations of the 40 CFR Part 503 Rule (commonly referred to as the Part 503 (Biosolids) Rule, published in 1993), in particular to the production and land application of Class A biosolids. The Part 503 Rule applies to POTWs (§503.10):

- with a design flow greater than 1 mgd;
- that serve a population of 10,000 people or more;
- that are Class I biosolids management facilities.

### Exceptional Quality Biosolids

Although not as such specified and defined in the Part 503 Rule, interpretation of the regulations indicates that four types of biosolids with a different quality can be distinguished. The term Exceptional Quality (EQ) biosolids was first introduced in a 1995 Federal publication (The Plain English Guide to the Part 503 Rule) and defined as the highest quality of biosolids meeting the most stringent limits and regulations of the Part 503 Rule.
In order to be classified as EQ, biosolids produced from sludge must meet the strictest requirements in all of the three following categories:

1 pollutant (heavy metals) concentration limits, as specified in §503.13;
2 reduction of pathogen densities, as specified in §503.32;
3 reduction of the vector attraction, as specified in §503.33.

The specific requirements for EQ biosolids will discussed in more detail in later sections of this Appendix.

### Safety Concerns of Biosolids Land Application

Land application of the various classes of biosolids is equally safe as is specifically emphasized by the EPA. For EQ biosolids, it is assumed that this product is as safe as any other fertilizer and, hence, EQ biosolids can be applied to land without any site restrictions, general requirements and management practices. Other classes of biosolids face regulations that become more stringent with decreasing product quality. It is because of these regulations that poorer quality biosolids can be applied equally safe as EQ biosolids, provided that regulations specific to the class of biosolids are being met. It should however be noted that the Part 503 Rule allows state and local authorities to impose additional requirements to biosolids land application (§503.5), and they may therefore require the use of EQ biosolids only.

### Class A Biosolids

The purpose of thermophilic digestion is to produce Class A biosolids, as described in this report. It should be noted that "Class A Biosolids" is not a specific category of biosolids under the Part 503 Rule. Class A biosolids meet the strictest pathogen reduction requirements, however, the Class A designation does not relate to the extend of meeting the requirements for vector attraction reduction and pollutant limit concentrations. Class A and EQ biosolids are therefore not necessarily the same, although it can be said that EQ biosolids are Class A with respect to pathogens.

### Pollutant Limit and Ceiling Concentrations

Regulations with respect to pollutant concentrations in biosolids have only been formulated for ten toxic heavy metals, as summarized in Table 15. Land application of any class of biosolids is not allowed if one or more of the pollutant ceiling concentrations are exceeded. If all heavy metal concentrations are less than the limit concentrations in Table 15, the biosolids are

considered to be safe with respect to pollutants. This is the case for EQ biosolids, which can be applied to land unrestricted provided the application rate is not greater than the agronomic rate.

Table 15. Pollutant ceiling and limit concentrations.

| Metal | Ceiling concentration[a] (mg/kg dry total solids) | Limit concentration[b] (mg/kg dry total solids) |
|---|---|---|
| Arsenic | 75 | 41 |
| Cadmium | 85 | 39 |
| Chromium | 3000 | 1200 |
| Copper | 4300 | 1500 |
| Lead | 840 | 300 |
| Mercury | 57 | 17 |
| Molybdenum[c] | 75 | |
| Nickel | 420 | 420 |
| Selenium | 100 | 36 |
| Zinc | 7500 | 2800 |

[a] Table 1 in §503.13. [b] Table 3 in §503.13. [c] Limits for molybdenum are pending.

**Pathogen Reductions**

In order to qualify as Class A, biosolids must meet a general requirement for pathogen reduction and in addition undergo one of six specified treatment alternatives. Limits for bacterial densities have been formulated for *Salmonella* sp. and fecal coliform. For Class A biosolids (and thus for EQ biosolids), only one of both bacterial densities need to be reduced to less than the limit, as specified in Table 16. These limits correspond to the method detection limits: thus, Class A biosolids can be considered safe with respect to pathogens.

Table 16. General bacterial density limits for Class A biosolids (§503.32).

| Organism | Class A |
|---|---|
| Fecal coliform | < 1000 MPN/g dry wt |
| *Salmonella* sp. bacteria | < 3 MPN/4 g dry wt |

Section §503.32 of the Part 503 Rule specifies 6 alternatives to achieve the Class A requirements. Thermophilic anaerobic digestion falls under alternative 1 (§503.32(a)(3)(ii)), containing four treatments with time-temperature specifications. Selection of the time-temperature relationship depends on the solids content of the biosolids (more or less than 7%), the particle size, and the selected ranges of temperature and/or time for treatment. For TITP sludge, which has a solids content significantly less than 7%, the following time-temperature equation would apply (§503.32(a)(3)(ii)D):

$$D = 50{,}070{,}000 / 10^{0.14T},$$

where T is the temperature ($^0$C) and D the required time of treatment (days). It is important to emphasize that the above equation should be applied to a batch process that guarantees a certain minimum holding time (where all material meets the time-temperature relationship) rather than to a continuous process (characterized by a mean residence time). Further requirements to this treatment include a temperature of 50$^0$C (122 $^0$F) or higher and a treatment time of at least 30 minutes.

Alternative 3 can be used to demonstrate that a new process fully meets the Class A pathogen requirements under the tested set of operating conditions. Apart from the general requirement, this includes reduction of the density of viable helminth ova to less than 1 ovum/4 g dry wt and reduction of the density of enteric viruses to less than 1 PFU/4 g dry wt. Such reductions can

only be demonstrated if enteric viruses and helminth ova were indeed present before the process. If they were not, than only the tested batch can be considered Class A biosolids. Consequently, each new batch would have to be tested for the absence of helminth ova and enteric viruses, which is in fact the requirement of Alternative 4 for unknown processes or processes that can not guarantee meeting the Class A pathogen requirements.

**Vector Attraction Reduction**

The Part 503 Rule lists 12 options to meet the vector attraction reduction, of which 8 options would apply for production of EQ biosolids (§503.33). Thermophilic anaerobic digestion at TITP reduces the mass of volatile solids by over 50%, which is greater than the imposed minimum reduction of 38% required in option 1 (§503.33(b)(1)). Thus, vector attraction reduction requirements are in general easily met by thermophilic anaerobic digestion at TITP.

Literature references pertinent to this appendix are included in Appendix 7.4.

## Appendix 7.2 Operational instructions

The following section contains detailed operational instruction for single stage batch thermophilic digestion during Phase III.

Some of the important points are listed in the following sections. Digesters 1, 2, and 3 will be used during initial feed hold and withdrawal cycles. During this period, Digester 3 is put out of service. After Digester 4 is put in service, Digester 3 will be taken out of service. Therefore, Digesters 1, 2, and 4 is used during this cycle.

***Feed cycle***

- During the feed cycle, all the digester feed, including the primary tank grease, will go to the feed digester for the day. Primary tank grease can only be fed to Digester 3 or 4. That means the grease can only be pumped out of the grease concentrator one day out of three days.
- At the beginning of the feed cycle for Digester 3 (or Digester 4 later on), turn on the grease pump by putting the hand-off-auto switch to the auto position. At the end of the feed cycle for Digester 3, switch off the grease pump.
- The target temperature of the feed digester is 133±1°F. It is very important that the temperature stays within the range by the end of the feed cycle. If you expect that it will be difficult to achieve the temperature, secure the feed and continue heating to bring the temperature within the range.
- The temperature sensor for each digester will be used for monitoring and control of the temperature. For Digester 3, the sensor on B-Battery on the suction side of the recirculation pumps will be used, because the sensor on the digester does not work.

***Hold cycle***

- The hold cycle is the most important cycle in terms of legality. During this period, we have to meet the time-and-temperature requirement.
- The hold cycle begins when the feed is complete and desired temperature is reached. At the beginning of the hold cycle, record in the log book the exact start-time of the hold cycle for the digester.
- There will be absolutely no feeding and withdrawal during the hold cycle.
- Please use the time-and-temperature requirement table to ensure compliance. Since the temperature may not be measured during the hold cycle (sensors only on the recirculation piping), assume the temperature during the hold cycle is, even if the hold digester is recirculated,

Temp during Hold Cycle = (Avg Temp in last one-hour in feed cycle) – (1°F)

For example, if the average temperature in the last one-hour of the feed cycle is 132.6°F, we can assume the temperature in the hold digester is 131.6°F.

- The hold cycle is complete when the sludge meet the time-and temperature requirement and is ready to be withdrawn for dewatering. Record, in the log book, the exact end-time of the hold cycle.

***Withdrawal cycle***

- During the withdrawal cycle, the biosolids are withdrawn to centrifuges for dewatering. By doing so, the level is lowered to receive the feed during the following (feed) cycle.

- There are two withdraw valves, in series, for each digester; one motorized and one manual (chain operated). For simplicity, the manual (chain) valve will stay open all the time. The motorized valve will be used for opening and shutting off sludge to centrifuges.
- The motorized withdraw valve will only be opened to feed sludge to centrifuges. This valve should stay closed when the digester is in the withdraw cycle, but centrifuges are shut down.

**Digester level control**

- In the feed cycle, the digester level is raised by feeding the digester. In the hold cycle, the level should remain constant because nothing is fed or withdrawn. And in the withdraw cycle, the digester level is lowered by draining sludge to centrifuges.
- The typical daily digester feed is 150,000 gallons/day. To accommodate the typical daily feed, the recommended low (by the end of withdraw cycle) and high (by the end of the feed and during the hold) levels of the digesters are 50 ft and 62 ft. However, since the digester feed can be higher or lower than the typical value, the lead operator should determine the actual operating levels after examining the primary sludge pumping, WAS rate, blender level, hopper levels, truck schedule, and etc.
- Do not raise the level of the digester higher than 65 ft under any circumstances.

**Operating procedure**

***For the days, Digester 1=Feed, Digester 2=Withdraw, Digester 3=Hold***

**0000 hrs**

1) Secure the grease pumping to Digester 3 by placing the hand-off-auto switch to the "off" position.

2) Switch the digester feed from Digester 3 to Digester 1 by the following steps. The steps must be followed in sequence in order to prevent contamination.
   a) Switch recirculation from Digester 2 to Digester 1 by opening the recirculation valves at the top and bottom of Digester 1.
   b) After the recirculation valves on Digester 1 are fully open, close the recirculation valves on Digester 2.
   c) Switch the digester feed from A-Battery to B-Battery.

3) Switch the steam heating from B-Battery to A-Battery.
   a) Close the motorized steam valve on B-Battery.
   b) Open the steam injection bypass valve (underneath the grating) on B-Battery.
   c) Close the steam injection block valves on B-Battery.
   d) Open the steam injection block valves on A-Battery.
   e) Close the steam injection bypass valve (underneath the grating) on A-Battery.
   f) Open the motorized steam valve on A-Battery.
   g) Adjust the motorized steam valve on A-Battery to get desired steam flow and pressure.

4) If centrifuges are running, switch centrifuge feed from Digester 1 to Digester 2.
   a) Open the withdraw valve on Digester 2.
   b) Close the withdraw valve on Digester 1.

5) Record the time of switching in the log book.

**0700 hrs**

1) Take a Digester 2 sample from the withdraw line in the 1000 ml bottle.

2) On Tuesdays and Thursdays, take the fecal coliform sample in a 200 ml sterilized bottle.

3) Deliver the sample(s) to the lab by 0715 hours.

***For the days, Digester 1=Hold, Digester 2=Feed, Digester 3=Withdraw***

**0000 hrs**

1) Switch the digester feed from Digester 1 to Digester 2 by the following steps.
   a) Switch recirculation from Digester 2 to Digester 1 by opening the recirculation valves at the top and bottom of Digester 1.
   b) After the recirculation valves on Digester 1 are fully open, close the recirculation valves on Digester 2.

2) If centrifuges are running, switch centrifuge feed from Digester 1 to Digester 2.

3) Record the time of switching in the log book.

**0700 hrs**

1) Take a Digester 3 sample from the withdraw line in the 1000 ml bottle.

2) On Tuesdays and Thursdays, take the fecal coliform sample in a 200 ml sterilized bottle.

3) Deliver the sample(s) to the lab by 0715 hours.

***For the days, Digester 1=Withdraw, Digester 2=Hold, Digester 3=Feed***

**0000 hrs**

1) Start the grease pumping to Digester 3 by placing the hand-off-auto switch to the "auto" position.

2) Switch the digester feed from Digester 2 to Digester 3 by the following steps.

3) Switch the steam heating from A-Battery to B-Battery.
   a) Close the motorized steam valve on A-Battery.
   b) Open the steam injection bypass valve (underneath the grating) on A-Battery.
   c) Close the steam injection block valves on A-Battery.
   d) Open the steam injection block valves on B-Battery.
   e) Close the steam injection bypass valve (underneath the grating) on B-Battery.
   f) Open the motorized steam valve on B-Battery.
   g) Adjust the motorized steam valve on B-Battery to get desired steam flow and pressure.

3) If centrifuges are running, switch centrifuge feed from Digester 3 to Digester 1.

4) Record the time of switching in the log book.

**0700 hrs**

1) Take a Digester 1 sample from the withdraw line in the 1000 ml bottle.

2) On Tuesdays and Thursdays, take the fecal coliform sample in a 200 ml sterilized bottle.

3) Deliver the sample(s) to the lab by 0715 hours.

**Other Notes**

- To meet the time-and-temperature requirement, we should look at both the holding time and the temperature. If we do not meet the holding time of 24 hours, we can still meet the requirement by increasing the temperature, or vice versa. For example, we only need 21.5 hours of holding time if the holding temperature is 131.6°F. On other instances, you can gain on holding time by faster feeding and withdrawal to make up for a lower temperature. The bottom line is meeting the requirement by working the two parameters.
- Not all the three digesters must start and complete the three cycles at the same time. It is a good habit to start the cycle at midnight and complete at the following midnight. However, depending on the operational need, the timing of the cycles can be altered slightly.
- If there is any questions or need for discussion, please contact Senior Operator, on shift.

## Appendix 7.3 Laboratory data

This appendix contains laboratory data on pathogen removal/disinfection during Phase III.

Terminal Island Treatment Plant - Class A Biosolids Project
Salmonella Test Results from BioVir

Month: **July, 2001** Draft: 10/22/01

| Sample Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|
| 7/10/01 | Dig #3 | 1027.6 | 1.99 | <2.2 |
| | | | | |
| 7/12/01 | Dig #3 | 1111.6 | 1.5 | <1.5 |
| | | | | |
| 7/17/01 | Dig #2 | 974.4 | 1.76 | <2.2 |
| | | | | |
| 7/19/01 | Dig #1 | 1078 | 2.18 | <2.2 |
| | | | | |
| 7/27/01 | Blending Tank | 532 | 3.19 | <2.2 |
| | | | | |
| 7/30/01 | Blending Tank | 557.2 | 3.15 | >16.0 |
| 7/30/01 | Digested Sludge | 1013.6 | 1.45 | <2.2 |
| 7/30/01 | Centrifuge Digester #3 | 386.4 | 16.6 | <2.2 |
| 7/30/01 | Truck | 417.2 | 17.6 | <2.2 |
| | | | | |
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Terminal Island Treatment Plant - Class A Biosolids Project
Salmonella Test Results from BioVir

Month: **August, 2001** Draft: 10/23/01

| Sample Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|
| 8/2/01 | Blending Tank | 500 (ml) | 3.15 | >16.0 |
| 8/2/01 | Digested Sludge | 1000 (ml) | 1.61 | <2.2 |
| 8/2/01 | Centrifuge | 212 | 28.2 | <2.2 |
| | | | | |
| 8/8/01 | Blending Tank | 543.2 | 3.20 | 5.8 |
| 8/8/01 | Digested Sludge | 1100.4 | 1.99 | <2.2 |
| 8/8/01 | Conveyor Belt (Centrifuge) | 156.8 | 23.1 | <1.6 |
| 8/8/01 | Truck | 302.4 | 20.8 | <1.8 |
| | | | | |
| 8/14/01 | Blending Tank | 2018.8 | 3.09 | <2.2 |
| 8/14/01 | Digested Sludge | 1954.4 | 1.78 | <2.2 |
| 8/14/01 | Centrifuge | 263.2 | 22.0 | <2.2 |
| | | | | |
| 8/15/01 | Blending Tank | 1038.4 | 3.12 | 7.8 |
| 8/15/01 | Digested Sludge | 1055.3 | 1.97 | <2.2 |
| 8/15/01 | Centrifuge | 515.3 | 20.0 | <2.2 |
| 8/15/01 | Truck | 370.1 | 18.0 | <2.2 |
| | | | | |
| 8/16/01 | Blending Tank | 2200.8 | 3.13 | >16.0 |
| 8/16/01 | Digester Sludge | 2144.8 | 2.11 | <2.2 |
| 8/16/01 | Centrifuge Cake | 744.8 | 22.3 | <2.2 |
| 8/16/01 | Truck | 781.2 | 22.4 | <2.2 |
| | | | | |
| | | | | |

Terminal Island Treatment Plant - Class A Biosolids Project
Salmonella Test Results from BioVir

Month: **October, 2001** Draft: 11/06/01

| Sample Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|
| 10/16/01 | Dig Sludge #4 | 1047.2 | 1.8 | <2.0 |
| | | | | |
| 10/17/01 | Digester #1 | 2094.4 | 1.85 | <1.8 |
| 10/17/01 | Hopper | 803.6 | 17.2 | <1.9 |

Terminal Island Treatment Plant - Class A Biosolids Project
Fecal Coliform Test Results

***Draft: 10/22/01***

Month: **July, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (ml) | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 7/2/01 | Dig #1 | | | | 1 | < 200 | < 200 | 3.14 | < 6.4E+01 |
| 7/2/01 | Dig #2 | | | | 1 | < 200 | < 200 | 2.2 | < 9.1E+01 |
| 7/10/01 | Dig #3 | | | | 1 | 130 | 130 | 2.06 | 6.3E+01 |
| 7/11/01 | Dig #2 | | | | 1 | 110 | 0 | 1.87 | 0.0E+00 |
| 7/12/01 | Dig #3 | | | | 1 | < 20 | < 0 | 1.54 | < 0.0E+00 |
| 7/13/01 | Dig #1 | | | | 1 | 2200 | 2200 | 1.21 | 1.8E+03 |
| 7/17/01 | Dig #2 | | | | 1 | < 20 | < 20 | 1.76 | < 1.1E+01 |
| 7/18/01 | Dig #3 | | | | 1 | < 20 | < 20 | 1.54 | < 1.3E+01 |
| 7/19/01 | Dig #1 | | | | 1 | 230 | 230 | 1.81 | 1.3E+02 |
| 7/20/01 | Dig #2 | | | | 1 | 1300 | 1300 | 1.92 | 6.8E+02 |
| | | | | | | | | | |
| 7/23/01 | Dig #2 | | | | 1 | 16000 | 16000 | 1.88 | 8.5E+03 |
| 7/23/01 | Sludge | | | | 1 | < 200 | < 200 | 2.31 | < 8.7E+01 |
| 7/23/01 | Centrifuge | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 26 | >= 6.2E+04 |
| 7/23/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.62 | >= 4.4E+05 |
| | | | | | | | | | |
| 7/24/01 | Dig #3 | | | | 1 | >= 16000 | >= 16000 | 1.58 | >= 1.0E+04 |
| | | | | | | | | | |
| 7/25/01 | Dig #1 | | | | 1 | 1300 | 1300 | 1.23 | 1.1E+03 |
| 7/25/01 | Blend | | | | 1 | >= 1600000 | >= 1600000 | 3.39 | >= 4.7E+05 |
| 7/25/01 | Dig. Sludge | | | | 1 | < 200 | < 200 | 1.82 | < 1.1E+02 |
| 7/25/01 | Centrifuge | 30 | 270 | 10 | 1 | 230 | 2300 | 17 | 1.4E+02 |
| 7/25/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 18.1 | >= 8.8E+04 |
| | | | | | | | | | |
| 7/26/01 | Dig #2 | | | | 1 | 170 | 170 | 2.08 | 8.2E+01 |
| | | | | | | | | | |
| 7/27/01 | Dig #3 | | | | 1 | 20 | 20 | 1.74 | 1.1E+01 |
| 7/27/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.32 | >= 4.8E+05 |
| 7/27/01 | Sludge | | | | 1 | 1400 | 1400 | 1.62 | 8.6E+02 |
| 7/27/01 | Centrifuge | 30 | 270 | 10 | 1 | < 200 | < 2000 | 14.7 | < 1.4E+02 |
| 7/27/01 | Truck | 30 | 270 | 10 | 1 | >= 1600000 | >= 16000000 | 15 | >= 1.1E+06 |
| | | | | | | | | | |
| 7/30/01 | Dig. #3 | | | | 1 | 50000 | 50000 | 1.64 | 3.0E+04 |
| 7/30/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.2 | >= 5.0E+05 |
| 7/30/01 | Dig. Sludge | | | | 1 | < 200 | < 200 | 1.53 | < 1.3E+02 |
| 7/30/01 | Centrifuge | 30 | 270 | 10 | 1 | 1700 | 17000 | 18.4 | 9.2E+02 |
| 7/30/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 22.8 | >= 7.0E+04 |
| | | | | | | | | | |
| 7/31/01 | Dig #1 | | | | 1 | 230 | 230 | 2.19 | 1.1E+02 |
| | | | | | | | | | |
| | | | | | | | | | |

* 1gm sample = 1 ml

Note:- Since there is no actual %TS analysis was done on the highlighted area, estimated 2.2%TS for Dig #2 was used

Terminal Island Treatment Plant - Class A Biosolids Project

Fecal Coliform Test Results

***Draft: 10/23/01***

Month: **August, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (ml) | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 8/1/01 | Dig. #2 | | | | 1 | 800 | 800 | 2.06 | 3.9E+02 |
| 8/1/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.09 | 5.2E+05 |
| 8/1/01 | Dig. Sludge | | | | 1 | < 200 | < 200 | 1.96 | < 1.0E+02 |
| 8/1/01 | Centrifuge | 30 | 270 | 10 | 1 | < 20 | < 200 | 17.8 | < 1.1E+01 |
| 8/1/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 16.8 | >= 9.5E+04 |
| | | | | | | | | | |
| 8/2/01 | Dig. #3 | | | | 1 | 20 | 20 | 1.61 | 1.2E+01 |
| | | | | | | | | | |
| 8/3/01 | Dig. #1 | | | | 1 | 500 | 500 | 2 | 2.5E+02 |
| 8/3/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 1.43 | 1.1E+06 |
| 8/3/01 | Dig. Sludge | | | | 1 | 1700 | 1700 | 2.2 | 7.7E+02 |
| 8/3/01 | Centrifuge | 30 | 270 | 10 | 1 | 30000 | 300000 | 20 | 1.5E+04 |
| 8/3/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 23.1 | >= 6.9E+04 |
| | | | | | | | | | |
| 8/6/01 | Dig. #1 | | | | 1 | 230 | 230 | 1.9 | 1.2E+02 |
| 8/6/01 | Blending Tank | | | | 1 | >= 16000 | >= 16000 | 2.06 | >= 7.8E+03 |
| 8/6/01 | Dig. Sludge | | | | 1 | 300 | 300 | 1.84 | 1.6E+02 |
| 8/6/01 | Centri./Conv. belt | 30 | 270 | 10 | 1 | 70 | 700 | 13.1 | 5.3E+01 |
| 8/6/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 17.9 | >= 8.9E+04 |
| | | | | | | | | | |
| 8/7/01 | Dig. #2 | | | | 1 | 130 | 130 | 2.3 | 5.7E+01 |
| | | | | | | | | | |
| 8/8/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.2 | >= 5.0E+05 |
| 8/8/01 | Dig. Sludge | | | | 1 | 5000 | 5000 | 1.99 | 2.5E+03 |
| 8/8/01 | Centrifuge | 30 | 270 | 10 | 1 | 300 | 3000 | 23.1 | 1.3E+02 |
| 8/8/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 20.8 | >= 7.7E+04 |
| | | | | | | | | | |
| 8/9/01 | Dig. #1 | | | | 1 | 130 | 130 | 1.92 | 6.8E+01 |
| | | | | | | | | | |
| 8/10/01 | Dig. #2 | | | | 1 | 40 | 40 | 1.98 | 2.0E+01 |
| 8/10/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.27 | >= 4.9E+05 |
| 8/10/01 | Sludge | | | | 1 | < 200 | < 200 | 2.14 | < 9.3E+01 |
| 8/10/01 | Centrifuge | 30 | 270 | 10 | 1 | AE | AE | 22.9 | AE |
| 8/10/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 23.3 | 6.9E+04 |
| | | | | | | | | | |
| 8/13/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 2.9 | 5.5E+05 |
| 8/13/01 | Sludge | | | | 1 | < 200 | < 200 | 1.6 | 1.2E+02 |
| 8/13/01 | Centrifuge | 30 | 270 | 10 | 1 | 110 | 1100 | 16.0 | 6.9E+01 |
| 8/13/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 21.1 | 7.6E+04 |
| | | | | | | | | | |

Terminal Island Treatment Plant - Class A Biosolids Project

Fecal Coliform Test Results

***Draft: 10/23/01***

Month: **August, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (ml) | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 8/14/01 | Dig. #3 | | | | 1 | 1300 | 1300 | 1.78 | 7.3E+02 |
| | | | | | | | | | |
| 8/16/01 | Dig. #2 | | | | 1 | 130 | 130 | 1.92 | 6.8E+01 |
| | | | | | | | | | |
| 8/17/01 | Dig. #3 | | | | 1 | < 20 | < 20 | 1.79 | 1.1E+01 |
| 8/17/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 3.04 | 5.3E+05 |
| 8/17/01 | Sludge | | | | 1 | 1300 | 1300 | 1.78 | 7.3E+02 |
| 8/17/01 | Centrifuge | 30 | 270 | 10 | 1 | 1700 | 17000 | 16.1 | 1.1E+03 |
| 8/17/01 | Truck | 30 | 270 | 10 | 1 | >= 1600000 | >= 16000000 | 21.7 | 7.4E+05 |
| | | | | | | | | | |
| 8/20/01 | Blending Tank | | | | 1 | >= 1600000 | >= 1600000 | 2.82 | 5.7E+05 |
| 8/20/01 | Sludge | | | | 1 | 800 | 800 | 1.74 | 4.6E+02 |
| 8/20/01 | Centrifuge | 30 | 270 | 10 | 1 | < 20 | < 200 | 16.2 | 1.2E+01 |
| 8/20/01 | Truck | 30 | 270 | 10 | 1 | >= 160000 | >= 1600000 | 19.7 | 8.1E+04 |
| | | | | | | | | | |
| 8/21/01 | Dig. #1 | | | | 1 | < 20 | < 20 | 0.48 | 4.2E+01 |
| | | | | | | | | | |
| 8/27/01 | Dig. #1 | | | | 1 | 110 | 110 | 2 | 5.5E+01 |
| | | | | | | | | | |
| 8/30/01 | Dig. #1 | | | | 1 | < 20 | < 20 | 1.73 | 1.2E+01 |
| | | | | | | | | | |
| 8/31/01 | Dig. #2 | | | | 1 | < 20 | < 20 | 2 | 1.0E+01 |
| | | | | | | | | | |
| | | | | | | | | | |

* 1gm sample = 1 ml

Note:- Since there is no actual %TS analysis was done on the highlighted area, estimated 2.2%TS for Digested Sludge and 20%TS Centrifuge were used

Terminal Island Treatment Plant - Class A Biosolids Project
Fecal Coliform Test Results

***Draft: 10/22/01***

Month: **September, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (ml) | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 9/4/01 | DIG #4 | | | | 1 | 1700 | 1700 | 1.63 | 1.0E+03 |
| 9/7/01 | DIG #4 | | | | 1 | 230 | 230 | 1.65 | 1.4E+02 |
| 9/10/01 | DIG #4 | | | | 1 | 16000 | 16000 | 1.76 | 9.1E+03 |
| 9/11/01 | DIG #1 | | | | 1 | 230 | 230 | 1.67 | 1.4E+02 |
| 9/12/01 | DIG #2 | | | | 1 | < 20 | < 20 | 1.96 | < 1.0E+01 |
| 9/13/01 | DIG #4 | | | | 1 | 900 | 900 | 1.99 | 4.5E+02 |
| 9/14/01 | DIG #1 | | | | 1 | 80 | 80 | 1.89 | 4.2E+01 |
| 9/17/01 | DIG #1 | | | | 1 | 230 | 230 | 2.08 | 1.1E+02 |
| 9/18/01 | DIG #2 | | | | 1 | 40 | 40 | 1.98 | 2.0E+01 |
| 9/19/01 | DIG #4 | | | | 1 | 800 | 800 | 1.74 | 4.6E+02 |
| 9/20/01 | DIG #1 | | | | 1 | 800 | 800 | 0.72 | 1.1E+03 |
| 9/21/01 | DIG #2 | | | | 1 | 230 | 230 | 1.99 | 1.2E+02 |
| 9/24/01 | DIG #2 | | | | 1 | 230 | 230 | 2.4 | 9.6E+01 |
| 9/25/01 | DIG #4 | | | | 1 | 800 | 800 | 1.95 | 4.1E+02 |
| 9/27/01 | DIG #2 | | | | 1 | 130 | 130 | 2.03 | 6.4E+01 |
| 9/28/01 | DIG #4 | | | | 1 | 230 | 230 | 1.88 | 1.2E+02 |

* 1gm sample = 1 ml

Terminal Island Treatment Plant - Class A Biosolids Project

Fecal Coliform Test Results

*Draft: 11/06/01*

Month: **October, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (ml) | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 10/1/01 | Dig #4 | | | | 1 | 80 | 80 | 1.88 | 4.3E+01 |
| | | | | | | | | | |
| 10/2/01 | Dig #1 | | | | 1 | < 20 | < 20 | 2 | < 1.0E+01 |
| 10/2/01 | Truck | 30 | 270 | 10 | 1 | 160000000 | 1600000000 | 25.8 | 6.2E+07 |
| 10/2/01 | Centrifuge | 30 | 270 | 10 | 1 | < 20000 | < 200000 | 29.2 | < 6.8E+03 |
| | | | | | | | | | |
| 10/5/01 | Dig #1 | | | | 1 | 230 | 230 | 2.03 | 1.1E+02 |
| 10/5/01 | Centrifuge | 30 | 270 | 10 | 1 | 1300 | 13000 | 25.8 | 5.0E+02 |
| 10/5/01 | Truck | 30 | 270 | 10 | 1 | 240000 | 2400000 | 27.1 | 8.9E+04 |
| | | | | | | | | | |
| 10/10/01 | Dig #4(0700) | | | | 1 | 130 | 130 | 1.69 | 7.7E+01 |
| 10/10/01 | Dig #4 | | | | 1 | 200 | 200 | 2.2 | 9.1E+01 |
| 10/10/01 | Centrifuge | 30 | 270 | 10 | 1 | < 200 | < 2000 | 20 | < 1.0E+02 |
| 10/10/01 | Truck | 30 | 270 | 10 | 1 | >= 1600000 | >= 16000000 | 20 | >= 8.0E+05 |
| | | | | | | | | | |
| 10/11/01 | Dig #1 | | | | 1 | < 20 | < 20 | 0.56 | < 3.6E+01 |
| 10/11/01 | Dig. Sludge | | | | 1 | < 200 | < 200 | 2.2 | < 9.1E+01 |
| 10/11/01 | Centrifuge #2 | 30 | 270 | 10 | 1 | 2600 | 26000 | 20 | 1.3E+03 |
| 10/11/01 | Truck | 30 | 270 | 10 | 1 | >= 1600000 | >= 16000000 | 20 | >= 8.0E+05 |
| | | | | | | | | | |
| 10/12/01 | Dig #2 | | | | 1 | < 20 | < 20 | 0.44 | < 4.5E+01 |
| | | | | | | | | | |
| 10/15/01 | Dig. Sluge | | | | 1 | 130 | 130 | 1.58 | 8.2E+01 |
| | | | | | | | | | |
| 10/16/01 | Dig #4 (0700) | | | | 1 | 300 | 300 | 1.8 | 1.7E+02 |
| 10/16/01 | Dig #4 | | | | 1 | 5000 | 5000 | 1.8 | 2.8E+03 |
| 10/16/01 | Conveyor Belt | 30 | 270 | 10 | 1 | < 200 | < 2000 | 16.7 | < 1.2E+02 |
| 10/16/01 | Truck | 30 | 270 | 10 | 1 | 900000 | 9000000 | 17.5 | 5.1E+05 |
| | | | | | | | | | |
| 10/17/01 | Dig #1 (0700) | | | | 1 | 40 | 40 | 1.15 | 3.5E+01 |
| 10/17/01 | Dig #1 | | | | 1 | 230 | 230 | 1.85 | 1.2E+02 |
| 10/17/01 | Hopper | 30 | 270 | 10 | 1 | 800 | 8000 | 17.2 | 4.7E+02 |
| 10/17/01 | Truck | 30 | 270 | 10 | 1 | 80000 | 800000 | 18.3 | 4.4E+04 |
| | | | | | | | | | |
| 10/18/01 | Dig. #2 | | | | 1 | 230 | 230 | 2.23 | 1.0E+02 |
| | | | | | | | | | |
| 10/19/01 | Dig. #4 | | | | 1 | 220 | 220 | 1.82 | 1.2E+02 |
| | | | | | | | | | |
| 10/22/01 | Dig. #4 | | | | 1 | 20 | 20 | 1.81 | 1.1E+01 |
| | | | | | | | | | |
| 10/23/01 | Dig #1 | | | | 1 | 80 | 80 | 1.6 | 5.0E+01 |
| | | | | | | | | | |
| 10/24/01 | Dig #2 | | | | 1 | 230 | 230 | 1.94 | 1.2E+02 |
| | | | | | | | | | |
| 10/25/01 | Dig #4 | | | | 1 | AE | AE | 1.8 | AE |
| | | | | | | | | | |
| 10/26/01 | Dig #1 | | | | 1 | 5000 | 5000 | 0.6 | 8.3E+03 |
| | | | | | | | | | |
| 10/29/01 | Dig #1 | | | | 1 | 130 | 130 | 2.0 | 6.5E+01 |
| | | | | | | | | | |
| 10/30/01 | Dig #2 | | | | 1 | 500 | 500 | 1.96 | 2.6E+02 |
| | | | | | | | | | |
| 10/31/01 | Dig #4 | | | | 1 | 270 | 270 | 0.72 | 3.8E+02 |
| | | | | | | | | | |

* 1gm sample = 1 ml

Note :- Since there are no actual analysis done on %TS at highlighted area, estimated value of 2.2%TS for Digested Sludge and 20%TS for Centrifuge, Conveyor Belt, and Truck were used

Terminal Island Treatment Plant: November 2001 - Class A Biosolids Project

**Fecal Coliform Test Results from EMD (Calculation Sheet)**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (m | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100 | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 11/1/01 | Dig #1 | | | | | 110 | 110 | 0.9 | 1.2E+02 |
| | | | | | | | | | |
| 11/2/01 | Dig #2 | | | | | 230 | 230 | 2.06 | 1.1E+02 |
| | | | | | | | | | |
| 11/5/01 | Dig #2 | | | | | 230 | 230 | 1.95 | 1.2E+02 |
| | | | | | | | | | |
| 11/6/01 | Dig #4 | | | | | 9000 | 9000 | 1.77 | 5.1E+03 |
| | | | | | | | | | |
| 11/7/01 | Dig #1 | | | | | 230 | 230 | 1.9 | 1.2E+02 |
| | | | | | | | | | |
| 11/8/01 | Dig #2 | | | | | 230 | 230 | 0.9 | 2.6E+02 |
| | | | | | | | | | |
| 11/9/01 | Dig #4 | | | | | 130 | 130 | 1.74 | 7.5E+01 |
| | | | | | | | | | |
| 11/13/01 | Dig #1 | | | | | 130 | 130 | 1.8 | 7.2E+01 |
| | | | | | | | | | |
| 11/14/01 | Dig #2 | | | | | 130 | 130 | 2.04 | 6.4E+01 |
| | | | | | | | | | |
| 11/15/01 | Dig #4 | | | | | 130 | 130 | 1.75 | 7.4E+01 |
| | | | | | | | | | |
| 11/16/01 | Dig #1 | | | | | 230 | 230 | 1.7 | 1.4E+02 |
| | | | | | | | | | |
| 11/20/01 | Dig #2 | | | | | AE | AE | 1.66 | AE |
| | | | | | | | | | |
| 11/21/01 | Dig #4 | | | | | 230 | 230 | 1.85 | 1.2E+02 |

Terminal Island Treatment Plant - Class A Biosolids Project
Helminth Ova Assay Results from BioVir

Month: **August, 2001** Draft: 10/23/01

| Sample Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|
| 7/25/01 - 8/4/01 | Blending Tank | 149.8 | 2.67 | No Work Performed * |
| 7/25/01 - 8/4/01 | Digester Sludge | 239.5 | 1.67 | <1 |
| 7/25/01 - 8/4/01 | Conveyor Belt | 19.2 | 20.81 | <1 |
| 7/25/01 - 8/4/01 | Truck | 19.1 | 20.93 | <1 |
| | | | | |
| 8/6/01 - 8/17/01 | Blending Tank | 1780.8 | 2.77 | NA ** |
| 8/6/01 - 8/17/01 | Digested Sludge | 1632.4 | 1.74 | NA ** |
| 8/6/01 - 8/17/01 | Conveyor Belt | 851.2 | 21.07 | <1 |
| 8/6/01 - 8/17/01 | Truck | 767.2 | 20.15 | <1 |

* Due to interference from the biomass
** Work not performed - Matrix interference

Terminal Island Treatment Plant - Class A Biosolids Project
Enteric Virus Test Results from BioVir

Month: **August, 2001** Draft: 10/23/01

| Sample Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|
| 7/25/01 - 8/4/01 | Blending Tank | 2320 | 0.91 | 201 |
| 7/25/01 - 8/4/01 | Digester Sludge | 2320 | 1.00 | <0.93 |
| 7/25/01 - 8/4/01 | Conveyor Belt | 1330 | 20.66 | <1 |
| 7/25/01 - 8/4/01 | Truck | 1870 | 21.45 | <.97 |
| | | | | |
| 8/6/01 - 8/17/01 | Blending Tank | 1783.6 | 1.78 | 41 |
| 8/6/01 - 8/17/01 | Digested Sludge | 1545.6 | 1.55 | <1 |
| 8/6/01 - 8/17/01 | Conveyor Belt | 828.8 | 20.40 | <1 |
| 8/6/01 - 8/17/01 | Truck | 753.2 | 21.95 | <1 |

Terminal Island Treatment Plant - Class A Biosolids Project
Salmonella Regrowth Test Results from BioVir

Month: **October, 2001** Draft: 11/06/01

| Sample Date | Analysis Date | Location | Sample Amount (g) | %TS (dry gram/100ml) | MPN/4 dry gram |
|---|---|---|---|---|---|
| 10/11/01 | 10/12/2001 (11:40 Hr) | Truck | 1019.2 | 22.7 | <1.9 |
| 10/11/01 | 10/15/2001 (9:35 Hr) | Truck | 1019.2 | 22.7 | >14.1 |
| 10/11/01 | 10/17/2001 (15:18 Hr) | Truck | 1019.2 | 22.7 | <1.9 |

Terminal Island Treatment Plant - Class A Biosolids Project
Regrowth Fecal Coliform Test Results

***Draft: 10/23/01***

Month: **August, 2001**

| Sample Date | Location | Sample* Amount (g) | Dilution* Solution (m | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 8/15/01 | Centrifuge Day 1 | 30 | 270 | 10 | 1 | < 2.0E+01 | < 2.0E+02 | 20 | < 1.0E+01 |
| 8/15/01 | Centrifuge Day 3 | 30 | 270 | 10 | 1 | < 2.0E+01 | < 2.0E+02 | 20 | < 1.0E+01 |
| 8/15/01 | Centrifuge Day 4 | 30 | 270 | 10 | 1 | < 2.0E+01 | < 2.0E+02 | 20 | < 1.0E+01 |
| | | | | | | | | | |
| 8/28/01 | Centrifuge Bottle 1 Day 1 | 30 | 270 | 10 | 1 | 8.0E+02 | 8.0E+03 | 19.2 | 4.2E+02 |
| 8/28/01 | Centrifuge Bottle 2 Day 1 | 30 | 270 | 10 | 1 | 8.0E+02 | 8.0E+03 | 19.2 | 4.2E+02 |
| 8/28/01 | Conveyor Belt Day 1 | 30 | 270 | 10 | 1 | 5.0E+02 | 5.0E+03 | 20 | 2.5E+02 |
| 8/28/01 | Digested Sludge Day 1 | 30 | 270 | 10 | 1 | 1.3E+01 | 1.3E+02 | 2.24 | 5.8E+01 |
| 8/28/01 | Diluted Polymer Day 1 | 30 | 270 | 10 | 1 | < 2.0E+00 | < 2.0E+01 | ns | |
| | | | | | | | | | |
| 8/28/01 | Centrifuge Bottle 1 Day2 | 30 | 270 | 10 | 1 | 3.0E+05 | 3.0E+06 | 19.2 | 1.6E+05 |
| 8/28/01 | Centrifuge Bottle 2 Day2 | 30 | 270 | 10 | 1 | 5.0E+04 | 5.0E+05 | 19.2 | 2.6E+04 |
| 8/28/01 | Conveyor Belt Day 2 | 30 | 270 | 10 | 1 | 5.0E+05 | 5.0E+06 | 20 | 2.5E+05 |
| 8/28/01 | Digested Sludge Day2 | 30 | 270 | 10 | 1 | 2.3E+01 | 2.3E+02 | 2.24 | 1.0E+02 |
| 8/28/01 | Diluted Polymer Day 2 | 30 | 270 | 10 | 1 | < 2.0E+00 | < 2.0E+01 | ns | |
| | | | | | | | | | |
| 8/28/01 | Centrifuge Bottle 1 Day 3 | 30 | 270 | 10 | 1 | 1.6E+06 | 1.6E+07 | 19.2 | 8.3E+05 |
| 8/28/01 | Centrifuge Bottle 2 Day3 | 30 | 270 | 10 | 1 | 9.0E+05 | 9.0E+06 | 19.2 | 4.7E+05 |
| 8/28/01 | Conveyor Belt Day 3 | 30 | 270 | 10 | 1 | >= 1.6E+06 | >= 1.6E+07 | 20 | >= 8.0E+05 |
| 8/28/01 | Digested Sludge Day 3 | 30 | 270 | 10 | 1 | 2.3E+01 | 2.3E+02 | 2.24 | 1.0E+02 |
| 8/28/01 | Diluted Polymer Day 3 | 30 | 270 | 10 | 1 | < 2.0E+00 | < 2.0E+01 | ns | |
| | | | | | | | | | |

* 1gm sample = 1 ml
Note:- Since there were no actual %TS analysis were done on the highlighted area, estimated 20 %TS value was used

Terminal Island Treatment Plant - Class A Biosolids Project
Regrowth Fecal Coliform Test Results

*Draft: 11/06/01*

Month: **October, 2001**

| Sample Date | Location | Sample* Amount (g | Dilution* Solution (n | Dilution* Factor | Additional Dil Factor | Raw Tube MPN/100ml | Sample* MPN/100ml | %TS (dry gm/100ml) | MPN/ dry gram |
|---|---|---|---|---|---|---|---|---|---|
| 10/11/01 | Truck Load. (0 Hr) | 30 | 270 | 10 | 1 | >= 1.6E+07 | >= 1.6E+08 | 20 | >= 8.0E+06 |
| 10/11/01 | Truck Load. (28 Hr) | 30 | 270 | 10 | 1 | >= 1.6E+07 | >= 1.6E+08 | 20 | >= 8.0E+06 |
| 10/11/01 | Truck Load. (49 Hr) | 30 | 270 | 10 | 1 | >= 1.6E+07 | >= 1.6E+08 | 20 | >= 8.0E+06 |
| 10/11/01 | Truck Load. (72 Hr) | 30 | 270 | 10 | 1 | 5.0E+08 | 5.0E+09 | 20 | 2.5E+08 |
| 10/11/01 | Truck Load. (98 Hr) | 30 | 270 | 10 | 1 | 1.6E+09 | 1.6E+10 | 20 | 8.0E+08 |
| 10/11/01 | Truck Load. (120 Hr) | 30 | 270 | 10 | 1 | 5.0E+08 | 5.0E+09 | 20 | 2.5E+08 |
| 10/11/01 | Truck Load. (144 Hr) | 30 | 270 | 10 | 1 | 1.6E+09 | 1.6E+10 | 20 | 8.0E+08 |
| 10/11/01 | Truck Load. (170 Hr) | 30 | 270 | 10 | 1 | 9.0E+08 | 9.0E+09 | 20 | 4.5E+08 |
| 10/11/01 | Truck Load. (192 Hr) | 30 | 270 | 10 | 1 | 5.0E+08 | 5.0E+09 | 20 | 2.5E+08 |
| 10/11/01 | Truck Load. (214 Hr) | 30 | 270 | 10 | 1 | 9.0E+08 | 9.0E+09 | 20 | 4.5E+08 |
| 10/11/01 | Truck Load. (238 Hr) | 30 | 270 | 10 | 1 | 2.4E+08 | 2.4E+09 | 20 | 1.2E+08 |
| 10/11/01 | Truck Load. (288 Hr) | 30 | 270 | 10 | 1 | 1.7E+08 | 1.7E+09 | 20 | 8.5E+07 |
| 10/11/01 | Truck Load. (337 Hr) | 30 | 270 | 10 | 1 | AE | AE | 20 | AE |
| 10/11/01 | Truck Load. (431 Hr) | 30 | 270 | 10 | 1 | 2.4E+08 | 2.4E+09 | 20 | 1.2E+08 |
| | | | | | | | | | |
| 10/24/01 | Centrifuge (0Hr.) | 30 | 270 | 10 | 1 | < 2.0E+01 | < 2.0E+02 | 20 | < 1.0E+01 |
| 10/24/01 | Centrifuge (21Hr.) | 30 | 270 | 10 | 1 | AE | AE | 20 | AE |
| 10/24/01 | Centrifuge (48Hr.) | 30 | 270 | 10 | 1 | >= 1.6E+05 | >= 1.6E+06 | 20 | >= 8.0E+04 |
| 10/24/01 | Centrifuge (71Hr.) | 30 | 270 | 10 | 1 | >= 1.6E+05 | >= 1.6E+06 | 20 | >= 8.0E+04 |
| 10/24/01 | Centrifuge (96Hr.) | 30 | 270 | 10 | 1 | NT | NT | 20 | NT |
| 10/24/01 | Centrifuge (119Hr.) | 30 | 270 | 10 | 1 | 2.2E+07 | 2.2E+08 | 20 | 1.1E+07 |
| 10/24/01 | Centrifuge (144Hr.) | 30 | 270 | 10 | 1 | 5.0E+06 | 5.0E+07 | 20 | 2.5E+06 |
| 10/24/01 | Centrifuge (167Hr.) | 30 | 270 | 10 | 1 | 1.3E+07 | 1.3E+08 | 20 | 6.5E+06 |
| 10/24/01 | Centrifuge (194Hr.) | 30 | 270 | 10 | 1 | 8.0E+06 | 8.0E+07 | 20 | 4.0E+06 |
| 10/24/01 | Centrifuge (216Hr.) | 30 | 270 | 10 | 1 | 1.7E+07 | 1.7E+08 | 20 | 8.5E+06 |
| 10/24/01 | Centrifuge (241Hr.) | 30 | 270 | 10 | 1 | 3.0E+07 | 3.0E+08 | 20 | 1.5E+07 |
| 10/24/01 | Centrifuge (262Hr.) | 30 | 270 | 10 | 1 | 3.0E+07 | 3.0E+08 | 20 | 1.5E+07 |
| 10/24/01 | Centrifuge (287Hr.) | 30 | 270 | 10 | 1 | 1.3E+07 | 1.3E+08 | 20 | 6.5E+06 |
| 10/24/01 | Centrifuge (314Hr.) | 30 | 270 | 10 | 1 | 5.0E+06 | 5.0E+07 | 20 | 2.5E+06 |
| | | | | | | | | | |

* 1gm sample = 1 ml
Note :- Since no actual sample was analyzed for %TS for regrowth, estimated 20%TS was used.

**Appendix 7.4 References**

Legal aspects of 40CFR 503:


1. USEPA (1993). Technical Regulations for Municipal Sludge Use or Disposal, *Federal Register*, Regulation 40 CFR 503, Document WWBKRG35, National Small Flows Clearinghouse, West Virginia U., Morgantown, WV.

2. USEPA (1994). Plain English Guide to the EPA Part 503 Biosolids Rule. EPA/832/R-93/003

3. USEPA (2000). Guide to Field Storage of Biosolids. EPA/832-B-00-007. July, 2000.


Analytical Methods:


4. Laboratory Section Procedure for the Characterization of Water and Waste (1989), 4th Edition, Sanitation District of Los Angeles County, Los Angeles, CA.

5. Standard Methods for the Examination of Water and Wastewater (1992), 18th Ed. American Public Health Association, Washington, DC, Part 9020, Part 9221 E, and Part 9260 D.

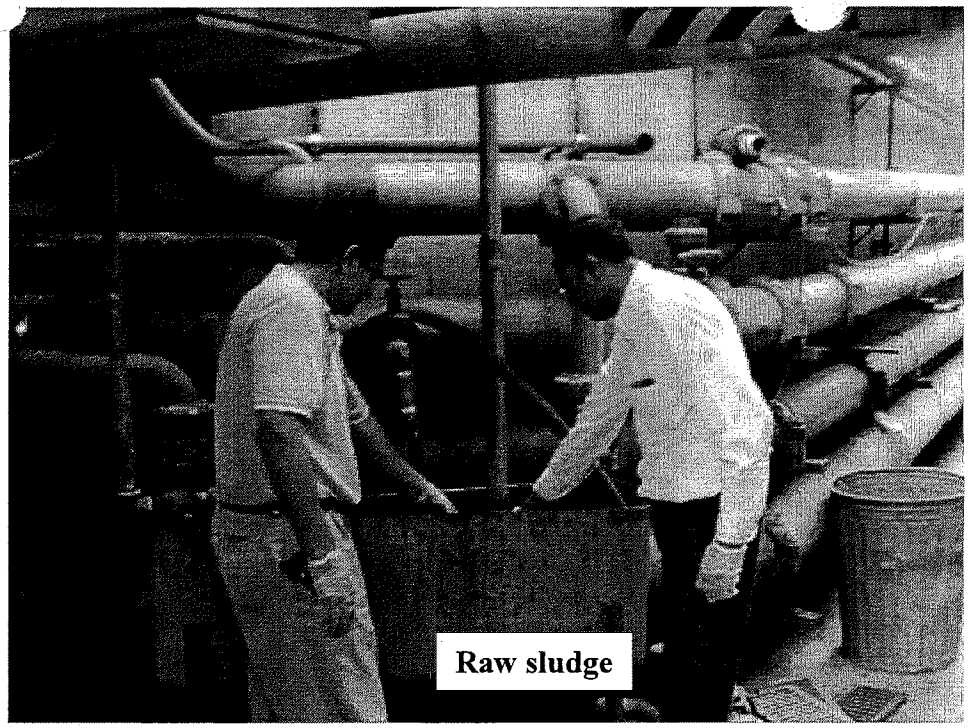
6. Annual Book of ASTM Standards (1992) Section 11 – Water and Environment Technology. ASTM D 4994-89, *Standard Practice for Recovery of Viruses from Wastewater Sludges.* ASTM, Philadelphia, Washington, DC.

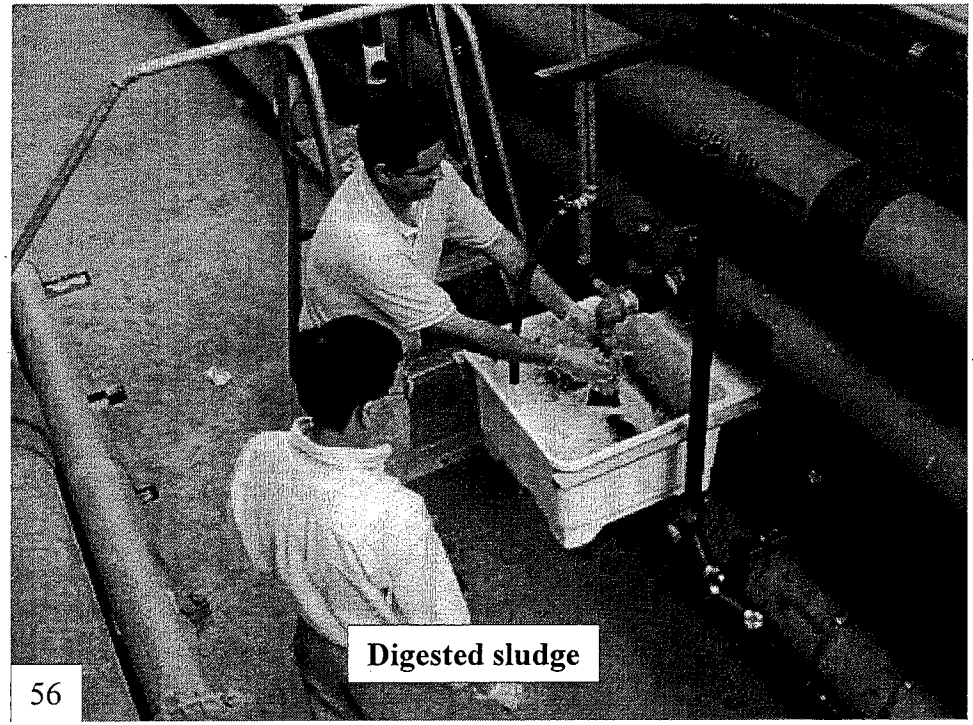
7. USEPA (1999). Environmental Regulations and Technology, Control of Pathogens and Vector Attraction in Sewage Sludge. EPA/625/R92/014.

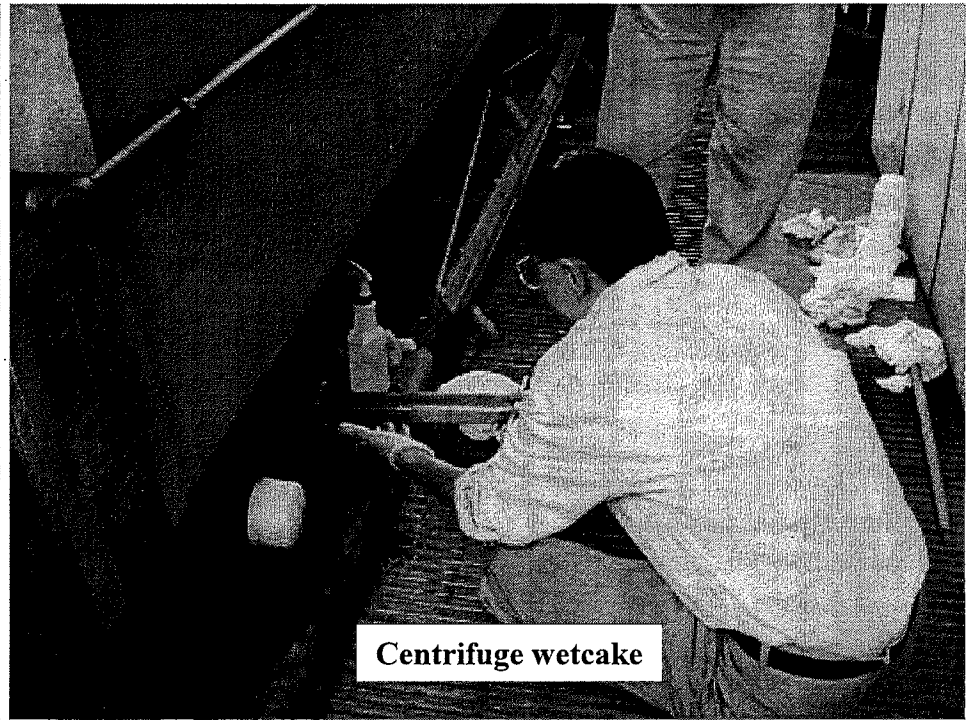
## Appendix 7.5 Photos

This appendix presents pictures of selected activities during Phase III.

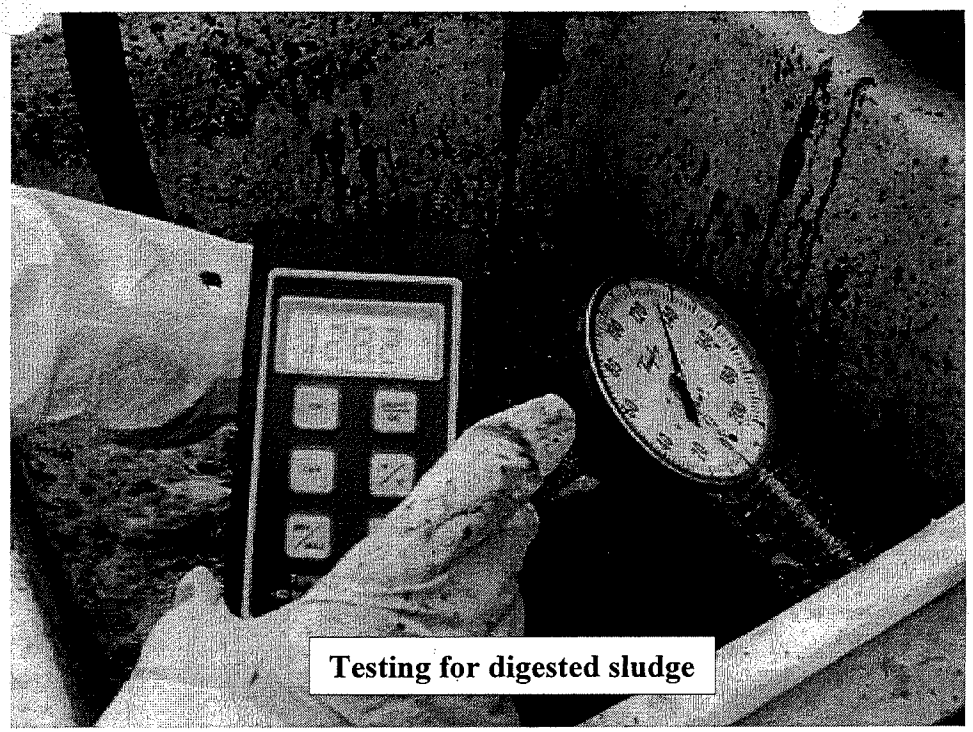
## SAMPLING


Raw sludge

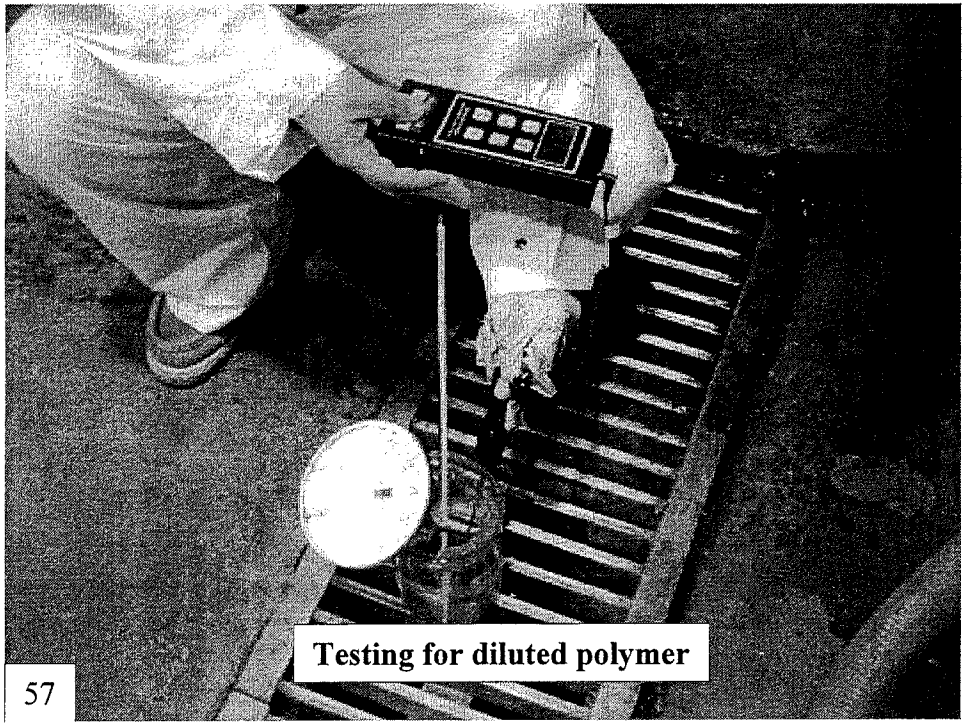

Digested sludge


Centrifuge wetcake

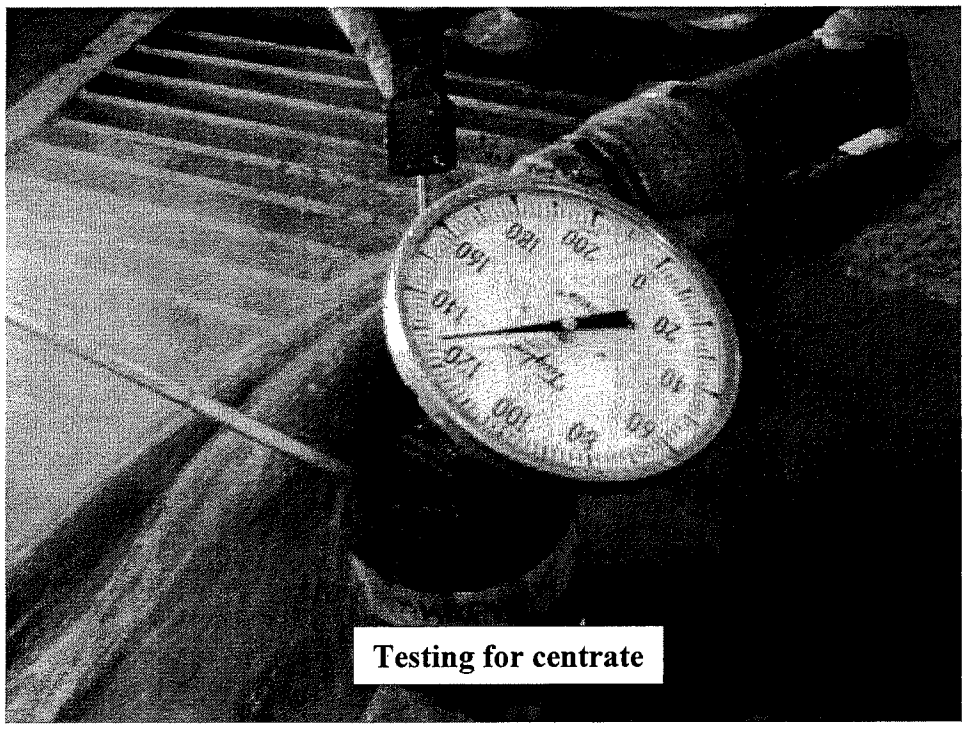
## TEMPERATURE PROFILES



Testing for digested sludge

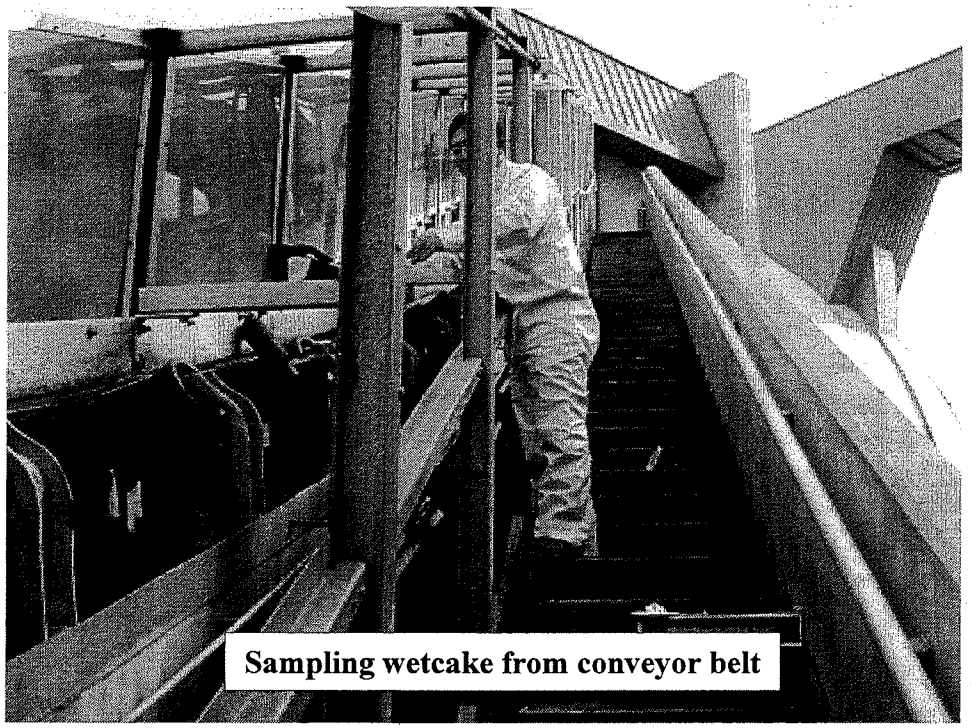


Testing for diluted polymer

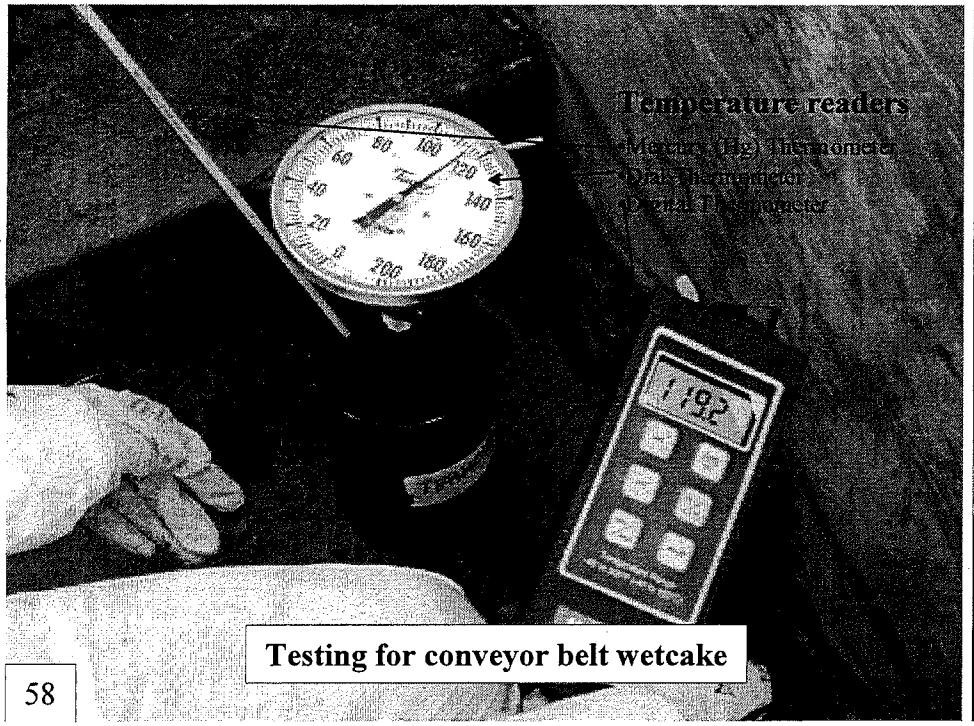


Testing for centrate

## TEMPERATURE PROFILES



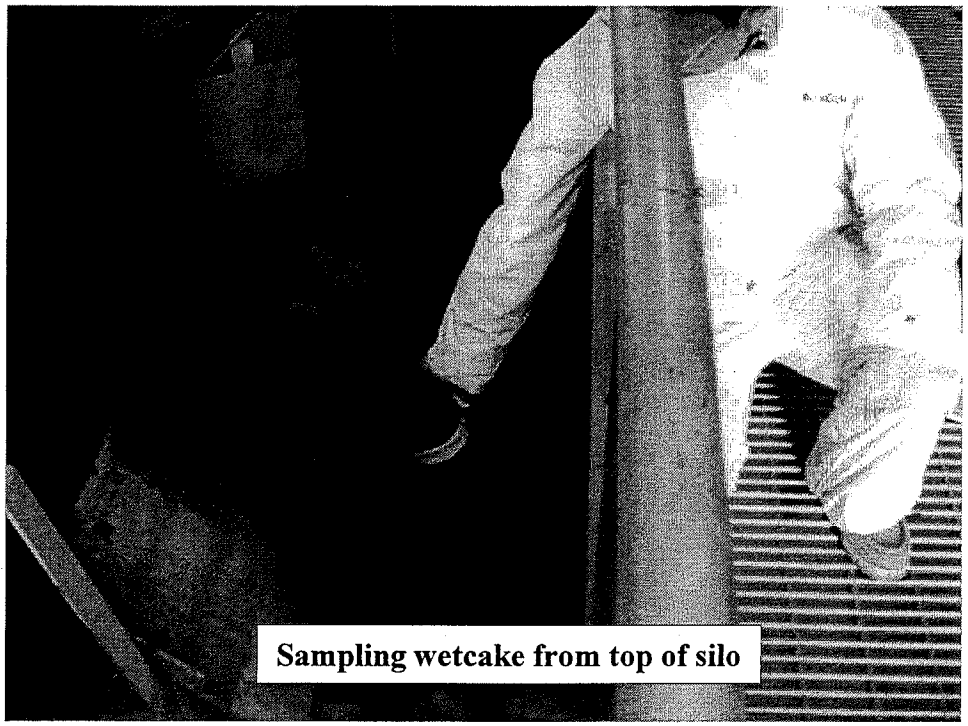
Sampling wetcake from conveyor belt



Temperature readers

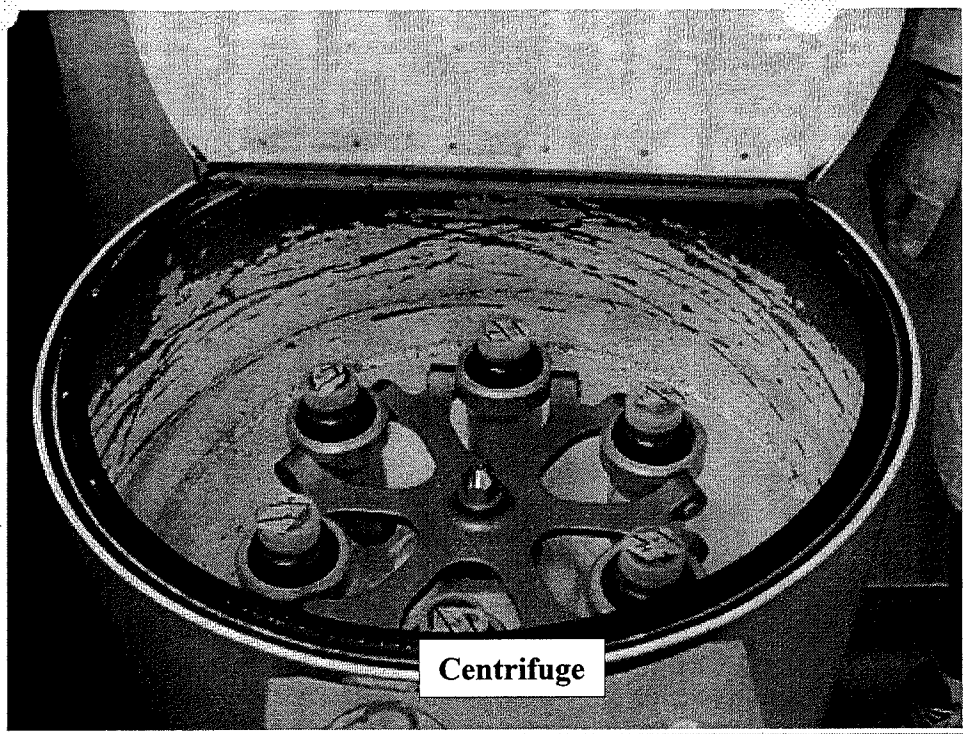
- Mercury (Hg) Thermometer
- Dial Thermometer
- Digital Thermometer

Testing for conveyor belt wetcake

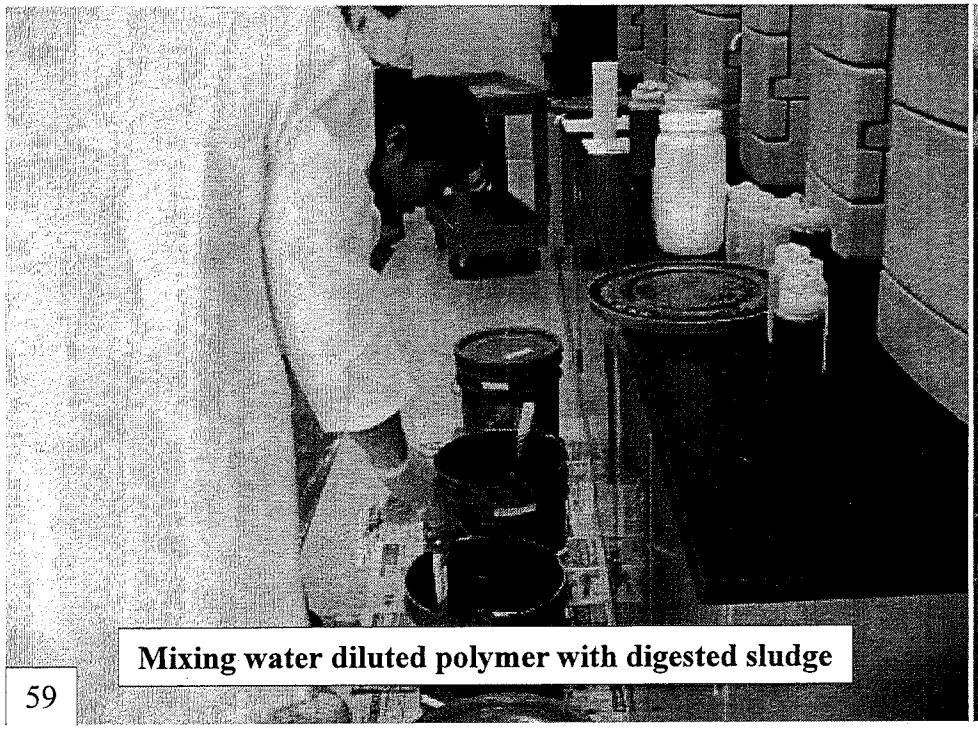


Sampling wetcake from top of silo

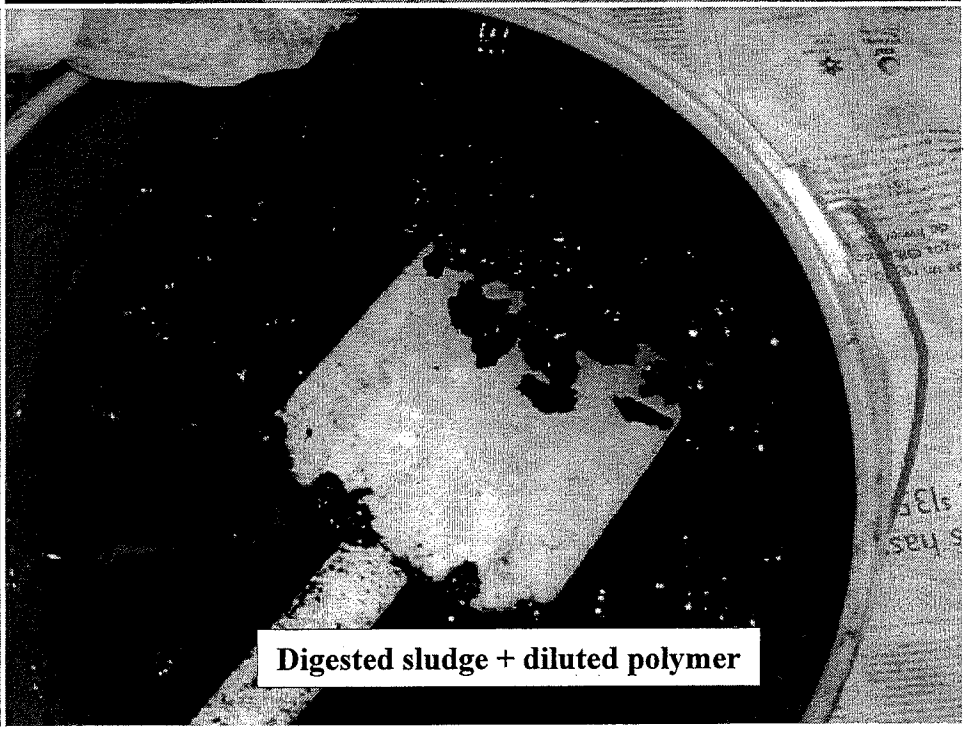
## CENTRIFUGE SIMULATION TESTING



Centrifuge



Mixing water diluted polymer with digested sludge



Digested sludge + diluted polymer