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Laura Seaman

AUTEUR DE LA THÈSE / AUTHOR OF THESIS

M.A.Sc. (Environmental Engineering)

GRADE / DEGREE

Department of Civil Engineering

FACULTÉ, ÉCOLE, DÉPARTEMENT / FACULTY, SCHOOL, DEPARTMENT

Advanced Aerobic Digestion to Optimize Pathogen Reduction: Staged Pre-Treatment in Aerobic Digestion

TITRE DE LA THÈSE / TITLE OF THESIS

Dr. K. Kennedy

DIRECTEUR (DIRECTRICE) DE LA THÈSE / THESIS SUPERVISOR

Dr. Parker

CO-DIRECTEUR (CO-DIRECTRICE) DE LA THÈSE / THESIS CO-SUPERVISOR

EXAMINATEURS (EXAMINATRICES) DE LA THÈSE / THESIS EXAMINERS

Dr. Christopher Lan

Dr. Leta Fernandes

Dr. Onita Basu

Gary W. Slater

Le Doyen de la Faculté des études supérieures et postdoctorales / Dean of the Faculty of Graduate and Postdoctoral Studies

ADVANCED AEROBIC DIGESTION TO OPTIMIZE PATHOGEN REDUCTION: STAGED PRE-TREATMENT IN AEROBIC DIGESTION

by

Laura Seaman

B. Eng., Carleton University

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ABSTRACT

Land application of biosolids is a desirable solution for smaller communities that utilize aerobic digestion. However, traditional aerobic digestion produces Class B biosolids at best which raises public concern regarding the fate of pathogens following land application. The main goal of this work was to determine a plan to help an aerobic digestion WWTP achieve improved pathogen destruction. An approach of studying the effect of a pre-treatment step prior to digestion was developed following site visits to eight aerobic digestion facilities in Ontario. The experimental phases of this work evaluated the effect of aeration rate, temperature and retention time on pathogen reduction in 12 setups. The four best conditions were carried out with digestion to evaluate the ultimate impact of pre-treatment on digestion. The results indicated that a micro-aerobic, highly reducing environment produces adverse conditions within the pre-treatment column which also impact subsequent digestion and resulted in decreased pathogens.

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NOMENCLATURE

4-NP	4-nonylphenol
CFU	Colony Forming Unit
mgd	Million Gallons per Day
MPN	Most Probable Number
PCDD	Polychlorinated dibenzo-p-dioxin
PCDF	Polychlorinated dibenzofuran
TCS	Triclosan

LIST OF ABBREVIATIONS

ATAD	Autothermal Thermophilic Aerobic Digestion
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
FC	Fecal Coliform
FS	Fecal Streptococci
HRT	Hydraulic Retention Time
IC	Ion Chromatographer
N/A	Not Applicable
MOE	Ontario Ministry of the Environment
ORP	Oxidation-Reduction Potential
PVC	Polyvinyl Chloride
RT	Retention Time
S	*Salmonella*
SBR	Sequencing Batch Reactor
SRT	Solids Retention Time
sCOD	Soluble Chemical Oxygen Demand
SOUR	Specific Oxygen Uptake Rate
SDR35	Standard Dimension Ratio 35
TS	Total Solids
TKN	Total Kjeldahl Nitrogen
TVFA	Total Volatile Fatty Acid
VFA	Volatile Fatty Acid
VS	Volatile Solids
VSS	Volatile Suspended Solids
WWTP	Wastewater Treatment Plant

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CHAPTER 1
INTRODUCTION

Aerobic digestion is a common practice for wastewater treatment facilities that treat smaller volumes of water. The purpose of aerobic digestion is to reduce vector attraction, total volume and pathogens. Land application of final sludges makes use of the nutrient rich product; however, land applying sludge raises concern regarding the fate of pathogens in the sludge.

The original objective of this work was to identify a solution for improving pathogen reduction at any aerobic digestion WWTP in Ontario. Site visits to aerobic digestion facilities in Elora, Arthur, Mount Forest, Palmerston, St. Jacobs, Heidelberg, Wellsley and Hawkesbury illustrated considerable differences in the conditions and practices that were in place. Given the variability in setup and resources between the eight plants, it was apparent that it would not be possible to develop one type of upgrade for all of the plants based only on modifying the current operations. Hence, it was decided to investigate the potential of employing a pre-treatment step that would be added to the existing processes to enhance pathogen destruction. The pre-treatment step could be implemented at existing sites through a retrofit that would require minimal costs to a municipality if a portion of an existing aerobic digester were sectioned off to form the pre-treatment column.

A review of the literature (Chapter 2) revealed that alternatives to conventional single stage aerobic digestion have included anoxic digestion, staged digestion, autothermal thermophilic aerobic digestion and the use of thickening systems. Most of the systems reported either upgrading that was performed to enhance volatile solids destruction or new installations. There were relatively few studies that addressed upgrading of existing aerobic digestion through the addition of a pre-treatment stage. The anticipated benefits of employing a pre-treatment stage included reduced bleed-through of pathogens, potential to accumulate pathogen inhibitors such as volatile fatty acids and ammonia and also the potential for autothermal temperature increases if they were efficiently aerated.

Hence the modified objective of this study was to evaluate the impact of pre-treatment process variables on the pre-treatment reactor itself and a downstream aerobic digester. The six pre-treatment parameters identified were temperature, aeration rate, retention time, feed solids concentration, feeding frequency and mechanical shearing. The work in this thesis evaluated the first three parameters: temperature, aeration rate and retention time. The differing parameters of the alternative configurations and their impact on digester performance were used to design pre-treatment columns.

The experimental work of this thesis was divided up into three phases which analyzed the three identified parameters. During phase 1, four pre-treatment columns were operated at room temperature with a 2 day retention time. The aeration rates were varied to cover the range from highly aerobic to highly reducing conditions. Chapter 3 contains the design of the pre-treatment columns and digesters, the source of the feed sludge and the procedures followed when sampling the operating parameters and evaluating process performance. Phase 2 was performed at the same aeration rates and retention time outlined in phase 1 but the temperature was increased through the use of a heating system. The conditions of the two pre-treatment columns which performed the best were repeated in phase 3 to evaluate their consistency as well as to carry out a 2-way factorial design which evaluated the two 'best' aeration rates at two retention times. During phase 3, the effluent of the pre-treatment columns was fed to aerobic digesters. Thus, phase 3 involved the evaluation of the pre-treatment step of the process train as well as the impact of pre-treatment on the digestion of the sludge.

The results and discussion for the three phases are included in Chapter 4. The conclusions that could be drawn from this study have been outlined in Chapter 5.

All of the data related to this work has been included in the appendices. Appendices A and B contain preliminary results which impacted the operating setups. Appendix C contains all of the raw data for all of the parameters measured throughout the experimental work.

CHAPTER 2

LITERATURE REVIEW

The treatment and disposal of sewage sludge has become an increasingly important challenge to engineers over the past few decades. The volume of sludge requiring treatment has increased as a result of expanding urban populations and larger volumes of light industrial wastes requiring treatment. Along with increasing volumes, there are increased concerns regarding possible contaminants in the sludge. Items such as personal care products and pharmaceuticals are finding their way into sewage sludge and their presence needs to be monitored and dealt with. Pathogens are always a concern when dealing with sewage sludge.

There are three common disposal methodologies that are employed with regards to sludge (biosolids). The three options include: landfilling, incineration and land application. Land application is often considered the most desirable option because it utilizes the nutrient rich properties of the treated municipal waste. A disadvantage of land application is the increased concern of pathogens.

Sludge stabilization through aerobic digestion is commonly employed prior to land application in many small communities. This literature review addresses an assessment of design and operational parameters for conventional and non-conventional aerobic digestion as well as the fate of pathogens in aerobic sludge digestion processes. In addition, the fate of anthropogenic chemicals in aerobic sludge digestion is addressed.

2.1 Aerobic Digestion

Vector attraction reduction (stabilization), pathogen reduction and mass reduction are the three primary objectives of sludge treatment. Vectors are hosts that have the ability of transferring infectious diseases. Examples of possible vectors are: insects, rodents, birds and small animals. Vector attraction reduction is generally achieved by minimizing the potential

for putrefaction of the sludges after land application. Pathogen reduction refers to reducing the number of pathogens that are applied to the land and able to transmit disease. Mass reduction refers to decreasing the amount of solids that require disposal.

Aerobic digestion is employed as a method of stabilization and mass reduction of waste sludge. Aerobic digestion can be applied to many different types of sludge including: waste-activated sludge, mixtures of trickling filtered sludge, waste activated sludge and primary sludge as well as sludge from extended aeration processes. Conventionally aerobic digestion has been used only for small plants (less than 0.2 m^3/s); however, it has been applied in plants with larger flows in recent years (up to 2 m^3/s) (Metcalf and Eddy, 2003). Aerobic digestion can be implemented in either batch or continuous flow configurations.

The advantages of aerobic digestion over anaerobic digestion include:

- Supernatant liquor has lower BOD concentrations
- End product is odourless, humus-like and biologically stable
- Sludge has greater fertilizer values (Banat et al., 2000 and Metcalf and Eddy, 2003)
- Simpler operation
- Less initial investment
- More suitable for digestion of nutrient-rich biosolids

The disadvantages of aerobic digestion include:

- Increased cost of power to ensure adequate oxygen supply
- Digested biosolids are more difficult to dewater
- Performance influenced by temperature, tank geometry, concentration of feed solids and type of mixing/aeration device
- No recovery of methane

The reactions that occur in aerobic digestion are similar to those involved in activated sludge processes. As the concentration of substrate in the solution decreases, microorganisms consume themselves (endogenous phase). Approximately 75% of cell tissue

is oxidized while the remaining 25% consists of inert substances and organic compounds which are not biodegradable.

The following equations describe the biochemical changes that may occur in an aerobic digester where $C_5H_7NO_2$ represents the cell mass of the microorganisms (Metcalf and Eddy, 2003). Equation 2.1 represents biomass reduction.

$$C_5H_7NO_2 + 5\ O_2 \rightarrow 4\ CO_2 + H_2O + NH_4HCO_3 \qquad \text{Equation 2.1}$$

The presence of oxygen in an aerobic digester results in the oxidation of cells to carbon dioxide, water and ammonia. If there is sufficient oxygen, the digestion proceeds with nitrification (equation 2.2). If nitrification is prohibited from occurring, the pH of the system could increase as a result of the generation of ammonia. Nitrification involves the released ammonia nitrogen being oxidized to nitrates, hydrogen and water.

$$NH_4^+ + 2\ O_2 \rightarrow NO_3 + 2\ H^+ + H_2O \qquad \text{Equation 2.2}$$

Nitrification results in a decreased pH of the system as a result of the released hydrogen ions. If the system remains in a nitrification state with oxygen continually being introduced, the system could achieve extremely low pH values. It is possible that at these low pH values, pathogen reduction could be achieved due to an adverse environment. Equation 2.3 represents the overall reaction with complete nitrification.

$$C_5H_7NO_2 + 7\ O_2 \rightarrow 5\ CO_2 + 3\ H_2O + HNO_3 \qquad \text{Equation 2.3}$$

Denitrification (equation 2.4) occurs in the absence of oxygen. When oxygen is not present, the nitrate acts as the electron acceptor in the degradation of cell mass. Nitrate and water react with the cell mass to produce ammonia, hydrogen carbonate and nitrogen gas. In some cases, plants that to not naturally observe denitrification may turn off their air supply in order to ensure its occurrence. Excessive denitrification can result in elevated pH values. It is possible that in these adverse conditions, pathogens may be inhibited. The overall biomass

reduction reaction with complete nitrification and denitrification is outlined by equation 2.5.

$$C_5H_7NO_2 + 4\ NO_3^- + H2O \rightarrow NH_4^+ + 5\ HCO_3^- + 2\ N_2 \qquad \text{Equation 2.4}$$

$$2\ C_5H_7NO_2 + 11.5\ O_2 \rightarrow 10\ CO_2 + 7\ H_2O + N_2 \qquad \text{Equation 2.5}$$

Table 2.1 outlines the typical values of design and operational parameters for aerobic digestion. This table will be discussed in detail in subsequent sections.

Table 2.1: Design Criteria for Aerobic Digesters (Source: Metcalf and Eddy, 2003)

Parameter		Value
Solids Retention Time	At 20°C	40 days
	At 15°C	60 days
Volatile Solids Loading		1.6 – 4.8 kg/m^3•day
Oxygen Requirements	Cell Tissue	2.3 kg O_2 / kg VSS destroyed
	BOD_5 in Primary Sludge	1.6 – 1.9 kg O_2 / kg VSS destroyed
Energy Requirements for Mixing	Mechanical Aerators	20 – 40 kW/10^3 m^3
	Diffused Air Mixing	0.02 – 0.04 m^3/m^3•min
Dissolved Oxygen Residual in Liquid		1 – 2 mg/L
Reduction of Volatile Suspended Solids		38 – 50 %

Table 2.2 outlines the guidelines provided by the Ontario Ministry of the Environment (MOE) when designing aerobic digestion process. The design and operating parameters of conventional aerobic digestion design will be outlined in sections 2 and 3 respectively. Traditionally, aerobic digestion has consisted of single stage digestion. An evaluation of conventional aerobic digestion will be described in section 4. Section 5 includes alternative aerobic digestion configurations. Differences between the design and operating parameters of these configurations and traditional aerobic digestion will be outlined when the alternative configuration is presented.

Table 2.2: MOE Aerobic Digestion Design Guidelines (1982)

Parameter	Value
Number of Stages	2
Tanks per Stage	1 (Unless economics permit more)
Loading	1,600 g VSS/m^3•day
Minimum Sludge Age	45 days
Volume	2/3 in first stage 1/3 in second stage
Air Requirement	0.85 L/m^3•s (Diffused aeration System)
Mixing Requirement	0.25 m/s (Minimum bottom velocity)
Tank Depth	3.6 – 4.6 m

2.2 Design Parameters

2.2.1 Physical Mixing

In many digesters, the physical mixing of the contents of an aerobic digester is intrinsically linked with the aeration of those contents. Physical mixing and aeration are commonly performed by the same equipment. Additionally, aeration may aid in physical mixing. Due to the large amount of oxygen required in aerobic digesters, it is possible that mechanical mixing is not required.

Typical mechanical aerators include submerged or surface mechanical aerators. Table 2.1 outlined the energy requirements of mechanical aerators as 20-40 kW/10^3 m^3. If diffused air is used to mix the contents of the digester, the energy requirement specified in Table 2.1 is 0.02-0.04 m^3/m^3•min.

In some storage type facilities, mechanical mixing may be employed without substantial aeration being provided. Generally, aerobic digesters are mixing-limited, that is to say that once sufficient air has been supplied to ensure mixing, the oxygen demand has been met. Therefore, it is not sensible to use more effective aeration systems such as fine-bubble diffusion when the system is mixing-limited (Enviroquip, 1998). Shear tubes can help to increase mixing when using fine-bubble diffusion.

2.2.2 Oxygen Requirements

Submerged aeration systems common to aerobic digestion include diffused air and sparger turbines. Diffused air can be provided by either fine bubble or coarse bubble systems. Fine bubble (fine-pore) systems make use of bubbles generated by membranes while coarse bubble (non-porous) systems utilize orifices, injectors and nozzles to create bubbles. A sparger turbine involves a low-speed turbine that injects compressed air into the digester.

Submerged technologies have an alternative option of using pure oxygen instead of air. The advantage of using pure oxygen in cold climates is that it is relatively insensitive to ambient temperatures. The ambient temperature does not have as great of an effect on the system because the pure oxygen results in an increased rate of biological activity and the exothermal nature of this activity results in an increase in temperature. Studies have shown that closed tanks that use pure oxygen have increased temperatures as well as increased rates of volatile solids reduction. A disadvantage of using pure oxygen is the increased cost. The most economically sound situation in which to use pure oxygen is when oxygen is already being generated on-site for use by the aeration basin (Metcalf and Eddy, 2003).

Common surface aeration systems employed in aerobic digestion include low-speed turbine aerators and high-speed floating aerators. Both systems involve the turbine/propeller exposing liquid droplets to the atmosphere.

The oxygen supplied to a system must satisfy the demand of the cell tissue. If primary sludge is introduced to the digester, the biochemical oxygen demand (BOD) must be satisfied as well. Cell tissue oxidation requires approximately 7 mols per mol of cells (approximately equivalent to 2.3 kg per kg of cells). The BOD demand is typically between 1.6 and 1.9 kg/kg destroyed (Metcalf and Eddy, 2003). The MOE suggests 0.85 litres of air be supplied per cubic meter of tank volume per second (Ministry of the Environment, 1982).

2.2.3 Feed Solids Concentration

The solids concentration of the incoming sludge determines many of the parameters required for digestion of the sludge. Any pre-treatment of the sludge has a large impact on the required treatment of the sludge. For example, if the sludge is pre-thickened, the solids concentration will be large, this results in increased oxygen requirements and a greater solids retention time. If the sludge is not pre-thickened or the incoming solids concentration is small, the volume of the digestion tank is larger and there will be more process control requirements such as decanting.

The above parameters lend themselves to high incoming feed solids concentrations but it should be noted that if the feed solids concentration is in the range of 4% solids, it may be difficult to ensure adequate mixing. Also, the supply of sufficient oxygen may prove challenging (Metcalf and Eddy, 2003).

2.2.4 Solids Retention Time

In the past, the typical solids retention time (SRT) of an aerobic digester was 10-20 days. However, the introduction of land application regulations that regulate the solids retention time in order to ensure pathogen destruction has increased the retention time to 40 days (20°C) and 60 days (15°C) (Metcalf and Eddy, 2003).

Surampalli and Banerji (1993) have found that increasing the SRT resulted in an increase in volatile solids (VS) reduction. Their study also concluded that the solids reduction does not increase infinitely and that it will plateau.

2.2.5 Temperature

The temperature of the system affects the oxygen transfer rate and kinetics of pathogen reduction (decay). If the seasonal temperature variation is great, systems should be designed to ensure that the aerobic system could supply sufficient oxygen transfer at the lowest

temperature. Possible solutions to large seasonal temperature variations include: tank material (concrete as opposed to steel), tank location (below as opposed to above ground), tank insulation, tank covers, heating of sludge and/or air supply. Surampalli and Banerji (1993) state that lower temperatures result in decreased volatile solids reduction. They attribute this to a decrease in metabolic activity of the microorganisms. Unfortunately, performance data was not provided to illustrate this point.

2.3 Operating Parameters

2.3.1 Dissolved Oxygen Concentration

The residual dissolved oxygen (DO) concentration is recommended to be a minimum of 1 mg/L. If the DO concentration is less than 1 mg/L, nitrification is inhibited (Metcalf and Eddy, 2003). Scheuerman et al. (1991) found that an increase in the DO concentration resulted in a decreased virus inactivation rate but the decrease was not statistically significant.

2.3.2 Respiration Rate

The extent of decomposition of the sludge is indicated by the oxygen uptake rate. In order to satisfy the vector attraction requirements of 40 CFR Part 503, the total sludge SOUR (specific oxygen uptake rate) at 20°C must be less than 1.5 mg O_2/hr per gram of sludge.

2.3.3 pH

The pH profile in a batch aerobic digester has a bell-shape when plotted with respect to time. There is an initial increase in the pH due to the release of ammonia from protein decomposition. Nitrification of the ammonia then results in a decrease in the pH of the system. Metcalf and Eddy (2003) suggest that the pH of an aerobic system be monitored as long hydraulic retention times can result in the pH dropping below 5.5. If the system cannot naturally maintain a higher pH, it is recommended that alkalinity feed equipment be

installed. Banat et al. (2000) recommend that the pH of an aerobic digester be maintained between 7 and 8 in order to maximize the rate of digestion.

2.4 Process Performance

2.4.1 Nitrification/Denitrification

Nitrification is a biological process that is accomplished by autotrophs and involves two steps. The first involves the oxidation of ammonia (NH_4-N) to nitrite (NO_2-N), while the second step involves the oxidation of nitrite (NO_2-N) to nitrate (NO_3-N). Denitrification is the biological reduction of nitrate to nitric oxide, nitrous oxide and nitrogen gas. In order to maximize denitrification, digesters may be cycled between aeration and mixing.

Nitrification is a sensitive process that can be affected by pH, toxicity, metals and un-ionized ammonia. When the pH in the system is below 6.8, the rate of nitrification declines dramatically. The optimal range of pH for nitrification is between 7.5 and 8; however, pH values between 7 and 7.2 are reasonable. If the above ranges of pH do not naturally occur in the system, alkalinity may be added. Approximately 50% of the alkalinity consumed by nitrification can be recovered by denitrification. Examples of toxic compounds that inhibit nitrification include: alcohols, cyanates, ethers, carbonates and benzene.

Denitrification occurs when heterotrophs (heterotrophic nitrifying bacteria) reduce NO_2-N to nitrogen gas. A carbon source is required for the reaction to proceed. Bock et al. (1995) found that when DO is not present, nitrate is used as an electron acceptor. However, if oxygen is present, ammonia is oxidized using oxygen as the electron acceptor.

As outlined in section 2.1, if denitrification is prohibited, the pH of the system may decrease to extremely low pH values and result in adverse conditions for pathogens. Meanwhile, denitrification could result in elevated pH values which inhibit pathogens. Overall, nitrification and denitrification should be encouraged in the system to ensure complete degradation of cell mass within the system and a balanced pH.

2.4.2 Solids Reduction

Mass reduction was previously mentioned as one of the primary objectives of sludge treatment. Mass reduction is achieved through solids destruction, which ultimately reduces the volume requiring disposal. In aerobic digestion, the extent of solids reduction is a function of liquid temperature and sludge age (SRT). Figure 1 illustrates this relationship. The recommended minimum temperature-day relationship is 550°C•days for well-stabilized biosolids. From Figure 1, 550°C•days results is a volatile solids reduction of approximately 42%. Typical volatile solids reductions are between 38-50% for aerobic digestion.

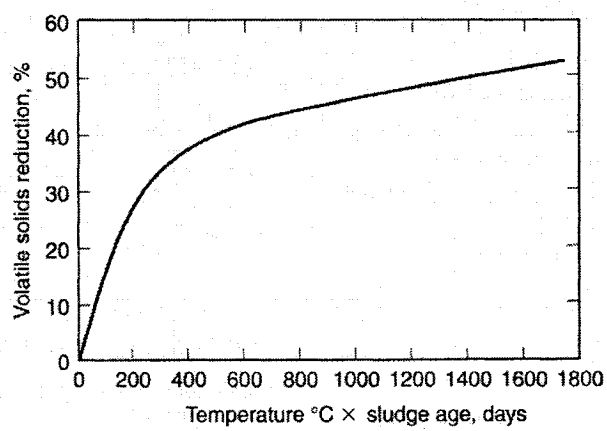

Figure 2.1: Volatile solids reduction in an aerobic digester as a function of digester liquid temperature and digester sludge age (Metcalf and Eddy, 2003)

2.4.3 Pathogen Reduction

The third and final process performance criteria analyzed in this work was pathogen reduction. As pathogen reduction was the primary focus of this work, extra attention was attributed to this subject. Section 2.6 covers the topic in full with subsections on mechanisms of pathogen reduction, results of bench scale studies and full scale applications.

2.5 Alternative configurations of Aerobic Digestion

2.5.1 Aerobic-Anoxic Digestion

Aerobic-anoxic digestion is similar to conventional aerobic digestion except that anoxic cycles are introduced in the digestion process. In these anoxic cycles, the nitrate-nitrogen that is produced in the aerobic digestion cycles/zones is used as an electron acceptor (denitrification). The digestion rates of anoxic zones are comparable to those of the aerobic zones. Aerobic-anoxic digestion produces alkalinity which offsets the alkalinity consumed during nitrification. Therefore, pH control is naturally provided to the system.

A summary of the benefits of aerobic-anoxic digestion (Daigger and Bailey, 2000) include:

- Reduced alkalinity consumption
- Reduced energy requirements
- Nitrogen removal

The study of Daigger and Bailey did not provide a quantifiable analysis demonstrating the observed reductions. Alkalinity consumption is reduced because of the alkalinity produced during denitrification. Energy requirements are reduced because the digester requires less oxygen input as the result of denitrification. The reduction of the nitrogen concentration of the sludge is advantageous due to nitrogen loading restrictions for land application. Nitrogen removal may result in larger volumes of sludge being able to be applied to the land while still meeting regulations.

Aerobic-anoxic digestion can occur through either a specific separate tank or by simply turning the digester air supply off. The length of the anoxic period is dependent on the nitrate concentration. After the nitrate concentration reaches 10 mg/L, the air supply is returned to the digester. Mixing is usually not required while the air supply is turned off as the sludge thickness prevents settling.

2.5.2 Staged Digestion

If multiple staged digesters replace a single stage aerobic digester, the overall system should begin to approach plug-flow characteristics. When multiple digesters are configured in stages, the solids retention time should be split equally between all of the digesters (Metcalf and Eddy, 2003).

Daigger and Bailey (2000) state that a staged operation can be either tanks-in-series or sequential batch reactors. These configurations will increase plug flow characteristics and reduce short-circuiting. They list the following advantages of this configuration:

- Improved solids stabilization
- Improved pathogen reduction

Performance data was not provided to illustrate the degree of the above advantages. At an aerobic digestion workshop (Enviroquip, 1998), Dr. Daigger reported that two tanks in series require 50% of the volume of a single stage digester.

2.5.3 Autothermal Thermophilic Aerobic Digestion (ATAD)

Interest in aerobic thermophilic processes has increased in recent years because of the potential of greater pathogen reduction over the more conventional processes. The aerobic thermophilic process has potential to achieve high disinfection and sludge treatment rates. ATAD processes usually involve the pre-thickening of waste activated sludge before digestion. The digesters are usually insulated and aerated using fine pore aeration. Bench testing for a new ATAD to be built in Plover, Wisconsin indicated a minimum operating temperature of 35°C in January and 47°C in the warmest month of the year. Full-scale operating data indicated it was possible to achieve higher temperatures (43°C) in colder months. The feed sludge was thickened to 6% by a gravity belt thickener and a 42% destruction of volatile solids was achieved in the digesters (Arant and Boden, 2000a). At the Plover facility, three digesters were operated in series. Aeration was provided by fine pore membrane diffusers through displacement blowers. Vertical turbine mixers in each digester

provided additional mixing. The volume of each digester was approximately 265 m^3. The digester design loading was approximately 72 m^3 of thickened sludge per day (Arant and Boden, 2000b). These values correspond to individual retention times of 3.7 days per digester, resulting in a total retention time of 11 days.

Though ATAD processes are advantageous due to their increased sludge stabilization and pathogen reduction abilities, there are numerous disadvantages that have been associated with the ATAD process. These include the following:

- Potential odour generation
- Oxygen delivery limitations
- Increased recycle loadings
- Foaming
- Difficulty in dewatering biosolids

The Plover facility did experience many of the above conditions but found that they could be addressed by simply decreasing the operating temperature (Arant and Boden, 2000b).

2.5.4 Thickening Systems

A final alternative configuration or system that has been suggested in terms of aerobic digestion is a pre-thickening system (Enviroquip, 2000). These systems can be gravitational or mechanical and are able to meet many standards of treatment. The system can be installed new or as a retrofit; anaerobic digesters have successfully been converted. Sludge is thickened to approximately 3%. The process includes a highly aerated basin (approximately 60 scfm per 1,000 ft^3 of volume) and a thickening cell. The intense aeration promotes nitrification while anoxic conditions in the thickener encourage denitrification. The pH of the system is maintained naturally by the nitrification/denitrification process.

2.6 Pathogen Reduction

2.6.1 Mechanisms

Due to the complicated kinetics of aerobic digesters, it is difficult to isolate the effect of different digester parameters on pathogen reduction. Many studies have determined that increased temperatures have the most significant impact on pathogen reduction. Meanwhile, a few studies have identified the combination of temperature and retention time as key factors. Volatile fatty acid concentration and pH are parameters that have not received much attention in studies. However, it may be possible that these two parameters are biologically fundamental to the survival of pathogens. Their possible effects on pathogen reduction will be discussed in detail with the plan that their effect may be evaluated in the laboratory experimentation.

Pathogens can be divided into four classes: bacteria, protozoa, helminths (worms) and viruses. Bacteria are generally of the least concern because they are usually the most fragile. Sunlight, drying and soil competition are all sources of bacterial reduction and destruction. Viruses can be reduced through sun exposure and desiccation; however, they are known to be more tolerant to soil competition and vegetation. Parasite ova and cysts are of greatest concern because they are resistant to disinfectants and are less affected by adverse environmental conditions. Although the latter organisms are of greatest concern with respect to exposure, it is commonly accepted that bacterial indicators can be employed to assess the efficiency of disinfection.

2.6.1.1 Temperature

Figure 2.1 illustrated the relationship between volatile solids reduction and liquid temperature as well as digester sludge age. Similar relationships have been developed for the time-temperature relationship with pathogen reduction. In general, the greater the temperature and exposure time, the greater the extent of pathogen reduction. Strauch (1998) developed time-temperature relationships for many different types of pathogens under

anaerobic conditions. Figure 2.2 illustrates these relationships. The time-temperature relationships illustrated in the graph result in 100% reduction of the pathogens. Strauch recommends the following relationships for complete pathogen inhibition: 7 minutes at 70°C, 30 minutes at 65°C, 2 hours at 60°C, 15 hours at 55°C and 3 days at 50°C. These values cannot be directly applied to aerobic systems but their trend should be similar. Increased temperatures resulted in reduced exposure times required to destroy all of the pathogens.

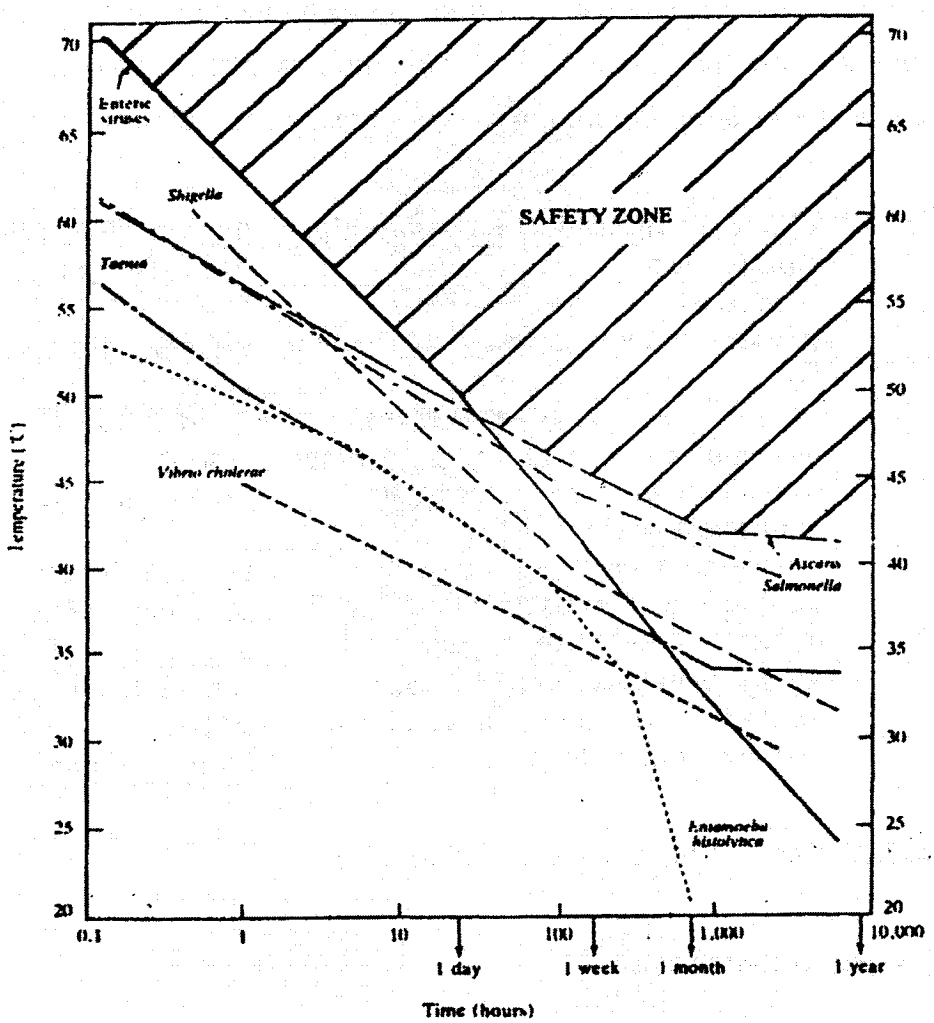

Figure 2.2: Time-temperature relationships that results in complete pathogen destruction (Strauch, 1998)

Freeze/thaw sludge conditioning has been proven as an effective method of pathogen reduction (Sanin et al., 1994). Extremely cold temperatures and freezing prevent microbial growth and may result in pathogen inactivation (Brock, 2000).

2.6.1.2 Retention Time

Low cost sanitation solutions include aerated lagoons and facultative ponds. The primary pathogen reduction mechanisms in these treatment processes are their extended retention times. The pathogens are kept in the system for sufficient time that they are inactivated and can no longer spread infectious diseases. It is possible that similar methodology or thinking may be applied to aerobic digestion. For example, an aerated lagoon (four day retention time) used in combination with a 10 day maturation pond was observed to achieve 93% fecal coliform reduction at 20°C (Fernandes, 2003).

2.6.1.3 pH

Similar to pathogens having optimum temperature ranges, pathogens have pH ranges within which they can optimally grow. Outside these ranges, the environmental conditions inhibit their growth. The most common range for most microorganisms is pH values between 5 and 9 (Brock, 2000).

Farrell et al. (1974) found that lime stabilization of primary sludge with a pH greater than 11.5 resulted in a 3 log reduction of fecal coliform bacteria after only one half hour of contact time. In the same study, the *Salmonella* concentrations were reduced to below detection limits.

Studies have shown that increasing the pH resulted in decreased microbial activity (Surampalli and Banerji, 1993). The same study cautions against increasing the pH in order to reduce pathogens. The concern in utilizing this technique is that when the pH is subsequently reduced, the pathogens that were not inactivated will be able to grow and thrive in the system because the organic matter was not reduced. Study parameters and results were not provided in the article.

While high pH values decreased microbial activity, it is possible that the opposite extreme is true. Nitrification can result in low pH values in the system. If these conditions

were maintained, it may be possible that pathogens would be inhibited.

2.6.1.4 Volatile Fatty Acids

Volatile fatty acids are produced in anaerobic digesters. Their presence and effect on anaerobic digestion has been studied intensively. VFA intermediates include: acetic, propionic, butyric and valeric acids. Fothergill and Mavinic (2000) performed a study on VFA production in thermophilic aerobic digestion of municipal sludges. It was discovered that decreasing aeration and retention times resulted in increased concentrations of VFAs. Increased VFA concentrations translated into increased process performance. Theoretically, increased VFA concentrations may aid in pathogen reduction.

VFA production from primary sludges has been found to be less than that obtained from secondary sludges. Mixing the sludges has been shown to increase the production and accumulation of VFAs (Fothergill and Mavinic, 2000).

In a study by McIntosh and Oleszkiewicz (1997), VFA production efficiency during thermophilic aerobic digestion of primary sludge was maximized to produce a carbon source for denitrification. The purpose of their study was to evaluate the effects of retention time and oxygen delivery on the rate of volatile solids conversion to short chain VFAs. Two oxygenation states were studied: anaerobic-aerated and anoxic. The anaerobic-aerated digesters had an oxygen airflow of 0.025 m^3/m^3•hour. The anoxic digesters received 0.14 m^3/m^3•hour of oxygen. The anaerobic-aerated digesters were evaluated at retention times of 12, 18 and 24 hours, while the anoxic digester was only analyzed at 24 hours. The highest VFA concentration increase occurred in the 18-hour anaerobic-aerated digester. The VFA concentrations increased from 0.047 mg HAc/mg VSS to 0.106 mg HAc/mg VSS. In this study, the VFAs were composed of 60.4% acetic acid, 19.3% propionic acid, 12.2% butyric acid and 8.1% valeric acid.

Chu et al, (1994) analyzed VFA acid production from primary sludge under three aeration conditions. The retention time of the batch process was 6 days. The total solids

concentration of the feed was 1.7%. Solids destruction was approximately 29% for a 294°C•day process. The aerobic condition did not produce any significant amount of VFAs. The microaerobic condition produced the largest amount of VFAs at 950 mg/L. Acetate and propionate made up 81% and 11% of the total VFA composition respectively.

Chu et al. (1996) modelled the metabolism of VFAs in thermophilic aerobic digestion of wastewater sludges. Figure 2.3 illustrates the response of acetate and propionate concentrations with time. Both volatile acid concentrations decreased with time. The concentration decrease was attributed to the presence of an electron acceptor (oxygen). Under anaerobic conditions, the complex organics were oxidized to simple organics. This conversion allowed fermentation of end products that remained in the system, thereby increasing the concentration of the VFAs. Figure 2.4 illustrates the response of butyrate and 2-methylbutyrate concentrations with respect to time. Butyrate concentrations were not measurable under the microaerobic conditions of the experiment. The concentration of 2-methybutyrate followed the same trend as acetate and propionate, its concentration decreased with time because the oxygen in the system acted as an electron acceptor. This conclusion was drawn because in the absence of oxygen, the VFAs concentrations all increased with time.

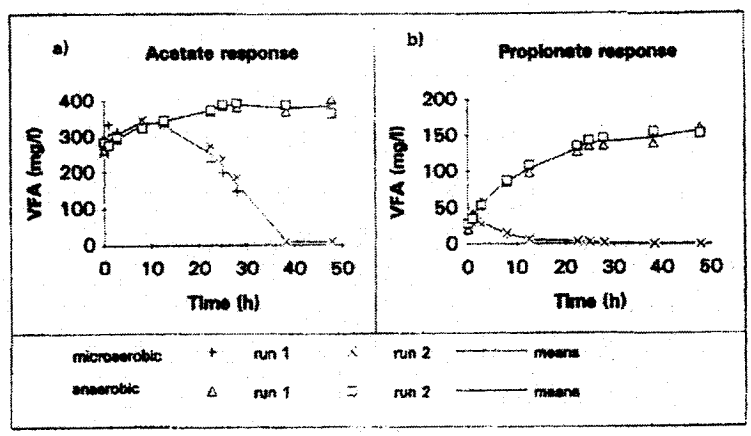

Figure 2.3: Acetate and propionate concentrations versus time

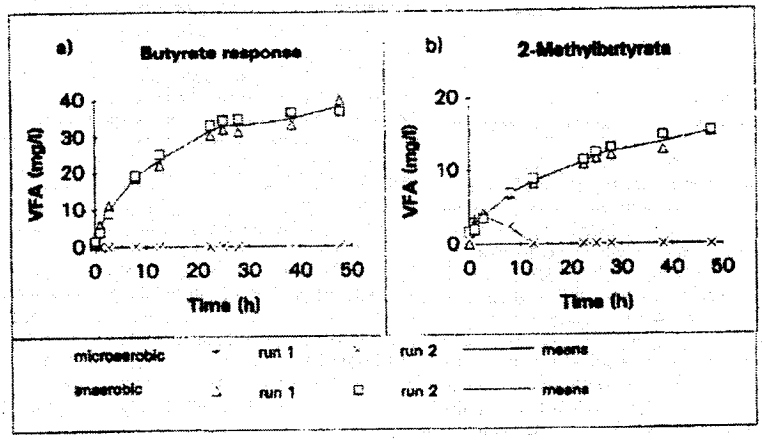

Figure 2.4: Butyrate and 2-methylbutyrate concentrations versus time

Singh et al. (1995) evaluated the effect of different metabolites of anaerobic digestion on pathogen growth. The VFA solutions were prepared by adding the respective sodium salts at 4 g/L to 20 mL of sterile nutrient broth. This solution was then inoculated with an exponentially growing culture. The results are summarized in Table 2.3. The initial counts of *E. coli, S .typhi* and *S. aureus* were 97 x 10^4 cfu/mL, 3 x 10^5 cfu/mL and 4 x 10^5 cfu/mL respectively. The percent of controls listed in Table 2.3 are the percentages of these counts observed after incubation for 72 hours at 20°C. All of the VFAs inhibited pathogen growth except for acetic acid. It may be of interest to see if similar effects could be observed in an aerobic digester.

Table 2.3: Effect of organic acids on the growth of pathogens at 20°C [Mean ± SD, n = 4] (Source: Singh et al., 1995)

Organic Acid	Percent of Control		
	E. coli	*S. typhi*	*S. aureus*
Acetate	92 ± 0.4	93 ± 0.1	97 ± 0.5
Propionate	60 ± 0.2	73 ± 0.3	46 ± 0.1
Butyrate	60 ± 0.5	75 ± 0.1	52 ± 0.4
Valerate	54 ± 0.1	71 ± 0.9	48 ± 0.8
Mixed Acids	40 ± 1.0	67 ± 0.3	49 ± 0.3

2.6.2 Bench Scale Studies

2.6.2.1 Studies Evaluating the Effect of Temperature

Scheuerman et al. (1991) identified temperature as the "single most important factor influencing the rate of virus inactivation". In their study, rectangular tanks with mechanical stirring were employed. Air spargers in the lower corners of the tank provided aeration and additional mixing. The aerobically digested and waste activated sludge was collected from three WWTPs. After the aerobic digesters were stabilized for the operating conditions that were to be examined, an appropriate volume of sludge was inoculated with viruses and added to the digester. Subsequent feed sludges were also seeded with viruses prior to addition to the digester.

Table 2.4 presents the process operating conditions as well as the reductions in poliovirus that were observed in the study. The only statistically different parameter in this study was the temperature. Hence, the increased pathogen reductions were attributed solely to the higher temperatures.

The mean daily change in Table 2.4 was calculated by the following formula:

$$\log daily change = \log_{10}\left[\frac{[\text{Viruses}]_{\text{day i}}}{[\text{Viruses Recovered}]_{\text{day}_{i-1}} + [\text{Viruses Added}]_{\text{day}_{i-1}}}\right]$$

where [Viruses] represent the concentration of viruses

Table 2.4: Effect of temperature on poliovirus (type 1, Lsc) survival in lab-scale digesters (Source: Scheuerman et al., 1991)

Temperature (°C)	Dissolved Oxygen (mg/L)	Total Solids (g/L)	Volatile Solids (g/L)	Hydrogen Ion (10^{-pH})	Mean Daily Change ($\log_{10}$)
28.0	5.8 *	10.4 *	4.8 *	5.0×10^{-6}	-0.77
17.6	5.2 *	7.9 *	5.7 *	1.0×10^{-6} *	-0.50
5.5	5.8 *	19.8	5.2 *	5.0×10^{-7} *	-0.21

Note: * indicates that values in the column are not statistically different (P = 0.05)

Similarly, Whitmore and Robertson (1995) attributed oocyst and cryptosporidium parvum reduction solely to increased temperatures. In this study, 5 L digesters were established using primary sludge and aerated at a rate of 0.5 L/min. Throughout the study, the digesters were fed in a draw-fill mode with primary sludge at a flow of 0.7 L/day. The digesters were spiked with an initial concentration of the target organisms. The study does not indicate if the digesters were fed after the initial spike. An oocyst inactivation of 80% was observed after three days exposure to 35°C digested sludge. The same reduction was observed after five exposure days with distilled water at the same temperature, indicating that temperature was the primary cause of inactivation. Singh et al. (1995) found that not only do increased temperatures result in increased rates of inactivation but they also increase the degree of inactivation.

2.6.2.2 Studies Evaluating the Effect of Temperature and Retention Time

In the same study by Scheuerman et al. (1991) that identified temperature as a factor in pathogen reduction, experimentation was performed to evaluate the impact of retention time. Table 2.5 outlines the data from this study which illustrates that significantly different retention time of 15 and 40 days at statistically equal temperatures (28°C and 27.1°C, respectively) resulted in statistically equal pathogen reductions.

Table 2.5: Effect of detention time on poliovirus (type 1, Lsc) survival in lab-scale digesters (Source: Scheueerman et al., 1991)

Detention Time (Days)	Temperature (°C)	Dissolved Oxygen (mg/L)	Total Solids (g/L)	Volatile Solids (g/L)	Mean Daily Change (log_{10})
15	28.0	5.8	10.4 *	4.8 *	-0.77 *
40	27.1	5.1	9.1 *	5.9 *	-0.98 *

Note: * indicates that values in the column are not statistically different (P = 0.05)

Contrarily, Martin et al. (1990) found that both temperature and retention time had a significant effect on pathogen reduction. Experimentation was carried out at the Trumansburg WWTP in New York. The facility employs conventional activated sludge process without a primary clarifier. Waste activated sludge was thickened using a gravity

thickener before stabilization in an aerobic digester. Their study looked at the fate of several enteric microorganisms.

Conventional and autoheated digesters were included in the bench scale studies. Table 2.6 summarizes the observed log reductions for the different responses. The results indicate that both temperature and residence time played a significant role in pathogen reduction. Increased residence time and mixed liquor temperatures resulted in increased pathogen reductions.

Table 2.6: Summary of observed reductions in the densities of indicator organisms and enteroviruses during autoheated and conventional aerobic digestion (Martin et al., 1990)

Digester	Residence Time (Days)	Mixed Liquor Temp. (°C)	Log_{10} Reduction			
			Total Coliforms	Fecal Coliforms	Fecal Streptococci	Entero-viruses
Autoheated	10	31.1 ± 1.2	0.84	1.04	0.60	1.08
	10	37.5 ± 1.3	0.90	1.10	0.82	2.43
	15	29.0 ± 1.5	1.44	1.32	0.80	1.03
	15	39.8 ± 2.4	2.20	1.58	1.23	> 2.33
	20	38.2 ± 0.9	2.55	2.42	1.60	> 3.16
Conventional	20	8.0 ± 1.6	0.68	0.64	0.33	0.72
	20	14.6 ± 2.1	1.27	1.01	1.07	0.95
	20	17.5 ± 2.3	1.70	1.38	1.17	0.98
	20	21.7 ± 2.0	0.69	1.18	1.00	0.85
	20	23.7 ± 1.1	2.11	1.74	1.42	1.06
	20	25.6 ± 1.8	1.43	0.56	0.72	0.28

Martin et al. (1990) attempted to develop an equation relating pathogen reduction to temperature and residence time. Zero-order and first-order Arrhenius type models were not successful. A simple empirical model was developed instead. The empirical model was able to model total coliforms, fecal coliforms, fecal streptococci and enterovirus log reduction with R-values of 0.85, 0.94, 0.87 and 0.90 respectively. The model uses the log_{10} of the microorganisms concentration as opposed to absolute concentration and the reaction rate coefficient was calculated as:

$$k = \frac{S_e - S_i}{\theta}$$

where k is the empirical reaction rate coefficient [$\log_{10}$ reduction per day]

S_i is the influent microorganism density [$\log_{10}$ CFU or PFU per 100mL]

S_e is the efluent microorganism density [$\log_{10}$ CFU or PFU per 100mL]

θ is the residence time [days]

2.6.3 Full Scale (Field) Studies

The following sections describe the studies that were conducted at seven sites. The results are of interest either because they deal with pathogen reduction or because the site was retrofitted for ATAD.

Fulton *(Source: Surampalli et al., 1993)*

The Fulton wastewater treatment plant treated approximately 1.7 mgd. The plant included a mechanical bar screen and aerated grit chamber. The wastewater then passed through an oxidation ditch that was designed for a retention time of 36 hours (flow of 2.92 mgd). The actual solids retention time of the oxidation ditch was calculated to be approximately 41 days. The clarifier produced sludge with a solids concentration of 1% and the sludge was pumped to a thickener. From the thickener, the sludge was stored in a tank. The retention time of the tank was unknown and the final sludge (3% solids) was land applied.

Table 2.7 presents the densities and reductions of pathogens at various locations throughout the plant. Analysis of pathogen densities at the Fulton wastewater treatment facility indicated that the plant was able to achieve Class B sludge (greater than 2 log reductions) without any additional treatment. The reduction was determined based on wastewater influent density and final sludge density. The success was attributed to the large sludge age of the oxidation ditch.

Table 2.7: Densities and Reductions of Fecal Coliform (FC), Fecal Streptococci (FS) and *Salmonella* (S) during Plant Samplings

Parameter	Influent (log_{10} numbers per gram VSS)	Effluent (log_{10} numbers per gram VSS)	Final Sludge (log_{10} numbers per gram VSS)	Log Reduction
FC	8.76	7.46	4.55	4.21
FS	6.69	6.42	4.85	1.84
S	6.98	6.07	4.98	2.0

Sludge from the Fulton facility was studied in the lab and analyzed for further reduction capabilities. The aerobic digester was run for 42 days at a temperature of 20°C while the stored sludge had the same retention time and temperature but was not aerated. Table 2.8 presents the reduction of pathogen densities that were achieved in the lab digestion. As expected, pathogen reduction was much greater in the aerobically digested sludge than the stored sludge.

Table 2.8: Reductions of Fecal Coliform (FC), Fecal Streptococci (FS) and *Salmonella* (S) during Laboratory Aeration and Storage

	Parameter	Aerobic Digestion (log_{10} density reductions)	Storage (log_{10} density reductions)
Aeration Tank Sludge	FC	2.24	1.75
	FS	3.48	1.05
	S	1.39	1.06
Storage Tank Sludge	FC	1.86	1.30
	FS	1.01	0.70
	S	1.23	1.04

This study illustrates that smaller facilities are able to achieve required pathogen reductions with simple technologies. It also illustrates the importance of pilot studies to determine what processes are required to achieve the desired reductions.

Osage Beach *(Source: Surampalli et al., 1993)*

The Osage Beach facility consisted of an aeration tank followed by a secondary clarifier. The plant was designed for a flow of 2.4 mgd and the influent flow into the facility was estimated at 0.7 mgd in the winter and 1.4 mgd in the summer. The aeration tank was designed to have a retention time of 18 hours. The mixed liquor concentration in the aeration tank was measured to be 3,500 mg/L and the volatile solids fraction was determined to be 84%. The sludge age in the aeration tank was calculated as 62 days. The sludge from the secondary clarifier was stored in a tank where it was decanted and some degree of sludge thickening occurred.

The study was performed in October. Results from the Osage Beach wastewater treatment plant were similar to those of the Fulton facility. Table 2.9 reports the densities of fecal coliform, fecal streptococci and *Salmonella* in the influent, effluent and final sludge. The log reductions indicate that without additional treatment, the plant was able to achieve pathogen reductions sufficiently large to meet Class B restrictions. Table 2.10 provides a summary of the reductions of fecal coliform, fecal streptococci and *Salmonella* after additional treatment in the lab. Samples were aerobically digested for 42 days at 20°C and stored for the same length of time at the same temperature. Aerobic digestion of the sludge resulted in greater pathogen reduction than storage.

Table 2.9: Densities and Reductions of Fecal Coliform (FC), Fecal Streptococci (FS) and *Salmonella* (S) during Plant Samplings

Parameter	Influent (log_{10} numbers per gram VSS)	Effluent (log_{10} numbers per gram VSS)	Final Sludge (log_{10} numbers per gram VSS)	Log Reduction
FC	8.3	8.21	4.74	3.56
FS	7.21	7.07	4.48	2.73
S	7.4	7.06	2.7	4.7

Table 2.10: Reductions of Fecal Coliform (FC), Fecal Streptococci (FS) and *Salmonella* (S) during Laboratory Aeration and Storage

	Parameter	Aerobic Digestion (log_{10} density reductions)	Storage (log_{10} density reductions)
Aeration Tank Sludge	FC	1.75	1.12
	FS	1.05	1.00
	S	2.04	1.16
Storage Tank Sludge	FC	1.63	1.25
	FS	1.40	1.31
	S	1.42	1.22

Salmon Arm, B.C. *(Source: Kelly, 1990)*

The plant treated the wastewater from the District of Salmon Arm (population 6,000) with an average flow of 2,300 m^3/day. Sludge production at the facility was estimated at 600 kg/day. This facility underwent a retrofit to install an ATAD process. The original aerobic digester (243 m^3) was divided into three unequally sized compartments. In the retrofit, the entire tank was insulated and the first compartment (60 m^3) was insulated from the remaining two compartments. Only two digesters were in use at the time of the experiment and the average retention time was 6.1 days. Total volatile solids loading in the reactor was 20 kg/m^3•day. The airflow to the reactor was 0.5-1.5 m^3/m^3•hour and the power density was 120-200 kW/m^3. The reactors were aerated with a Turborator (a BC developed aerator-mixer).

The first compartment was able to achieve and maintain operating temperatures of 40°C, 45°C, and 48°C for three different operating conditions. The second compartment could easily maintain temperatures above 55°C. The first compartment appeared to produce and accumulate VFAs, reaching concentrations of 10,000 mg/L. It should be noted that these high concentrations of VFAs are usually only observed in the presence of microaerobic

environments where the oxygen supply is not sufficient to satisfy all of the oxygen demand.

Pathogen reduction was not measured continuously throughout the study. Pathogen reduction at the Salmon Arm facility was found to be good. Coliforms were generally reduced to less than 2 MPN/gram. *Salmonella* reduction was not measurable because the incoming concentrations had less than 2 MPN/10 grams. *Streptococci* reduction was not quantified but was deemed to be adequate in the report. Overall, except during start-up or short-term disruptions due to temperature decrease (low HRTs), the facility was able to achieve indicator pathogen concentrations of less than 100 MPN per wet gram.

Plum Creek, Colorado *(Source: Daigger and Bailey, 2000)*

The Plum Creek wastewater treatment facility originally operated a single storage tank; however, in this study, the storage tank was converted to a staged digester (Volume = 142.3 m^3). A diffused aeration system with a capacity of 40 m^3/min per 1,000 m^3 of digester volume was installed (medium bubble). After changes were made to the plant, low VS reductions were observed and the facility received many odour complaints. The solids concentration was reduced (from 5% to 3.5-4%) and anoxic stages were introduced into the process by terminating air supply and allowing denitrification to occur. These modifications improved the process by decreasing odours and increasing solids reduction. After the modifications were made at the facility, a 38% VS reduction was achieved during warmer months (Aug.- Oct.) with solids retention times less than 20 days. Through cold months, the facility observed poorer performance with a VS reduction around 32%.

Paris, Illinois *(Source: Daigger and Bailey, 2000)*

Originally the Paris plant employed two circular anaerobic digesters; however, these were converted to aerobic digesters for the study. A fine-bubble diffused aeration system was installed with a capacity of 0.05 $m^3/m^3 \cdot min$ and the two digesters were operated in series. The digesters were fed a mixture of primary and waste-activated sludge. The feed sludge was thickened to approximately 8% solids with a combination belt filter press/gravity

belt thickener. Thickened sludge was mixed with unthickened sludge to produce a solids concentration of approximately 5% prior to entering the digesters.

The facility observed nitrification in the digester and consequently allowed for denitrification by turning off the aeration system for 4 to 6 hours each day. Overall, a 60% VS reduction was observed with a SRT of 34 days. The digester was found to be naturally auto-heated. The temperatures were approximately 10-15°C above ambient temperature; this was attributed to tank insulation, heat from air compressors and heat from internal processes (Enviroquip, 1997). Through the study period, fecal coliform densities of approximately 1,000 organisms/g TS were observed indicating excellent pathogen reduction. SOUR values of less than 0.5 mg O_2/g VSS • hour were measured which indicated a stable sludge.

Clyde, Ohio *(Source: Daigger and Bailey, 2000)*

The original operation of the Clyde plant included a gravity thickener, followed by two anaerobic digesters, a gravity belt thickener and two square holding tanks that were connected in series. Operating problems arose throughout the study at this facility which resulted in multiple changes in the plant configuration and operating conditions. There were three different stages of this study and they will be referred to as phases 1-3. In the first phase, the digesters were converted to aerobic digesters with the installation of a diffused aeration system (capacity = 0.03 m^3/m^3•min). Aeration equipment was also installed in the storage tanks. The SRT in the two digesters was roughly 27 days and resulted in a VS reduction of approximately 20%. During this initial phase, it was observed that insufficient air supply to maintain aerobic conditions resulted in septic conditions and odours. As a solution, the storage tanks were converted to digesters (phase 2). The original two digesters were operated in parallel while the two new digesters were operated in series. The modifications increased the SRT by 20 days. With this phase configuration and operating conditions, class B sludge requirements were met. However, due to low DO concentrations in the original digesters, the airflow to the original two digesters was increased to 0.04 Nm^3/m^3•min and they were operated in series (phase 3). The first digester was fed with excess oxygen to ensure nitrification and the air supply to the second digester was turned off

intermittedly to allow denitrification. This resulted in a stable pH throughout the remainder of the process. The final configuration was able to achieve SOUR values less than 1.5 mg O_2/g VSS • hour. The process was found to meet US EPA (Class B) pathogen requirements.

Los Lunas, New Mexico *(Source: Daigger and Bailey, 2000)*

This facility was designed with four aerobic digesters operated in series and in the study, these digesters were covered in order to ensure a minimum temperature of 15°C. A gravity belt thickener increased the solids concentration to 8% prior to digestion. The process was designed for the first three basins to have SRTs of 60 days and produce an effluent solids concentration of 5%. The SRT of the fourth basin was allowed to fluctuate in order to accommodate storage.

Most of the solids destruction occurred in the first basin where a minimum SRT of 15 days was maintained. The DO concentration in this basin was usually less than 1 mg/L. The DO in the remaining tanks was always greater than 1 mg/L. The digester temperatures were observed to be between 27°C and 33°C and the SRT was observed as low as 45 days. With the elevated temperatures, the facility was able to meet US EPA (Class B) pathogen requirements. Figure 2.5 illustrates the digester temperature and volatile solids reduction observed at the Los Lunas facility. The volatile solids reduction varies by more than 30 percent while the temperature is approximately constant at 30°C.

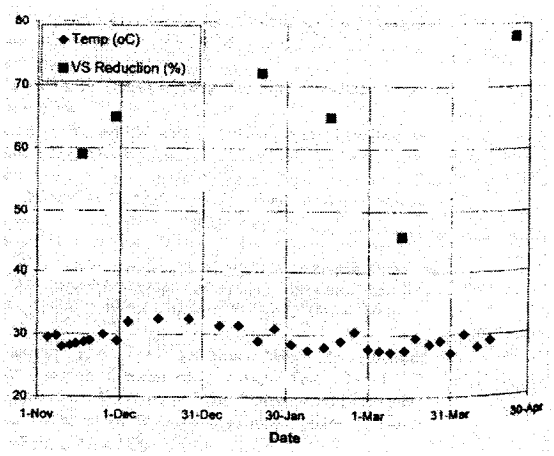

Figure 2.5: Digester temperature and volatile solids reduction efficiency data

Summary of Full-Scale Studies

At the Fulton and Osage Beach facilities, the traditional wastewater treatment without digestion was able to achieve greater than 2 log reductions. Subsequent laboratory treatment of the sludge resulted in even greater pathogen reductions. The Salmon Arm facility received a retrofit in order to install an autothermal thermophilic aerobic digestion process. The insulation of the tanks and the addition of an efficient aerator increased digester temperatures and resulted in significant pathogen reductions. Overall, except during start-up or short-term disruptions due to temperature decrease (low HRTs), the facility was able to achieve indicator pathogen concentrations of less than 100 MPN per wet gram. No data was provided to measure the increase from the original plant.

The conversion of the single storage tank to a staged digester at the Plum Creek facility along with modified operating conditions such as aerobic/anoxic cycling resulted in volatile solids reductions of approximately 32-38 percent depending on the season. Though the facility was designed to meet Class B specifications, no pathogen reduction values have been published.

At the Paris, Illinois WWTP, the conversion of two anaerobic digesters to aerobic digesters resulted in a volatile solids reduction of 60% with an SRT of 34 days. At this facility, the air supply was turned off daily to allow denitrification to occur. The combination of tank insulation, heat from the air compressors and internally generated heat resulted in digester temperatures 10-15°C above ambient temperature. The pathogen reduction was determined to be excellent with fecal coliform densities of approximately 1,000 organisms/g TS.

Multiple adjustments to the design and operating parameters of the Clyde, Ohio facility resulted in the final conversion of two anaerobic and two storage tanks to aerobic digesters, all operated in series. In the end, the facility was able to meet pathogen requirements and achieve SOUR values less than 1.5 mg O_2/g VSS • hour, indicating a stable sludge.

At the Los Lunas facility, four aerobic digesters that were already operating in series

were covered in order to ensure a minimum temperature of 15°C. With the elevated temperatures, the facility was able to meet pathogen requirements. The volatile solids reduction is approximately constant year round at 30%.

2.7 Fate of Anthropogenic Chemicals in Aerobic Digestion

Concerns regarding the fate of anthropogenic chemicals after treatment at WWTPs have generally concentrated on the wastewater side. Relatively few studies were found that addressed the fate of anthropogenic chemicals in aerobic sludge digestion. The following sections address studies that examined the fate of 4-nonylphenol, triclosan, polychlorinated dibenzo-p-dioxins and dibenzofurans in aerobic digestion.

4-Nonylphenol

Some detergents contain nonylphenol ethoxylates which break down to form 4-nonylphenol. 4-nonylphenol (4-NP) is a persistent, lipophilic compound that tends to bioaccumulate and is also a suspected endocrine disrupter. In an experiment by Banat et al. (2000), batch aerobic digesters were employed to digest waste activated sludge. The digesters were dosed with 50 and 100 mg/L of 4-NP respectively. These are much higher concentrations than those typical in a WWTP. The results indicated that increasing the aeration time decreased the concentration of 4-NP. Both of the digesters were able to achieve 66% reduction of 4-NP after approximately 250 hours. The presence of 4-NP affected the rate of sludge oxidation and reduced the efficiency of COD removal. For increased 4-NP concentrations, the COD removal decreased marginally (approximately 8% reduction between COD removal of the blank sample and 100 mg/L 4-NP dosed sample) while nitrogen and phosphorous concentrations in the sludge decreased slightly as well.

Triclosan

Triclosan (TCS) is commonly present in personal care products as it is an antimicrobial agent. The presence of TCS in these products has warranted many studies on its effect on humans. Under no circumstances is TCS harmful to humans. Aerobic digestion achieves high TCS removal rates. TCS is hydrophobic and when it is brought into contact with a hypochlorite solution, it degrades into higher chlorinated closans. Interest in treating TCS is a result of concern regarding these higher chlorinated closans. A study by McAvoy et al. (2002) found that activated sludge processes are able to achieve approximately 96% removal of TCS.

Aerobic and anaerobic digestion of sludge spiked with TCS was compared. TCS appears to be more readily biodegradable under aerobic conditions. Most of the plants studied dewatered and incinerated their sludge resulting in little data for analysis. However, waste activated sludge from the West Union WWTP was treated in an aerobic digester. A study at West Union evaluated primary removal and overall removal. Primary removal accounted for 48.1% while overall removal was approximated at 82.5%. There was no account for the differences in overall removal between the two studies. This could be an indication of the variability of TCS removal in a WWTP.

The West Union treatment facility was found to achieve the greatest reduction of TCS concentration in primary sludge. A TCS concentration of 12.2 μg/g was reduced to 1.5 μg/g. Concentrations were reduced to as little as 0.53 μg/g at the same facility. Unfortunately, there were no specifications provided for the aerobic digester at this facility.

Polychlorinated dibenzo-p-dioxins and dibenzofurans

Organochlorine compounds such as polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) are of concern due to their potential persistence in soils. Disse et al. (1995) studied the effect of aerobic digestion on sludges contaminated with PCDDs and PCDFs. In a bench scale study, batch reactors (3L) were aerated at a rate of 10 mL/min and

operated at 36°C to treat raw sludge. Two sludges were digested aerobically: sludge B and sludge C. Sludge B was a municipal sludge with middle-class industry and there was no heavy industry contributing to the sludge. Sludge C was also municipal sludge but included effluent from a metal-working industry. The impact of aerobic digestion on the homologous groups present in the two sludge samples is illustrated in Figure 2.6. Aerobic digestion resulted in significant reductions of PCDD/F congeners. The aerobic digester was observed to decrease the concentration of all of the homologous groups.

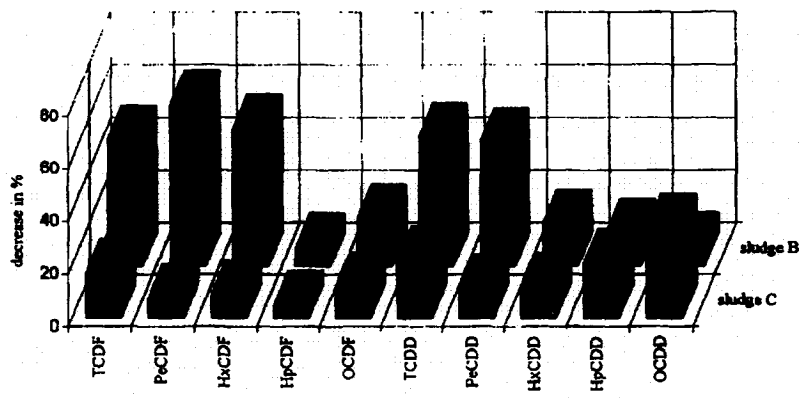

Figure 2.6: Percentage decrease of different PCDD/F homologues in aerobic digestion

Figures 2.7 and 2.8 illustrate the effect of aerobic digestion on the different PCDD/F congeners in sludges B and C respectively. Treatment of both sludges resulted in significant reductions. Aerobic digestion was found to degrade congeners by more than 40% and hence was shown to significantly degrade PCDD/F.

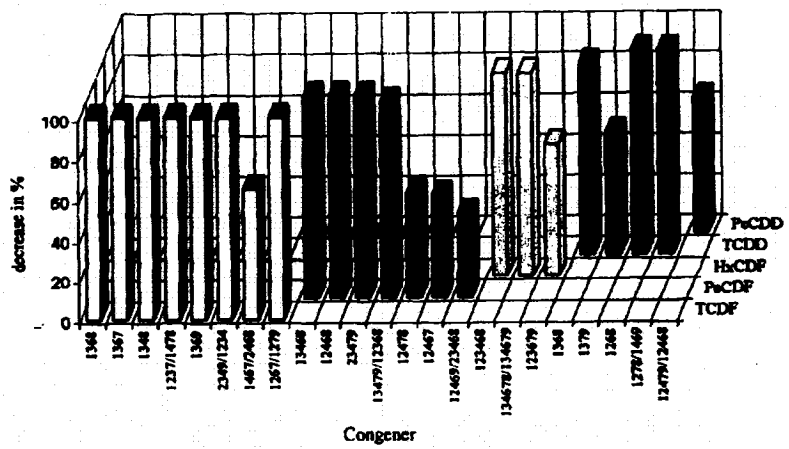

Figure 2.7: Percentage decrease of different PCDD/F congeners in aerobic digestion of sludge B

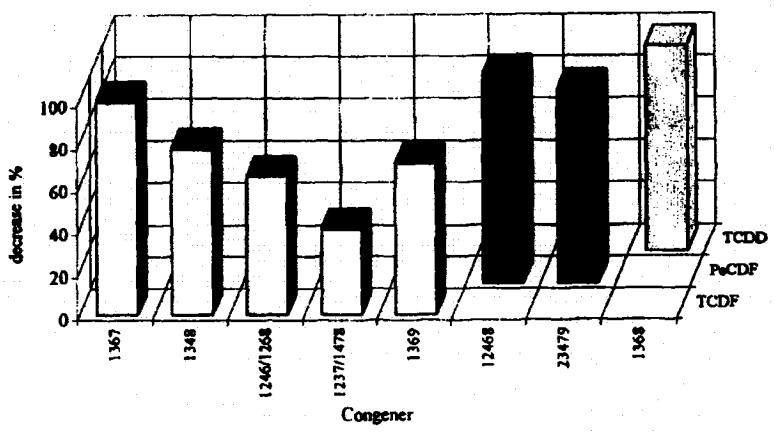

Figure 2.8: Percentage decrease of different PCDD/F congeners in aerobic digestion of sludge C

Summary

The fate of anthropogenic chemicals during aerobic digestion has not been studied extensively. Sludges contaminated with concentrations of 4-nonylphenol higher than those traditionally found in WWTP were effectively reduced by approximately 66%. Aerobic digestion was found to decrease triclosan concentrations from 12.2 μg/g in primary sludge to 1.5 μg/g. The operating parameters of the digester were not provided. Aerobic digestion was observed to achieve significant reductions of all homologues and congeners of polychlorinated dibenzo-p-dioxins and dibenzofurans.

CHAPTER 3
MATERIALS AND METHODS

This chapter outlines the design and construction materials of the pre-treatment columns and digesters and outlines the experimental plan. The origin of the feed sludge and the method used for its collection is covered within this chapter as well as the methodologies of measuring all of the parameters analyzed throughout this experimental work.

3.1 Experimental Design and Setup

Section 3.1 presents the design of the pre-treatment columns and the lab-scale digesters as well as the operating strategy used during the three phases of experimental work.

3.1.1 Pre-treatment Column Design

In order to ensure maximum oxygen transfer, the pre-treatment reactor was shaped as a column and fine bubble airstones were used. The fine bubbles and increased depth of a reactor increases oxygen transfer due to the increased surface area of the bubbles and the longer contact time for mass transfer. The volume was chosen to minimize the sludge requirements for the project.

The pre-treatment reactors were lab-scale, semi-batch and completely mixed. Figure 3.1 illustrates the design of the pre-treatment columns. Each day, the required volume based on the retention time was drawn from the column through the outlet port and then the feed sludge was added to the column through the feed port at the top of the reactor. In order to ensure that the columns were completely mixed, specifically in the low aeration rate columns, additional mixing was implemented. Mechanical mixing of all of the columns ensured that the columns receiving minimal oxygen would be completely mixed as well as consistency across the board.

The columns were supplied with lab air that was pumped into the system using aquarium pumps (Tetratec Deep water, DW96-2). The air was humidified before entering the columns by passing through a 20 L container which contained tap water. The use of lab air ensured that the air was approximately room temperature as opposed to the bench air whose temperature could fluctuate with the season. The humidified air ensured that water was not stripped from the columns over time and that no energy was lost to the evaporation of water. These considerations were primarily important during phase 1 which was operated at room temperature but were carried through the entire experimental procedure.

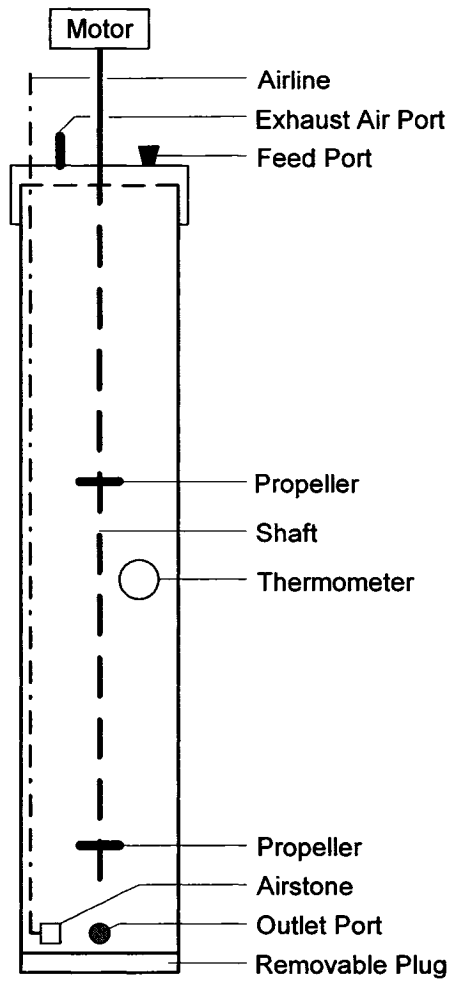

Figure 3.1: Sketch of the components of the pre-treatment column design

The mixing drive motors were Tallboys (mixer model 134-2), two 7.6 cm (3 inches) propellers were used to ensure adequate mixing. One was positioned 3.2 cm (2 inches) from the bottom of the column while the second was approximately 57.2 cm (22.5 inches) from

the bottom which was approximately 3.2 cm (2 inches) off the middle of the column. The shaft was 0.8 cm (5/16 inch) in diameter and 106.7 cm (42 inch) long and was made of stainless steel. A wooden stand with a small hole was installed in the plug to ensure that the shaft was centered within the column.

The removable bottom plug was a threaded cleanout plug that allowed for the replacement of the airstones without dismantling the entire column. It also supported thorough cleaning of the columns when required.

The lid and exhaust air port were included due to concerns of odour issues based on ATAD operations. The lid forced the off-gas to pass through flexible tubing and exhausted to a fume hood located in the lab. A SDR35 PVC 10.2 cm (4 inch) cap was used as the lid which ensured a tight seal at the top of the column. Four holes were drilled into the cap, the feed port was capped with a #4 rubber stopper, the center hole allowed the shaft to pass through, the off-gas port contained a 0.6 cm (¼ inch) barbed fitting to which the flexible tubing could be attached. The fourth hole allowed the airline to pass through.

As previously mentioned, the columns were supplied with humidified lab air. Penn-Plax check-valve air-filters protected the pumps and filtered oil residue from the air. The tubing was standard aquarium tubing and was secured to the interior side of the column with four 1.3 cm (½ inch) diameter, 2.5 cm (1 inch) long sections of PVC pipe to reduce twisting around the propellers. The fine bubble diffusers were Penn-Plax Aqua-Mist 1 cm airstones. Rotometers were employed to regulate the air supply and were changed during the course of the experiment depending on the desired air flowrate. All of the flowmeters were tested with a tipping bucket to use to ensure their accuracy.

A thermometer was installed at the approximate centre of the column to allow for temperature measurements to be made during phase 1 and to ensure the operation of the heating systems during phases 2 and 3. The heating system consisted of a Traceable® temperature controller which included a temperature probe. The columns were wrapped in 1.8 m (6 feet) of TRM North America variable wattage heat tracing and 2-3 layers of

Reflectix insulation (reflects 97% of radiant energy).

The pre-treatment column was constructed of SDR35 sewer grade PVC piping. During phase 1, the columns were approximately 91.4 cm (36 inches) long. This depth allowed for 19 cm (7.5 inches) of headspace in case of foaming. During phase 1, foaming was not an issue. In order to better monitor the volume inside the columns; the depth was reduced to 83.8 cm (33 inches) for phases 2 and 3. The modifications ensured a proper working volume and continued to allow approximately 6 cm of headspace.

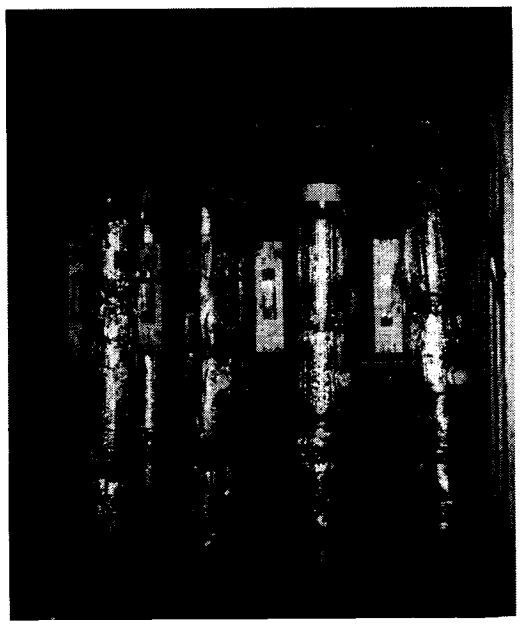

Figure 3.2: Four pre-treatment columns setup and operating in the laboratory

Figure 3.2 illustrates the setup of four pre-treatment columns in the lab. It is apparent from the photo that the columns were mounted on a frame which allowed for many of the additional apparatus to also be mounted on the frame such as the mixers, flowmeters, temperature controllers, etc.

3.1.2 Digester Design

The digesters were also operated as lab-scale, semi-batch, completely mixed systems. A retention time of 40 days was chosen based on the average room temperature of the lab (Metcalf and Eddy, 2003). The 40 day retention time dictated a 40 L volume to ensure adequate sludge to perform all of the sample analysis. A 1 L daily digester feed volume could also be satisfied based on the 1.5 L exchange that occurred in the pre-treatment step of process trains 3 and 4 during phase 3 with 500 mL remaining for pre-treatment parameter analysis.

Figure 3.3 illustrates the design of the lab-scale digesters. Digester effluent was captured from the exit port located at the bottom of the digester; digester feeding was performed by addition to the top after removing the lid of the reactors. The lid was made of a 0.3 cm (1/8 inch) thick PVC sheet cut into a 32.3 cm diameter circle and fitted with guides to hold the lid in place. To curb possible odour issues, the exhaust gas was forced through a 0.6cm (¼ inch) barbed fitting in the lid which connected to 1.3 cm (½ inch) plastic tubing which carried the air to a lab fume hood. Weather stripping was installed around the rim of the digesters to maximize the seal between the lid and the digester while still allowing easy removal for daily feeding.

The air supplied to the digesters was compressed bench air and was filtered through a 1 m long, 10 cm diameter tube containing fiberglass to remove any residual oil from the air stream. Sufficient air was supplied to the digesters to ensure that the dissolved oxygen concentration was close to saturation and that the contents of the digesters were completely mixed. The flowrate of the air supply was not measured. The digesters were connected so as to ensure equal air supply to all of the digesters.

The digester was constructed of 30.5 cm (12 inch) SDR35 sewer grade PVC pipe. The round shape of the digesters minimized dead zones. The exterior height of the digesters was 74 cm and the depth above the diffuser was 64 cm which allowed for approximately 8 cm of headspace. Fine bubble aeration was used in the digester to maximize oxygen transfer.

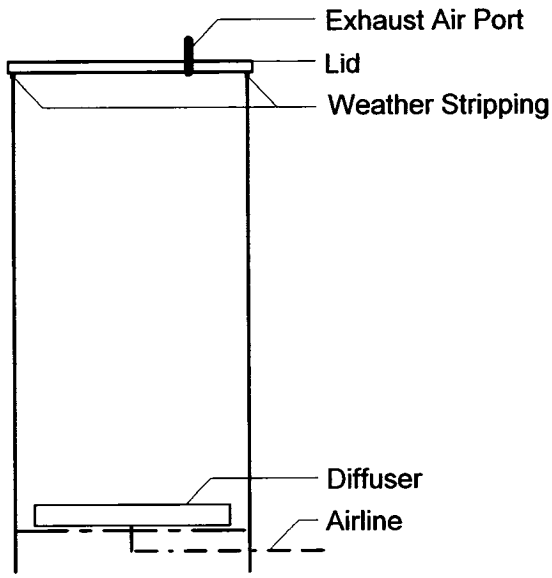

Figure 3.3: Sketch of the components of the lab-scale digester design

The diffuser used was a 22.9 cm (9 inch) diameter fine bubble EPDM membrane diffuser which allowed for a high capacity and was resistant to plugging. The bottom of the digester was almost entirely covered by the diffuser resulting in complete mixing with virtually no dead zones. Figure 3.4 illustrates the setup of a digester in the lab. The outlet port, lid and off-gas capture system are all apparent in the photo.

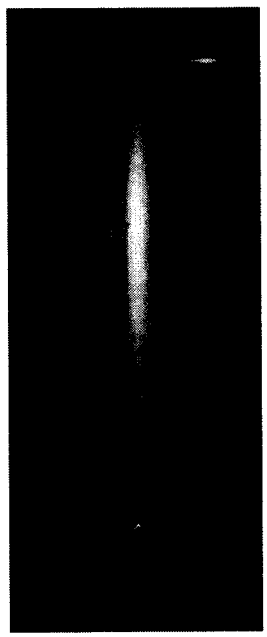

Figure 3.4: One digester setup and operating in the laboratory

3.1.3 Operating Strategy

Section 3.1.3 outlines the operating strategy used in each of the steps within the process trains during the three phases of the experimental work. Each of the subsections will cover one of the phases, outlining the steps of that phase (pre-treatment and digestion) as well as the design parameters applied at each of the steps.

3.1.3.1 Phase 1

Phase 1 was setup to evaluate the effect of different aeration rates on the operating parameters and process performance of the pre-treatment columns. The four columns had a retention time of 2 days and were operated at room temperature over the 104 days which comprised phase 1. The temperature of the columns was measured during this phase to determine if any heat that was being released by the microbial reactions would result in a change in the temperature of the reactors.

Figure 3.5 illustrates the setup of phase 1 and the design parameters implemented. The aeration rates under evaluation provided a broad range of ORP values ranging from a highly aerated environment to a micro-aerobic, highly reducing environment. Appendix A includes the batch test which was performed to determine the appropriate range of air flowrates. It was hypothesized based on the results of the literature review that the low aeration rates and their subsequent micro-aerobic environments would promote the accumulation of volatile fatty acids which would in turn inhibit pathogens.

3.1.3.2 Phase 2

Phase 2 of the experimental work involved evaluating the effect of temperature and aeration rates on the operation of the pre-treatment columns. Figure 3.6 illustrates the setup of this phase and the design parameters implemented to carry out the evaluations of the effect of temperature and aeration rates. The aeration rates are the same as were established using the batch test during phase 1. Phase 2 was accomplished in the least amount of time of all

three phases, lasting only 71 days.

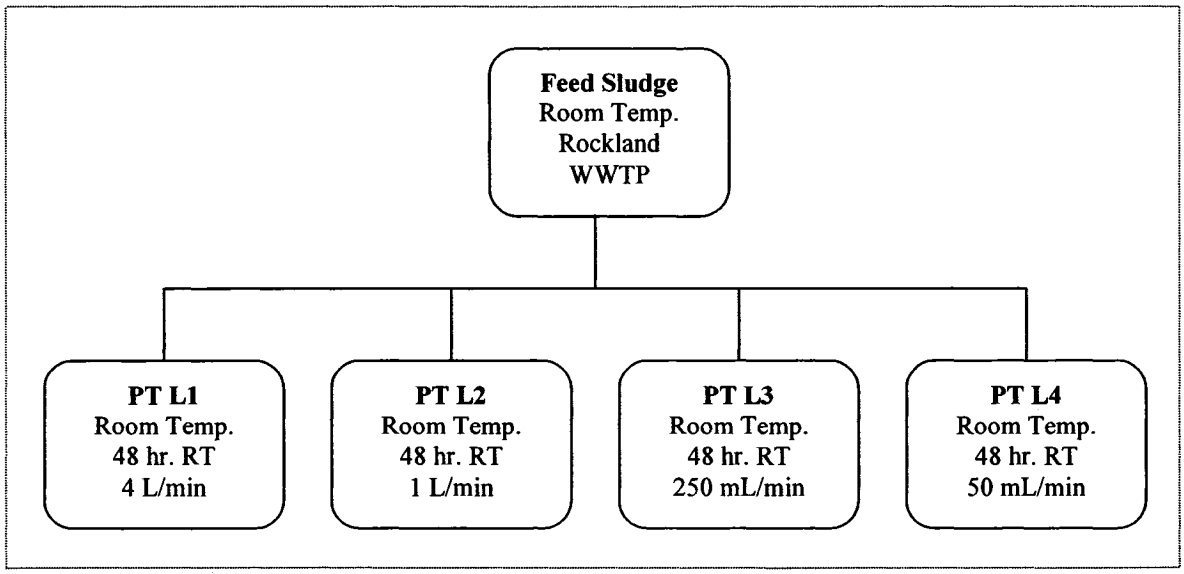

Figure 3.5: Design parameters of the four pre-treatment columns during phase 1

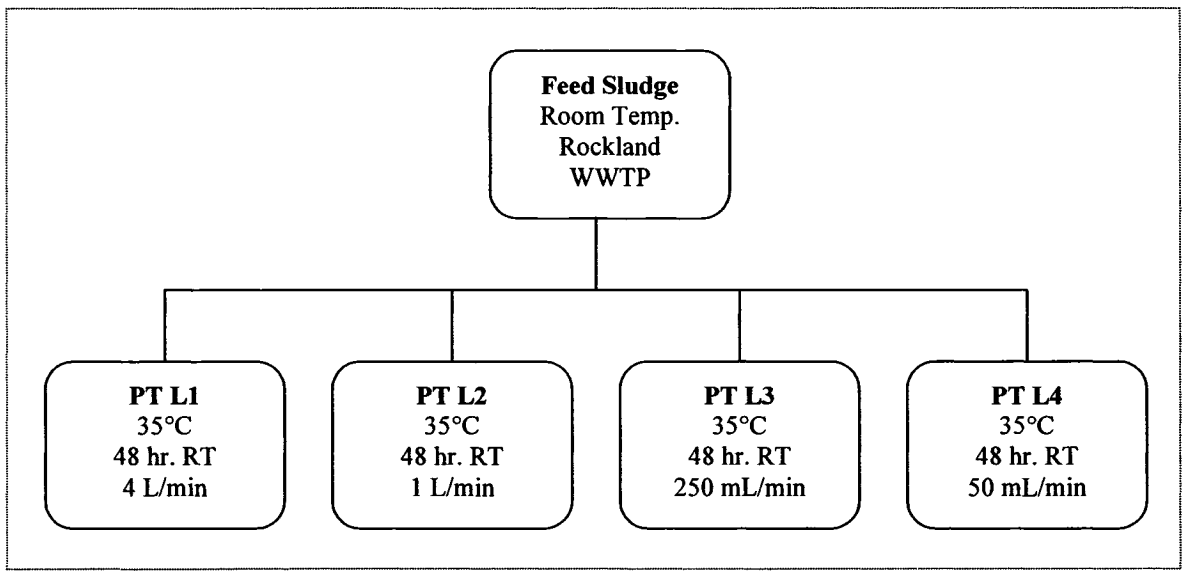

Figure 3.6: Design parameters of the four pre-treatment columns during phase 2

3.1.3.3 Phase 3

Phase 3 involved not only the pre-treatment step but also the subsequent digestion step which completed the process trains. Four pre-treatment columns were analyzed in this

phase. They were setup in a 2-way factorial design to evaluate the effect of aeration rate and retention time. This phase continued the evaluation of two air flowrates from phases 1 and 2, examining each of the aeration rates at a retention time of 2 and 4 days. Figure 3.7 presents the five process trains analyzed and the design parameters for each step within the process trains.

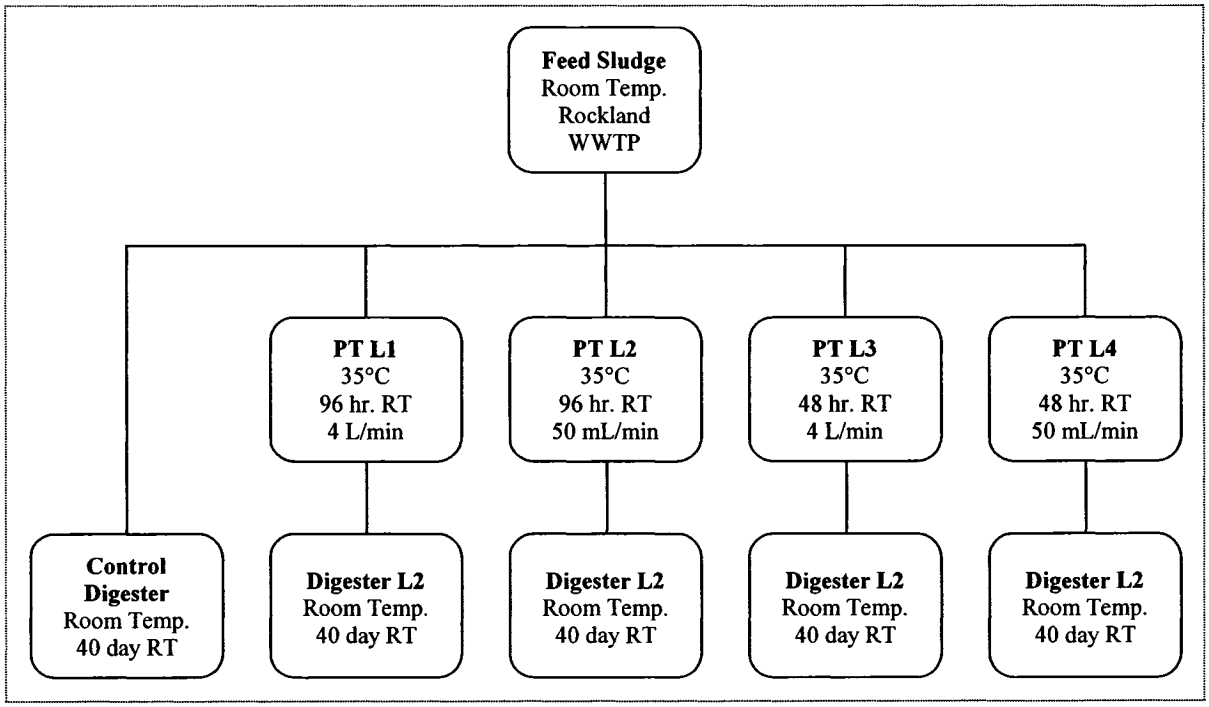

Figure 3.7: Design parameters of the four pre-treatment columns and five digesters during phase 3

The control digester did not involve any pre-treatment and was fed with 1 L of feed sludge daily, beginning on June 16, 2005 and continuing until the digester had reached its volume of 40 L. After that point, 1 L of sludge was exchanged daily. The control digester was included in order to establish a basis for comparing the effects of pre-treatment on aerobic digestion. The remaining four process trains included pre-treatment. The digesters of these process trains were filled using a similar manner as the control digester. The only influent the digesters received was from the corresponding pre-treatment column. Therefore, any column effluent not required for analysis was added daily to the digester until it reached the capacity of 40 L. From that point on, only 1 L of sludge was exchanged daily. All five digesters were operated in the same fashion, only the design parameters of the pre-treatment columns varied between process trains. This phase lasted 143 days due to the extended time required for the digesters to achieve steady state and the extensive sampling required.

3.2 Source of Feed Sludge

The sludge employed for this study was obtained from the Rockland WWTP (located approximately 40 km north-east of Ottawa). The plant treats the municipal wastewater of the residents of the city and there is minimal to no industrial waste. The plant employs three sequencing batch reactors (SBRs), operated in parallel. The SBRs were on eight hour cycle which was comprised of four sections: static fill, aerobic mix, settle and decant.

Influent wastewater to the Rockland WWTP first passes through a screen to remove large debris followed by a cyclone degritter. Alum is added to support coagulation and phosphorus removal. The wastewater then enters one of the three SBRs during the 2.67 hour fill cycle. After the static fill portion of the cycle, the contents of the SBR are mixed by coarse aeration and allowed to react for 3.33 hours. The eight hour cycle of the SBR is then completed with one hour each of settling and decanting.

3.3 Sampling Methodology

The mixed solids concentrations within the SBRs at the Rockland WWTP were consistently lower than 0.5% and hence it was necessary to thicken the sludge prior to digestion in this study. The plant operators filled two or three 200 L barrels during the wasting of an SBR. The sludge in the barrels was allowed to settle for a few hours. After settling, the supernatant was pumped from the barrels using a submersible pump. The thickened wastewater from the bottom of the barrels was transferred to 20 L buckets which were transported to the lab and stored in a 4°C refrigerator for up to one week prior to use as the feed sludge of this experiment.

3.4 Analytical Procedures

The analysis performed during experimental work has been grouped into operating parameters and process performance parameters. Operating parameters provided information on the environmental conditions within the reactors while process performance

parameters described the treatment efficiency of the reactors. Operating parameters that were analyzed for this work include: dissolved oxygen concentrations, oxidation-reduction potentials, pH, alkalinity, total volatile fatty acid concentrations, individual volatile fatty acid concentrations and soluble chemical oxygen demand. The procedures involved in sampling these parameters are outlined in the following subsections. Process performance evaluations were performed on the nitrogen series (aqueous ammonia, nitrite-nitrogen, nitrate-nitrogen and total kjeldahl nitrogen), solids destruction (total and volatile solids), settling and microbial destruction (fecal coliforms, *E. coli*, *Salmonella* spp. and *Clostridium perfringens*). The procedures followed to measure these concentrations and evaluate the performance of the reactors are also described in the following subsections.

3.4.1 Dissolved Oxygen

The extremely low dissolved oxygen (DO) concentrations of some of the pre-treatment reactors dictated that the DO be measured within the actual columns and digesters. This ensured a value that best represented the conditions within the reactor. A Martek Instruments Incorporated Mark 21 DO probe was used for these measurements due to its ability to measure in the ppb range. The probe was placed in the column or reactor and left to stabilize. The time required for stabilization varied depending on the concentration and temperature within the column/digester. The instrument measured the temperature and was calibrated to adjust for changes in temperature. After stabilization, the DO concentration was recorded and the probe was subsequently rinsed thoroughly with distilled water (Barnstead Fistreem II GlassStill). The process was repeated until three measurements had been made.

3.4.2 Oxidation-Reduction Potential

The oxidation-reduction potentials (ORPs) of the pre-treatment columns and digesters were also measured in situ. Three values were recorded (probe was rinsed with distilled water between measurements). The ORP was measured by a combination electrode that was connected to a portable Orion model 290A meter. The probe and meter were calibrated

approximately every two weeks with YSI 3682 Zobell solution. When not in use, the probe was stored in pH electrode storage solution.

3.4.3 pH

The pH within the pre-treatment columns and digesters was determined by inserting a calibrated pH probe into the column/digester. Due to the stable nature of the pH, it did not vary with time in the reactor; therefore, only one measurement was taken. The probe was connected to a Corning 340 pH meter which was calibrated prior to use with Fischer Scientific buffer solutions 4, 7 and 10.

3.4.4 Alkalinity and Total Volatile Fatty Acids

The alkalinity and TVFA concentrations of the contents of the pre-treatment columns were determined using the titration method of Anderson and Yang (1992). The titration was performed in duplicate with the average value being reported for each data point.

Approximately 250 mL of a sample was spun at 5,000 rpm in a Thermo IEC centrifuge for 5 minutes. 50 mL of the supernatant was transferred to a clean, dry beaker. A clean, dry magnetic stir bar was added in the solution, the beaker was placed on a magnetic stirrer. The initial pH of this solution was recorded. The titrant was 2.8 mL of H_2SO_4 in 1L of distilled water. The solution was titrated to pHs 5.1 and 3.5, the volume of titrant required for each titration was recorded. The initial pH and two titration volumes were input into a spreadsheet that employed the relations developed by Anderson and Yang (1992). The spreadsheet produced the alkalinity and total volatile fatty acid concentration. Samples were analyzed in duplicate.

3.4.5 Aqueous Ammonia

The aqueous ammonia concentration was determined using a VWR sympHony electrode that had been calibrated to relate mV and the aqueous ammonia concentration

when the pH was greater than 12. The pH of the sludge sample was increased to 12 using 10N NaOH. The pH was determined using a Corning 340 pH meter which was calibrated bi-weekly with Fischer Scientific buffer solutions 4, 7 and 10. The VWR sympHony electrode was connected to an Orion 420A pH meter that was set to relative millivolts. The voltage was measured and compared to the calibration curve. Duplicate samples were analyzed for each data point.

3.4.6 Nitrite and Nitrate Nitrogen

The nitrite-nitrogen and nitrate-nitrogen concentrations were measured using an anion column on a Lachat Instruments IC5000 Ion Chromatography System. For accurate measurements, the gain was set to 1 with an eluent flowrate of 2 mL/min. QuickChem Method 10-510-00-1-A prescribed the operations required for the determination of anions in waters and solid extracts.

Supernatant from a sample that had been spun in the centrifuge was filtered through a 0.20 μm filter. The reagent water (distilled water) and eluent (2 mM sodium bicarbonate, 2.6 mM sodium carbonate) solutions required filtration to this magnitude as well. The eluent required degassing prior to each use. The eluent and regenerant (0.25 M sulfuric acid) solutions were made in bulk and stored for up to one month in the refrigerator prior to use.

3.4.7 Individual Volatile Fatty Acids

The measurement and characterization of individual volatile fatty acids was performed using the Lachat Instruments IC5000 Ion Chromatography System. QuickChem Method 23-550-00-1-A prescribed the operations required for the determination of organic acids in fermentation media. The system required a 0.1 gain and 0.5 mL/min eluent flowrate for measurements.

Samples required equivalent preparation as outlined in section 3.4.7 for the anion column. The reagent water was the same for both columns (0.20 μm filtered distilled water).

The eluent solution (0.20 μm filtered 8mM sulfuric acid) was made in advance and stored in the refrigerator but it required degassing prior to each sampling session. Fresh regenerant solution (0.5 M tetremethylammonium hydroxide) was made on the day of analysis.

3.4.8 Microbial Analysis

Microbial analysis requires sterile instrumentation. All instruments were autoclaved (Market Forge Sterilmatic, Model Number STM-E) for 15-20 minutes prior to use.

Serial dilutions of the sludge samples were made using autoclaved dilution water containing 1.25 mL of stock phosphate buffer solution and 5 mL of magnesium chloride. Standard method 9050c.1a outlines the preparation of the stock phosphate buffer solution. The serial dilutions were done by factors of ten; the first dilution contained 5 mL of sludge sample and 45 mL of dilution water. To completely mix the sample, it was inverted 30 times or placed on the Vortex for 15 seconds. The second dilution contained 5 mL of the first diluted sample and 45 mL of dilution water. The process was continued up to five times in order to properly plate the samples with the correct diluation.

When a sample was initially plated, multiple dilutions were employed in order to establish the range of concentration. Subsequent analysis required only one or two dilutions be plated. Each sample was plated in duplicate.

Fecal coliform, *E. coli* and *Salmonella* spp. concentrations were monitored as indicators of pathogen reduction using the membrane filtration technique which is subsequently described. *Clostridium perfringens* concentrations were determined using the pour method and the methodology is outlined in section 3.4.8.4. Each of these organisms required a different combination of nutrients to grow. The subsections of 3.4.8 outline the methodology employed to make the agar for each of the four organisms.

Membrane Filtration

For each sample, a sterilized funnel was placed in an Erlenmeyer flask set up with a trap and connected to a vacuum pump. Sterilized tweezers were used to place a membrane filter on the magnetic funnel. The sterilized pipette tips were used to transfer a homogeneous sample from the dilution tube to the funnel and filter. The volume of sample typically used was 5 mL but the sample volume was sometimes varied in order to ensure that 20-200 colonies formed on the plate. The pump was turned on to pull the sample through the filter and subsequently turned off. Sterilized tweezers were used to transfer the filter paper to the appropriate plate. To sterilize the tweezers between samples, they were immersed in alcohol which was then burnt off.

Incubation

Plates were stored upside down in an incubator. Fecal coliform plates were stored in a 45°C incubator (Precision Economy Incubator). *E. coli*, *Salmonella* spp. and *Clostridium perfringen* plates were incubated at 35°C (Fisher Scientific Low Temperature Incubator). After 24 hours, the CFU (colony forming units) were counted for each plate.

3.4.8.1 Fecal Coliforms

Distilled water (1 L) was autoclaved for 15-20 minutes in a 2 L Erlenmeyer flask. FC agar (52 g) was added to the water and combined using a magnetic stirring hot plate (Thermolyne Cimarec 3). Once the solution came to a boil, 10 mL of a 1% solution of rosolic acid in 1 N HCL was added and left to boil. The solution was removed from heat once it began to foam. The pH of the solution was adjusted to 7.4 as necessary using either 1 N HCl or 1 N NaOH. The solution was left to cool to approximately 60°C and then approximately 20 mL was poured into a sterile plate. The plate was promptly covered with its lid and left to solidify. If the plates were not used immediately, they were stored upside down in a refrigerator for up to one week.

3.4.8.2 *E. coli*

In a 2 L Erlenmeyer flask, 1 L of autoclaved distilled water, 39.5 g of FC basal medium and 100 mg of x-GAL were combined. Once the solution began to foam, it was removed from heat. The pH was adjusted to 7.4 and the same method was employed as was outlined for fecal coliforms to pour the media into the plates.

3.4.8.3 *Salmonella* spp.

The same method was employed as previously outlined except that only 60 g of SS agar were dissolved in 1L and the pH was adjusted to 7.

3.4.8.4 *Clostridium Perfringens*

In a 2 L Erlenmeyer flask, 1 L of distilled water and 41 g of SPS agar were combined. Once the solution began to foam, it was removed from heat and autoclaved for 15 minutes. The pH of the solution was adjusted to 7 as necessary using either 1 N HCl or 1 N NaOH. The solution was left to cool to approximately 60°C. In a sterile plate, 0.2 mL of the diluted sludge sample was pipetted and combined with approximately 20 mL of cooled agar. The two were mixed gently by swirling the Petri dish five times in each direction on the flat surface of the work bench. The plate was promptly covered with its lid and left to solidify. *Clostridium perfringens* require an anaerobic environment to grow. The plates were placed upside down in an anaerobic jar with activated GasPak envelopes, catalyst and an indicator. The pour method prevented the *Clostridium perfringen* plates from being stored in the fridge.

3.4.9 Analytical Methods

The five following procedures were drawn from the book: Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992. The Standard Method used is listed and the instrumentation is noted.

3.4.9.1 Solids Concentrations

Two types of solids concentrations were measured for this work, the total and volatile solids concentrations. Standard Methods 2540 B and 2540 C were followed for the TS and VS determinations. For each sample, duplicate measurements were made. Crucibles were cleaned, placed in the oven to completely dry and left to cool in a Wheaton USA dessicator prior to weighing to determine the initial mass of the clean crucibles (Weight A). A 20 mL volume of each sample was transferred to a crucible which was placed in the Fischer Scientific Isotemp Oven, Model 718F and left overnight at a temperature of 105°C. The crucibles were transferred to the dessicator for a minimum of two hours prior to weighing (Weight B). Following weighing, the crucibles were transferred to the Neyo 2-160 Series II oven and fired at 550°C for 2 hours. The crucibles cooled in the insulated oven to avoid cracking and were then transferred to the dessicator for a minimum of two hours prior to weighing (Weight C).

3.4.9.1.1 Total Solids

The total solids concentration was determined by averaging the two concentrations yielded by the duplicate samples and the following formula, equation 3.1.

$$\text{Total Solids Concentration (g/L)} = \frac{\text{Weight B [g]} - \text{Weight A [g]}}{0.02\ \text{L}} \qquad \text{Equation 3.1}$$

3.4.9.1.2 Volatile Solids

The volatile solids concentration was determined by averaging the two concentrations yielded by the duplicate samples and the following formula, equation 3.2.

$$\text{Volatile Solids Concentration (g/L)} = \frac{\text{Weight B [g]} - \text{Weight C [g]}}{0.02\ \text{L}} \qquad \text{Equation 3.2}$$

3.4.9.2 Soluble Chemical Oxygen Demand

Standard Method 5220 D, the closed reflux method was used to determine the soluble chemical oxygen demand of the samples. Samples were measured in duplicate with multiple dilutions when required to ensure the quality of results. The oven used was the Fischer Scientific Isotemp Oven, Model 718F. The spectrophotometer utilized was the Milton Roy Spectronic 20D.

3.4.9.3 Settling

Imhoff cones were employed to measure the settleability of the solids according to Standard Method 2540 F. The volume reported was the volume of settled solids per 1 L sample volume after being allowed to settle in the cone for 1 hour.

3.4.10 Total Kjeldahl Nitrogen

The total kjeldahl nitrogen was measured by an outside lab (Caduceon Environmental Laboratories) which employed the EPA 351.2 method which measures TKN using a colourimetric, semi-automated, block digester method to perform the analysis. Due to the cost of the analyses, samples were alternately analyzed in duplicate and single samples.

CHAPTER 4
RESULTS AND DISCUSSION

Chapter four presents the results of the experimental work of this thesis. A discussion of the results is included along with the data presentation. The work has been presented in graphical format against time. Time was initiated (day 0) on January 1, 2005 when the pre-treatment columns had been running for almost one month. In order to draw attention to specific comparisons, further graphs were included.

The results of phases 1 and 2 have been grouped together because they were very similar in nature and to allow for easy comparison between the two. The results of these phases are presented in section 4.1 while section 4.2 covers the results of phase 3 of this experiment. Phase 3 included pre-treatment and digestion. Results of both of these treatments have been presented on the same graph in order to allow for comparison between the initial feed, pre-treatment column effluent and digester effluent. A summary and interpretation of the impact of various results as the mechanisms of pathogen reduction are outlined in section 4.3.

4.1 Results of Phases 1 and 2

Phase 1 of this experimental work examined the effect of varying aeration rates on sludge pre-treatment at room temperature. The retention time during this phase was 2 days and the feed solids concentration varied between 16.6 and 20.5 g/L. This phase was initiated on December 1, 2004; steady-state was assumed to have been reached by January 1, 2005 because more than three hydraulic retention times had passed. Between January 8, 2005 and March 25, 2005, seven data points were collected for the operating parameters: dissolved oxygen, oxidation-reduction potential, pH, soluble chemical oxygen demand, alkalinity, total volatile fatty acids concentration. The process performance was evaluated based on the seven data points collected for the nitrogen series, solids concentration and microbial destruction. The nitrogen series consisted of nitrite, nitrate and aqueous ammonia

concentrations and were used to evaluate the occurrence of nitrification. Total and volatile solids concentrations will determine solids destruction. Fecal coliform, *E. coli*, *Salmonella* spp. and *Clostridium perfringens* concentrations will determine microbial reduction.

The operating and process performance parameters were grouped into like sections. Grouping of the parameters allowed for easy comparison between related parameters, reduced repetition of observations and allowed for one discussion of each of the three performance criteria (nitrification, solids destruction and microbial reduction) to occur.

Phase 2 of this experimental work also examined the effect of varying aeration rates on sludge pre-treatment but it was carried out at an elevated temperature of 35°C. The retention time during this phase was maintained at 2 days and the feed solids concentration varied between 14.9 and 25.4 g/L. This phase was initiated on March 29, 2005; between April 10, 2005 and May 20, 2005, seven data sets were collected for all of the parameters of interest in this work.

The operating parameters monitored during the experimental work (DO, ORP, pH, sCOD, alkalinity and TVFAs) will be used to establish the environments in the pre-treatment columns. It was desirable to establish harsh or extreme environments that increased microbial reduction both within the column and during subsequent digestion.

Dissolved Oxygen and Oxidation-Reduction Potential

A relationship exists between DO and ORP in that highly aerobic environments should result in DO concentrations close to saturation and highly oxidizing environments represented by a high, positive ORP value. It is reassuring to see that this expectation was met in all eight of the conditions observed during phases 1 and 2 of this work. The DO concentration measured for each of the eight conditions is included in Figure 4.1. Pre-treatment column L1 which had an aeration rate of approximately 4 L/min had a high DO concentration that was close to saturation. Throughout phase 1 there was an obvious trend that the greater the aeration rate, the greater the DO concentration. The same trend was

apparent during phase 2; however, the values were lower than those observed during phase 1. Table 4.1 presents the averaged DO concentrations and ORP values of the two phases for comparison.

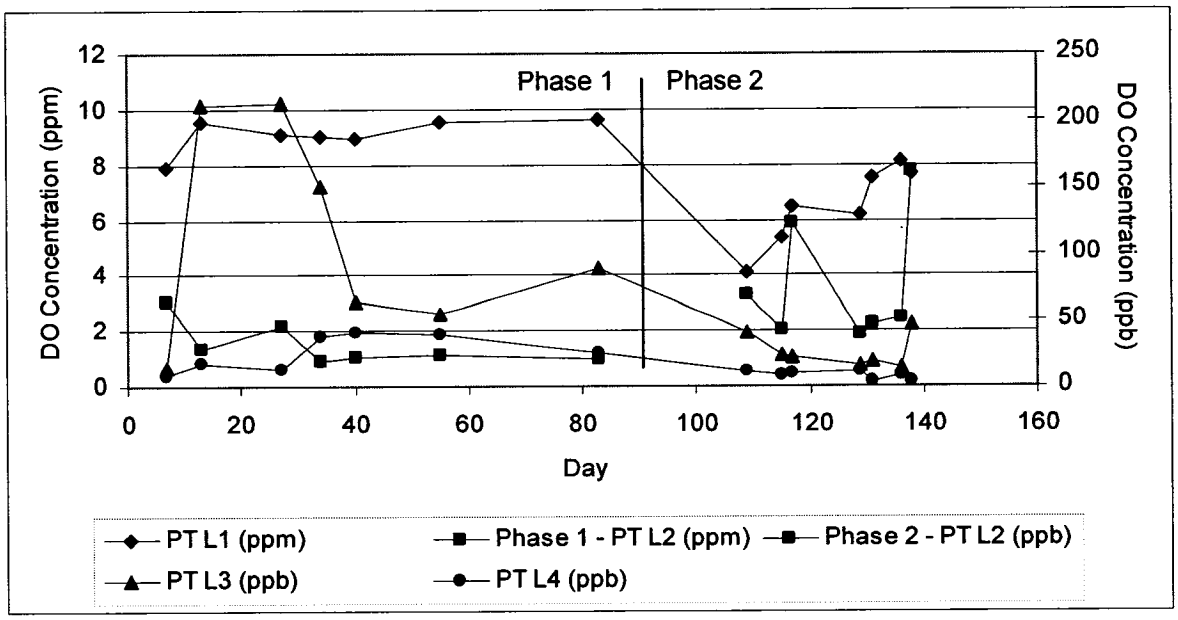

Figure 4.1: Dissolved oxygen concentrations in four pre-treatment columns during phases 1 and 2

Table 4.1: Average dissolved oxygen concentrations and ORP values in four pre-treatment columns during phases 1 and 2 (Mean ± Standard Deviation)

Air Flowrate	Phase 1		Phase 2	
	Average DO	Average ORP	Average DO	Average ORP
4.5 L/min	9.1 ± 0.6 ppm	138 ± 58 mV	6.5 ± 1.4 ppm	150 ± 20 mV
1 L/min	1.5 ± 0.8 ppm	-230 ± 26 mV	76 ± 47 ppb	-288 ± 16 mV
250 mL/min	142 ± 78 ppb	-277 ± 41 mV	26 ± 13 ppb	-316 ± 18 mV
50 mL/min	25 ± 13 ppb	-309 ± 54 mV	7 ± 3 ppb	-340 ± 17 mV

There was a noticeable decline in the DO concentration with time; this could be explained by a build up of biofilm on the aeration stone or possibly deterioration of the stone with time. However, the most likely explanation is the increase in temperature. A lower solubility of oxygen would have been observed at the higher temperature of phase 2.

Figure 4.2 illustrates that the ORP values measured during both phase 1 and phase 2 were very similar. It does not appear that increased temperature had any impact on the ORP. Contrary to the DO concentrations which were stratified similar to the varying aeration rates, the ORP values were not significantly varying. The values indicated that the conditions within the pre-treatment columns were either oxidizing or reducing, there was no intermediate condition. Based on the ORP values, the extreme aeration rate of 4 L/min resulted in a oxidizing environment while the three other aeration rates (1 L/min, 250 mL/min and 50 mL/min) resulted in strongly reducing environments. The negative ORP values of the three lower aeration rates indicate that micro-aerobic conditions were achieved.

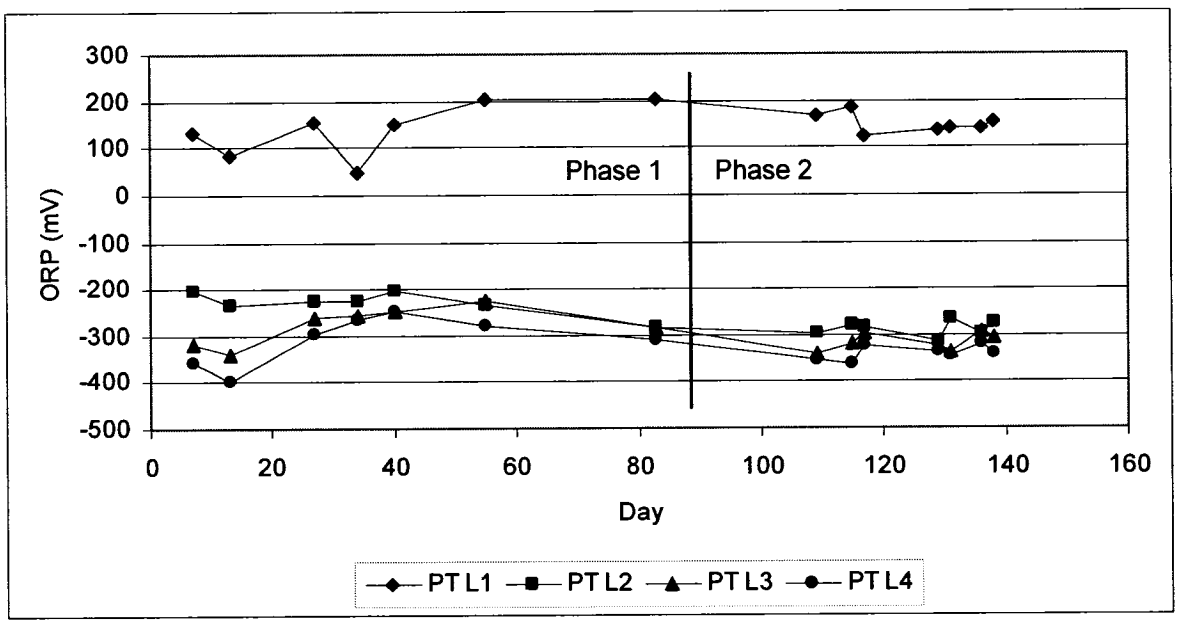

Figure 4.2: Oxidation-reduction potentials in four pre-treatment columns during phases 1 and 2

Temperature appeared to slightly impact the negative ORP values. During phase 2 with the elevated temperature, the ORP values in the three reducing pre-treatment columns were lower (10-25%) than observed during phase 1. This was likely due to elevated rates of oxygen consumption and a lower solubility of oxygen at the elevated temperature which corresponds to the observed decrease in DO concentrations at the higher temperature.

pH and Alkalinity

The pH and alkalinity provide information on the relative concentrations of acids and basic substances that are present in a sample. Alkalinity is consumed when acids such as VFAs or nitric acid are generated biologically by fermentation and nitrification processes respectively. Alkalinity can be generated when NH_3^+ is liberated due to deamination of proteins.

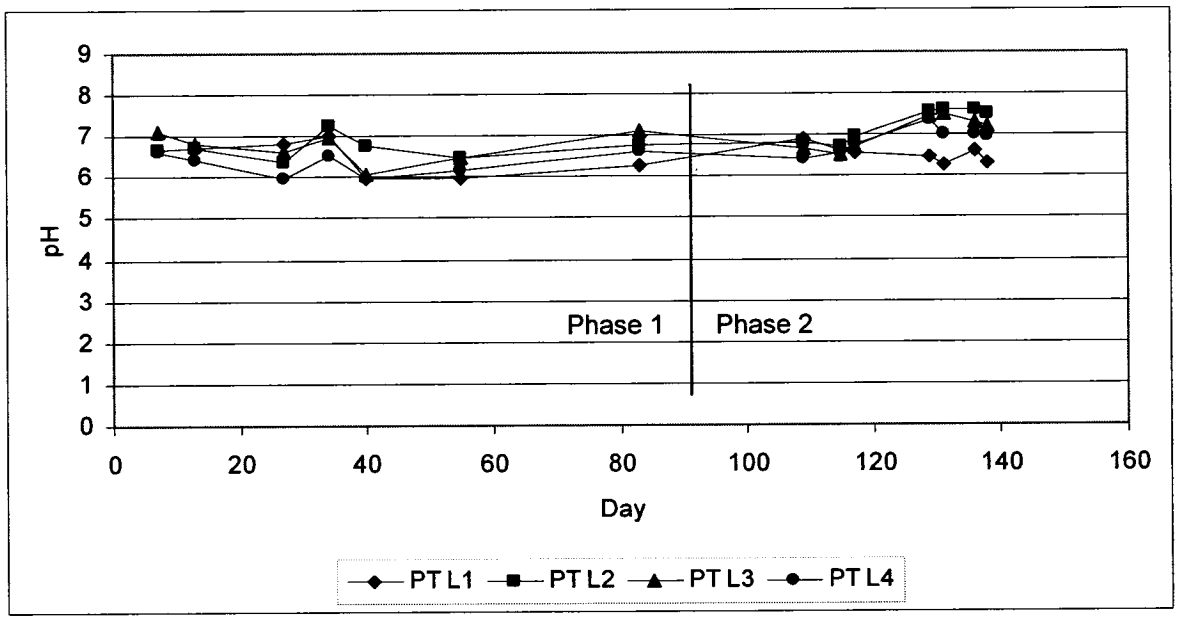

Figure 4.3: pH values in four pre-treatment columns during phases 1 and 2

Figure 4.3 illustrates that the pH values in the pre-treatment columns during phase 1 were fairly consistent which lends itself to the conclusion that the columns were in a steady state. The variability of the pH values prevented a differentiation between the columns and no reactor(s) appeared to be consistently lower or higher than the others. In phase 2 with an increased operating temperature, the pH values appeared to be slightly higher in all of the columns operating at negative ORP values. This may be due to increased NH_4-N release (as outlined in Figure 4.9).

The alkalinity values outlined in Figure 4.4 correspond well to the other operating parameters measured. The lower alkalinity measured in PT L1 was consistently low,

differentiating it from the other pre-treatment columns. Along with the low VFA concentrations and significant nitrate concentrations which will be presented and discussed in the coming pages, these measurements indicate that nitrification was occurring in PT L1.

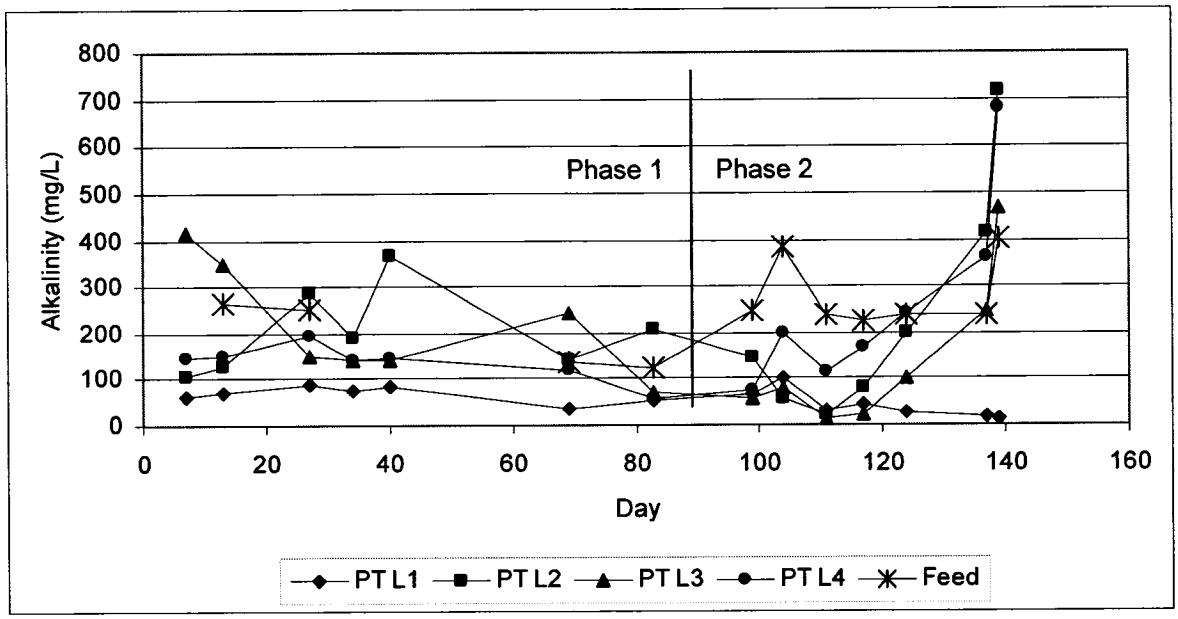

Figure 4.4: Alkalinity in four pre-treatment columns during phases 1 and 2

Soluble COD and Total VFAs

Soluble COD and TVFAs will be discussed collectively due to their interdependence; soluble COD is made up of complex COD and VFAs. The measured sCOD and TVFAs concentrations in the pre-treatment columns during phases 1 and 2 of the experimental work are presented in Figures 4.5 and 4.6 respectively.

Similar patterns in the concentrations of TVFAs and sCOD were observed in the four pre-treatment reactors in phases 1 and 2. Hence, the results suggest that a significant fraction of the sCOD consisted of VFAs.

Increased temperatures in the second phase resulted in slightly increased concentrations of both sCOD and TVFAs. The elevated temperature appeared to result in increased rates of hydrolysis. The increased rate of hydrolysis of the volatile solids would result in increased

concentrations of fermentation end products such as VFAs. The increased presence of VFAs would then contribute to the increased sCOD.

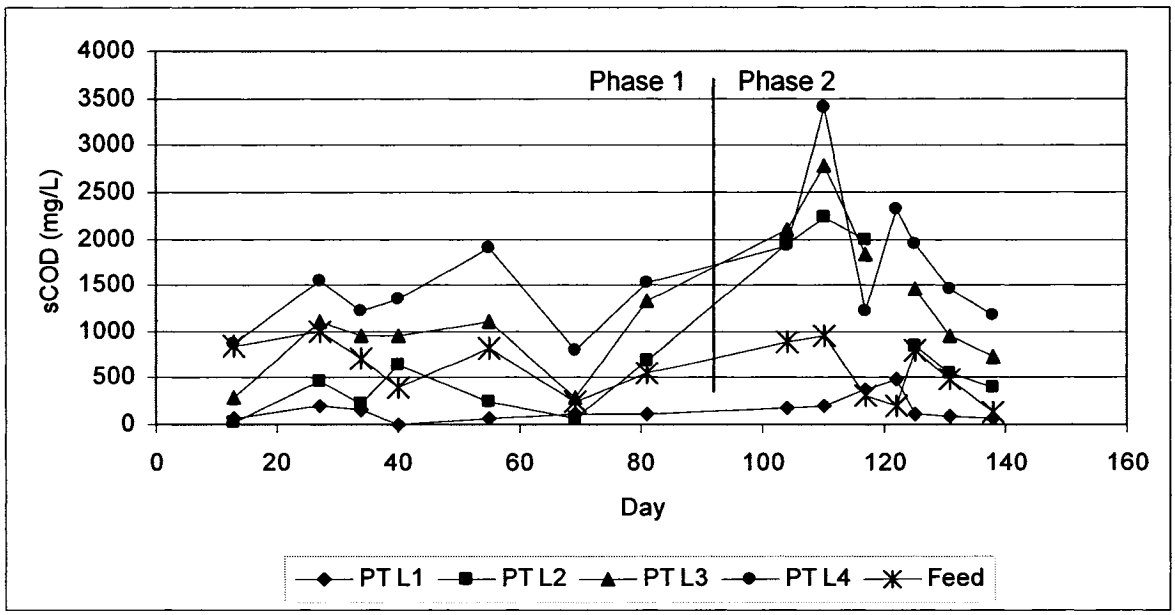

Figure 4.5: Soluble chemical oxygen demand in four pre-treatment columns during phases 1 and 2

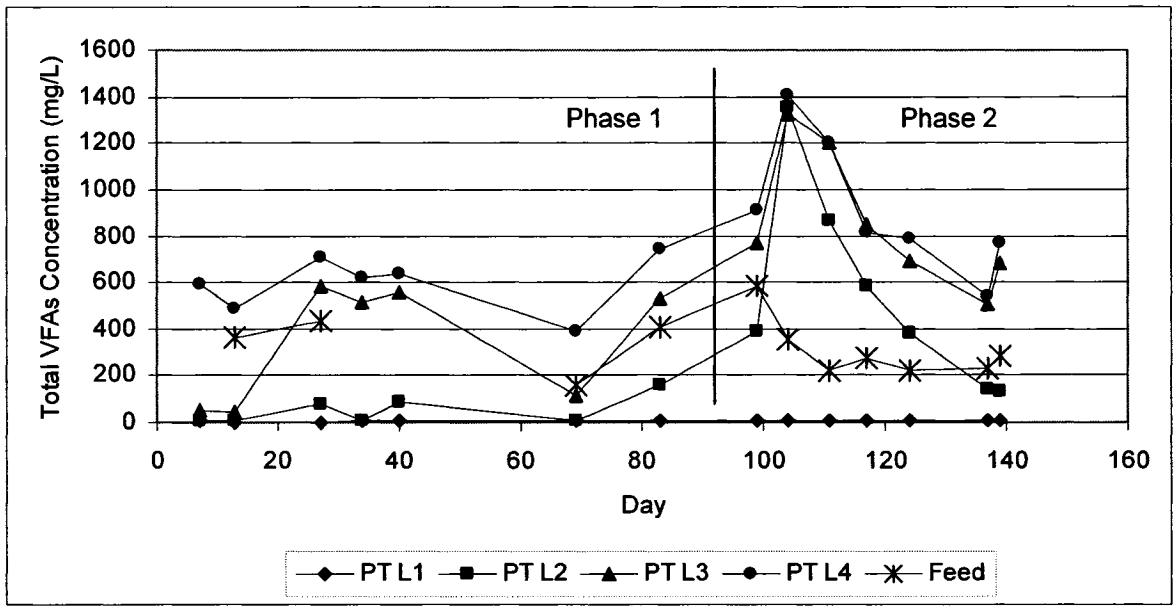

Figure 4.6: Total volatile fatty acid concentrations in four pre-treatment columns during phases 1 and 2

The TVFA concentrations in the highly aerobic pre-treatment column (PT L1) were consistently less than the detection limit of the titration used to determine the concentrations.

The absence of these fermentative end products while cells were being broken down indicates that the VFAs were being consumed as rapidly as they were being generated.

The three remaining columns which were under micro-aerobic conditions accumulated TVFAs in their liquor. This indicates that while hydrolysis was occurring in these columns, the VFAs were not further degraded. The occurrence of this complies with the hypothesis based on the work of Fothergill and Mavinic (2000); decreasing the air supply would increase the presence and concentration of VFAs in the pre-treatment column.

Nitrogen Series: Nitrite, Nitrate and Aqueous Ammonia

Nitrite is the product of chemical modification of ammonia by specialized bacteria in the first step of nitrification. The second step of nitrification involves the oxidation of nitrite to nitrate. The presence of these two compounds in the liquor solution of the pre-treatment reactors provides a measure of whether nitrification was occurring in the columns. Aqueous ammonia concentrations of the four pre-treatment columns are also a possible indicator of nitrification. The NH_4-N concentrations are indicative of the net effects of protein decay and nitrification. Decreased ammonia concentrations indicate that it was being oxidized to nitrates, hydrogen and water. Meanwhile, increased concentration of ammonia can be attributed to cellular destruction within the columns. Protein degradation produces carbon dioxide, water and ammonia through oxidation.

The optimal pH range for nitrification is around 7 – 8 but it may occur outside of this range. The concentration of alkalinity required to maintain a pH of 7 is 70 – 80 mg/L as $CaCO_3$ (Metcalf and Eddy, 2003) but may vary depending on the amount of NH_4-N that is available for nitrification. Figure 4.3 illustrated that the pH values in the pre-treatment columns were just outside the optimal range while Figure 4.4 suggested that sufficient alkalinity was present to facilitate the process of nitrification.

Examining Figure 4.7 (Nitrite-nitrogen concentrations) and 4.8 (Nitrate-nitrogen) collectively indicates that complete nitrification was only occurring in the highly aerobic pre-

treatment column PT L1. The sporadic accumulation of nitrite-nitrogen in the micro-aerobic pre-treatment columns indicates that the first step of nitrification was active; however, it appeared to be inconsistent. The elevated concentration of nitrate-nitrogen in PT L1 during both phase 1 and phase 2 signifies that while the first step of nitrification may have been occurring within all of the reactors, the entire process of nitrification was only being carried out in the highly aerobic environment of PT L1. The smaller concentrations of nitrite-nitrogen observed in PT L1 also lend themselves to this theory. The nitrite-nitrogen being produced from oxidation was further oxidizing to nitrate-nitrogen and not accumulating in the column liquor. The absence of highly active nitrification was almost certainly due to the limited oxygen available in these reactors.

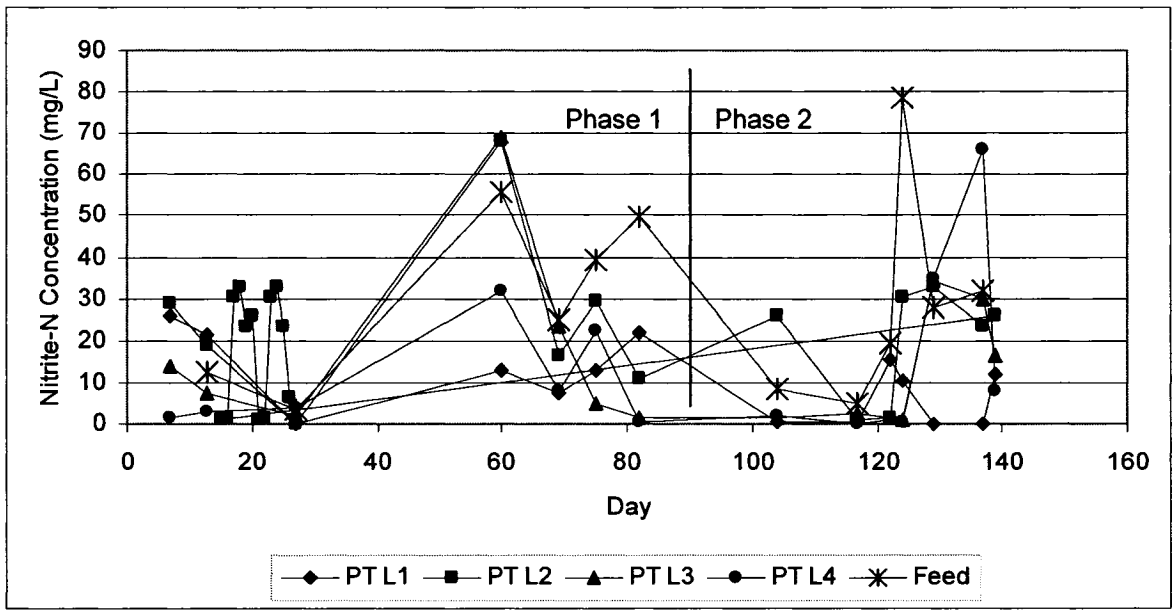

Figure 4.7: Nitrite-nitrogen concentrations in four pre-treatment columns during phases 1 and 2

Considering the nitrate data along with the aqueous ammonia concentration data presented in Figure 4.9 confirms the assessment of nitrification occurring only in PT L1. The low ammonia concentration of this pre-treatment column indicates that the ammonia was being oxidized during nitrification while in the three micro-aerobic columns, the elevated concentration over the initial (feed) ammonia concentration indicates that cell degradation was occurring in these reactors but the conditions in the columns did not support nitrification. The nitrification equations presented in the literature review section of this

work identified oxygen as a reactant along with ammonia to produce the nitrates in nitrification. It appears that while there was sufficient oxygen for nitrification to be initiated in the three micro-aerobic columns, conditions were not sufficient to complete or sustain the process.

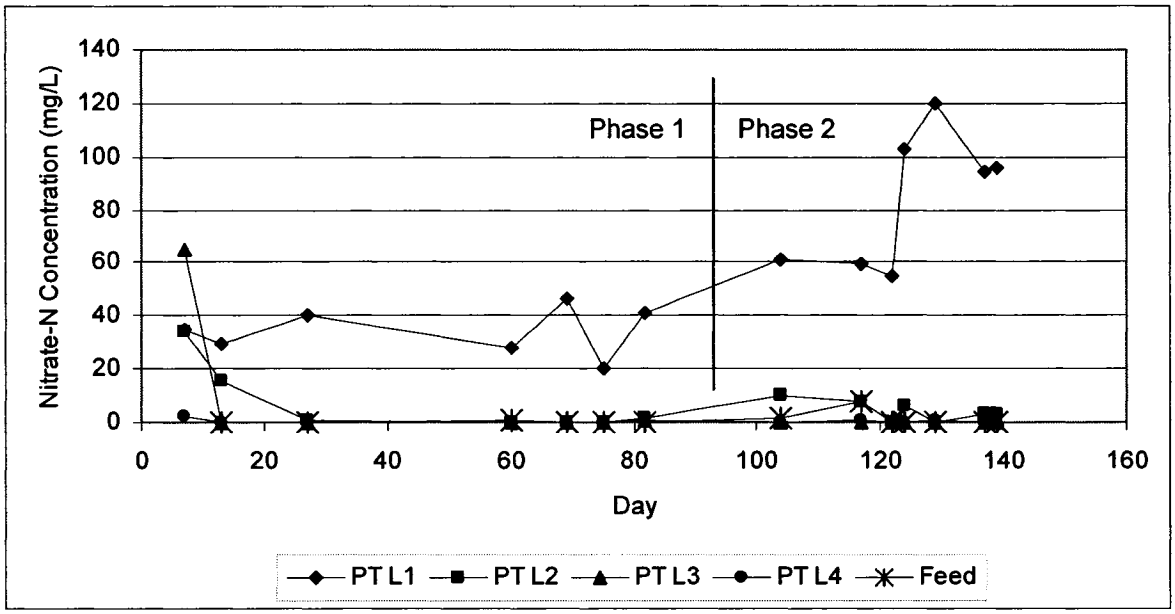

Figure 4.8: Nitrate-nitrogen concentrations in four pre-treatment columns during phases 1 and 2

Temperature appeared to impact the nitrification process in this study; however, the onset of the temperature effect appeared to be somewhat delayed. After phase 2 was initiated and sufficient time passed to allow the assumption of steady state to be made, temperature did not appear to impact the nitrogen series. However, after approximately day 120, large increases were observed in nitrate-nitrogen (PT L1) and aqueous ammonia concentrations (PT L2, L3, L4). The increased nitrate concentration observed in PT L1 after day 120 was likely due to increased ammonia being available for oxidation. An elevated ammonia concentration was not observed and this was likely due to nitrification occurring quickly, preventing accumulation of NH_4-N in the pre-treatment column. The ammonia was being oxidized as quickly as it was being produced. Contrarily, increased ammonia concentrations were apparent in the three micro-aerobic environments. Their presence confirms that nitrification was not occurring in these columns, allowing the ammonia concentration to build up.

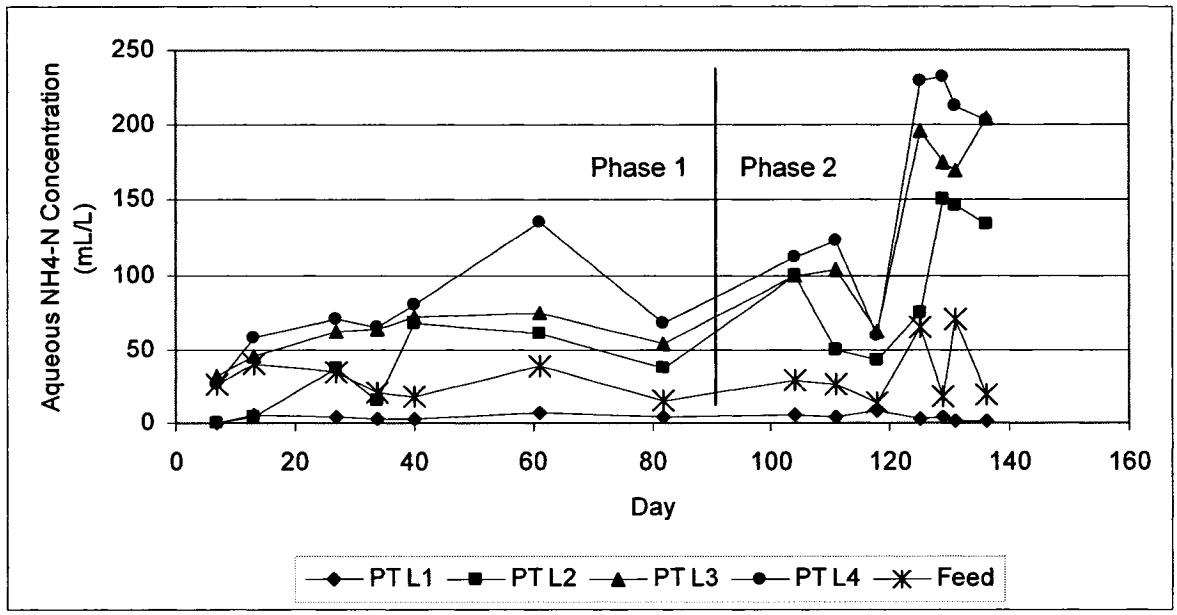

Figure 4.9: Aqueous ammonia concentrations in four pre-treatment columns during phases 1 and 2

The increased ammonia concentrations in all of the pre-treatment columns in phase 2 are a result of the increased hydrolysis of solids releasing more ammonia at the increased temperature. It appears that while the temperature was increased shortly after the last observation of phase 1 and sufficient time was allowed to pass before measurements were made for phase 2, the temperature did not fully impact the hydrolysis and nitrification rates until after day 120.

The elevated NH_4-N concentrations in pre-treatment columns L2, L3 and L4 were likely responsible for the elevated alkalinity concentrations in those reactors.

Solids: Total and Volatile

The total solids concentrations measured during phases 1 and 2 were similar and followed the same trends. The average values measured for each of the columns during both phases are presented in Figure 4.10. There did not appear to be any significant difference in the solids destruction between any of the eight conditions evaluated.

Figure 4.11 presents the VS concentrations that were measured in phases 1 and 2. As with the TS data, there did not appear to be a large difference in the VS concentrations either between reactors or between the feed and effluent values.

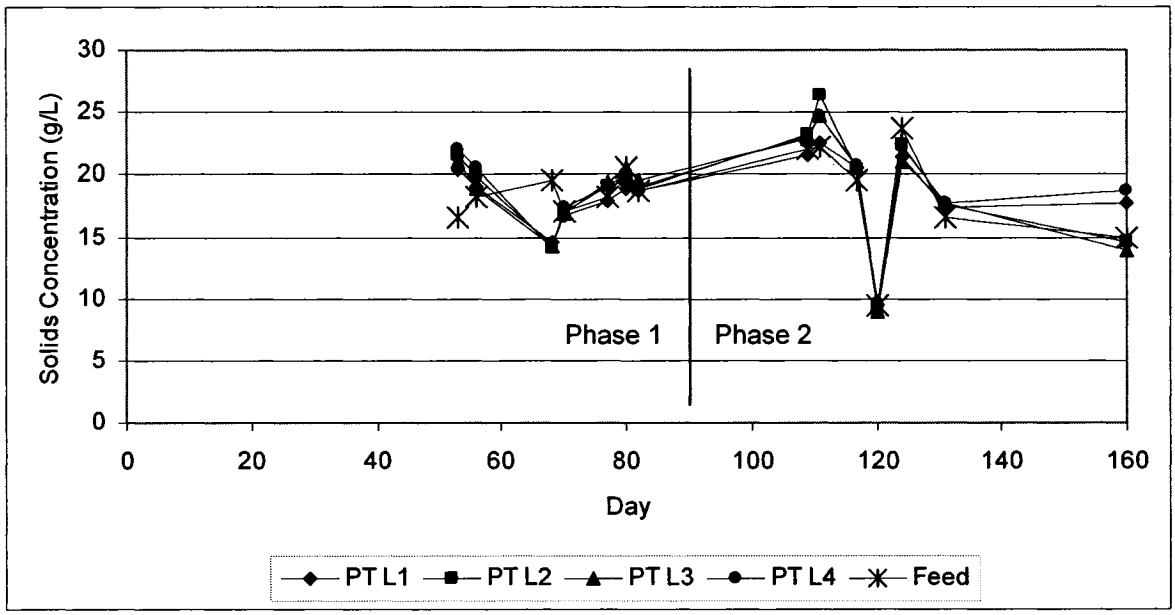

Figure 4.10: Total solids concentrations in four pre-treatment columns during phases 1 and 2

Table 4.2 outlines the average total and volatile solids concentrations measured during phases 1 and 2 for the four pre-treatment columns and the feed. From these values it can be seen that the treatment in the reactors did not significantly impact on the concentrations. The error associated with these measurements was too great to make any conclusions as to the effect of the reactors on sludge stabilization. The positive destruction percentages of phase 2 indicate that more treatment occurred during phase 2 as compared to phase 1. Though this supports the idea of increased hydrolysis at the increased temperature, it was not possible to

make any conclusions based on the solids data measured due to the error associated with such small destructions.

Table 4.2: Average total and volatile solids concentration during phases 1 and 2 (Mean ± Std. Deviation)

PHASE 1	Feed	PT L1	PT L2	PT L3	PT L4
Solids Concentration (g/L)	18.4 ± 1.4	18.1 ± 1.9	18.6 ± 2.3	18.7 ± 2.4	18.9 ± 2.6
Vol. Solids Conc'n (g/L)	12.6 ± 1.6	12.7 ± 1.4	13.3 ± 1.9	13.4 ± 1.9	13.7 ± 2.2
Solids Destruction (%)	N/A	1.8	-1.0	-1.4	-2.6
Vol. Solids Destruct. (%)	N/A	-1.0	-5.7	-6.5	-8.8
PHASE 2	Feed	PT L1	PT L2	PT L3	PT L4
Solids Concentration (g/L)	20.6 ± 3.8	20.6 ± 2.3	21.1 ± 3.9	20.6 ± 3.6	21.6 ± 2.7
Vol. Solids Conc'n (g/L)	12.4 ± 3.6	11.6 ± 1.9	12.2 ± 3.0	11.9 ± 2.7	12.8 ± 2.2
Solids Destruction (%)	N/A	0.0	-2.4	0.2	-5.2
Vol. Solids Destruct. (%)	N/A	6.4	1.1	4	-3.1

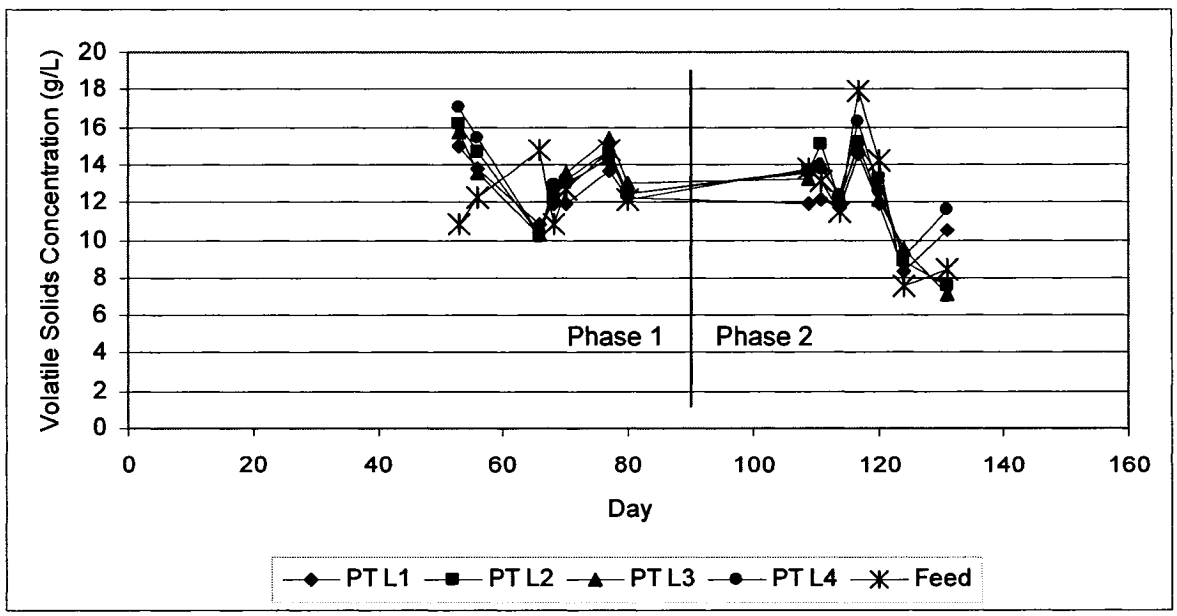

Figure 4.11: Volatile solids concentrations in four pre-treatment columns during phases 1 and 2

The minimal solids destruction observed to this point in this experimental work was not unexpected. There were two factors which decreased the likelihood of observing significant solids destruction during phases 1 and 2. First, the feed used for this work was from an extended air environment which would allow for significant cell degradation to occur at the treatment plant prior to use in this study. Secondly, the retention time in the pre-treatment columns was only two days which was not sufficient time to expect significant solids destruction.

Microbial Analysis

In addition to evaluating the effect of design parameters such as aeration rate, temperature and retention time on operating parameters, studying the ultimate effect of the design parameters and the subsequent reactor environments on pathogen reduction was the primary goal of this experimental work. The four pathogen indicators considered were fecal coliforms, *E. coli*, *Salmonella* spp. and *Clostridium perfringens*.

Fecal Coliforms

The concentrations of fecal coliforms measured during the seven collection dates for each of the first two phases of this work are illustrated in Figure 4.12. From this plot it is evident that the concentrations of fecal coliforms in PT L1 were smaller than the other reactors. From the graph it is also evident that the concentrations in the three micro-aerobic pre-treatment columns were easily influenced by the influent feed fecal coliform concentration. The final data point during phase 1 had a significantly increased concentration in fecal coliforms in the feed as well as moderate increases in the three micro-aerobic pre-treatment columns. PT L1 seemed to be able to reduce the increased fecal coliform influent concentrations while the remaining columns were incapable of reducing the increased loading. This trend carried over to the second phase of the experiment. The fecal coliform concentrations did not fluctuate as much in PT L1 as compared to PT L2 and PT L3. The increased temperature in phase 2 did however seem to result in increased inactivation in PT L4. The fecal coliform concentrations in PT L4 during the second phase

were significantly reduced and much less varying.

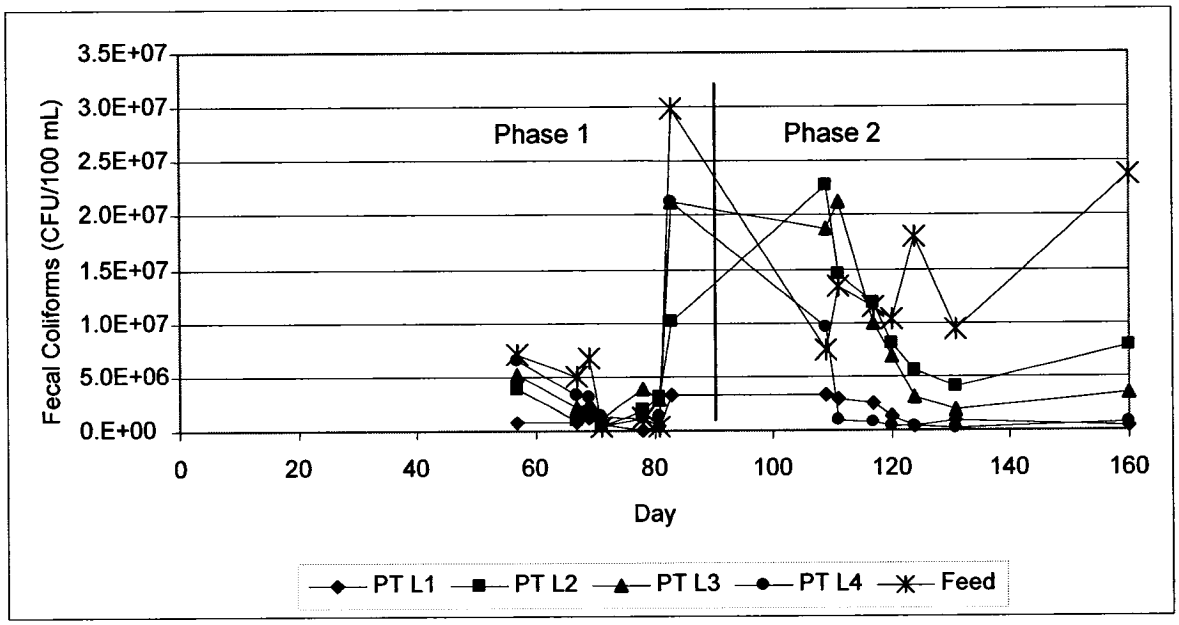

Figure 4.12: Fecal coliform concentrations in four pre-treatment columns during phases 1 and 2

To more easily identify the trends in concentrations and variability, the raw data were compiled and presented as a bar graph in Figure 4.13. From this plot it is apparent that the greatest fecal coliform reduction in phase 1 occurred in PT L1. It appears that in phase 1, a greater aeration rate resulted in greater reductions. It is also apparent that the variability associated with PT L1 during phase 1 was much less than all of the other columns. The same observations were made for PT L1 during phase 2 but it appears that the increased temperature resulted in greater reduction in PT L4. During phase 2 PT L4 was performing similarly to PT L1 with lower average concentrations and less variability. During phase 2, the two intermediate aeration rates performed the worst while the two extreme aeration rates offered the best fecal coliform reductions.

Due to the increased feed fecal coliform concentration during phase 2, it was difficult to evaluate the effect of temperature on the overall reductions. Table 4.3 outlines the average log reductions for all of the pre-treatment columns during the two phases. The values confirm the previous observations of a greater destruction in PT L1 during phase 1 and superior performance in columns 1 and 4 during phase 2.

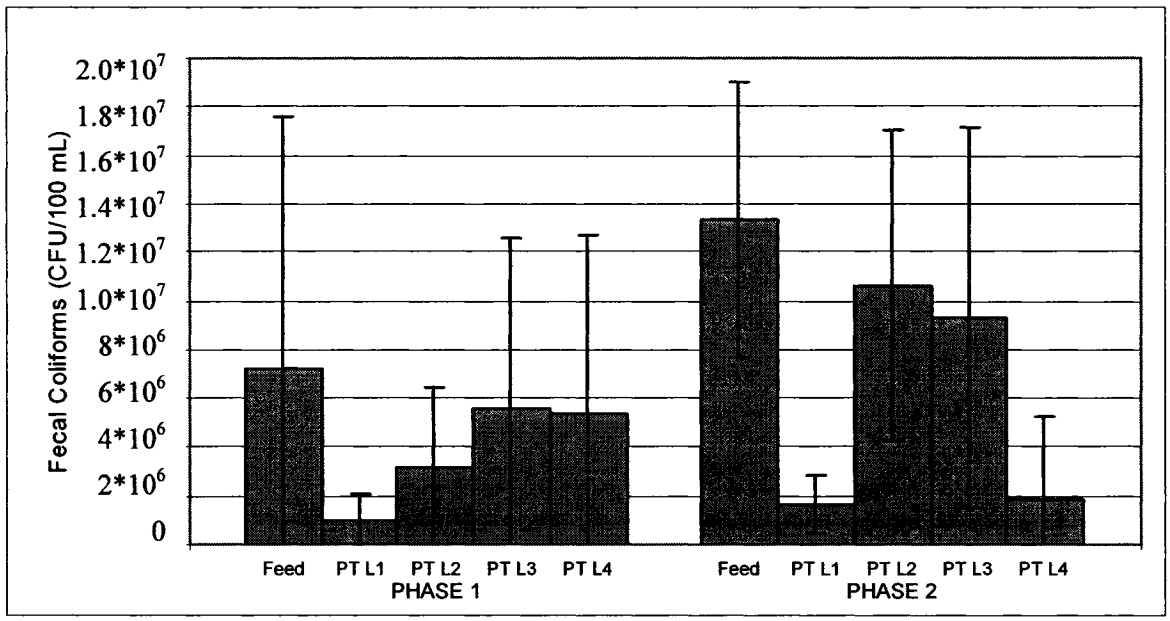

Figure 4.13: Average fecal coliform concentrations during phases 1 and 2

With respect to the effect of temperature on fecal coliform destruction, it was observed that temperature greatly increased the effectiveness of PT L4 in terms of fecal coliform destruction; however, it appeared to have negligible impact on PT L3 which was also under micro-aerobic conditions. Increased temperature during phase 2 actually decreased the efficiency of PT L2 and depending on the method of calculation, it minimally impacted pathogen destruction in PT L1. The reactor conditions of PT L1 and PT L4 were repeated in phase 3 of this experimental work and therefore, further conclusions regarding the impact of pre-treatment on fecal coliform destruction will be discussed subsequently.

Table 4.3: Fecal coliform log reductions during phases 1 and 2

PHASE 1				
	PT L1	PT L2	PT L3	PT L4
Calculation 1 †	1.14 ± 0.62	0.57 ± 0.49	0.31 ± 0.41	0.37 ± 0.46
Calculation 2 ‡	0.87	0.36	0.11	0.12
PHASE 2				
	PT L1	PT L2	PT L3	PT L4
Calculation 1	1.05 ± 0.41	0.16 ± 0.25	0.31 ± 0.40	1.26 ± 0.55
Calculation 2	0.91	0.10	0.16	0.86

† Average of Log(Feed Concentration$_i$ / PT Column Concentration$_i$) for i = 1 to 7

‡ Log (Average feed concentration / Average PT Column Concentration)

E. Coli

Figure 4.14 outlines the *E. coli* concentrations in the feed and pre-treatment column effluents with time for the first two phases of the experimental work. The influent feed concentration varied over time and apparently resulted in varying pre-treatment column effluent concentrations. Similar to trends observed in the fecal coliform data, PT L1 had consistently lower effluent concentrations. The effluent *E. coli* concentrations from PT L1 did not appear to be impacted by *E. Coli* loading. Figure 4.15 which presents the average concentrations and their standard deviations confirmed this observation due to the lower average value and smaller error associated with PT L1 in phase 1.

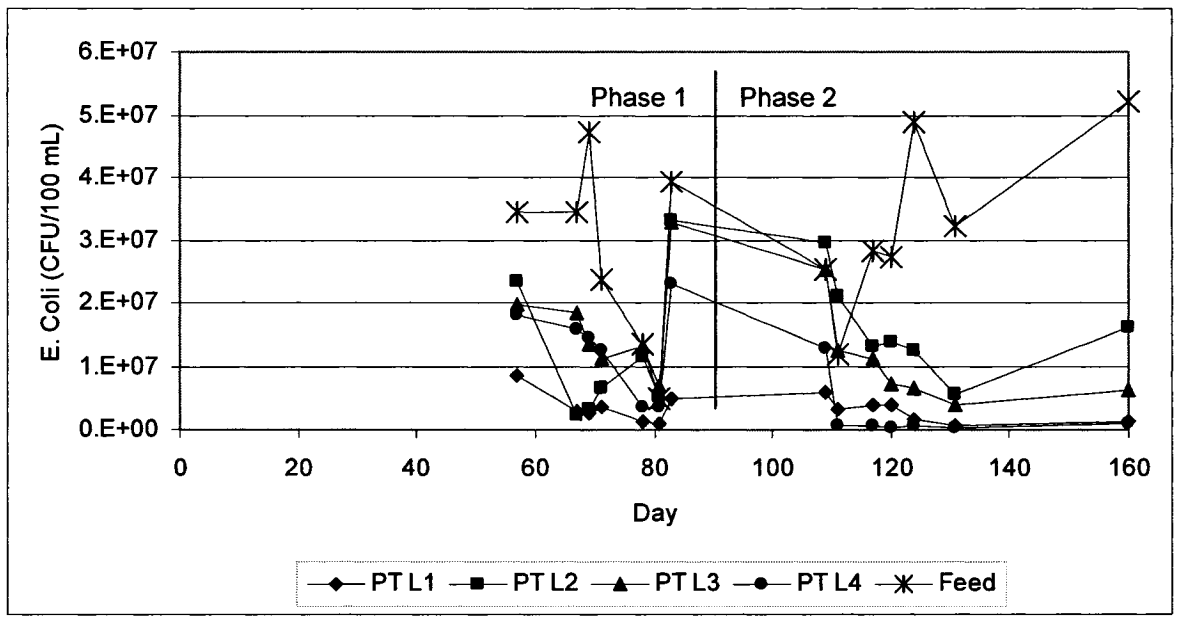

Figure 4.14: *E. coli* concentrations in four pre-treatment columns during phases 1 and 2

The increased temperature of phase 2 over phase 1 had a similar impact on the *E. coli* concentrations as it did for fecal coliforms. The similar responses were reasonable since *E. coli* is a fecal coliform. In phase 2 lower *E. coli* concentrations were observed in pre-treatment columns 1 and 4; however, the variability of PT L4 was larger than that of PT L1. As with fecal coliforms, *E. coli* concentrations during phase 1 generally increased as conditions became more reducing. In phase 2, the extreme aeration rates performed the best with respect to *E. coli* destruction within the pre-treatment columns.

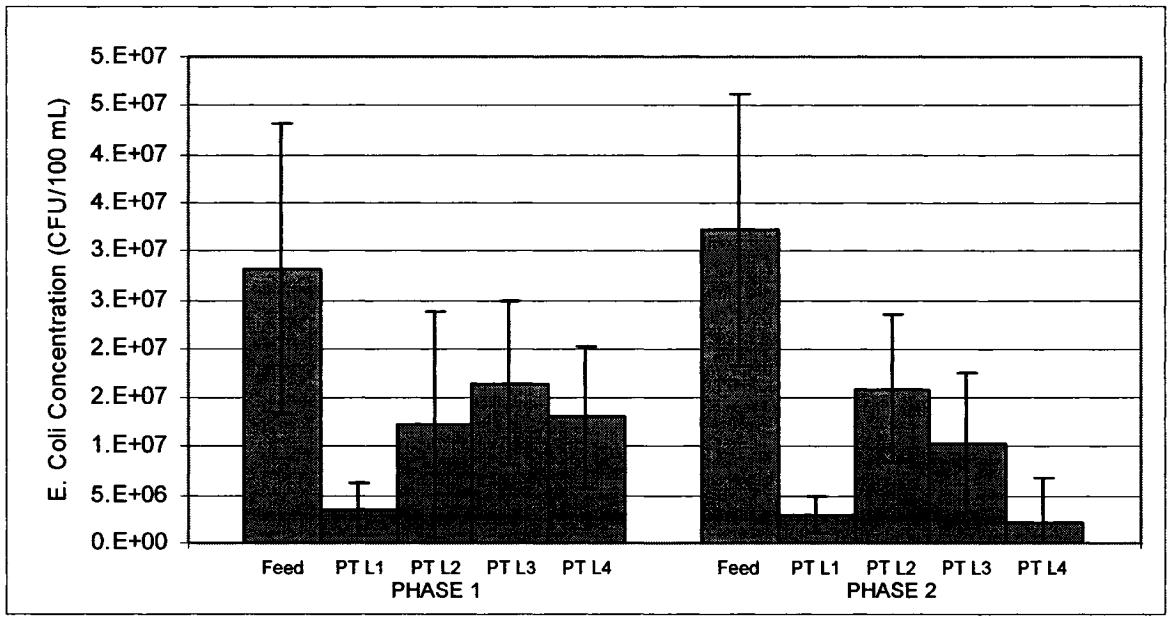

Figure 4.15: Average *E. coli* concentrations during phases 1 and 2

The log reductions outlined in Table 4.4 confirm that the greatest reduction occurred in PT L1 during phase 1. Phase 2 results indicated that PT L4 resulted in the greatest reduction with PT L1 demonstrating slightly less reductions..

Table 4.4: *E. coli* log reductions during phases 1 and 2

PHASE 1				
	PT L1	PT L2	PT L3	PT L4
Calculation 1 †	1.01 ± 0.34	0.54 ± 0.43	0.28 ± 0.21	0.42 ± 0.33
Calculation 2 ‡	0.90	0.36	0.23	0.34
PHASE 2				
	PT L1	PT L2	PT L3	PT L4
Calculation 1	1.14 ± 0.35	0.35 ± 0.22	0.57 ± 0.27	1.60 ± 0.56
Calculation 2	1.04	0.30	0.49	1.47

† Average of Log(Feed Concentration$_i$ / PT Column Concentration$_i$) for i = 1 to 7

‡ Log (Average feed concentration / Average PT Column Concentration)

Salmonella spp.

The *Salmonella* spp. concentrations measured during phases 1 and 2 of the experimental work are presented with respect to time in Figure 4.16. The concentration values were approximately one order of magnitude lower than the fecal coliform and *E. coli* concentrations which would be expected on the basis of their presence in wastewater

samples. From Figure 4.16 it is evident that similar to the previous microbial data, the feed *Salmonella* spp. concentrations were variable with time. It can also be seen that the *Salmonella* spp. response in PT L1 was more variable that that previously observed.

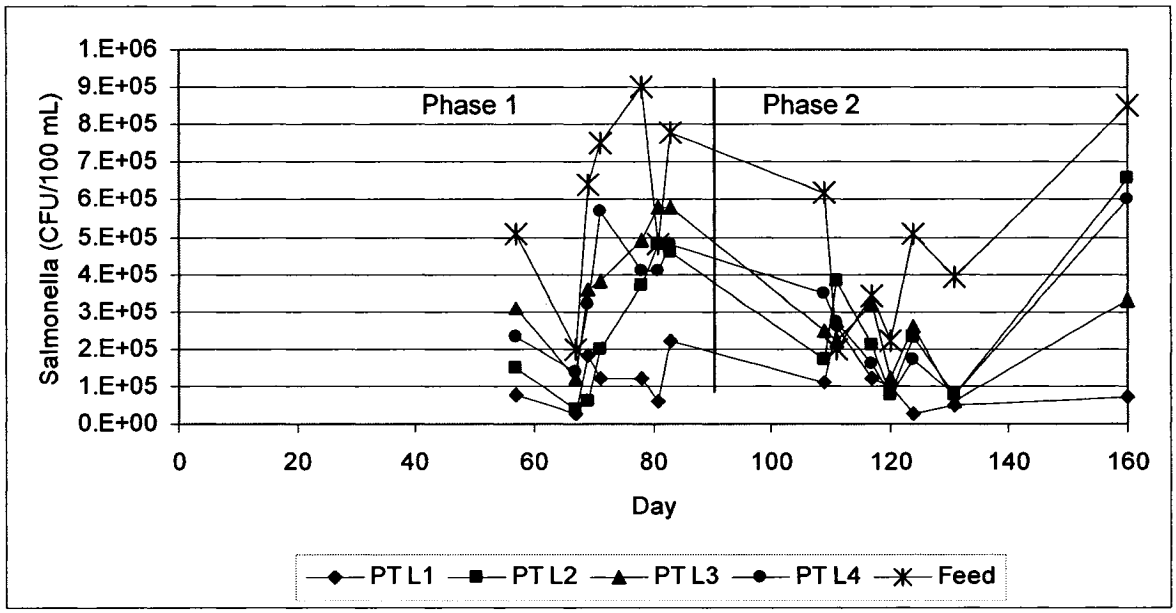

Figure 4.16: *Salmonella* spp. concentrations in four pre-treatment columns during phases 1 and 2

Figure 4.17 presents the averaged concentrations and their standard deviations for both phase 1 and phase 2. From this graph it is evident that PT L1 achieved superior *Salmonella* spp. destruction in both phase 1 and phase 2. The graph does not indicate the enhanced results expected of PT L4 during the second phase. The trend of the responses during phase 1 was similar to those of fecal coliforms and *E. coli*. PT L1 performed the best while the concentrations increased with decreased aeration rates and PT L4 performed only slightly better than PT L3.

Figure 4.17 suggests that increased temperature during phase 2 resulted in lower *Salmonella* spp. concentrations in the low ORP reactors. However, Table 4.5 which presents the log reduction in each of the pre-treatment columns indicates that the lower influent feed *Salmonella* spp. concentration during phase 2 may have been responsible for this result. It was expected that the increased temperature would result in increased pathogen destruction. In the case of *Salmonella* spp. the impact was not evident. This was likely due to too small of a temperature increase or too small of exposure to the higher temperature. Phase 3 of the

experimental work examined columns with longer retention time and conclusions with respect to the effect of temperature on *Salmonella* spp. concentration will be made subsequently.

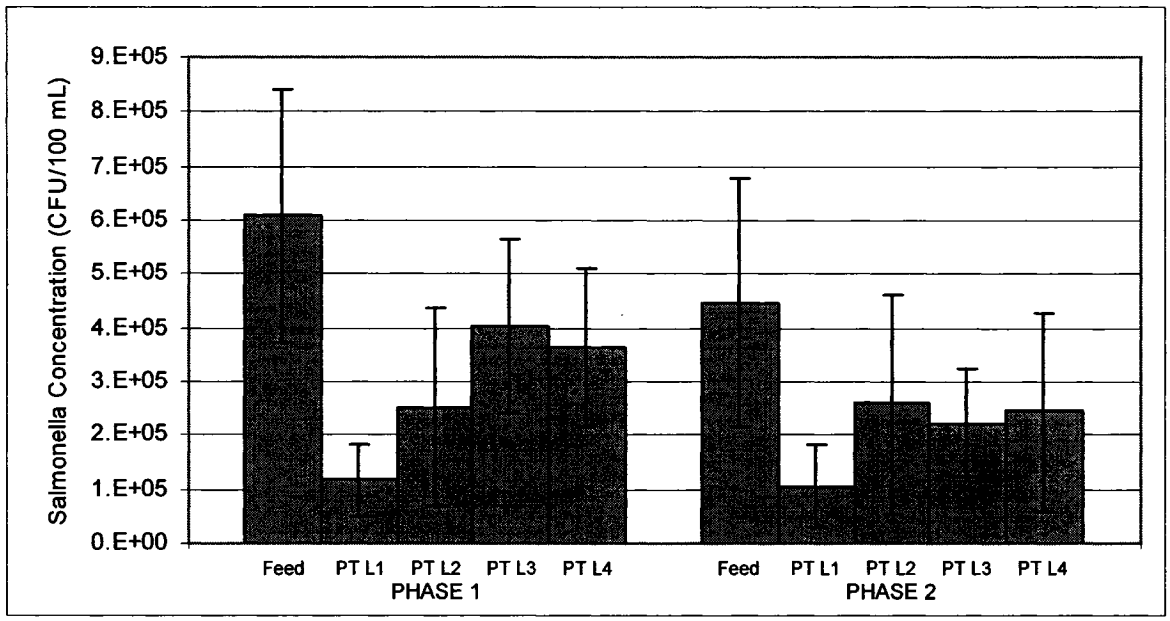

Figure 4.17: Average *Salmonella* spp. concentrations during phases 1 and 2

Table 4.5: *Salmonella.* spp. log reductions during phases 1 and 2

PHASE 1				
	PT L1	PT L2	PT L3	PT L4
Calculation 1 †	0.79 ± 0.29	0.53 ± 0.43	0.22 ± 0.24	0.26 ± 0.21
Calculation 2 ‡	0.72	0.38	0.18	0.22
PHASE 2				
	PT L1	PT L2	PT L3	PT L4
Calculation 1	0.71 ± 0.30	0.35 ± 0.33	0.36 ± 0.27	0.37 ± 0.32
Calculation 2	0.63	0.24	0.30	0.26

† Average of Log(Feed Concentration$_i$ / PT Column Concentration$_i$) for i = 1 to 7

‡ Log (Average feed concentration / Average PT Column Concentration)

Clostridium Perfringens

Clostridium perfringens concentrations that were observed in this study are presented in Figure 4.18. The results indicate that pre-treatment had little impact on *Clostridium perfringens*. In some cases the effluent concentrations were greater than the influent concentrations suggesting *Clostridium perfringen* growth in the pre-treatment columns. The *Clostridium perfringen* data was not further analyzed but it was measured during phase 3 to determine whether digestion would impact its concentration.

Clostridium perfringen is an anaerobic, spore forming rod (Brock, 2000) which would lead one to believe that it should not be able to survive in the presence of excess oxygen, specifically in PT L1. The absence of deterioration of *Clostridium perfringens* in the pre-treatment columns indicates that it is a virulent organism. Its ability to form spores and to thrive at elevated temperatures offers resistance to conditions that kill many other types of pathogen indicators.

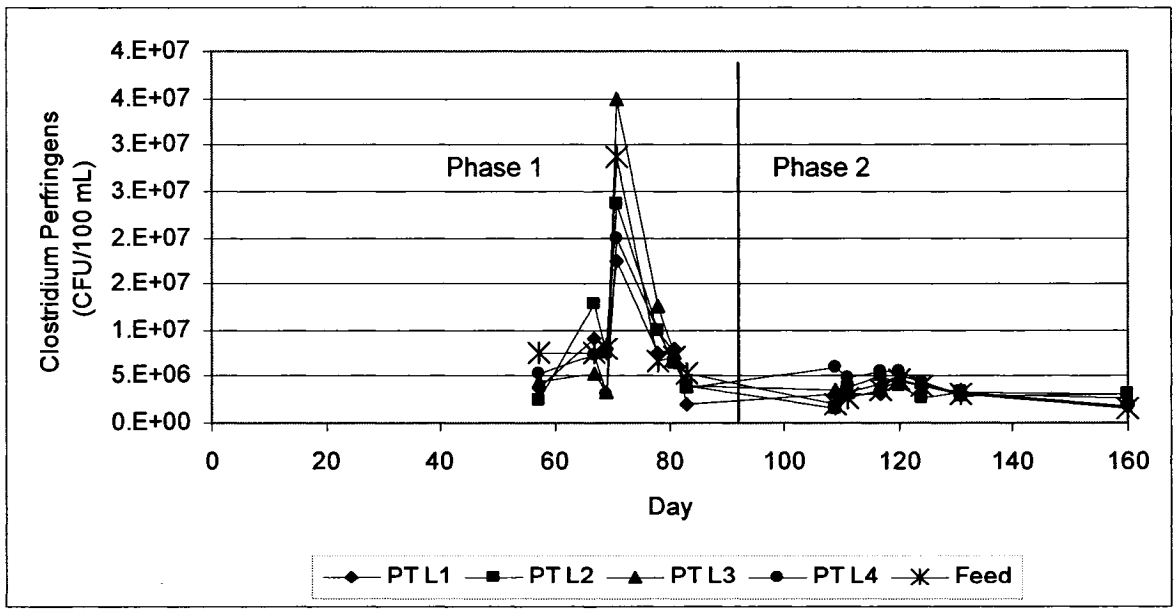

Figure 4.18: *Clostridium perfringens* concentrations in four pre-treatment columns during phases 1 and 2

4.2 Results of Phase 3

Phases 1 and 2 evaluated the effect of oxygen supply and temperature on sludge pre-treatment. The results of phase 2 indicated that PT L1 (highly aerobic) and PT L4 (highly reducing) had the most promise with respect to pathogen destruction. Exploring a 2-way factorial design analyzing oxygen supply and retention time resulted in these conditions being duplicated during phase 3. The two other pre-treatment columns had a longer hydraulic retention time of 96 hours. Table 4.6 summarizes the conditions of the four pre-treatment columns.

Table 4.6: Phase 3 pre-treatment column design parameters

	PT L1	PT L2	PT L3	PT L4
Air Flowrate	4 L/min	50 mL/min	4 L/min	50 mL/min
Retention Time	4 days	4 days	2 days	2 days
Temperature	35°C	35°C	35°C	35°C

PT L3 was a duplicate of PT L1 from phase 2 and the conditions in PT L4 were unchanged from phase 2. The duplication of conditions allowed for analysis of consistency of the work. The discussion of phase 3 results will include references to both the results of phases 1 and 2 as well as a comparison with the duplicate runs.

Phase 3 was initiated in the pre-treatment columns on June 10, 2005 and the digesters were started up on June 16, 2005. Data collection from the pre-treatment reactors began on June 23, 2003 with seven points being collected between then and August 14, 2005. Data collection from the digesters began on September 27, 2005 when steady state was confirmed and ran through October 30, 2005. Three additional pre-treatment column data points were collected during the observation period of the digesters to monitor their performance and these values have been included in the discussion.

Dissolved Oxygen and Oxidation-Reduction Potential

The DO concentrations measured in the pre-treatment columns and the digesters during phase 3 are presented in Figure 4.19. It was expected that the concentration in the pre-treatment columns, PT L1 and PT L3 would be approximately equal since they were both being aerated at a rate of 4 L/min. The difference between the DO in these two reactors was not interpreted to be significant since the ORP values (Figure 4.20) indicated that both reactors were highly aerobic and similar in terms of the conditions within the pre-treatment columns.

The DO concentrations in PT L2 and PT L4 were significantly smaller due to the much lower air supply rate of only 50 mL/min. The average DO concentration was approximately 30 ppb in these reactors. The measurement of such small DO concentration was challenging and hence their accuracy was not certain. The ORP values of these two pre-treatment columns were both highly reducing (approximately -340 mV), confirming that a micro-aerated environment had been established within the two columns.

The results indicate that the extreme aeration rates that were proven to be successful in pathogen destruction in phase 2 were repeated in this experiment with two different retention times.

In both pairs of columns, the ORP values appeared to decline slightly with time. This may be due to a decline in the DO concentration that was not easily measured due to the low concentrations in the micro-aerated reactors. The DO concentration in the aerobic pre-treatment columns also decreased with time. The air stones used to provide fine bubble diffused air to the treatment columns were only replaced between phases. At each cleaning, a thick biofilm (1-2 cm) was observed to have formed around the airstones. If this experiment were to be repeated in the future over a similar length of time, it may be advantageous to routinely replace the airstones as this could be the reason for the declining aeration of the columns.

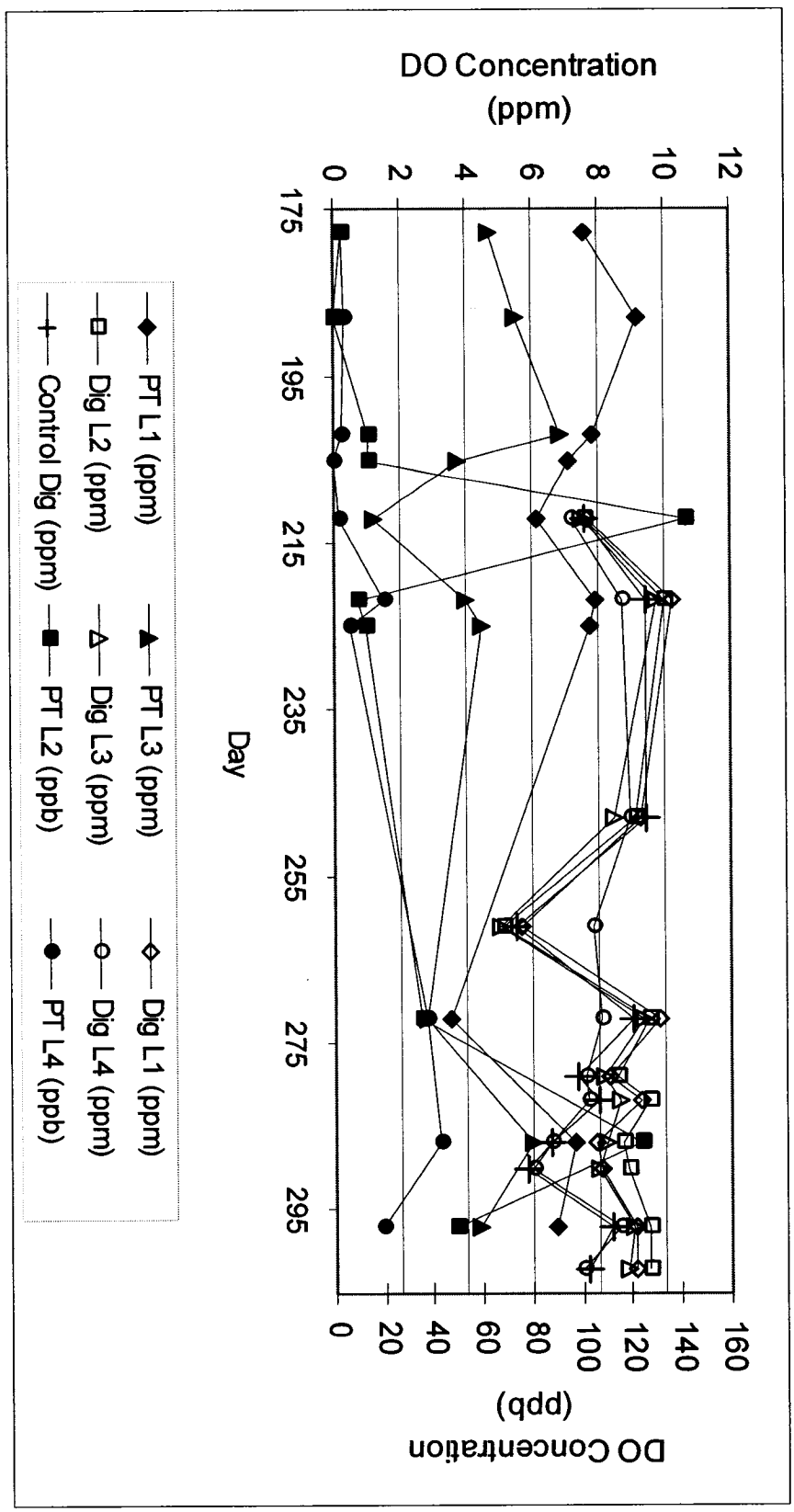

Figure 4.19: Phase 3 dissolved oxygen concentrations

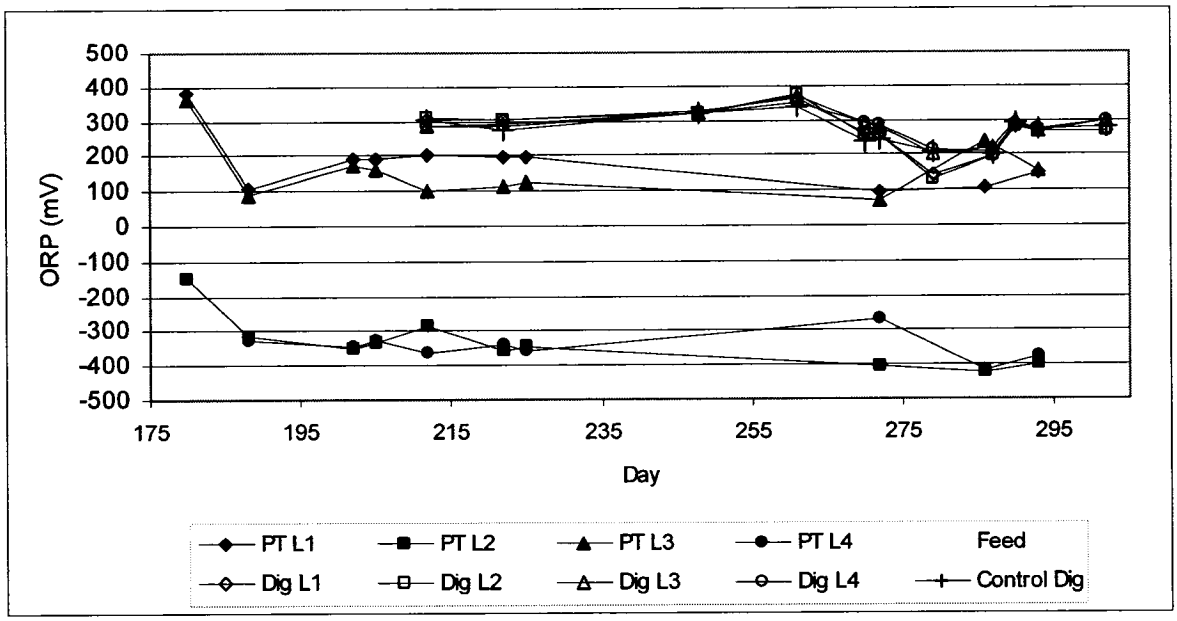

Figure 4.20: Phase 3 oxidation-reduction potentials

No mechanical mixing was provided to the digesters, mixing was accomplished due to the high aeration rate maintained in the digesters. This also provided DO concentrations close to saturation and high ORP values. The values were very similar and due to the overlap, it was not possible to detect any differences between the digesters. Due to the highly aerobic environment it was doubtful that there would be much difference between the digesters due to the amount of excess air.

pH and Alkalinity

The pH values measured during phase 3 are presented in graphical form in Figure 4.21. During phases 1 and 2, the pH values were similar with little difference between the columns. The pH values measured in the pre-treatment columns during phase 3 seem to give an indication of the conditions within the reactors. Initially, the lowest pH was in PT L1 but later in the phase, it increased significantly. As will be subsequently demonstrated, this was likely due to nitrification occurring in the column which brought the pH down due to the consumption of alkalinity but prior to the final three measurements, nitrification stopped within the column. PT L2 had the highest pH over the first seven data points. The elevated pH corresponded to an elevated alkalinity and high concentration of NH_4-N in the micro-aerated pre-treatment column.

The pHs of columns 3 and 4 were similar. PT L4 had high alkalinity which was probably due to the high concentration of NH_4-N. It is difficult to explain what conditions within PT L3 lend themselves to the pH being so similar to PT L4 since it's ammonia concentrations were significantly lower. PT L2 had the highest alkalinity which corresponds to its elevated aqueous NH_4-N concentrations.

The low pH values of the digesters indicate that nitrification had consumed all of the alkalinity within the streams resulting in such low pH values. These values were significantly below the optimal range of nitrification. However, not all of the data coincides with nitrification occurring within the digesters as will be outlined in the following sections.

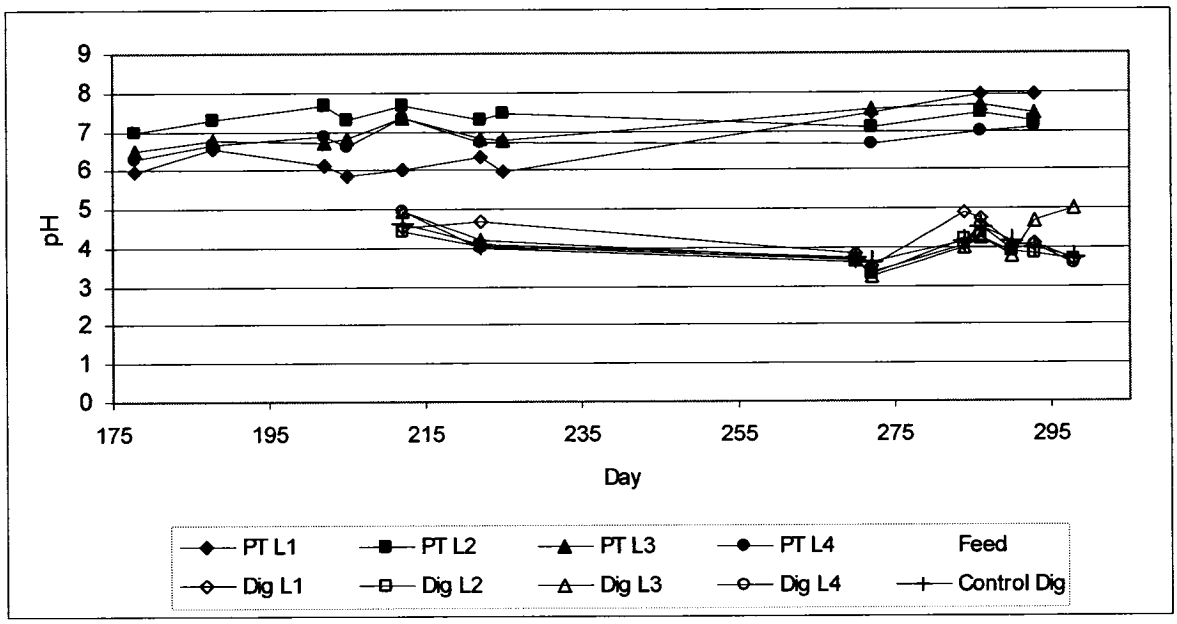

Figure 4.21: Phase 3 pH values

The alkalinities measured during phase 3 are presented in Figure 4.22. Values were only presented for the feed and pre-treatment streams because by definition, there was no alkalinity in the digesters due to their low pH values. The alkalinity was high in pre-treatment columns 2 and 4 which can be attributed to the high NH_4-N concentrations in these two reactors. Lower alkalinity values in PT L1 and PT L3 suggest that it may have been consumed during nitrification.

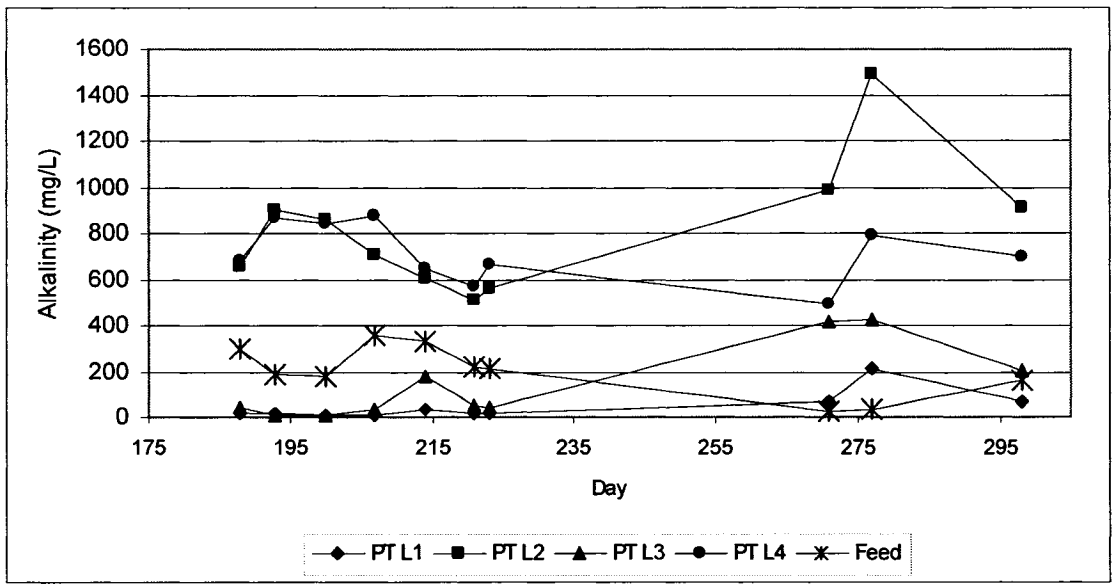

Figure 4.22: Alkalinity in four pre-treatment columns during phase 3

Soluble COD and Total VFAs

As previously mentioned, soluble chemical oxygen demand is made up of complex and VFA COD. Therefore, these two parameters have been presented together for analysis. Figure 4.23 and Figure 4.24 illustrate sCOD and TVFAs concentrations respectively. Similar patterns were observed for both responses suggesting that a majority of the sCOD was due to the presence of VFAs.

The low sCOD concentrations in pre-treatment columns 1 and 3 coincide with negligible concentrations of VFAs. This was likely due to their consumption as they are being produced. As expected, based on the previous phases, elevated concentrations of sCOD and VFAs were observed in micro-aerated pre-treatment columns 2 and 4. The higher sCOD concentrations observed in PT L2 may be due to an increased accumulation within the reactor due to the longer retention time however these values did not correspond to higher TVFA concentrations. It would appear that the conditions in the pre-treatment reactors changed around day 275. At this time, the sCOD values increased slightly but more significantly, an increase in TVFAs concentrations was observed in all but PT L1. The previously mentioned airstone deterioration with time and the possible subsequent decreased oxygen transfer would explain the decreasing trend in the DO and ORP values. The trend

towards more anaerobic conditions within the pre-treatment columns explains the increased production of fermentative end products.

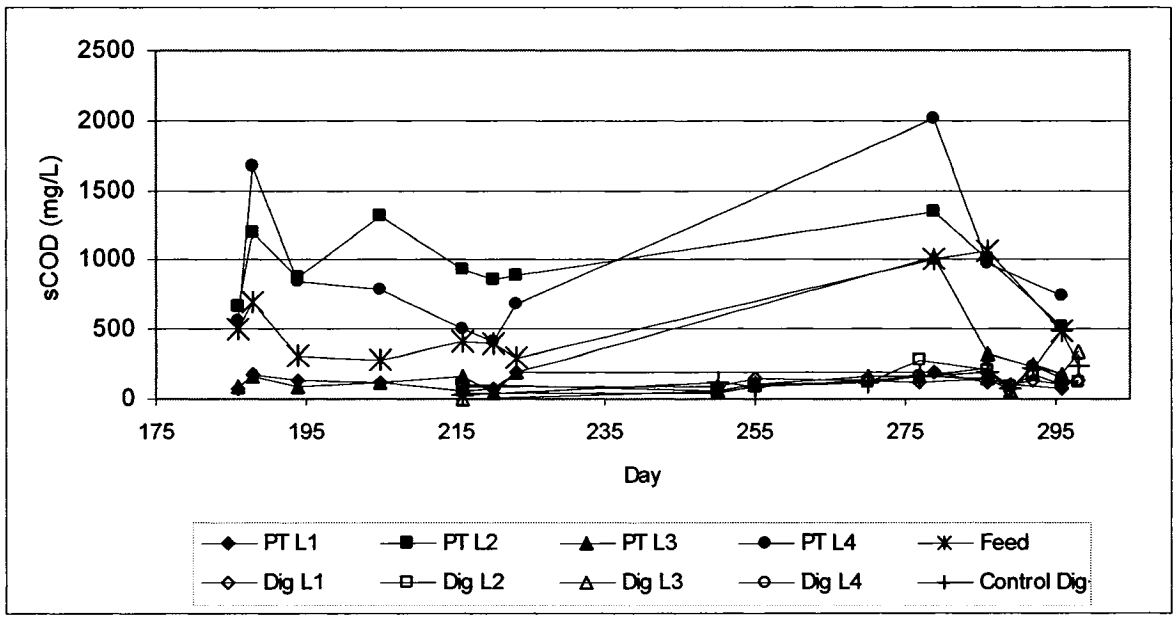

Figure 4.23: Phase 3 soluble chemical oxygen demands

VFAs were not detected in the digesters as the low pH of the digesters did not allow for the titration method of TVFAs to be employed. IC measurements confirmed no measurable concentrations of the individual VFAs (acetate, propionate and butyrate) were present in any of the digesters (detection limit = 6 mg/L). The absence of VFAs explains the low sCOD values which would consist solely of complex COD. The absence of VFAs in the digesters was likely due to them being biodegraded in the highly aerobic conditions in the digesters. The results indicate that the relatively low pH of the aerobic digesters did not inhibit heterotrophic consumption of VFAs.

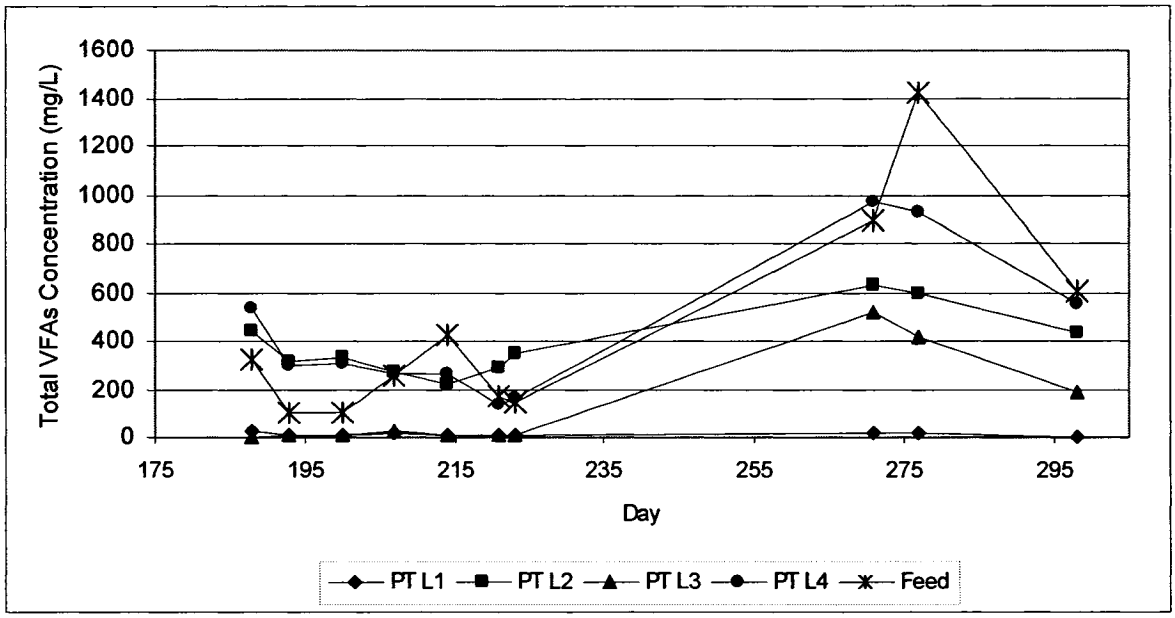

Figure 4.24: Total volatile fatty acid concentrations in four pre-treatment columns during phase 3

The process performance in this experimental work was evaluated by examining:

- Nitrogen Series
- Solids Concentrations
- Settling
- Microbial Analysis

The nitrogen series included nitrite, nitrate, aqueous ammonia and TKN concentrations. The concentrations of these parameters were employed to examine the extent of nitrification in the pre-treatment columns and the subsequent digesters. Total and volatile solids concentrations were measured for ten streams within the five process trains. The streams included feed concentration, four pre-treatment column effluents and five digester effluents. The concentrations of total and volatile solids were employed to determine the ability of the process trains to stabilize the sludge solids and reduce the mass of solids. WWTPs depend on decanting to concentrate solids within their storage tanks in order to optimize storage through the winter months. The ability of the biosolids to settle in the storage tanks is an important characteristic for application of this work. The settling of the sludges was measured during phase 3 of this study. The concentrations of fecal coliforms, *E. coli*, *Salmonella* spp. and *Clostridium perfringens* in the ten streams were examined to evaluate

the effectiveness of each of the process trains with regards to pathogen reduction.

Nitrogen Series: Nitrite, Nitrate, Aqueous Ammonia and TKN

The nitrite-nitrogen concentrations of the ten streams analyzed are presented in Figure 4.25. The nitrite ion is a product of the first step of nitrification; however, the absence of nitrite-nitrogen does not signify that nitrification is not occurring. In phases 1 and 2, PT L1 did not have significant concentrations of nitrite-nitrogen as it was being consumed as quickly as it was being produced resulting in minimal concentrations being measured.

In phase 3, pre-treatment columns 2, 3 and 4 all at some point contained elevated concentrations of nitrite. PT L2 most commonly contained some level of nitrite-nitrogen. The initially high nitrite-nitrogen concentrations observed in the digesters were discarded as they appeared to be outliers. All the subsequent data points for digesters 2, 3, 4 and the control had no measurable concentrations of nitrite-nitrogen. Digester L1 contained 57.1 mg/L for the first data point, 1.3 for the second and 0.1 for the third. Nitrite-nitrogen was not detected in the final four data points.

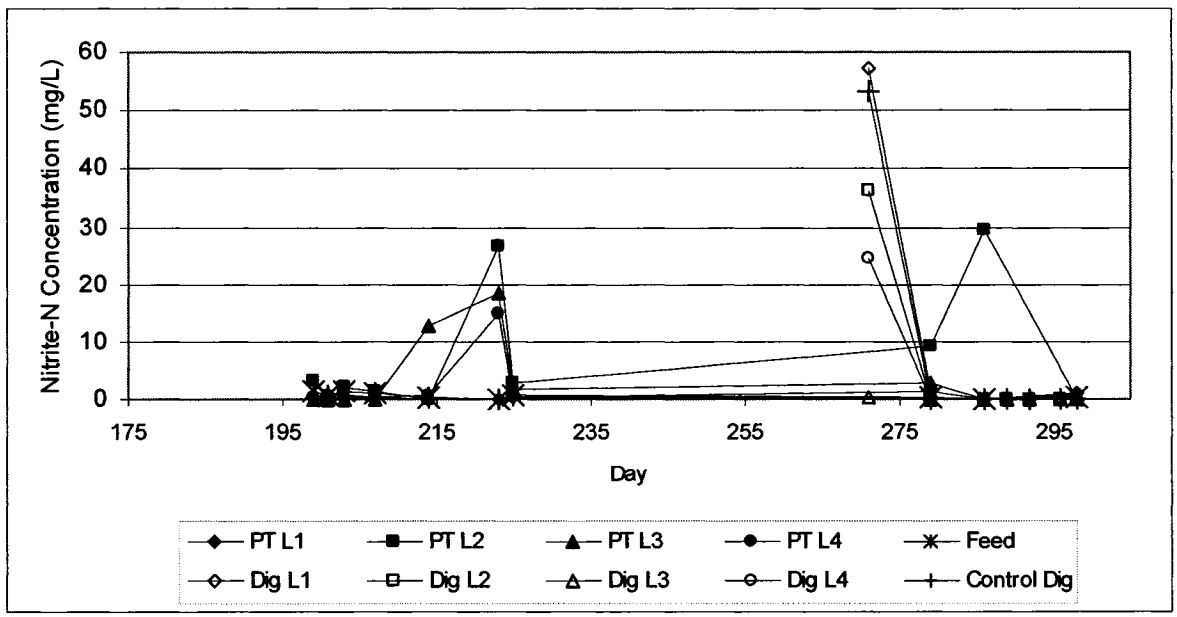

Figure 4.25: Phase 3 nitrite-nitrogen concentrations

Nitrate-nitrogen is a product of nitrification; therefore, presence of this ion confirms the occurrence of nitrification. Figure 4.26 which outlines the nitrate-nitrogen concentrations measured during phase 3 of this work confirms that nitrification was occurring in PT L1 during phase 3. The lower concentration measured in PT L3 indicates that nitrification was also occurring in that pre-treatment column but to a lesser extent than in PT L1. The difference between these two columns was their retention time (2 days versus 4 days). The longer retention time of PT L1 (4 days) provided additional residence time in the reactor for nitrification.

The concentrations of nitrate-nitrogen present in the digesters were more varied. Digester L1 initially had a large concentration but over time, the concentration continually decreased. Digesters L2 and L4 behaved similarly with consistently low concentrations indicating that limited nitrification occurred in these digesters. The control and L3 digesters had intermediate concentrations with one large value measured in the middle of testing.

Analysis of the pH data for pre-treatment column L1 identified the possibility that during the interval in pre-treatment sampling, nitrification was lost in PT L1. The nitrate data confirms this hypothesis with lower concentrations measured during the final two data points collected. The absence of nitrification in L1 during the latter stages of the experiment may explain the declining nitrate-nitrogen concentration measured in the digester. The mid-range concentrations of nitrate-nitrogen measured in digester L3 and the control digester indicate that some nitrification was occurring in these digesters. The low concentrations measured in digester L2 and L4 indicate that minimal nitrification was occurring in these digester based on the nitrate-nitrogen data alone.

The low pH values in all of the digesters suggest at least partial nitrification. The ammonia data presented in Figure 4.27 was used to draw conclusions regarding the occurrence of nitrification. The pre-treatment column NH_4-N concentrations were consistent with the results from phases 1 and 2. The lower NH_4-N concentrations of PT L1 and L3 indicate that ammonia was being used as a reactant in nitrification. The elevated

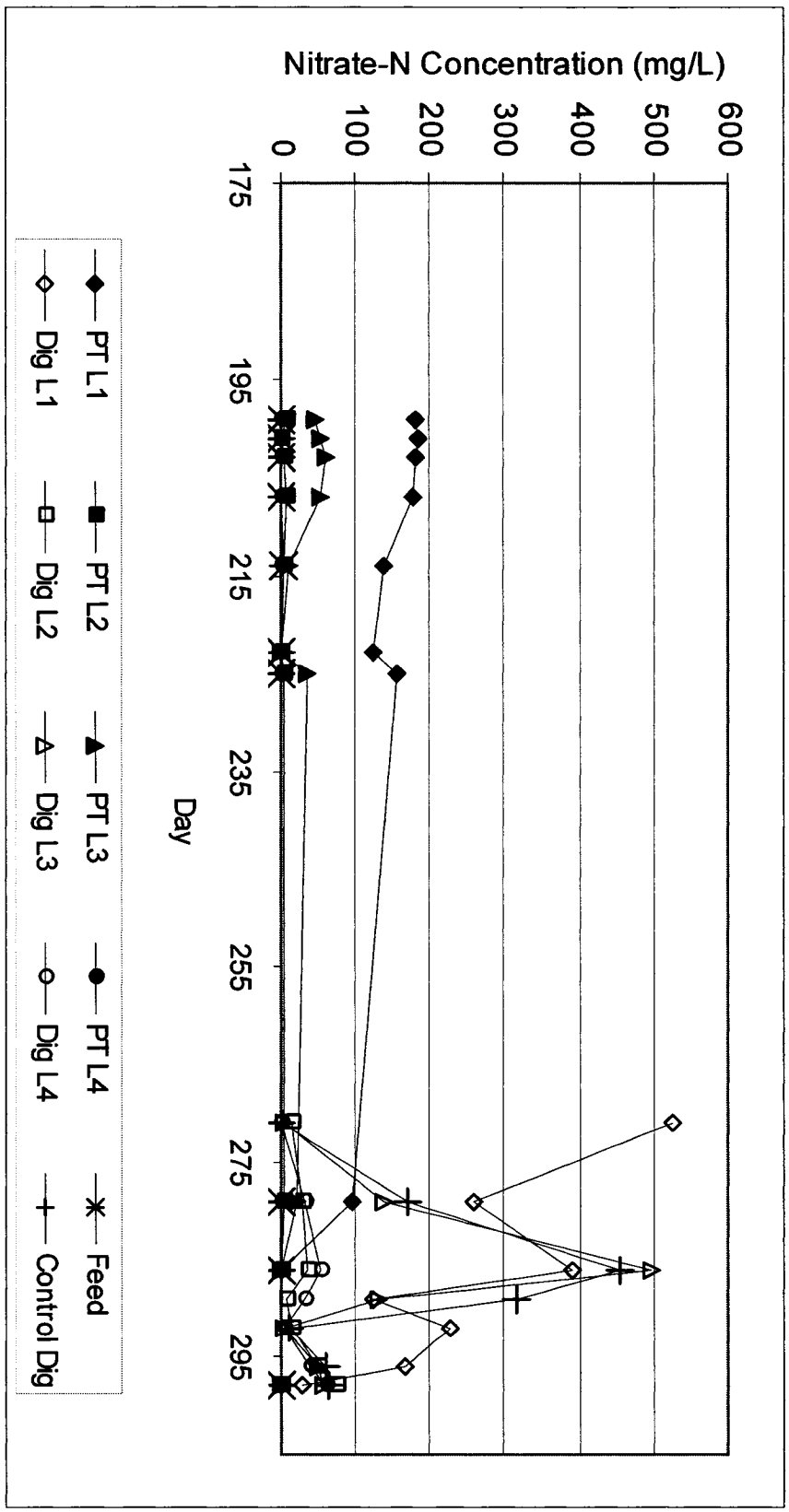

Figure 4.26: Phase 3 nitrate-nitrogen concentrations

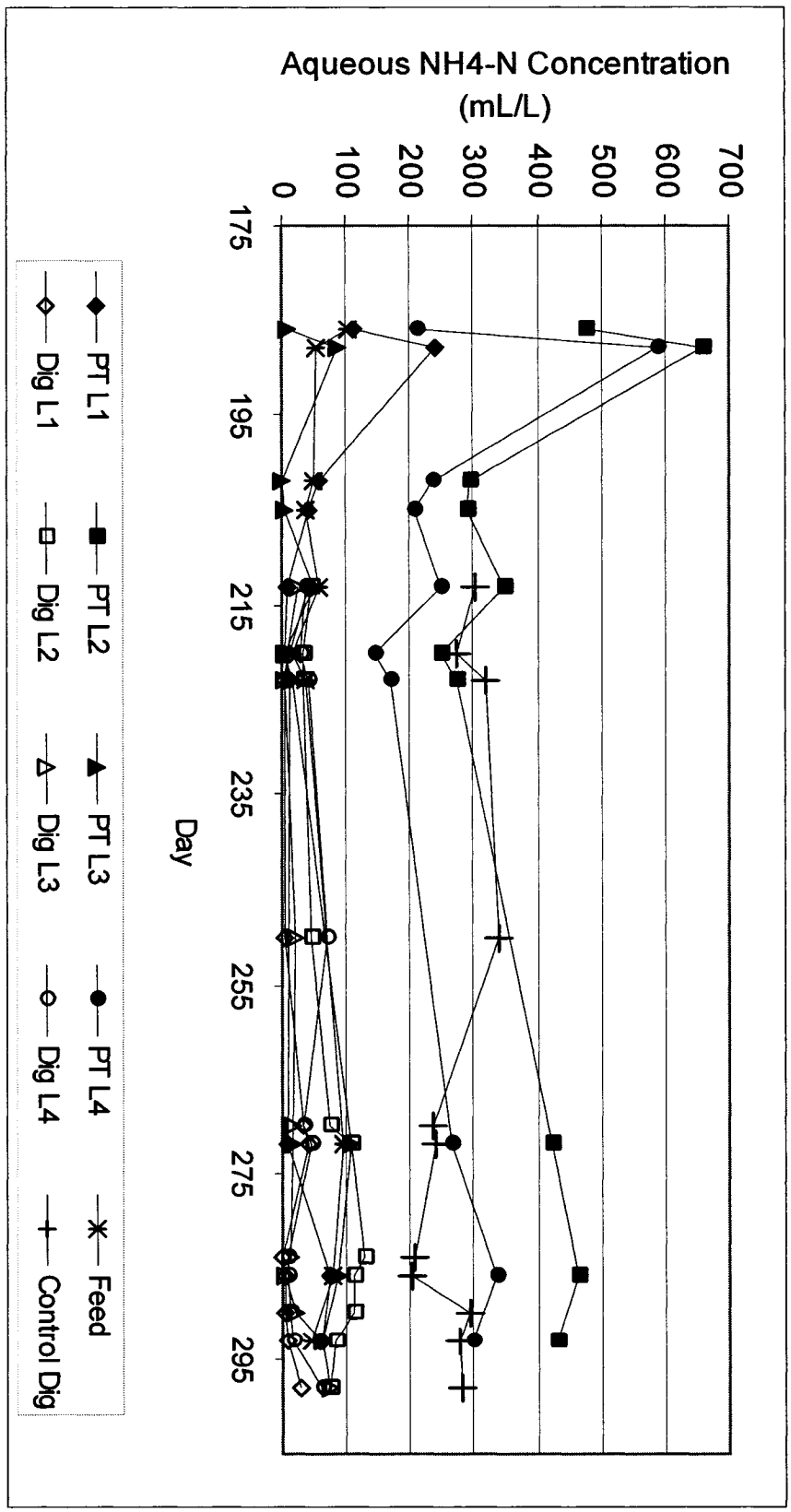

Figure 4.27: Phase 3 aqueous ammonia nitrogen concentrations

concentrations measured in the micro-aerobic pre-treatment columns (L2 and L4) indicate that hydrolysis was degrading protein which released ammonia. The ammonia being produced in these columns accumulated to steady state levels with fairly consistent concentrations. These columns were then supplying their corresponding digester with a supply of ammonia.

The elevated concentrations of NH_4-N that were measured in the control digester were likely a result of hydrolysis of the feed sludge. The NH_4-N concentrations indicate that degradation was occurring within the digester but the conditions did not support complete oxidation of the ammonia. The NH_4-N concentrations in the L1 digester were low. The low concentrations in the influent and the occurrence of nitrification in the digester explain the low ammonia concentrations that were maintained in the digesters. The L2 stream had high concentrations of ammonia introduced into the digester from the pre-treatment column and these elevated concentrations were reduced to stable lower concentrations which indicate that at least partial nitrification was occurring in the digester. The NH_4-N concentration measured in digester L2 was higher than the other digesters. This could be attributed to either sub-optimal conditions for nitrification or residual NH_4-N concentration due to the high influent concentration being introduced to the digester. The remaining digesters all had very small concentrations of NH_4-N which indicates that nitrification was occurring. The conditions of the L3 stream were similar to that of L1 while the elevated influent concentration of L4 put it in the same category as L2. The low pH of the aerobic digesters was likely responsible for reducing the extent of nitrification that may have occurred at the extended HRT.

Table 4.7 presents the average TKN and nitrate-nitrogen concentrations measured in the five process streams. TKN values include organic nitrogen, ammonia gas and ammonium ion. Therefore, in this work they included organic nitrogen and NH_4-N which is why NH_4-N was not duplicated in the table. The total nitrogen in a sample includes TKN, NO_3-N and NO_2-N. Figure 4.25 illustrated that the nitrite-nitrogen concentration were negligible in the samples analyzed.

Table 4.7: Average TKN, nitrate-nitrogen and total nitrogen concentrations in five process streams

Units: mg/L		Control	L1	L2	L3	L4
TKN	Influent Feed Concentration	992 ± 106				
	Pre-treatment Concentration	N/A	820 ± 280	767 ± 176	680 ± 198	999 ± 117
	Digester Concentration	614 ± 28	515 ± 48	427 ± 55	541 ± 33	562 ± 76
NO_3-N	Influent Feed Concentration	0.38 ± 0.60				
	Pre-treatment Concentration	N/A	124 ± 71	2.6 ± 2.6	28.2 ± 24.7	0.7 ± 0.6
	Digester Concentration	154 ± 173	246 ± 168	31 ± 25	126 ± 172	31 ± 23
Total N	Influent Feed Concentration	992 ± 107				
	Pre-treatment Concentration	N/A	944 ± 351	770 ± 179	708 ± 217	1,000 ± 118
	Digester Concentration	768 ± 201	761 ± 216	458 ± 80	667 ± 205	593 ± 99

The total nitrogen values in each of the streams indicate the extent of nitrification/denitrification occurring in the process streams by way of nitrogen removal. There appeared to be a slight decrease in total nitrogen in pre-treatment columns 2 and 3. Both of these columns contained smaller concentrations of TKN over the feed influent concentrations and only small concentrations of nitrate-nitrogen were measured in these two reactors. The small NO_3-N concentrations were believed to be due to the fact that no nitrification was occurring within these two columns. However, combined with the

decreased total nitrogen concentrations, it is possible that nitrification was occurring in these columns and the absence of excess oxygen in these streams allowed for the occurrence of denitrification resulting in decreased nitrogen concentrations. The nitrogen removal was small as a result of only minimal nitrification occurring due to the lack of excess oxygen.

Analyzing the total nitrogen concentrations in the digesters provides a measure of nitrogen removal in the entire process stream. If the standard deviation is considered when comparing the total nitrogen concentrations in the control digester as well as digesters 1 and 3, it is apparent that no significant nitrogen removal was achieved. In each of these digesters, elevated nitrate-nitrogen concentrations were observed indicating that nitrification was occurring. However, the similar total nitrogen concentrations when compared to the feed concentration indicate that denitrification was not occurring as there was not nitrogen removal from the system.

Contrarily, digesters 2 and 4 have lower effluent nitrogen concentrations than the influent feed total nitrogen concentration, indicating that nitrogen removal did occur within these process trains through denitrification. Both of these process trains saw reducing conditions in the pre-treatment reactors. It is apparent that these conditions influenced the ability of the process steps to aid in denitrification. While the nitrogen species analyzed to date could neither confirm nor deny the occurrence of nitrification, the possible explanation is that the decreased oxygen availability in the pre-treatment columns impacted environmental conditions and assisted denitrification.

Solids: Total and Volatile

Solids destruction can be an indication of sludge stabilization which is an important element of land application. Application of unstabilized sludge on land can lead to vector attraction when land applied. Typically 38% volatile solids reduction over the digestion process is required. However, the sludge used in this experiment was exposed to extended aeration at the WWTP prior to use therefore minimizing the amount of destruction capable by the process trains under investigation. The total and volatile solids destructions observed

in phases 1 and 2 were minimal in value and negligible once experimental error was considered. Total and volatile solids will be presented separately in this section but their conclusions will be summarized together.

Figure 4.28 presents the average values of the duplicate samples for each of the ten samples studied during phase 3 of this experimental work. From the graph, it is evident that during phase 3, the pre-treatment column total solids concentrations were lower than the influent feed concentrations except for the elevated concentrations measured in PT L4 over the last three samples. The total solids concentrations in the digesters were generally equal to or lower than the pre-treatment columns concentrations. The extended length of time in the digesters was expected to result in solids degradation in these reactors. The results support this expectation. Digester L2 appeared to have a consistently lower total solids concentration than the other ten streams over the last six data points. Digester L3 appeared to have poor destruction around day 255 but seems to have performed well over the last 4 sample points.

Table 4.8 presents the average total solids concentration in the ten streams analyzed over the duration of phase 3. The percentage reduction for the nine streams was calculated in reference to the initial feed concentration. The percent reduction calculated for the digesters was not calculated relative to the pre-treatment column effluent due to the increased concentrations observed in Digester L1 relative to pre-treatment.

The destructions calculated for the pre-treatment step seem high as minimal destruction was observed during the 2 day retention time in the previous phases. Pre-treatment columns 1 and 2 had retention times of 4 days which would allow for greater destruction but reductions of 13 and 17% seem high for a sludge source that had already been partially degraded at the WWTP. The retention times of L3 and L4 were only two days and the 2% reduction observed in L4 coincided with the data of the previous phases however, the 14% reduction observed in L3 seemed high based on the conditions within the reactor and the results of the previous phases.

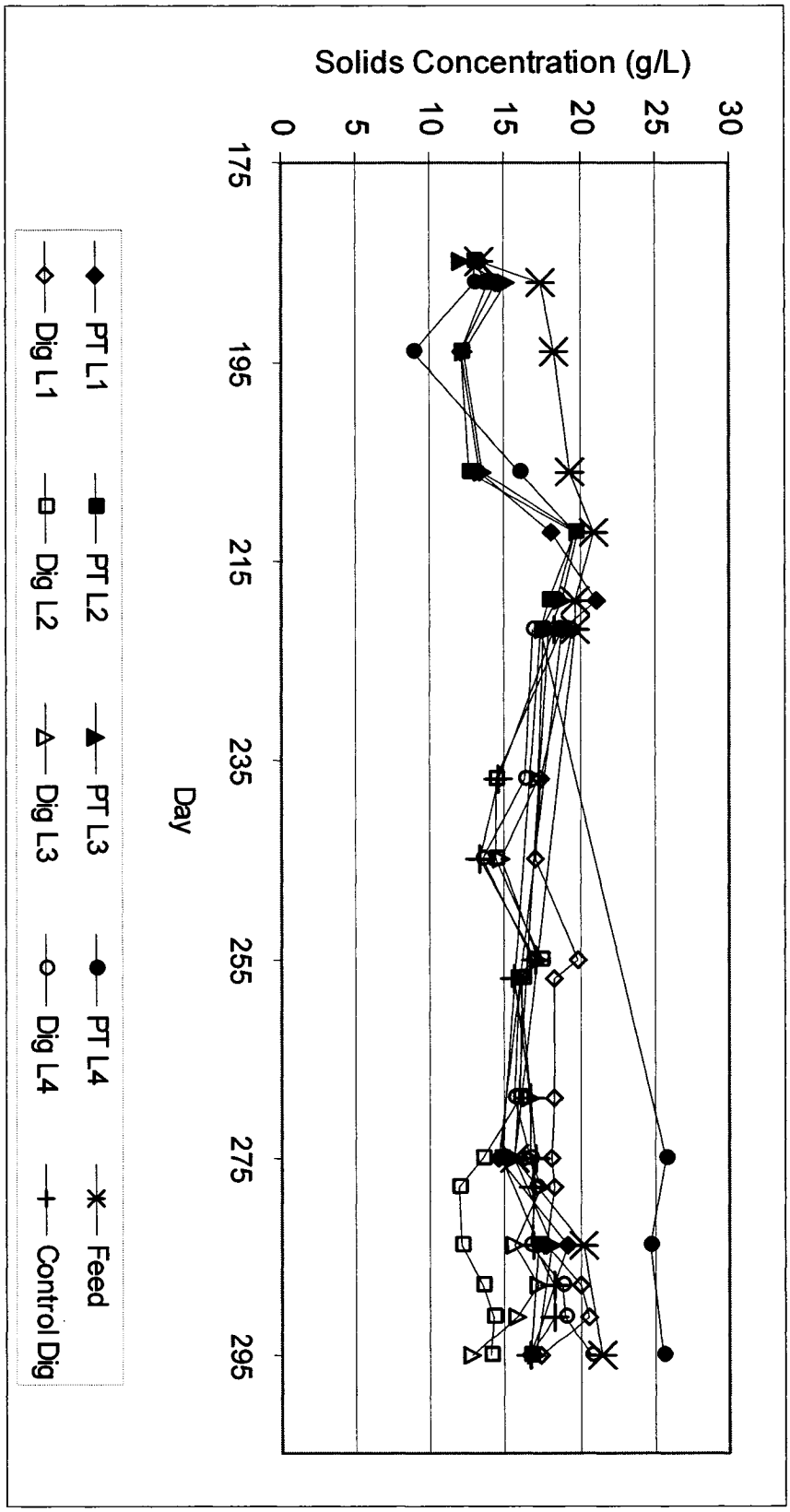

Figure 4.28: Phase 3 total solids concentrations

Table 4.8: Average total solids concentrations and percent reductions over feed during phase 3

Concentrations (g/L)	Control	L1	L2	L3	L4
Influent Feed	18.6 ± 2.6				
Pre-treatment Columns	N/A	16.1 ± 3.0 (13%)	15.5 ± 2.6 (17%)	16.1 ± 2.7 (14%)	18.2 ± 5.8 (2%)
Digesters	16.6 ± 1.5 (11%)	18.5 ± 1.2 (0%)	14.7 ± 2.1 (21%)	16.2 ± 1.4 (13%)	17.0 ± 1.8 (9%)

In the digesters, the control digester had approximately 11% reduction of total solids. Digesters 1 and 4 had 0 and 9% reductions indicating that the pre-treatment in these process trains may have negatively impacted total solids destruction. Digesters 2 and 3 had increased reductions over the control process train indicating that the pre-treatment steps in these process trains may have aided in total solids destruction. Process train L1 had high destruction in the pre-treatment reactor which could be explained by the longer retention time of this pre-treatment step but the overall calculation of total solids production in the digester was unlikely. Digester L2 had the greatest reduction at 21% with approximately 17% occurring in the pre-treatment phase and only 4% destruction occurring in the digester. Elevated destruction in the column was possibly due to the longer retention time (4 days) but it was unexpected that the column achieved 17% reduction while the 40 day digester achieved only 4%. It may be that the sludge could not degrade further than that observed in digester L2. Process train L3 achieved destruction in the pre-treatment column which was unexpected based on the results in phases 1 and 2 and limited destruction in the digestion process. The final process train, L4, had minimal destruction during the pre-treatment step which agreed with the results of the previous phases and approximately 7% reduction in the digestion phase. The destruction observed in this process train seemed reasonable based on expectations and the results of previous phases.

The total solids concentration had relatively high variabilities. The feed sample standard deviation was 14% of its average concentration value. The pre-treatment column effluents were even more variable at 17-32% (standard deviation over average concentrations). Digestion of the solids decreased the variability leading to more consistent results with percentages ranging from 6 to 14.

Figure 4.29 illustrates the volatile solids concentrations measured for all ten streams during phase 3. Similar trends were observed for VS as was previously described for TS. The pre-treatment column concentrations were significantly lower than the influent feed concentration during the sampling events between days 185 and 210. Elevated concentrations were measured in PT L4 over the final three sampling events. The concentrations were greater than the feed concentrations which made them difficult to explain. In addition, similar to the total solids response it is apparent that the digester L2 volatile solids concentrations were lower than all other process streams over the last six data points indicating that process train L2 outperformed the others in terms of VS destruction.

Table 4.9: Average volatile solids concentrations and percent reductions over feed during phase 3

Concentrations (g/L)	Control	L1	L2	L3	L4
Influent Feed Concentration	12.6 ± 1.9				
Pre-treatment Concentration	N/A	10.3 ± 2.1 (18.6%)	9.71 ± 1.6 (23.0%)	10.4 ± 1.8 (17.9%)	12.0 ± 4.2 (4.5%)
Digester Concentration	11.1 ± 1.3 (12.3%)	11.8 ± 1.1 (6.7%)	9.53 ± 1.3 (24.4%)	10.4 ± 1.3 (17.4%)	11.3 ± 1.9 (10.8%)

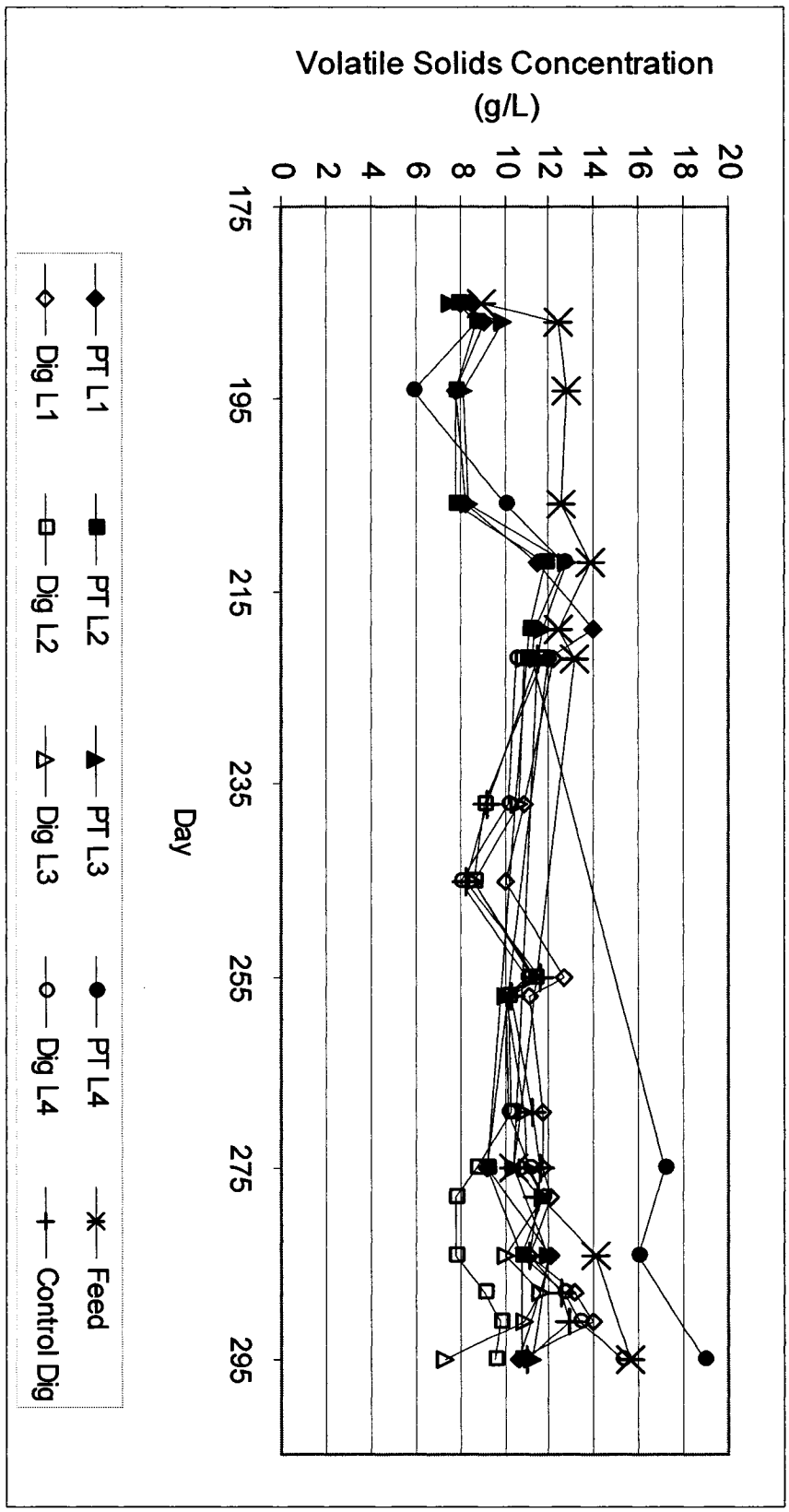

Figure 4.29: Phase 3 volatile solids concentrations

Reductions relative to the average influent feed VS concentration were calculated for the remaining nine process streams and these results are presented in Table 4.9. Within the error associated with the values, the control digester and process trains 1 and 4 performed equally in terms of VS reductions (approximately 10%). Process train L3 performed slightly better while L2 performed the best. A panel discussion on extended air VS reductions (Enviroquip, 1999) suggested that digestion of extended aeration sludge would achieve the expected 38% VS reduction only under rare circumstances. The 24% reduction achieved by PT L2 was consistent with the literature results.

Similar to the total solids concentrations, digestion decreased the variability of the volatile solids concentration. During phase 3, the standard deviation of the feed was 15% of the average concentration. The variability associated with pre-treatment column concentrations was 6-35% while the percentages ranged from 9-17 for the digester concentrations. The variability of the pre-treatment column L2 was the lowest at 6%. This indicates that this process step was able to achieve the greatest reduction with the least degree of variability indicating that it would be suitable for application at a WWTP due to its consistently low values.

Settling

Smaller communities which practice aerobic digestion and land application typically land apply at a farmer's convenience in the spring before planting and in the fall following the harvest. Based on this pattern, WWTPs are required to store their solids through the winter and summer months. In order to utilize all of their storage space to the best of their capabilities, the operators often allow the solids in the storage tanks and digesters to settle and subsequently decant in order to maximize the available storage space. Settling tests were performed in order to evaluate whether the pre-treatment of the sludge would impact the need for storage space at the WWTPs.

Figure 4.31 presents the results of the settling tests. These were performed on the ten streams of the five process trains. One litre Imhoff cones were filled with a sample. The

sludge was left to settle for 45 minutes as outlined in Standard Method 2540 F (American Public Health Association, 1992). After 45 minutes, the sides of the cone were tapped to release particles from the edges of the cone and to encourage settling if pockets had developed within the settled volume. After 15 additional minutes, the settled volume of solids was recorded. In summary, sludge was left to settle for one hour at which point the volume below the sludge blanket was recorded.

The feed samples settled approximately 35 mL/L on average while no pre-treatment column sample ever settled more than 1 mL/L. The feed samples had been stored in a fridge with minimal disturbance for up to one week prior to use. The stock feed settled about 25-50% during this time. It is reasonable that the action of stirring the feed prior to use in the experiment did not significantly change the characteristics of the feed which allowed for settling.

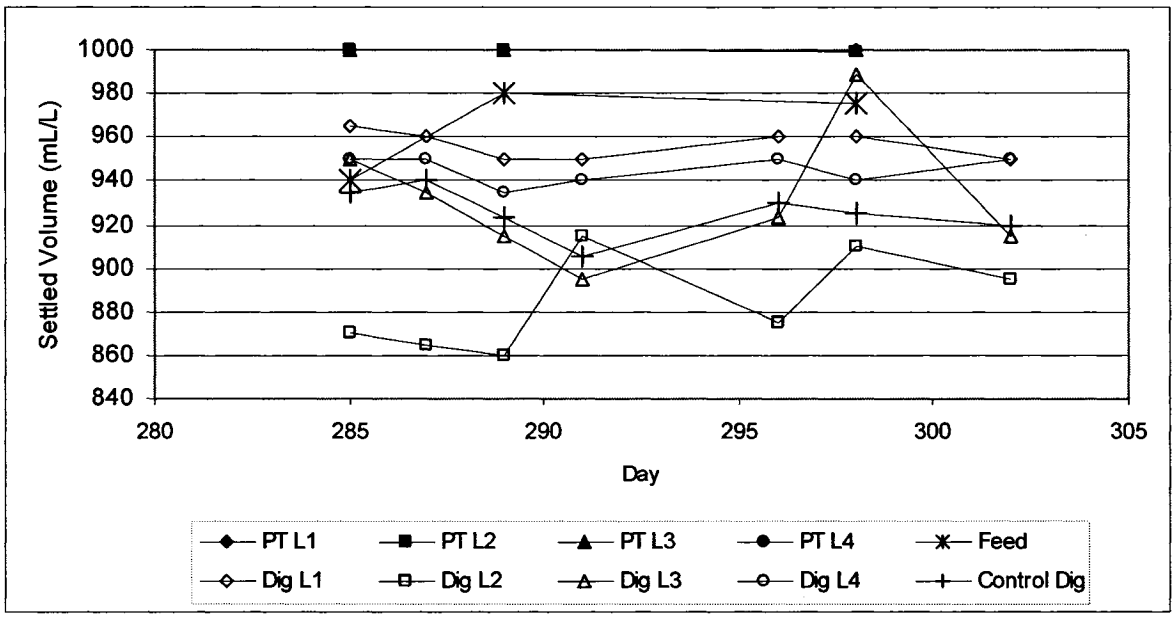

Figure 4.30: Phase 3 settling results

The properties of the pre-treatment column samples which prevent them from settling similarly to the feed samples are possibly that they have been constantly mixing for 2-4 days in the columns which allowed for a more homogeneous sample which was not as conducive to settling. The settling characteristics of the sludge did not change significantly between the

feed and pre-treatment columns samples. The feed samples were simply prone to settling based on the storage length while the column samples were not.

Contrary to the feed and column results, digestion significantly impacted the settling characteristics of the sludge samples. From Figure 4.31 it can be seen that digester L2 typically performed better than the remaining reactors with improved settling observed. Table 4.10 presents the average settled volume for each of the digesters for comparison. The digester order of performance is as follows: L2, Control, L3, L4 and L1. Therefore, the pre-treatment stage in the process train L2 helped to improve the settleability of the sludges as compared to the control. The remaining pre-treatment columns appeared to hinder settling in comparison with the control digester.

Table 4.10: Average settled volumes in the digesters during phase 3

Digester	Settled Volume (per Liter)
Control Digester	75 ± 6 mL
Digester L1	44 ± 22 mL
Digester L2	116 ± 31 mL
Digester L3	68 ± 6 mL
Digester L4	55 ± 11 mL

Microbial Analysis

The concentrations of fecal coliforms, *E. coli*, *Salmonella* spp. and *Clostridium perfringens* in the ten streams (feed, four pre-treatment columns and five digesters) were measured to allow for the evaluation of the five process streams studied in phase 3. The following subsection will cover the results of these streams as well as compare the column effluents measured during phase 3 with those measured during phases 1 and 2 in order to identify the best design parameters in terms of pathogen reduction. The duplicate runs between phases 2 and 3 will also examine the consistency of the results in this testing.

Fecal Coliforms

The fecal coliform concentrations measured during phases 1 and 2 showed that the highly aerobic conditions in PT L1 significantly reduced the fecal coliform concentrations in the pre-treatment columns after only 2 days. The temperature increase of phase 2 over phase 1 impacted the effectiveness of PT L4 which performed similarly to PT L1 during phase 2. In addition to the lower fecal coliform concentrations observed in these two reactors, the variability of the measurements was also significantly reduced in these two pre-treatment columns.

Phase 3 of the experimental work repeated these conditions in PT L3 and PT L4 respectively and included two more pre-treatment columns operating at a retention time of 4 days (PT L1 and PT L2). The fecal coliform concentrations measured in the influent feed stream, the four pre-treatment column effluents as well as the digester effluents are presented in Figure 4.31. The scale of this graph is logarithmic which allows for easier interpretation. From Figure 4.31 it can be seen that the pre-treatment columns consistently achieved at least one log reduction in all the reactors. The digesters typically achieved 1-2 additional log reductions during the 40 day retention time. Digesters L2 and L4 appear to have performed the best based on the graphical results of Figure 4.32 which presents the average concentrations in each of the digesters during phase 3 with the error bars set at their standard deviations. From this graph, the reduced concentrations and variability of digester L2 effluent is evident. Not only is the lower concentration an important aspect, the small variability associated with this process train indicates that it would offer a promising solution in the plant situation in that it adequately handles changes in loading without significant impact on the final concentration.

The duplicate runs between phases 2 and 3 were compared to examine whether the results of the experiment were reproducible. Figure 4.33 illustrates that the results were reproducible. In phase 3, the concentrations in the duplicate columns were very similar to those measured during phase 2. The variability of the fecal coliform concentration measured in PT L4 decreased slightly for phase 3 but that of the highly aerated, 2 day retention time

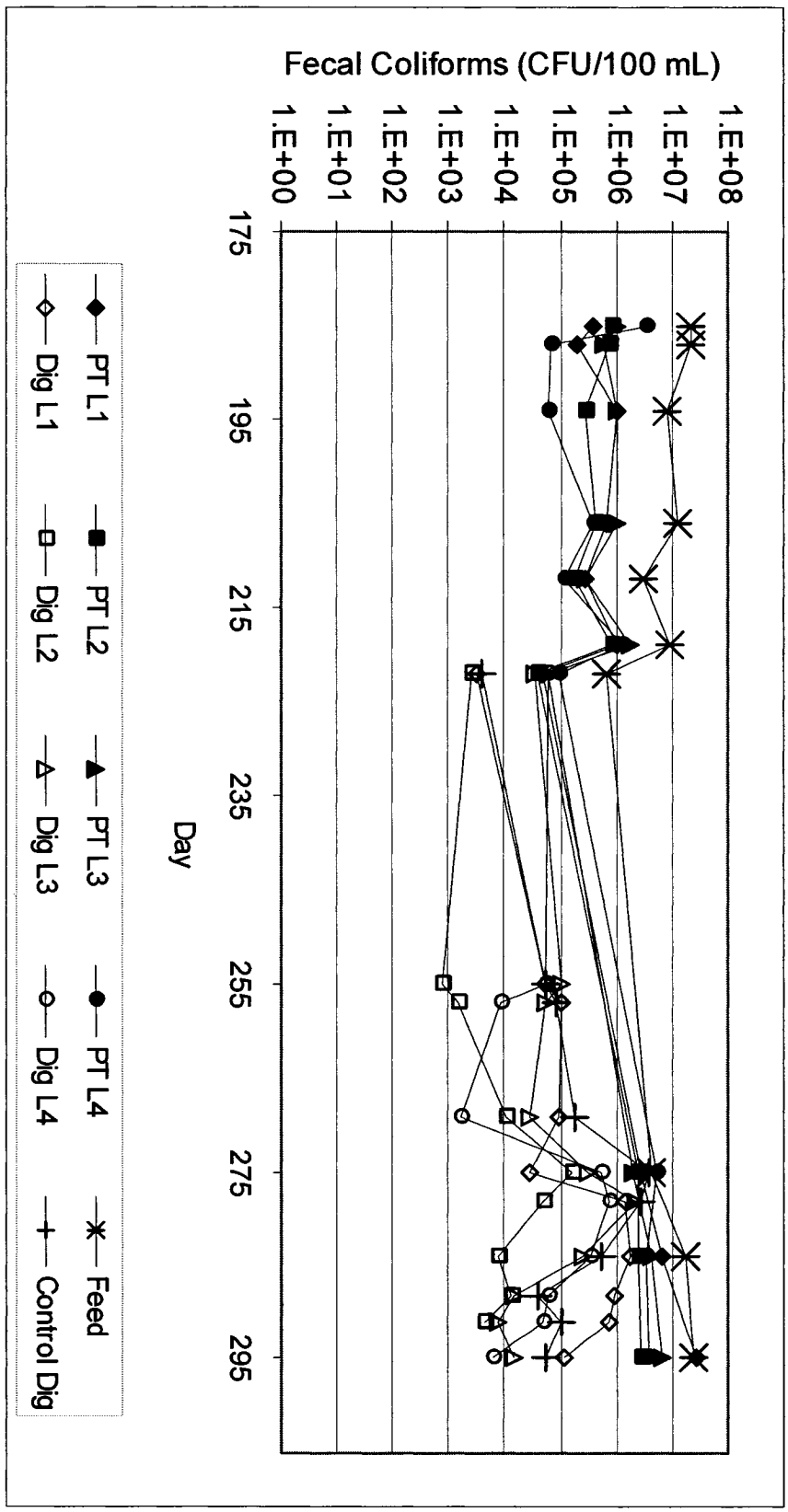

Figure 4.31: Phase 3 fecal coliform concentrations

column increased slightly. The increased variability could be due to the increased variability of the feed during that phase.

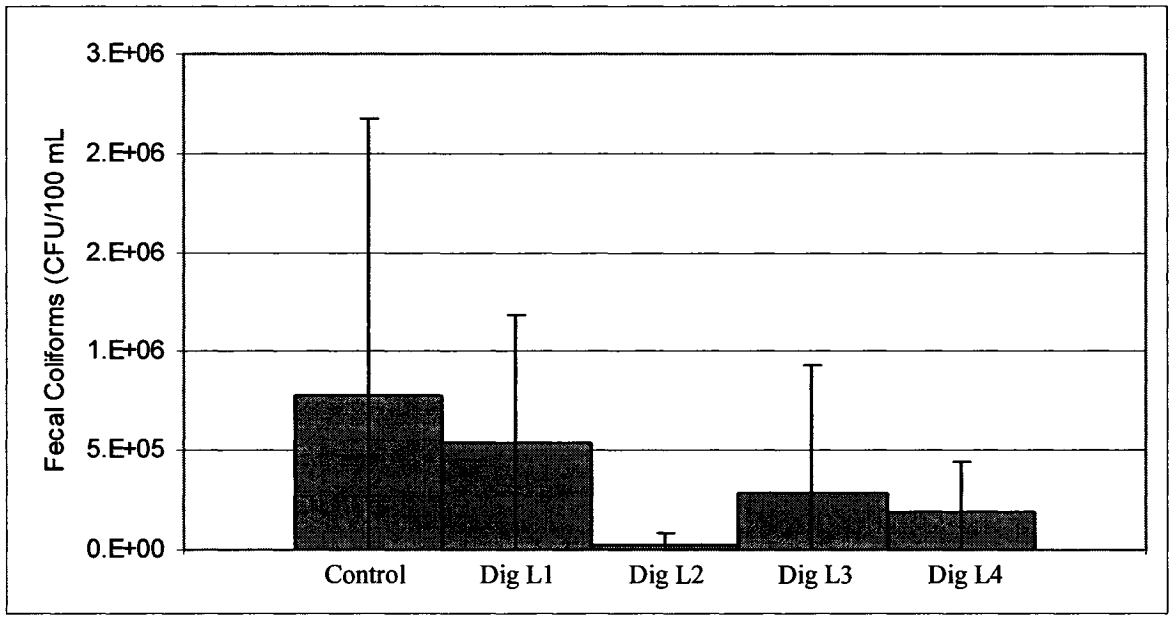

Figure 4.32: Average digester fecal coliform concentrations

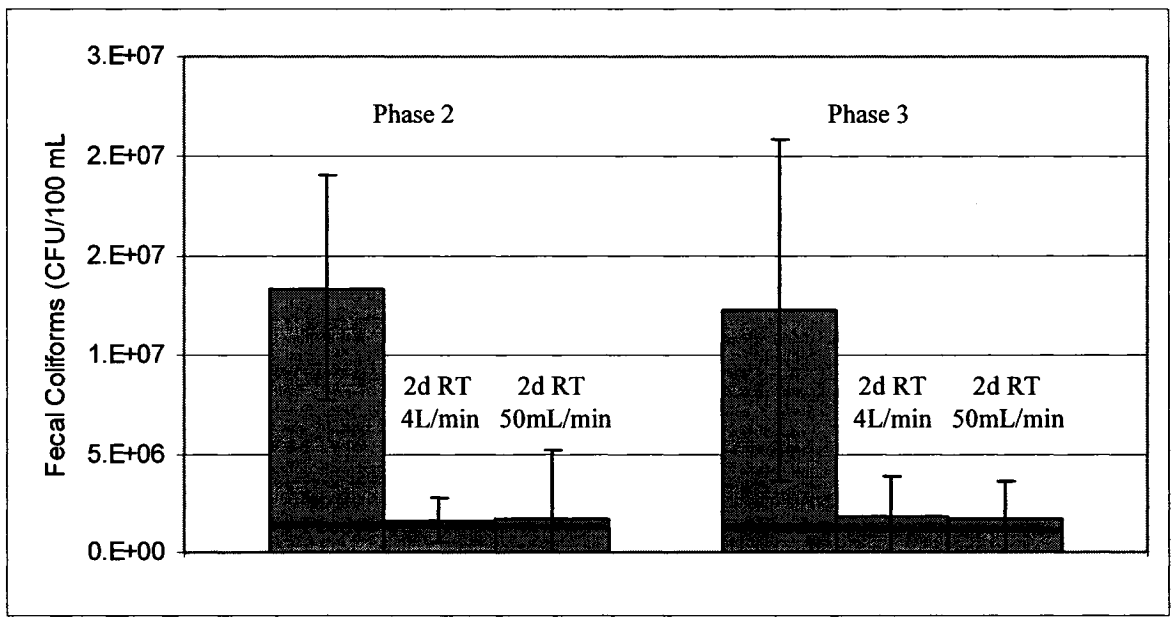

Figure 4.33: Average feed and selected column fecal coliform concentrations from phases 2 and 3

In summary, PT L2 achieved the greatest fecal coliform reduction. The performance of the remaining digesters in order was 4, 3, 1 while the control digester had the least reduction indicating that sludge pre-treatment positively impacted fecal coliform destruction.

E. Coli

The results from phases 1 and 2 indicated that *E. coli* responded in a similar manner as the fecal coliforms with the extreme aeration pre-treatment columns performing significantly better in terms of reduction. These phases were repeated in phase 3 in pre-treatment columns L3 and L4.

Figure 4.34 presents the average of the duplicate samples measured for the ten process streams during phase 3. Similar to the fecal coliform responses, it is apparent that the pre-treatment columns each reduced the *E. coli* concentrations by approximately one log reduction. The reductions observed in the digesters were much more varied. Typically the range of log reductions was between 1 and 3. Digester L2 continued to perform the best in terms of total reduction.

In order to better compare the digester effluents which represented the *E. coli* reduction through the entire process train, Figure 4.35 illustrates the average digester *E. coli* concentrations along with their standard deviations in order to evaluate variability. It is evident from Figure 4.35 that process trains L2 and L4 performed the best in terms of *E. coli* reductions. The variability of these digesters was also lower indicating a more predictable response to varying influent concentrations. The average *E. coli* concentration in digester L3 was approximately double the average concentrations in digesters 2 and 4. The larger average concentrations in the control digester and digester L1 indicate poor pathogen destruction in comparison with the other process trains.

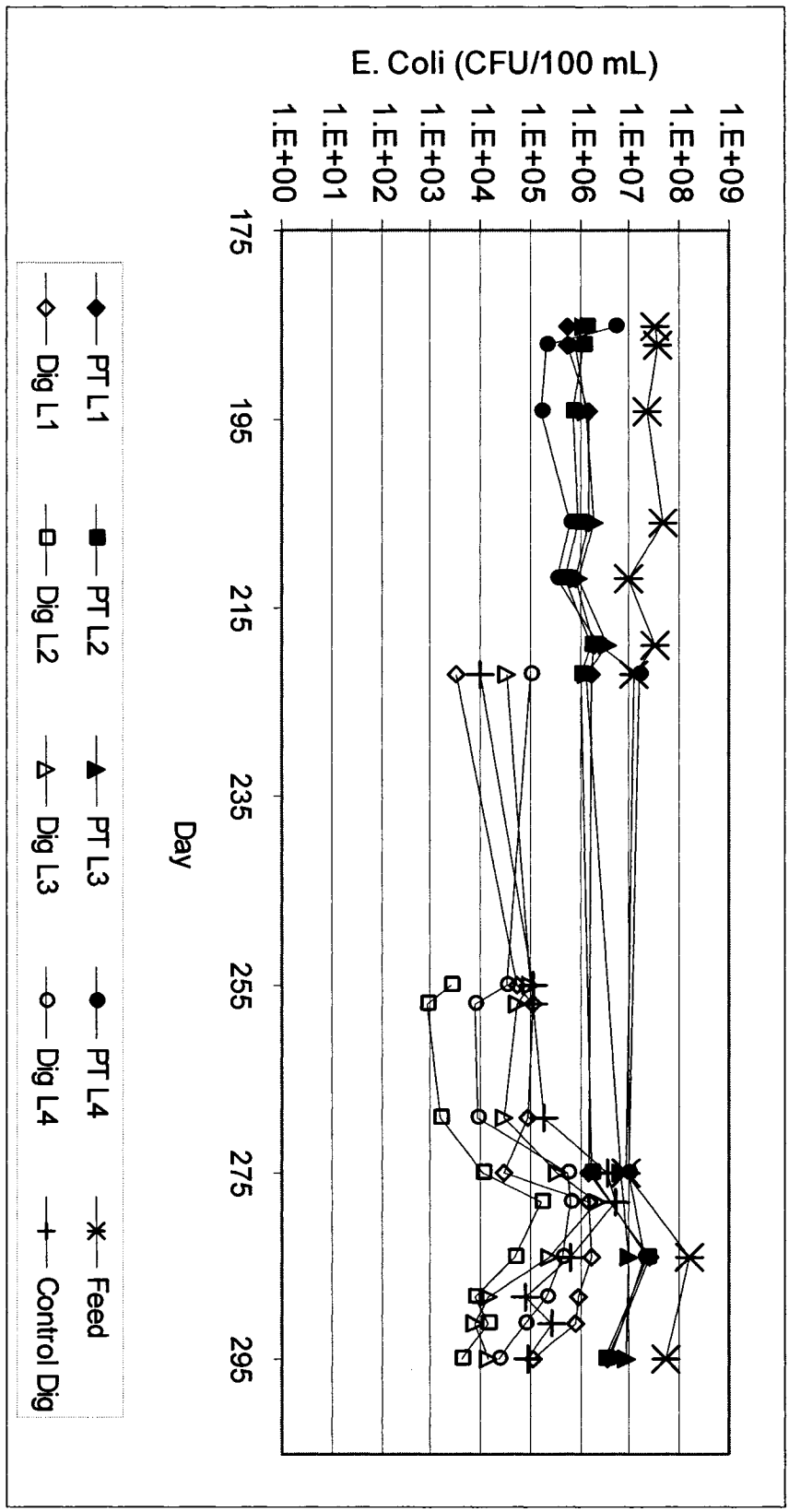

Figure 4.34: Phase 3 *E. coli* concentrations

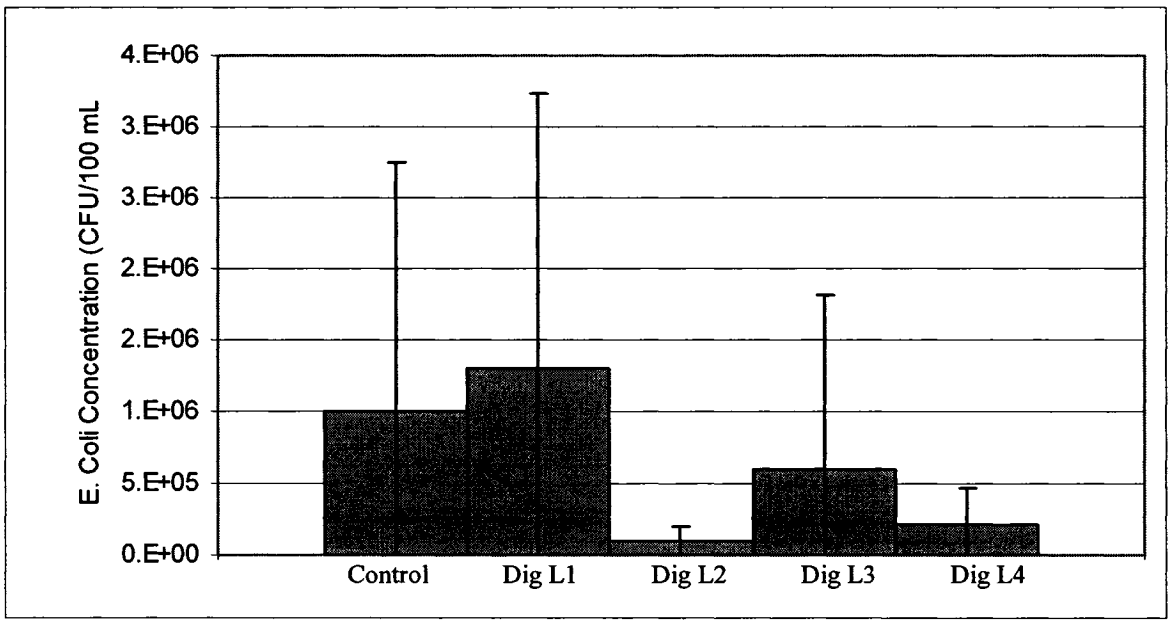

Figure 4.35: Average digester *E. coli* concentrations

Figure 4.36 outlines the average concentrations measured in each of the ten process streams during phase 3 of this experiment. From the graph, it is evident that the pre-treatment columns all achieved approximately equal reductions. However, the conditions of the pre-treatment columns impacted the results observed in the digesters. This graph indicates that the columns achieved approximately one log reduction while the digesters achieved another 0.5 to 1.5 log reduction. Thus, the differing conditions established in the pre-treatment columns significantly impacted the reductions observed in the digesters.

As previously mentioned, two of the pre-treatment columns of phase 2 were repeated in phase 3. The measurements of these four pre-treatment columns have been included in Figure 4.37 in order to compare the results. Each of the pre-treatment columns achieved low concentrations. The concentrations and variabilities measured in phase 3 were slightly greater than those measured in phase 2. This was probably due to the increased feed concentrations and variability during phase 3. Though the concentrations and variabilities increased slightly with the increased feed concentration and variability, the columns were still successful at significantly reducing the *E. coli* concentrations even with the increased concentrations and variability. This indicates that this system may be able to perform in a consistent and reliable fashion in a real world application.

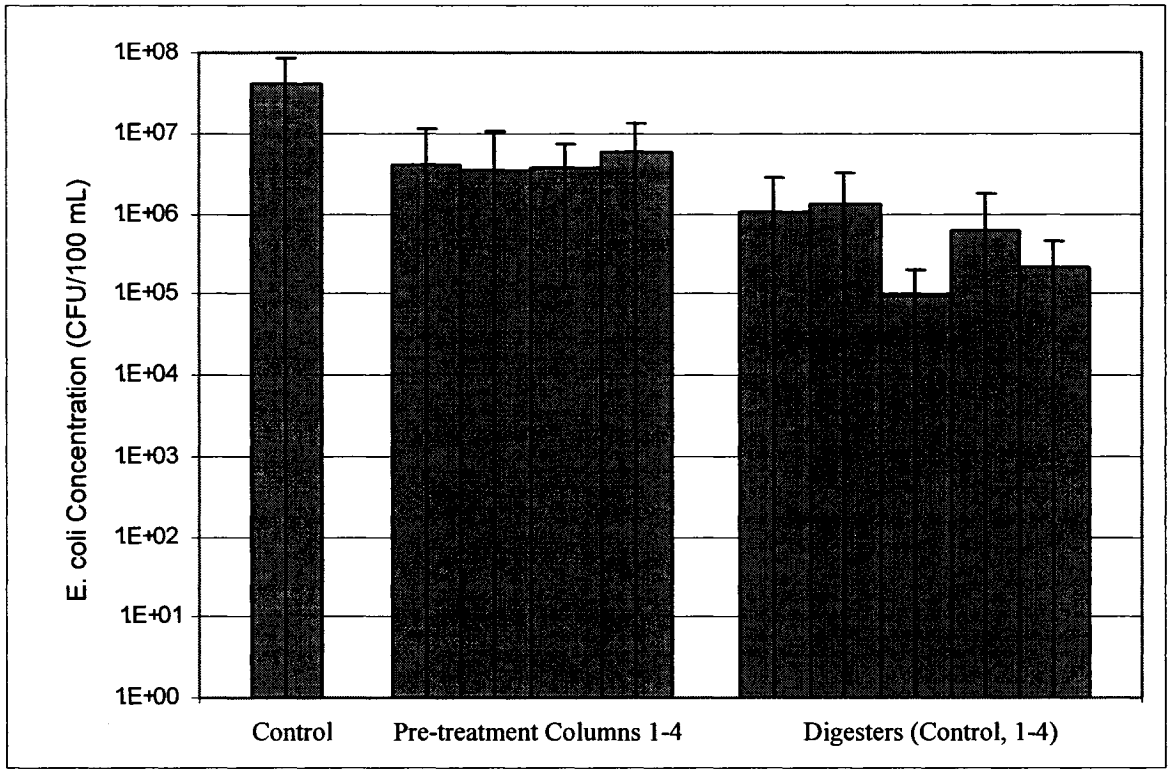

Figure 4.36: Average *E. coli* concentration in ten streams during phase 3

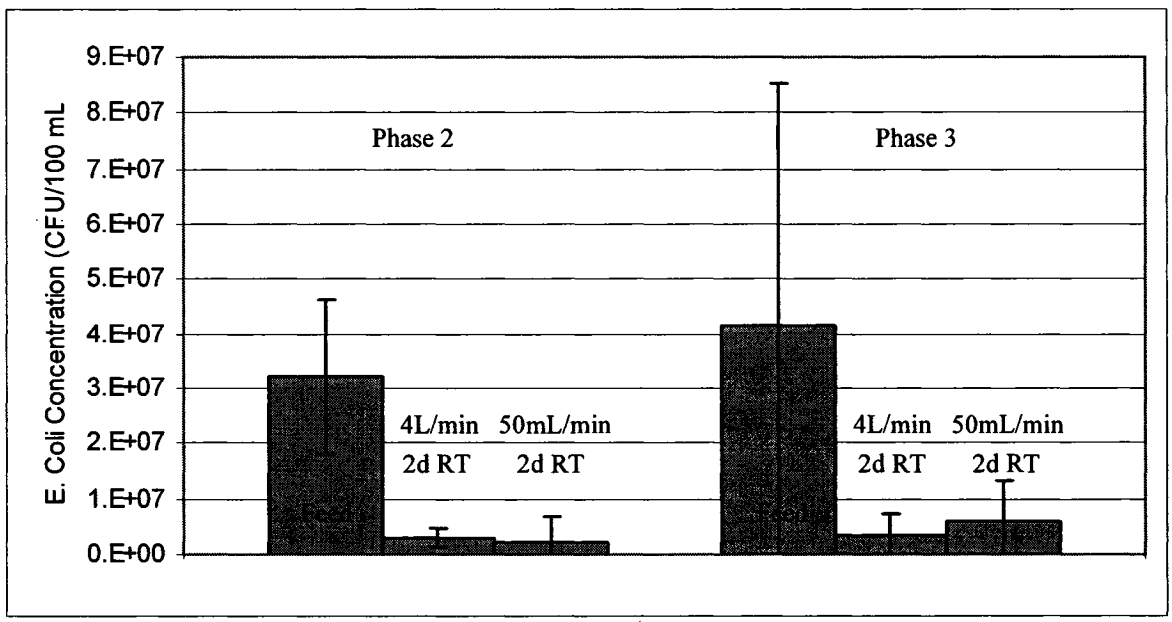

Figure 4.37: Average feed and selected column *E. coli* concentrations from phases 2 and 3

Salmonella spp.

Measurements made during phases 1 and 2 indicated that the highly aerobic environment of pre-treatment column L1 achieved the greatest *Salmonella* spp. destruction. Decreased feed *Salmonella* spp. concentrations in phase 2 resulted in lower column effluent concentrations. The log reductions observed at the two temperatures of phases 1 and 2 were not significantly different. Phase 3 of this work included duplicate runs of two of the phase 2 pre-treatment column conditions.

Figure 4.38 presents the *Salmonella* spp. concentrations measured in each of the ten streams during phase 3. Figure 4.38 illustrates that the pre-treatment columns were able to reduce the *Salmonella* spp. concentrations by approximately one log while the digesters were able to achieve 1-2 more log reductions. Figure 4.39 allows for an easier comparison of the reductions achieved by the entire process trains. From Figure 4.39 it is evident that process train L1 performed the worst in terms of *Salmonella* spp. reduction while the control and remaining digesters performed similarly. The log scale of Figure 4.40 which includes the digester concentrations illustrates the difference between the digester effluents more specifically. It is evident that process trains 2, 3 and 4 achieved greater *Salmonella* spp. destruction with L2 continuing to produce the best results.

The results of the duplicate runs between phase 2 and 3 have been included in Figure 4.41. It is evident that in each case, the pre-treatment columns were able to significantly impact the *Salmonella* spp. concentration in the short retention time of two days. The slight increases in concentration and variability observed in the results of phase 3 were likely due to the increased feed concentration and variability during that phase. The pre-treatment columns continued to perform well under the circumstances.

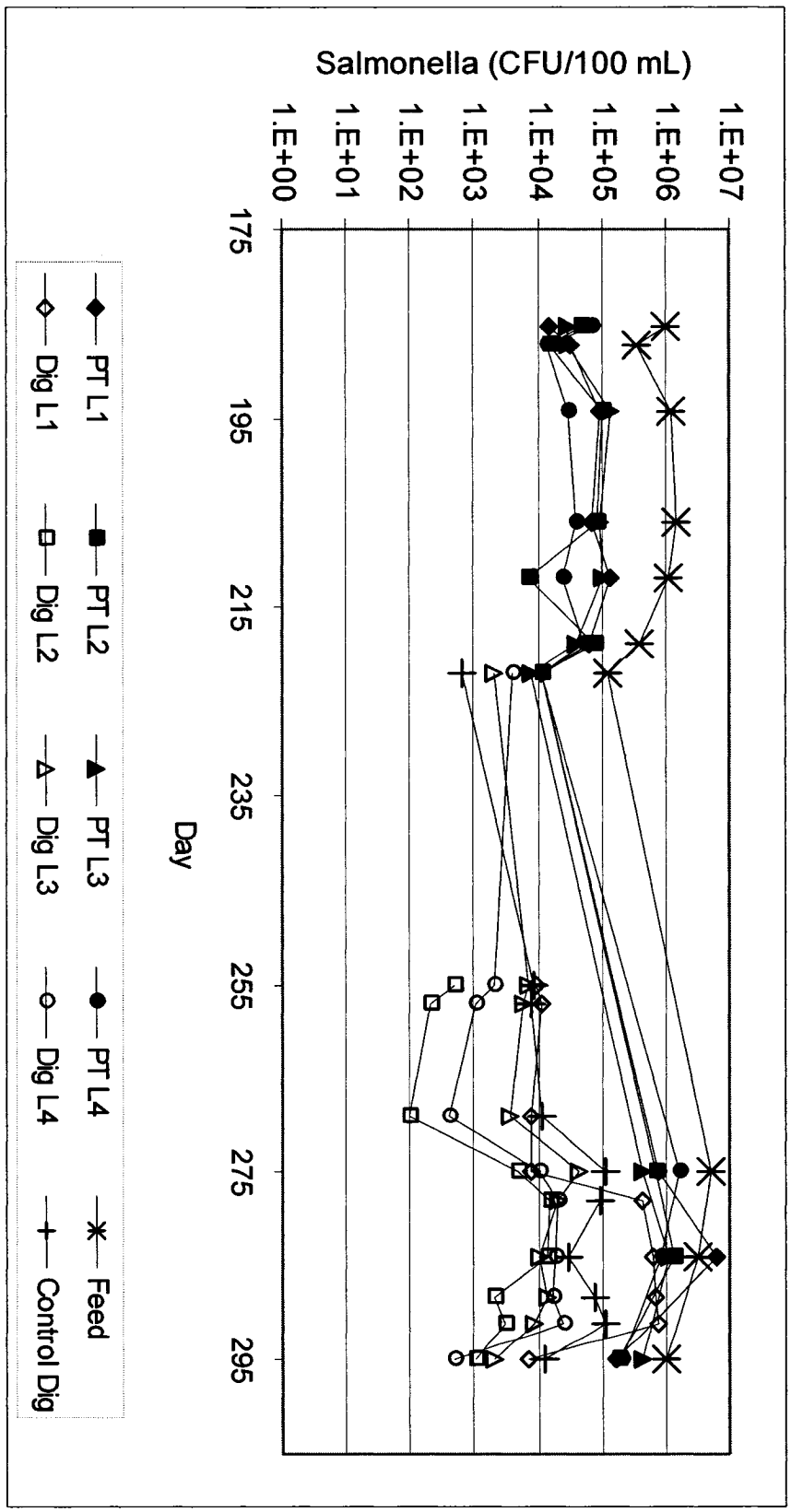

Figure 4.38: Phase 3 *Salmonella* spp. concentrations

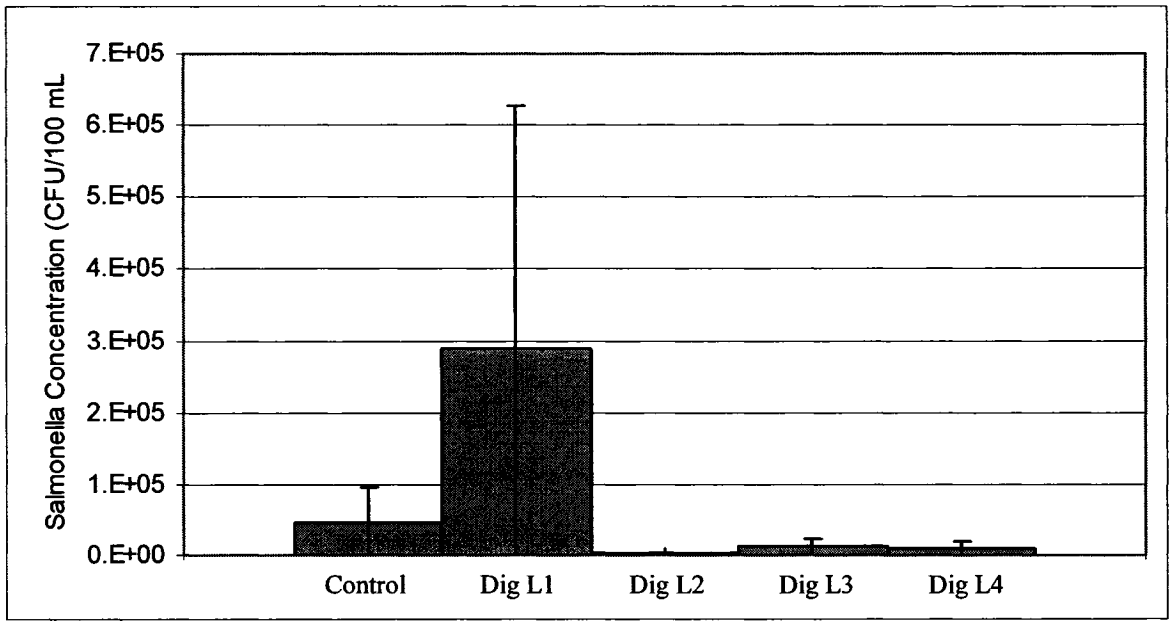

Figure 4.39: Average digester *Salmonella* spp. concentrations

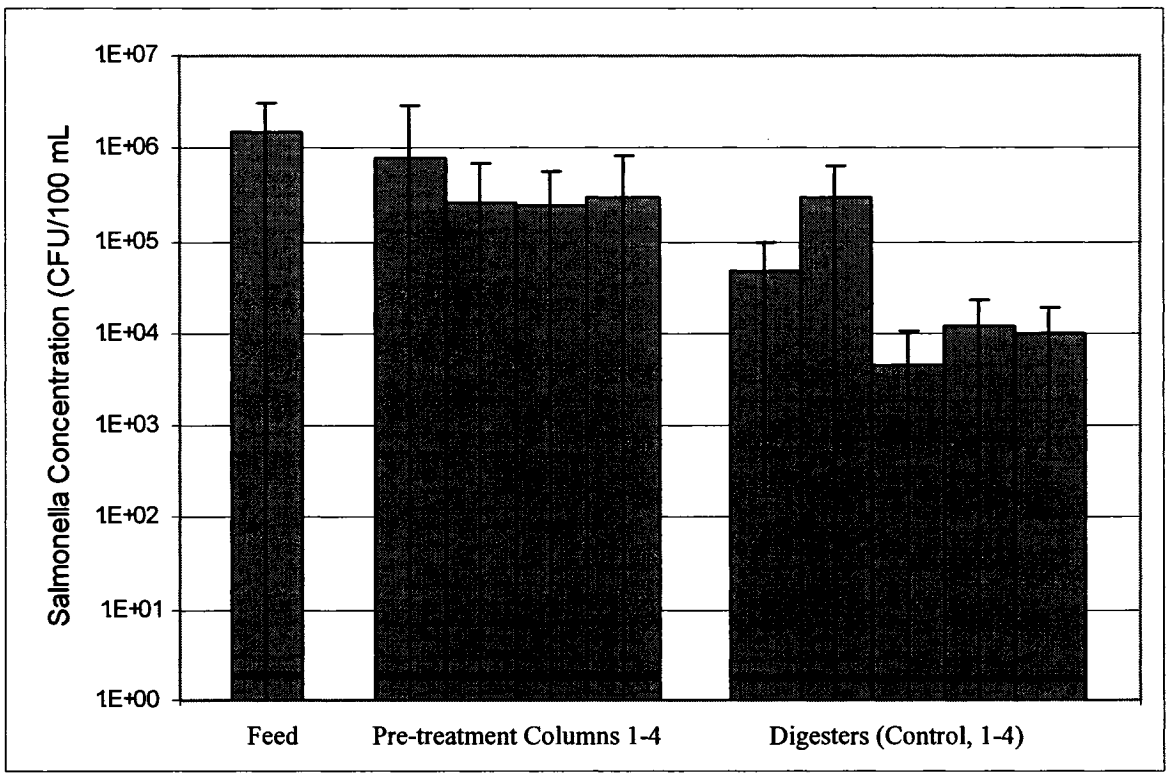

Figure 4.40: Average *Salmonella* spp. concentration in ten streams during phase 3

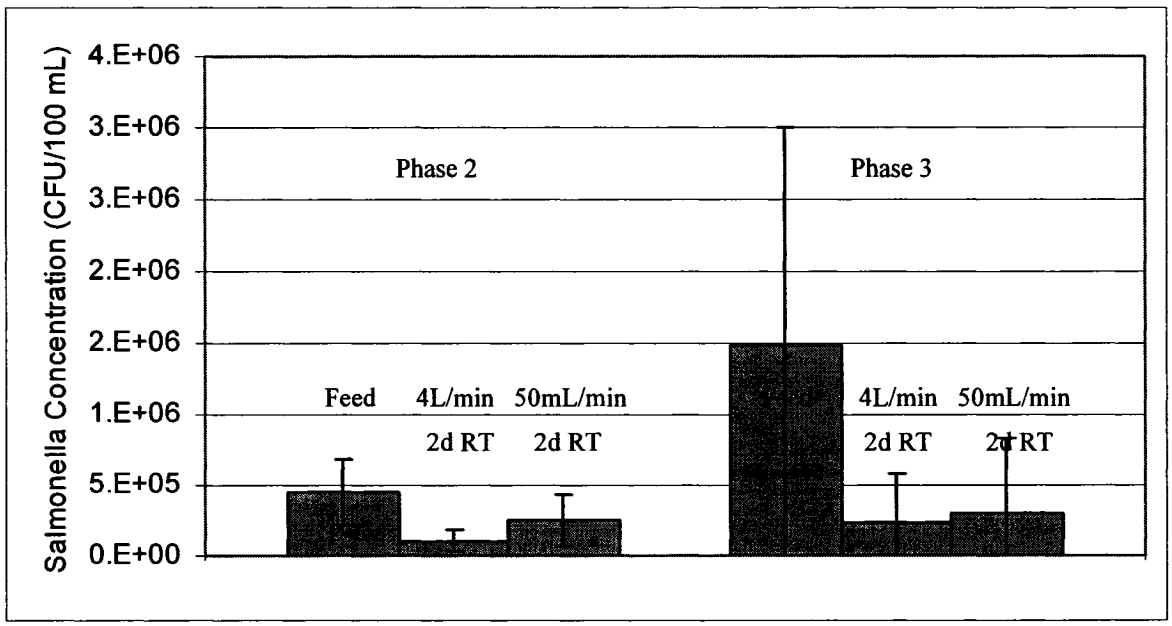

Figure 4.41: Average feed and selected column *Salmonella* spp. concentrations from phases 2 and 3

Clostridium Perfringens

The *Clostridium perfringens* concentrations measured during phase 3 of this work are presented in Figure 4.42. Similar to the results from phases 1 and 2, the values are difficult to explain. In most cases, greater *Clostridium perfringens* concentrations were measured in the digesters over the pre-treatment columns as well as the feed. This would indicate that *Clostridium perfringens* were growing in the digesters. As previously outlined, the treatments performed in this work did not have the strength to impact *Clostridium perfringens*. No further analysis was done on this data.

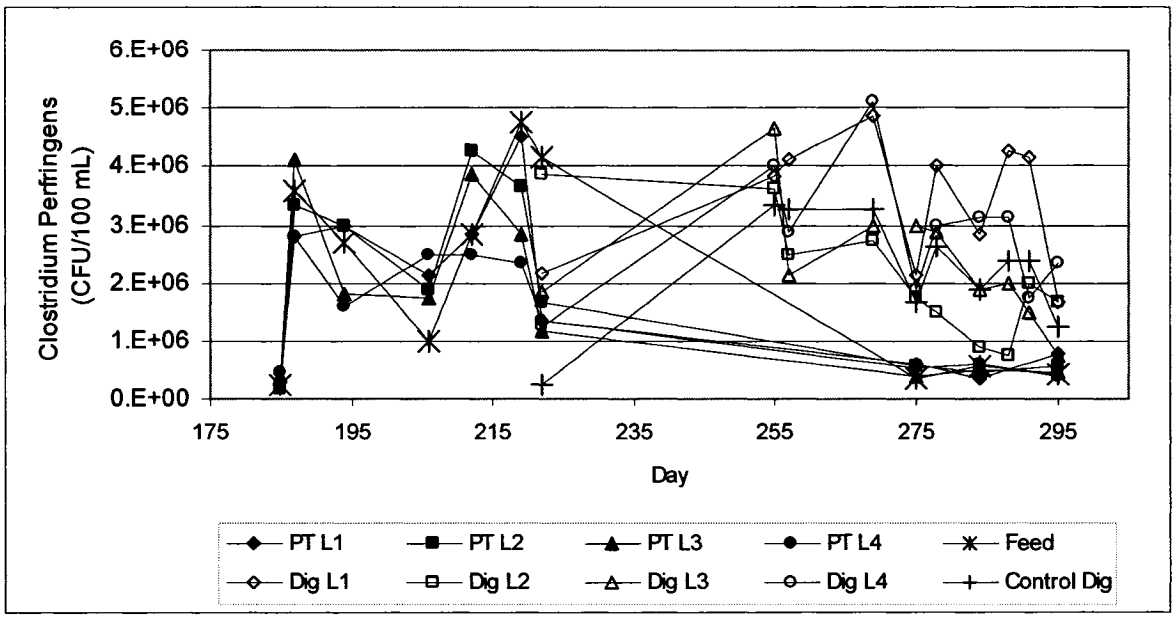

Figure 4.42: Phase 3 *Clostridium perfringens* concentrations

4.3 Pathogen Inhibition Theories

The primary objective of the experimental work was to identify the pre-treatment column operating parameters which optimized pathogen reduction. Results of phase 3 identified process train L2 as the superior performer in terms of pathogen reduction. The effluent of this process train resulted in small concentrations and less variability. Process train L4 also performed well indicating that micro-aerobic pre-treatment conditions reduced pathogen concentrations.

Originally, it was hypothesized that micro-aerobic conditions within the pre-treatment columns would encourage fermentative end products such as volatile fatty acids which would in turn inhibit pathogens. However, the average TVFA concentration in pre-treatment columns 2 and 4 were 388 ± 136 mg/L and 441 ± 301 mg/L respectively. These values are not statistically different and do not explain the increased performance of process train L2.

An article published by Mendez et al. (2004) identified ammonia as a pathogen inhibitor. Ammonia was used in their study as a disinfectant for wastewater sludge. The sludge examined in their experiment was primary sludge. The study evaluated the effect of

ammonia concentration and temperature on pathogen destruction. The organisms measured were fecal coliforms, *Salmonella* spp. and helminth ova. Complete inactivation of helminth ova occurred when 20% w/w of ammonia was added to the sludge samples at 50°C. After two hours of contact time at room temperature, the same mixture resulted in six log reductions of *Salmonella* spp. and seven log reductions of fecal coliforms.

The concentration and reductions of the ammonia experiment were greater than those observed in this work. But the relationship appears to be similar. The average aqueous ammonia concentrations of the pre-treatment columns 2 and 3 were 390 ± 126 mL/L and 270 ± 125 mL/L respectively. Also, the digester effluents had average concentrations of 77 ± 35 mL/L and 32 ± 21 mL/L respectively. The increased concentrations in process train L2 may be responsible for the increased pathogen inactivation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Based on the observations of site visits and information collected during a literature review, pre-treatment columns were investigated as a means of improving pathogen reduction based on staged digestion. The pre-treatment column was operated in order for the parameters to impact the column's environmental conditions. Phase 1 of the experimental analysis studied the impact of aeration rates on pathogen destruction. The retention time of these columns was 2 days and they were operated at room temperature. Effluent pathogen concentrations during phase 1 indicated that the highly aerated conditions in pre-treatment column L1 resulted in the greatest pathogen inhibition. Decreased pathogen concentrations were hypothesized to be attributed to predation by higher organisms; this was not confirmed through experimentation.

Phase 2 of the experiment was operated at the same aeration rate and retention time as phase 1. The temperature of the pre-treatment columns was increased during phase 2 to 35°C with the aid of temperature controllers. Pre-treatment column L1 performed slightly better under the increased temperature conditions. In addition, the highly reducing conditions in the least aerated pre-treatment column L4 saw similar destruction to L1. Predation in the highly aerated L1 pre-treatment column is believed to inhibit pathogens while the increased aqueous ammonia concentration in pre-treatment column L4 may be responsible for pathogen destruction in that column.

The impact of three operating parameters was studied in this work, including aeration rate, temperature and retention time. Phase 2 did not identify an optimal aeration rate but did isolate a preferred temperature of 35°C; therefore, moving forward to phase 3, the two extreme aeration rates were evaluated at retention times of 2 and 4 days. During phase 3, the pre-treatment column effluent was fed to digesters allowing the entire process stream to be analyzed.

The pre-treatment columns of phase 3 were able to typically achieve one log reduction over the influent feed. While subsequent digestion was able to further reduce the pathogenic concentrations by 1 – 2 ½ further logs. The highly reducing conditions in the pre-treatment columns L2 and L4 significantly impacted the pathogen reduction of the process trains resulting in greater inhibition. The reducing conditions resulted in greater aqueous ammonia concentrations which are hypothesized to have been responsible for the decreased pathogenic concentrations. The greater aqueous ammonia concentrations in pre-treatment column L2 explains the greater reduction over pre-treatment column L4. The reduction observed in these process trains were greater than that observed in the control process train indicating that pre-treatment positively impacted pathogen inhibition.

In conclusion, the process train which resulted in the greatest pathogen reduction was L2 indicating that the optimal operating parameters were the highly reducing conditions of a micro-aerated digester and the longer retention time of 4 days at 35°C.

These three operating parameters are the extreme of the ranges tested. The highly reducing conditions in pre-treatment columns L2 and L4 were accomplished by the microaerobic environment generated at the smallest air flowrate analyzed (50mL/min). The two retention times analyzed were 2 and 4 days with 4 days resulting in the greater inhibition. The increased temperature of 35°C performed better than room temperature.

Due to the variability of the feed and the variability associated with biosolids, statistical test were unable to prove significance. However, based on the reduced mean concentrations and the reduce variabilities of these means, it can be concluded that the experimentation was a significant step in identifying a possible alternative treatment. Positive conclusions can be drawn from the results but only on a more qualitative premise, no significant conclusion may be drawn statistically.

Since the most promising results were observed under the extreme conditions, it would be of interest to evaluate the effect of greater extremes. There may be a trade-off if these parameters were further investigated. Depending on results of digesters run in the field, a

temperature greater than 35°C may not be achievable due to autothermal activity in traditional aerobic digestion facilities without an external heat source. Decreasing the air supply would possibly result in settling of the solids within the column without mechanical mixing and a longer retention time would require either additional volume or would not be able to handle the same volume of sludge.

If this experiment were to be carried out again, it is recommended that the airstone in the pre-treatment column be considered. Significant biofilm accumulated on the airstone during each of the experimental phases which is believed to be responsible for a decline in the dissolved oxygen concentration with time. Future experimentation could look at the non-clogging characteristics of the EPDM membrane or develop a maintenance schedule for the airstone.

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APPENDICES

APPENDIX A

Establishing Pre-Treatment Column Air Flowrates

It was important to examine a range of air flowrates in order to determine the optimal rate of air supplied, the proposal for this work outlined the desire to study a range of air flowrates that corresponded to an ORP range of 300 mV to -300 mV. A batch test was performed prior to column setup which used air to volume ratios found in the literature to determine oxygen availability to the sludge for the conditions of this experiment. Oxygen availability is dependent on the air supply rate and the rate of oxygen uptake; it can be characterized by the oxidation-reduction potential (ORP). In the batch test, a range of air flowrates were supplied to 1 L volumes of sludge in beakers that were constantly being stirred by mechanical mixers rotating at approximately 90 rpm. The ORP was measured at time equal to 0, 1 hour and 20 hours. The results are presented in Table A1. As expected, the sludge samples receiving more air resulted in higher ORP values. These indicated an aerobic environment while the sludge sample receiving the least amount of air resulted in a negative ORP value which indicated a micro-aerobic, reducing environment.

Table A1: Batch test results - ORP values (mV) for various air flowrates

Time	Air Flow (mL/min)		
	2,842	155	13
0	- 46	- 150	- 213
1 hour	12	- 193	- 271
20 hours	225	102	- 330

The average flowrates used in the batch test were scaled to corresponding ratios of air to reactor volume and then scaled up for the pre-treatment columns. Table A2 outlines the results of these calculations.

Table A2: Air flowrates extracted from the batch test results

Average Flowrate (mL/min)	Volume of Air Supplied / Reactor Volume (vvm)	Flowrate for 6 L Column (mL/min)
2,842	2.8	16,800
155	0.16	930
13	0.013	78

The range of air flowrates that were scaled up for the pre-treatment reactors ranged from 80 to 17,000 mL per minute. The reactors were setup and it was determined that the 17 L/min air supply rate was in excess of that required and experimentation with the columns found that 4 L/min was sufficient to achieve the +300 mV ORP value and a dissolved oxygen concentration close to saturation. In order to properly distribute the air supply rates, the values were approximately one quarter of the previous pre-treatment column.

APPENDIX B

Evidence of Autothermal Activity in the Pre-Treatment Columns

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The temperature of the feed sludge was allowed to reach room temperature prior to addition to the pre-treatment columns in order to allow for the evaluation of increased pre-treatment column temperatures due to microbial activity within the columns. Figure B1 illustrates the room temperature as well as the temperatures in each of the pre-treatment columns during the 104 days of analysis for this phase. It was hoped that the autothermal characteristics could be replicated and taken advantage of in a pre-treatment scenario. While substantial temperature increases would not be observable in the experimental work based on the volume being examined, the occurrence of a temperature increase promotes the autothermal hypothesis for pre-treatment.

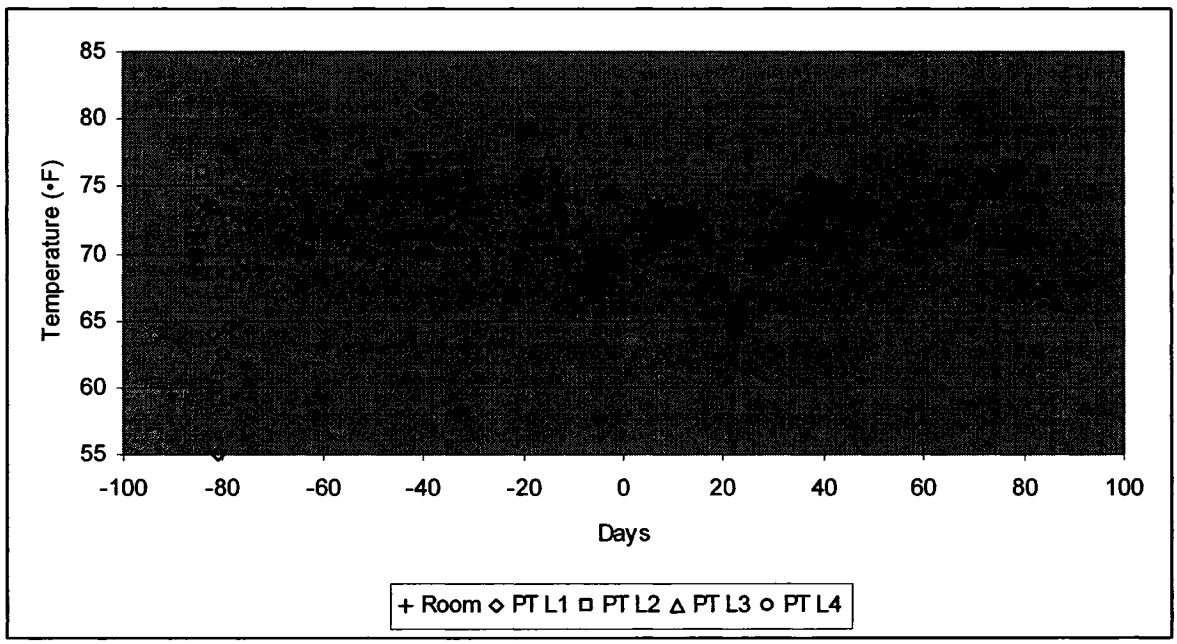

Figure B1: Room and pre-treatment column temperatures during phase 1

In Figure B2 which looks exclusively at days which include room temperature, it is apparent that the microbial reactions occurring within the pre-treatment columns are releasing some heat. Due to the small residence time of the pre-treatment column, it was

deemed unrealistic to achieve thermophilic temperatures naturally in real world applications and installation of heating equipment was deemed improbable in application. Therefore, it was decided that further experimentation would be carried out at 35°C, this was a realistic temperature that could be attained naturally at a plant by the exothermic microbial reactions.

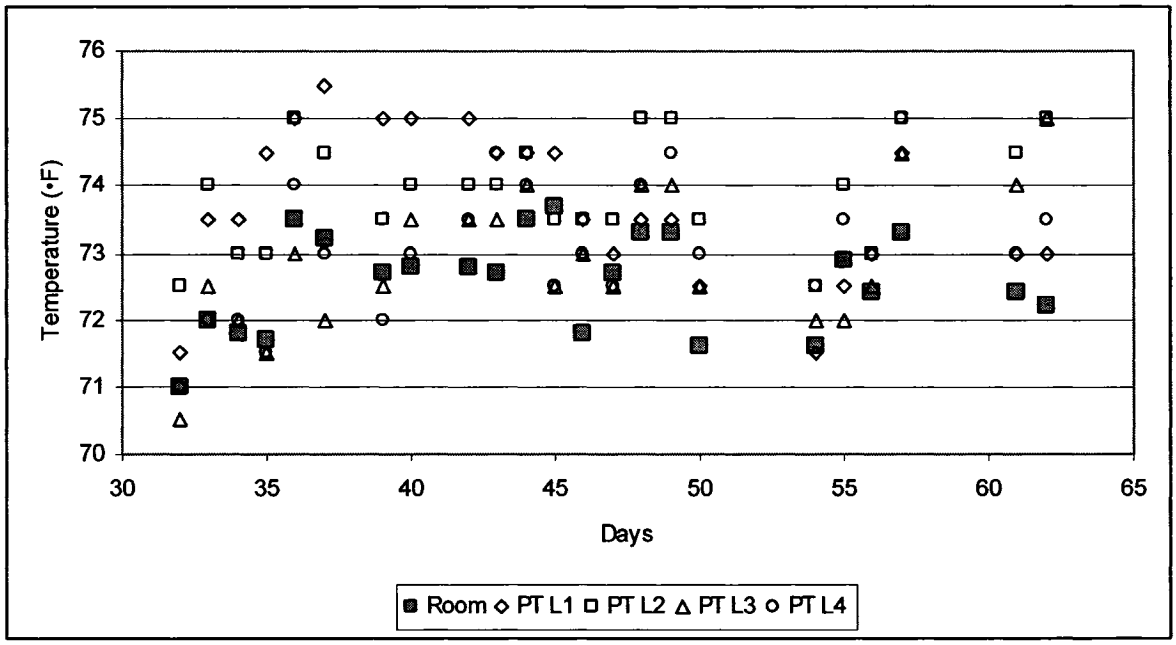

Figure B2: Closer look at room and pre-treatment column temperatures during phase 1

APPENDIX C

Experimental Data

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1) Phase 1 Results (Tabular Format)

Parameter	Reactor	1	2	3	4	5	6	7	AVERAGE
DO	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Feb 25 05	Mar 25 05	
	L1	7.9	9.6	9.1	9.1	9.0	9.5	9.6	9.11 ppm
	L2	3.1	1.3	2.2	0.9	1.1	1.1	1.0	1.52 ppm
	L3	13.4	410.7	212.0	150.7	62.9	53.7	89.1	141.8 ppb
	L4	8.0	17.1	12.5	36.7	40.0	38.4	25.4	25.43 ppb
DO Values to graph (ppb)	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Feb 25 05	Mar 25 05	
	L1	7890.0	9570.0	9125.0	9050.0	8970.0	9510.0	9620.0	9105.00
	L2	3063.3	1326.0	2194.5	907.0	1065.7	1087.0	986.0	1518.50
	L3	13.4	410.7	212.0	150.7	62.9	53.7	89.1	141.80
	L4	8.0	17.1	12.5	36.7	40.0	38.4	25.4	25.43
pH	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Feb 25 05	Mar 25 05	
	L1	6.68	6.74	6.82	7.01	5.97	5.95	6.28	6.49
	L2	6.68	6.70	6.37	7.24	6.76	6.46	6.75	6.71
	L3	7.12	6.81	6.59	6.95	6.04	6.47	7.10	6.72
	L4	6.60	6.42	5.96	6.52	5.96	6.15	6.62	6.32
Rel. ORP (mV)	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Feb 25 05	Mar 25 05	
	L1	131.1	82.5	155.4	46.4	147.8	200.6	204.8	138.38
	L2	-202.2	-233.0	-227.4	-225.9	-206.0	-234.8	-281.8	-230.16
	L3	-319.7	-340.8	-262.3	-257.0	-246.7	-225.2	-283.6	-276.49
	L4	-360.3	-399.1	-296.0	-264.8	-247.5	-280.4	-311.8	-308.57
NH3 Aq Conc'n (mL/L)	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Mar 3 05	Mar 24 05	
	L1	0.59	5.08	4.07	3.02	3.26	7.48	4.15	3.95
	L2	0.64	3.86	37.43	15.24	68.30	60.74	36.76	31.85
	L3	31.32	45.01	62.23	63.63	72.19	74.84	53.68	57.56
	L4	26.25	57.85	70.41	65.46	80.64	134.87	67.08	71.79
	Feed	26.92	39.71	34.46	20.82	18.40	38.90	15.45	27.81
Alkalinity (mg/L)	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Mar 11 05	Mar 25 05	
	L1	61.14	71.95	87.73	73.70	84.83	36.32	52.68	66.91
	L2	108.26	128.56	287.96	188.11	367.21	140.12	205.91	203.73
	L3	416.22	350.54	152.45	139.97	143.64	241.24	72.75	216.68
	L4	146.79	149.46	193.11	141.43	145.58	121.27	55.34	136.14
	Feed		264.78	252.87			134.85	122.05	193.64

Parameter		1	2	3	4	5	6	7	AVERAGE
Total VFA (mg/L)	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Mar 11 05	Mar 25 05	
	L1	-7.55	0.23	2.66	-4.88	-20.16	-23.08	-24.38	-11.02
	L2	-12.96	-2.44	81.53	4.64	90.06	-21.36	160.30	42.82
	L3	50.24	46.63	584.52	510.81	553.39	112.48	527.14	340.74
	L4	590.10	487.58	703.42	614.86	638.75	388.98	739.80	594.78
	Feed		360.78	432.95			156.87	402.47	338.27
Nitrite Conc'n	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Mar 2 05	Mar 11 05	Mar 17 05	Mar 24 05	
	L1	25.96	21.53	0.00	12.86	7.52	13.11	21.68	14.67
	L2	29.08	19.11	0.00	68.07	16.57	29.467	10.72	24.72
	L3	14.10	7.61	1.90	69.06	23.54	5.162	1.51	17.55
	L4	1.68	3.22	4.04	31.58	7.89	22.228	0.50	10.16
	Feed		12.60	3.64	55.94	24.76	39.19	49.49	30.94
Nitrate Conc'n	Date	Jan. 8 05	Jan. 14 05	Jan. 28 05	Mar 2 05	Mar 11 05	Mar 17 05	Mar 24 05	
	L1	34.51	29.61	40.57	27.7875	46.5935	20.45	41.24	34.39
	L2	34.35	15.85	0.56	0.064	0.13	0.04	1.60	7.51
	L3	64.66	0.07	0.36	0.096	0.17	0.099	1.05	9.50
	L4	2.05	0.04	0.33	0.111	0.0435	0.041	0.551	0.45
	Feed		0.05	0.10	0.4095	0.039	0.061	0.182	0.14
Solids Conc'n (g/L)	Date	Feb 23 05	Feb 26 05	Mar 10 05	Mar 12 05	Mar 19 05	Mar 22 05	Mar 24 04	
	L1	20.34	19.04	14.64	16.79	17.96	18.97	18.77	18.07
	L2	21.58	19.88	14.20	17.14	19.05	19.49	18.82	18.60
	L3	21.03	18.90	14.20	16.93	19.40	20.62	19.58	18.67
	L4	22.03	20.57	14.08	17.44	18.99	20.12	19.00	18.89
	Feed	16.62	18.15	19.52	17.04	18.23	20.53	18.79	18.41
Fixed Solids Conc'n (g/L)	Date	Feb 23 05	Feb 26 05	Mar 8 05	Mar 10 05	Mar 12 05	Mar 19 05	Mar 22 05	
	L1	5.41	5.32	3.86	4.90	6.09	5.31	6.55	5.35
	L2	5.44	5.24	3.95	4.75	6.06	5.14	6.33	5.27
	L3	5.24	5.30	3.92	4.57	5.88	5.20	6.61	5.25
	L4	5.02	5.16	3.83	4.57	5.79	5.35	6.51	5.18
	Feed	5.82	5.87	4.79	6.19	5.58	5.73	6.68	5.81
COD	Date	Jan. 14 05	Jan. 28 05	Feb 4 05	Feb 10 05	Feb 25 05	Mar 11 05	Mar 23 05	
	L1	63.566	192.1	155.643	9.81534	63.7997	107.969	119.887	101.83
	L2	21.0329	468.332	213.133	638.698	239.074	65.903	695.487	334.52
	L3	283.243	1104.93	953.49	942.273	1112.41	279.737	1320.86	856.71
	L4	852.532	1549.42	1219.91	1344.23	1895.76	791.537	1519.98	1310.48
	Feed	849.728	998.36	702.498	390.744	811.168	252.394	543.349	649.75

Parameter		1	2	3	4	5	6	7	AVE.
Fecal (#/gram solids)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	362,443	573,114	765,289	309,800	16,706	210,859	1,758,359	570939
	L2	1,961,771	827,986	1,063,193	169,170	997,244	1,590,355	5,419,766	1,718,498
	L3	2,752,051	1,784,691	1,690,141	631,921	1,959,268	1,406,061	10,877,059	3,014,456
	L4	3,160,710	2,620,016	2,201,705	745,520	579,329	646,123	11,209,051	3,023,208
	Feed	3,911,307	3,198,176	3,433,256	176,031	603,567	146,145	15,914,837	3,911,903
E. Coli (#/gram solids)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	4.5E+06	2.4E+06	1.7E+06	2.1E+06	6.7E+05	4.8E+05	2.7E+06	2,081,770
	L2	1.2E+07	1.9E+06	2.4E+06	3.9E+06	6.0E+06	2.6E+06	1.7E+07	6,459,067
	L3	1.0E+07	1.5E+07	9.4E+06	6.7E+06	6.8E+06	3.3E+06	1.7E+07	9,740,194
	L4	8.8E+06	1.3E+07	1.0E+07	7.1E+06	1.9E+06	1.8E+06	1.2E+07	7,787,702
	Feed	1.9E+07	2.2E+07	2.4E+07	1.4E+07	7.4E+06	2.4E+06	2.1E+07	15,713,325
Salmonella (#/gram solids)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	4.2E+04	2.5E+04	1.2E+05	7.1E+04	6.8E+04	3.3E+04	1.2E+05	68599
	L2	7.5E+04	3.3E+04	4.2E+04	1.2E+05	1.9E+05	2.5E+05	2.4E+05	136051
	L3	1.6E+05	9.8E+04	2.5E+05	2.2E+05	2.5E+05	2.8E+05	3.0E+05	224326
	L4	1.1E+05	1.1E+05	2.3E+05	3.3E+05	2.2E+05	2.0E+05	2.5E+05	207459
	Feed	2.8E+05	1.3E+05	3.3E+05	4.4E+05	4.9E+05	2.3E+05	4.2E+05	331726
Clostridium Perfringens (#/gram solids)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	2.0E+06	7.6E+06	5.5E+06	1.0E+07	8.4E+05	4.2E+06	1.1E+06	4,516,878
	L2	1.2E+06	1.1E+07	5.3E+06	1.4E+07	5.2E+05	3.3E+06	2.1E+06	5,269,166
	L3	2.4E+06	4.3E+06	2.3E+06	2.1E+07	6.4E+05	3.6E+06	2.0E+06	5,145,829
	L4	2.2E+06	5.9E+06	2.2E+06	1.1E+07	7.0E+05	3.7E+06	1.9E+06	4,023,614
	Feed	4.1E+06	4.9E+06	4.0E+06	1.7E+07	1.1E+06	3.4E+06	2.8E+06	5,324,004

Parameter		1	2	3	4	5	6	7	AVE.
Fecal (CFU/100 mL)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	6.9E+05	6.8E+05	1.1E+06	5.2E+05	3.0E+04	4.0E+05	3.3E+06	962,857
	L2	3.9E+06	1.0E+06	1.5E+06	2.9E+05	1.9E+06	3.1E+06	1.0E+07	3,128,571
	L3	5.2E+06	2.2E+06	2.4E+06	1.1E+06	3.8E+06	2.9E+06	2.1E+07	5,550,000
	L4	6.5E+06	3.2E+06	3.1E+06	1.3E+06	1.1E+06	1.3E+06	2.1E+07	5,402,857
	Feed	7.1E+06	4.9E+06	6.7E+06	3.0E+05	1.1E+06	3.0E+05	3.0E+07	7,187,143
E. Coli (CFU/100 mL)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	8.6E+06	2.9E+06	2.5E+06	3.5E+06	1.2E+06	9.2E+05	5.0E+06	3,517,143
	L2	2.3E+07	2.3E+06	3.4E+06	6.7E+06	1.2E+07	5.1E+06	3.3E+07	12,185,714
	L3	2.0E+07	1.8E+07	1.3E+07	1.1E+07	1.3E+07	6.9E+06	3.3E+07	16,457,143
	L4	1.8E+07	1.6E+07	1.4E+07	1.2E+07	3.7E+06	3.7E+06	2.3E+07	12,985,714
	Feed	3.4E+07	3.4E+07	4.7E+07	2.4E+07	1.4E+07	4.9E+06	3.9E+07	28,157,143
Salmonella (CFU/100 mL)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	80,000	30,000	180,000	120,000	123,000	62,000	220,000	116,429
	L2	150,000	40,000	60,000	200,000	370,000	480,000	460,000	251,429
	L3	310,000	120,000	360,000	380,000	490,000	580,000	580,000	402,857
	L4	230,000	140,000	320,000	570,000	410,000	410,000	480,000	365,714
	Feed	510,000	200,000	640,000	750,000	900,000	480,000	780,000	608,571
Clostridium Perfringens (CFU/100 mL)	Date	Feb 27 05	Mar 9 05	Mar 11 05	Mar 13 05	Mar 20 05	Mar 23 05	Mar 25 05	
	L1	3.9E+06	9.0E+06	8.0E+06	1.8E+07	7.5E+06	8.0E+06	2.0E+06	7,978,571
	L2	2.4E+06	1.3E+07	7.5E+06	2.4E+07	1.0E+07	6.5E+06	4.0E+06	9,557,143
	L3	4.5E+06	5.3E+06	3.3E+06	3.5E+07	1.3E+07	7.5E+06	4.0E+06	10,297,619
	L4	5.3E+06	7.3E+06	3.2E+06	2.0E+07	1.0E+07	7.5E+06	3.7E+06	8,119,048
	Feed	7.5E+06	7.5E+06	7.9E+06	2.9E+07	6.7E+06	7.0E+06	5.3E+06	10,089,286

2) Phase 2 Results (Tabular Format)

Parameter	Reactor	1	2	3	4	5	6	7	AVERAGE
DO	Date	April 20-05	April 26-05	April 28-05	May 10-05	May 12-05	May 17-05	May 19-05	
	L1	4.125 ppm	5.36 ppm	6.5 ppm	6.18 ppm	7.51 ppm	8.09 ppm	7.68 ppm	6.5 ppm
	L2	67.6 ppb	42.3 ppb	122.4 ppb	39.5 ppb	46.6 ppb	50.9 ppb	161.5 ppb	76 ppb
	L3	40.2 ppb	22.7 ppb	21.99 ppb	15.43 ppb	18.07 ppb	13.88 ppb	47.2 ppb	26 ppb
	L4	10.25 ppb	7.6 ppb	200 ppb	10.7 ppb	2.63 ppb	7.35 ppb	3.37 ppb	7 ppb
DO Values to graph (ppb)	Date	April 20-05	April 26-05	April 28-05	May 10-05	May 12-05	May 17-05	May 19-05	
	L1	4125	5360	6500	6180	7510	8090	7680	6492.14
	L2	67.6	42.3	122.4	39.5	46.6	50.9	161.5	75.83
	L3	40.2	22.7	21.99	15.43	18.07	13.88	47.2	25.64
	L4	10.25	7.6		10.7	2.63	7.35	3.37	6.98
pH	Date	April 20-05	April 26-05	April 28-05	May 10-05	May 12-05	May 17-05	May 19-05	
	L1	6.93	6.61	6.56	6.48	6.25	6.62	6.33	6.5
	L2	6.82	6.69	6.97	7.54	7.62	7.61	7.5	7.3
	L3	6.68	6.52	6.72	7.48	7.49	7.33	7.23	7.1
	L4	6.43	6.54	6.74	7.36	7.01	7	6.98	6.9
Rel. ORP (mV)	Date	April 20-05	April 26-05	April 28-05	May 10-05	May 12-05	May 17-05	May 19-05	
	L1	168.6	182.9	124.8	138.5	140.6	142.2	153.4	150
	L2	-296.1	-279.7	-284.2	-314.8	-267.5	-295.7	-274.5	-288
	L3	-341.3	-318.4	-297.1	-321.8	-334.3	-292.9	-304.6	-316
	L4	-353.65	-364.4	-322.6	-337.6	-347.5	-316.7	-340.4	-340
NH3 Aq Conc'n (mL/L)	Date	April 15-05	April 22-05	April 29-05	May 6-05	May 10-05	May 12-05	May 17-05	
	L1	5.68	4.13	7.95	3.28	4.68	2.04	1.88	4.2
	L2	99.03	49.99	43.39	74.36	150.40	146.56	134.15	99.7
	L3	99.21	103.62	62.73	196.56	174.85	169.90	204.34	144.5
	L4	112.29	123.54	59.86	229.26	232.51	212.49	202.62	167.5
	Feed	29.61	26.13	14.48	65.06	18.49	70.98	19.59	34.9
Alkalinity (mg/L)	Date	April 10-05	April 15-05	April 22-05	April 28-05	May 5-05	May 18-05	May 20-05	
	L1	67.0	101.6	32.7	44.3	25.9	19.2	13.8	43
	L2	144.4	59.2	20.1	80.9	198.0	415.8	713.8	233
	L3	55.6	79.2	11.5	23.3	103.8	247.8	470.7	142
	L4	75.2	197.1	116.7	168.0	245.3	360.9	678.5	263
	Feed	248.3	386.4	236.6	227.6	237.7	239.7	404.3	283
Total VFA (mg/L)	Date	April 10-05	April 15-05	April 22-05	April 28-05	May 5-05	May 18-05	May 20-05	
	L1	-17.1	-12.2	-22.8	-15.4	-21.6	-20.9	-1.9	-16
	L2	392.0	1,349.8	869.7	580.4	382.1	138.0	131.1	549
	L3	767.5	1,329.4	1,205.8	850.8	692.0	499.9	677.1	860
	L4	913.2	1,408.4	1,205.1	813.9	787.2	537.6	769.8	919
	Feed	582.2	350.2	221.7	270.1	220.7	230.2	280.0	308

Parameter		1	2	3	4	5	6	7	AVERAGE
Nitrite Conc'n	Date	April 15-05	April 28-05	May 3-05	May 5-05	May 10-05	May 18-05	May 20-05	
	L1	0.343	0.396	15.6	10.468	0	0	11.935	5.53
	L2	25.733	1.082	1.53	30.108	32.864	23.426	6.533	17.33
	L3	1.519	2.642	1.274	0.941	34.194	29.663	16.45	12.38
	L4	1.805	0.062	1.228	0.3	35.013	65.985	7.747	16.02
	Feed	8.257	5.097	19.448	78.391	27.798	31.6885	220.681	55.91
Nitrate Conc'n	Date	April 15-05	April 28-05	May 3-05	May 5-05	May 10-05	May 18-05	May 20-05	
	L1	60.84	59.447	55.274	102.979	119.892	94.211	96.064	84.10
	L2	10.05	7.528	0.216	6.467	0.214	2.711	3.436	4.37
	L3	0.167	0.27	0.082	0.258	0.05	0.218	0.086	0.16
	L4	0.382	0.617	0.092	0.338	0.393	0.128	0.355	0.33
	Feed	1.283	7.437	0.045	0.156	0.214	0.294	0	1.35
Solids Conc'n (g/L)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	June 10-05	
	L1	21.54	22.49	20.53	9.52	21.41	17.35	17.71	18.65
	L2	23.27	26.32	20.41	9.05	22.30	17.55	14.63	19.08
	L3	22.87	24.61	20.59	8.95	21.06	17.72	13.96	18.54
	L4	23.01	24.76	20.78	9.59	22.20	17.80	18.67	19.55
	Feed	21.96	22.17	19.49	9.50	23.75	16.49	14.86	18.32
Fixed Solids Conc'n (g/L)	Date	April 20-05	April 22-05	April 25-05	April 28-05	May 1-05	May 5-05	May 12-05	
	L1	9.65	10.40	8.82	8.57	9.52	9.03	7.18	9.02
	L2	9.63	11.20	8.39	7.92	9.05	8.67	7.09	8.85
	L3	9.61	10.67	8.33	8.07	8.95	8.24	6.89	8.68
	L4	9.40	10.96	8.48	8.03	9.59	8.68	7.11	8.89
	Feed	8.20	9.09	7.98	7.39	9.50	8.92	6.43	8.22
COD	Date	April 15-05	April 21-05	April 28-05	May 3-05	May 6-05	May 12-05	May 19-05	
	L1	173.2	206.8	379.3	481.0	108.7	98.2	62.4	216
	L2	1,937.8	2,233.0	1,985.4		836.6	560.9	396.1	1,325
	L3	2,090.7	2,786.9	1,823.3		1,461.8	944.1	724.5	1,639
	L4	1,925.2	3,414.3	1,225.3	2,318.0	1,945.5	1,451.3	1,170.8	1,922
	Feed	894.6	950.7	305.7	197.7	797.8	480.3	138.8	538

Parameter		1	2	3	4	5	6	7	AVE.
Fecal (#/gram solids)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	May 17-05	
	L1	1.5E+06	1.3E+06	1.2E+06	6.1E+05	1.9E+05	5.2E+05	1.7E+05	774,941
	L2	9.8E+06	5.5E+06	5.8E+06	3.5E+06	2.5E+06	2.3E+06	5.4E+06	4,957,109
	L3	8.2E+06	8.7E+06	4.9E+06	3.0E+06	1.4E+06	1.1E+06	2.5E+06	4,235,056
	L4	4.1E+06	3.9E+05	3.3E+05	1.8E+05	1.8E+05	9.0E+04	3.6E+05	807,792
	Feed	3.4E+06	6.0E+06	5.9E+06	4.1E+06	7.6E+06	5.6E+06	1.6E+07	6,932,960
E. Coli (#/gram solids)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	May 17-05	
	L1	2.8E+06	1.5E+06	1.9E+06	1.6E+06	8.4E+05	3.5E+05	6.8E+05	1,386,408
	L2	1.3E+07	8.0E+06	6.0E+06	6.0E+06	6.5E+06	3.2E+06	1.1E+07	7,633,838
	L3	1.1E+07	5.1E+06	5.4E+06	3.1E+06	3.2E+06	2.1E+06	4.4E+06	4,907,480
	L4	5.6E+06	2.8E+05	2.8E+05	1.4E+05	2.3E+05	1.5E+05	4.6E+05	1,015,682
	Feed	1.1E+07	5.4E+06	1.4E+07	1.1E+07	2.1E+07	1.9E+07	3.5E+07	16,719,478
Salmonella (#/gram solids)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	May 17-05	
	L1	51,074	115,594	58,444	43,253	14,015	28,823	39,526	50,104
	L2	73,048	144,349	102,916	34,651	103,116	45,584	451,128	136,399
	L3	109,314	89,376	155,453	52,134	123,457	33,855	236,347	114,277
	L4	152,141	109,058	76,988	32,949	76,559	44,938	321,328	116,280
	Feed	282,299	90,212	174,493	86,759	214,692	236,471	572,005	236,705
Clostridium Perfringens (#/gram solids)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	May 17-05	
	L1	1.4E+06	1.3E+06	1.5E+06	1.9E+06	1.8E+06	1.9E+06	1.1E+06	1,562,508
	L2	6.4E+05	1.5E+06	2.5E+06	1.7E+06	1.2E+06	1.9E+06	2.1E+06	1,630,413
	L3	1.5E+06	1.4E+06	2.0E+06	2.2E+06	2.1E+06	1.8E+06	1.9E+06	1,827,359
	L4	2.6E+06	2.0E+06	2.7E+06	2.3E+06	2.0E+06	1.6E+06	1.6E+06	2,118,840
	Feed	9.1E+05	1.2E+06	1.9E+06	1.9E+06	1.7E+06	1.8E+06	1.0E+06	1,479,911

Parameter		1	2	3	4	5	6	7	AVE.
Fecal (CFU/100 mL)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	June 10-05	
	L1	3.2E+06	2.9E+06	2.4E+06	1.4E+06	4.0E+05	9.0E+05	3.0E+05	1,642,857
	L2	2.3E+07	1.5E+07	1.2E+07	8.0E+06	5.6E+06	4.0E+06	7.9E+06	10,642,857
	L3	1.9E+07	2.1E+07	1.0E+07	6.8E+06	3.0E+06	1.9E+06	3.5E+06	9,314,286
	L4	9.5E+06	9.6E+05	6.8E+05	4.4E+05	4.0E+05	1.6E+05	6.7E+05	1,830,000
	Feed	7.4E+06	1.3E+07	1.1E+07	1.0E+07	1.8E+07	9.3E+06	2.4E+07	13,371,429
E. Coli (CFU/100 mL)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	June 10-05	
	L1	6.0E+06	3.4E+06	3.9E+06	3.8E+06	1.8E+06	6.0E+05	1.2E+06	2,957,143
	L2	3.0E+07	2.1E+07	1.3E+07	1.4E+07	1.3E+07	5.6E+06	1.6E+07	15,971,429
	L3	2.5E+07	1.3E+07	1.1E+07	7.2E+06	6.7E+06	3.8E+06	6.1E+06	10,385,714
	L4	1.3E+07	7.0E+05	5.9E+05	3.5E+05	5.1E+05	2.6E+05	8.5E+05	2,295,714
	Feed	2.5E+07	1.2E+07	2.8E+07	2.7E+07	4.9E+07	3.2E+07	5.2E+07	32,185,714
Salmonella (CFU/100 mL)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	June 10-05	
	L1	1.1E+05	2.6E+05	1.2E+05	1.0E+05	3.0E+04	5.0E+04	7.0E+04	105,714
	L2	1.7E+05	3.8E+05	2.1E+05	8.0E+04	2.3E+05	8.0E+04	6.6E+05	258,571
	L3	2.5E+05	2.2E+05	3.2E+05	1.2E+05	2.6E+05	6.0E+04	3.3E+05	222,857
	L4	3.5E+05	2.7E+05	1.6E+05	8.0E+04	1.7E+05	8.0E+04	6.0E+05	244,286
	Feed	6.2E+05	2.0E+05	3.4E+05	2.2E+05	5.1E+05	3.9E+05	8.5E+05	447,143
Clostridium Perfringens (CFU/100 mL)	Date	April 20-05	April 22-05	April 28-05	May 1-05	May 5-05	May 12-05	June 10-05	
	L1	3.0E+06	3.0E+06	3.1E+06	4.5E+06	3.9E+06	3.3E+06	1.9E+06	3,232,143
	L2	1.5E+06	3.8E+06	5.0E+06	3.9E+06	2.7E+06	3.3E+06	3.1E+06	3,321,429
	L3	3.5E+06	3.3E+06	4.1E+06	5.0E+06	4.3E+06	3.1E+06	2.7E+06	3,726,190
	L4	6.0E+06	4.8E+06	5.6E+06	5.6E+06	4.5E+06	2.9E+06	3.0E+06	4,636,905
	Feed	2.0E+06	2.7E+06	3.6E+06	4.8E+06	4.0E+06	3.0E+06	1.5E+06	3,077,381

3) Phase 3 Pre-treatment Column Results (Tabular Format)

Parameter		1	2	3	4	5	6	7	8	9	10	Average
DO	Date	June 28-05	July 8-05	July 22-05	July 25-02	Aug 1-05	Aug 11-05	Aug 14-05	Sept 30-05	Oct 15-05	Oct 25-05	
	L1	7.59 ppm	9.23 ppm	7.85 ppm	7.15 ppm	6.15 ppm	7.89 ppm	7.75 ppm	3.54 mg/L	7.30 mg/L	6.75 mg/L	7.12 ppm
	L2	3.42 ppb	0.42 ppb	14.12 ppb	14.23 ppb	141.9 ppb	10.02 ppb	12.62 ppb	35.5 ppb	123.6 ppb	49.06 ppb	40.5 ppb
	L3	4.72 ppm	5.50 ppm	6.85 ppm	3.74 ppm	1.2 ppm	4.02 ppm	4.52 ppm	2.83 mg/L	6.00 mg/L	4.38 mg?l	4.38 ppm
	L4	3.03 ppb	4.41 ppb	2.81 ppb	0.37 ppb	2.43 ppb	19.8 ppb	6.72 ppb	37.1 ppb	42.4 ppb	19.54 ppb	13.9 ppb
pH	Date	June 28-05	July 8-05	July 22-05	July 25-02	Aug 1-05	Aug 11-05	Aug 14-05	Sept 30-05	Oct 14-05	Oct 21-05	
	L1	5.96	6.56	6.11	5.87	6.02	6.33	5.95	7.43	7.91	7.92	6.6
	L2	6.98	7.32	7.67	7.3	7.66	7.32	7.45	7.08	7.47	7.22	7.3
	L3	6.49	6.77	6.69	6.81	7.33	6.83	6.75	7.57	7.65	7.47	7.0
	L4	6.31	6.65	6.88	6.63	7.37	6.71	6.71	6.66	7.0	7.08	6.8
ORP (mV)	Date	June 30-05	Jul 8-05	July 22-05	July 25-05	Aug 1-05	Aug 11-05	Aug 14-05	Aprt 30-05	Oct 14-05	Oct 21-05	
	L1	382.7	109.2	188.2	190.4	201.8	193.8	198.9	95.8	107.1	150.8	181.9
	L2	-147.1	-313.2	-353.6	-334.8	-288.3	-355.2	-342.5	-407.7	-423.1	-396.8	-336.2
	L3	362.2	87.3	172.0	163.1	100.7	114.4	125.9	74.3	237.7	152.7	159.0
	L4		-329.7	-345.9	-328.3	-360.5	-339.2	-356.7	-267.8	-416.8	-375.7	-346.7

Parameter		1	2	3	4	5	6	7	8	9	10	Average
Ammonia (mL/L)	Date	Jul 6 - 05	Jul 8-05	Jul 2-05	Jul 25-05	Aug 2-05	Aug 9 - 05	Aug 12-05	Sept 30-05	Oct 14-05	Oct 21 - 05	
	L1	112.66	240.20	57.77	39.46	7.67	2.98	14.13	6.9285	76.207	64.172	62.2
	L2	476.65	658.60	292.40	289.96	346.52	249.61	272.87	420.88	461.97	431.23	390.1
	L3	8.73	87.37	1.03	3.17	42.60	3.28	15.20	109.7	84.971	60.525	42.3
	L4	210.68	586.97	236.81	208.04	248.60	143.90	168.52	263.1	336.84	297.03	270.1
	Feed	102.93	52.02	49.50	38.84	59.36	18.54	37.81	95.588	76.811	45.37	57.7
Alkalinity (mg/L)	Date	Jul 8 - 05	Jul 13-05	Jul 20-05	Jul 27-05	Aug 3-05	Aug 10 -05	Aug 12-05	Sept 29-05	Oct 5-05	Oct 26 - 05	
	L1	14.5	17.0	12.1	7.2	30.0	20.7	15.2	65.731	211.12	66.27	46.0
	L2	652.6	905.6	861.6	703.5	607.9	510.0	557.5	987.11	1486.7	910.16	818.3
	L3	39.3	12.1	11.8	33.6	179.4	46.9	43.3	415.51	421.81	201.58	140.5
	L4	678.3	868.4	842.9	876.1	649.3	567.1	660.0	492.64	790.04	696.6	712.1
	Feed	299.3	189.0	175.5	355.6	331.0	217.8	210.6	29.577	38.276	164.4	201.1
Total VFA (mg/L)	Date	Jul 8 - 05	Jul 13-05	Jul 20-05	Jul 27-05	Aug 3-05	Aug 10 -05	Aug 12-05	Sept 29-05	Oct 5-05	Oct 26 - 05	
	L1	23.7	-12.0	6.5	19.4	-33.2	-23.1	-30.3	13.762	18.746	2.47	-1.4
	L2	443.0	312.6	334.4	272.0	219.4	285.6	350.8	627.59	593.48	436.47	387.5
	L3	3.1	6.5	6.8	22.1	-11.9	-45.0	-14.3	516.46	419.1	187.82	109.1
	L4	536.1	295.8	304.2	268.0	259.9	134.8	163.1	967.53	931.42	552.91	441.4
	Feed	324.5	102.0	103.7	259.5	427.1	167.1	142.3	892.19	1423	600.8	444.2

Parameter		1	2	3	4	5	6	7	8	9	10	Average
Nitrite Concentration	Date	Jul 29-05	Jul 21-05	Jul 23-05	Jul 27-05	Aug 3-05	Aug 12-05	Aug 14-05	Oct 7-05	Oct 14-05	Oct 26-05	
	L1	0.223	0.424	0.323	0.524	0	0.057	0.235	0.374	0	1.095	0.3
	L2	3.203	0	2.302	1.378	0.137	26.693	2.924	9.104	29.413	0.058	7.5
	L3	0.078	0.052	0.048	0.066	12.609	18.364	1.854	2.956	0	0.771	3.7
	L4	0.476	0.534	0.625	0.452	0.537	14.785	0.526	1.518	0	0	1.9
	Feed	1.569	0.619	1.275	0.967	0.497	0	0.854	0.531	0	0.209	0.7
Nitrate Concentration	Date	Jul 29-05	Jul 21-05	Jul 23-05	Jul 27-05	Aug 3-05	Aug 12-05	Aug 14-05	Oct 7-05	Oct 14-05	Oct 26-05	
	L1	182.28	182.97	180.76	178.32	138.77	124.12	156.17	96.822	0	0.129	124.0
	L2	8.68	0.344	2.356	5.721	2.141	1.669	2.278	2.121	0.666	0.111	2.6
	L3	44.668	54.543	60.745	53.684	10.167	0	25.854	22.004	0.042	0.068	28.2
	L4	1.53	0	0.053	0.564	1.676	1.012	0.968	0.545	0.117	0.148	0.7
	Feed	0.055	0.056	0.054	0.045	1.941	0.446	0.767	0.312	0	0.125	0.4
Total Solids Concentration (g/L)	Date	Jul 5-05	Jul 7-05	Jul 14-05	Jul 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	13.23	14.46	12.13	13.25	18.15	21.06	18.89	14.623	19.087	16.634	16.1
	L2	12.98	13.78	12.14	12.59	19.67	17.84	17.42	14.735	17.305	16.616	15.5
	L3	12.14	15.15	12.34	13.54	19.96	18.78	17.86	15.702	18.1	16.958	16.1
	L4	12.89	12.91	8.80	16.01	19.70	18.42	17.39	25.778	24.602	25.6	18.2
	Feed	13.25	17.41	18.37	19.33	20.93	19.62	19.70	15.57	20.285	21.54	18.6

Parameter		1	2	3	4	5	6	7	8	9	10	Average
Fixed Solids Concentrations (g/L)	Date	Jul 5-05	Jul 7-05	Jul 14-05	Jul 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	5.18	5.35	4.36	5.00	6.64	7.08	6.94	5.41	6.98	5.93	5.9
	L2	5.04	4.98	4.31	4.82	7.82	6.68	6.40	5.48	6.58	5.85	5.8
	L3	4.59	5.21	4.18	5.19	7.19	7.04	6.44	5.28	6.17	5.70	5.7
	L4	4.49	4.18	2.89	5.97	7.09	7.09	6.09	8.59	8.64	6.71	6.2
	Feed	4.31	5.00	5.57	6.76	7.14	7.14	6.62	5.19	6.25	5.93	6.0
sCOD	Date	Jul 6-05	Jul 8-05	Jul 14-05	Jul 25-05	Aug 5-05	Aug 9-05	Aug 12-05	Oct 5-05	Oct 14-05	Oct 24-05	
	L1	79.9	182.3	126.2	123.1	58.6	75.1	196.3	192.2	110.99	75.8	122.0
	L2	670.9	1,200	869.1	1,315	932.4	858.1	886.6	1,351	1,002	521.12	960.6
	L3	88.3	166.9	86.9	115.6	162.2	42.0	196.3	1,019	318.08	181.38	237.7
	L4	568.8	1,666	840.7	785.7	500.7	414.4	681.5	2,011	981.32	744.45	919.5
	Feed	496.4	691.3	311.3	285.3	411.4	399.4	292.4	1,003	1,063	489.99	544.3

Parameter		1	2	3	4	5	6	7	8	9	10	OVERALL
Fecal (CFU/100 mL)	Date	July 5-05	July 7-05	July 14-05	July 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	380,000	210,000	990,000	630,000	290,000	980,000	50,000	2750000	6250000	28000000	4,053,000
	L2	830,000	730,000	290,000	410,000	180,000	850,000	40,000	2550000	2450000	2700000	1,103,000
	L3	1,020,000	590,000	1,070,000	1,020,000	270,000	1,740,000	60,000	1950000	4450000	6650000	1,882,000
	L4	3,500,000	70,000	60,000	400,000	120,000	1,290,000	90,000	5150000	3550000	3600000	1,783,000
	Feed	22,200,000	22,900,000	8,300,000	12,500,000	3,100,000	8,800,000	700,000	4100000	17150000	23000000	12,275,000
E. Coli (CFU/100 mL)	Date	July 5-05	July 7-05	July 14-05	July 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	590,000	560,000	1,600,000	1,570,000	780,000	1,930,000	1,710,000	1450000	25000000	3550000	3,874,000
	L2	1,280,000	1,150,000	680,000	950,000	520,000	1,690,000	1,050,000	1650000	23250000	3000000	3,522,000
	L3	1,240,000	810,000	1,360,000	1,820,000	870,000	3,410,000	1,387,912	6400000	9950000	6900000	3,614,791
	L4	5,200,000	200,000	160,000	660,000	330,000	2,380,000	15,975,000	9700000	21000000	4250000	5,985,500
	Feed	32,200,000	37,900,000	22,800,000	48,000,000	9,900,000	34,100,000	12,550,000	8750000	158500000	50500000	41,520,000
Salmonella (CFU/100 mL)	Date	July 5-05	July 7-05	July 14-05	July 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	16,000	33,000	97,000	72,000	141,000	62,000	12,000	750000	6500000	170000	785,300
	L2	46,000	15,000	107,000	81,000	7,000	78,000	12,000	700000	1300000	190000	253,600
	L3	31,000	30,000	134,000	97,000	101,000	39,000	8,000	450000	1100000	420000	241,000
	L4	70,000	14,000	30,000	40,000	24,000	54,000	11,000	1650000	850000	195000	293,000
	Feed	1,010,000	350,000	1,230,000	1,440,000	1,070,000	400,000	120,000	5000000	3250000	1000000	1,487,000
Clostridium Perfringens (CFU/100 mL)	Date	July 5-05	July 7-05	July 14-05	July 26-05	Aug 1-05	Aug 8-05	Aug 11-05	Oct 3-05	Oct 12-05	Oct 23-05	
	L1	325,000	2,800,000	3,000,000	2,125,000	2,833,333	4,500,000	1,333,333	600000	350000	775000	1,864,167
	L2	166,667	3,333,333	3,000,000	1,875,000	4,250,000	3,666,667	1,666,667	566666.667	475000	575000	1,957,500
	L3	383,333	4,133,333	1,800,000	1,750,000	3,875,000	2,833,333	1,166,667	400000	500000	450000	1,729,167
	L4	450,000	2,800,000	1,600,000	2,500,000	2,500,000	2,333,333	1,333,333	550000	600000	400000	1,506,667
	Feed	250,000	3,600,000	2,700,000	1,000,000	2,833,333	4,750,000	4,166,667	366666.667	575000	425000	2,066,667

4) Phase 3 Digestion Results (Tabular Format)

Parameter	Reactor	Approaching SS#4 - Digester Data 1	2	3	4	5	AVERAGE	STEADY STATE #4 - Digester Data 1	2	3	4	5	6	7	AVERAGE	Overall Average
COD	Date	Aug 5-05	Sept. 8-05	Sept. 15-05				Sept. 28-05	Oct. 5-05	Oct. 11-05	Oct. 17-05	Oct. 20-05	Oct. 21-05	Oct. 25-05		
	Control	29781	120466	906865			803083	12182	16513	16579	803	2206	4900	2832	265	174
	L1	879875	839901	142128			1316745	1299	1265	1516	1047	1394	1015	1354	127	120
	L2	100157	526882	97465			857288	1245	2775	2003	857	1800	1042	1164	166	135
	L3	67675	592065	105769			568891	1665	1570	1162	588	2518	1814	3411	166	147
	L4	419805	914919	906865			613832	1354	1638	2220	614	2901	1189	1218	155	127
Solids Concn (g/L)	Date	Aug 11-05	Aug 25-05	Sept. 3-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 18-05	Oct. 19-05	Oct. 28-05		
	Control	182425	14475	1324	189825	15885	165895	16685	170865	168125	1667	1827	1826	1674	1723	1680
	L1	194125	174125	17025	19885	1827	18413	1836	1804	1827	1781	2001	2053	1735	1882	1854
	L2	18885	1435	1434	1738	161475	163865	1594	1341	1183	1199	1357	1429	1404	1368	1467
	L3	176945	1719	1468	17235	1602	165865	1660	1662	1738	1568	1719	1588	1278	1602	1624
	L4	167775	163325	134925	188825	15916	15683	1563	1676	1704	1568	1875	1901	2081	1780	1710
Volatile Solids Concn (g/L)	Date	Aug 11-05	Aug 25-05	Sept. 3-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 18-05	Oct. 19-05	Oct. 28-05		
	Control	67175	5275	4925	5415	53325	588917	538	54825	532	578	572	540	577	551	554
	L1	73125	68825	7	7285	7.1475	70675	661	63175	621	671	685	660	688	665	677
	L2	705	5295	57025	5985	59825	5989	559	4665	395	422	449	441	447	465	515
	L3	67315	6665	5985	6055	59575	625	577	55825	569	566	566	491	542	553	582
	L4	6255	61475	5485	58575	586	5911	546	58075	529	591	611	559	565	565	576

Parameter	Reactor	Approaching SS#4 - Digester Data 1	2	3	4	AVERAGE	STEADY STATE #4 - Digester Data 1	2	3	4	5	6	7	AVERAGE	Overall Average
DO (ppm)	Date	Aug 1-05	Aug. 11-05	Sept 6-05	Sept. 19-05		Sept. 30-05	Oct. 7-05	Oct. 10-05	Oct. 15-05	Oct. 18-05	Oct. 25-05	Oct. 30-05		
	Control	7.60ppm	9.43ppm	9.47ppm	5.54ppm		9.04	7.4	8.02	6.53	5.88	8.37	7.67	7.6	7.6
	L1	7.71ppm	10.24ppm	9.32ppm	5.72ppm		9.83	8.35	9.28	7.96	8.05	9.16	9.09	8.8	8.8
	L2	7.59ppm	9.93ppm	9.12ppm	5.15ppm		9.49	8.55	9.49	8.73	8.89	9.56	9.49	9.2	9.2
	L3	7.49ppm	9.74ppm	8.46ppm	5.03ppm		9.33	8.2	8.64	8.23	8.03	9.08	8.87	8.6	8.6
	L4	7.18ppm	8.69ppm	8.95ppm	7.84ppm		8.08	7.63	7.71	6.53	6.02	8.67	7.56	7.5	7.5
pH	Date	Aug 1-05	Sept. 19-05				Sept. 28-05	Sept. 30-05	Oct. 12-05	Oct. 14-05	Oct. 18-05	Oct. 21-05	Oct. 26-05		
	Control	4.645	4.08			4.3625	3.73	3.62	4.13	4.55	4.17	3.99	3.73	4.0	4.1
	L1	4.51	4.7			4.605	3.84	3.51	4.83	4.76	4.06	4.09	3.69	4.1	4.2
	L2	4.395	4.03			4.2125	3.68	3.29	4.21	4.26	3.88	3.88	3.67	3.8	3.9
	L3	4.955	4.19			4.5725	3.69	3.26	4.00	4.27	3.80	4.69	4.98	4.1	4.2
	L4	4.93	4.02			4.475	3.62	3.35	4.04	4.56	3.93	4.04	3.56	3.9	4.0
Rel. ORP (mV)	Date	Aug 1-05	Aug. 11-05	Sept 6-05	Sept. 19-05		Sept. 28-05	Sept. 30-05	Oct. 7-05	Oct. 15-05	Oct. 18-05	Oct. 21-05	Oct. 30-05		
	Control	302.4	275.4	318.6	337.6	308.5	298.1	241.2	208.6	201.6	294.6	276.1	279.8	249	270
	L1	303.1	304.7	324.6	361.6	323.5	262.4	254.1	141.1	195.7	286	270.5	270.2	240	270
	L2	309.6	305.5	322.4	372.5	327.5	257.7	235.6	132	199.1	277	269.2	288.5	237	270
	L3	287.8	290.5	320.5	367.2	316.5	291	279	202.3	217.5	298	267.2	298	265	284
	L4	288.3	286.2	319.7	353.4	311.9	289.8	288.4	212.4	211.2	285.9	273.3	289.2	268	283
NH3-Aq Conc'n (mL/L)	Date	Aug 2-05	Aug 9-05	Aug. 12-05	Sept. 8-05		Sept. 28-05	Sept. 30-05	Oct. 12-05	Oct. 14-05	Oct. 18-05	Oct. 21-05	Oct. 26-05		
	Control	70.87524	42.78449	30.13838	41.00112	46.19981	8.88	6.49	7.42	9.31	14.90	16.75	60.48524	17.7	28.1
	L1	42.78309	12.44797	3.882578	6.012803	16.28162	32.75	40.68	1.98	3.40	3.26	9.05	27.13	16.9	16.7
	L2	45.11617	31.70868	32.81381	43.74596	38.34616	75.13	108.63	128.92	113.31	111.49	82.29	73.76	98.8	76.8
	L3	22.80259	7.958758	2.446845	20.93242	13.5339	14.68	16.96	14.13	2.85	18.99	61.22	75.27	29.2	23.5
	L4	35.91414	27.24721	41.33468	70.54803	44.01109	34.16	43.68	7.19	6.98	11.22	15.70	60.49	25.6	32.3

		STEADY STATE #4 - Digester Data							
Parameter	Reactor	1	2	3	4	5	6	7	AVERAGE
Nitrite Conc'n	Date	Sept. 29-05	Oct. 7-05	Oct. 14-05	Oct. 17-05	Oct. 20-05	Oct. 24-05	Oct. 26-05	
	L1	57.0845	1.306	0.145	0	0	0	0	8.36
	L2	36.148	0	0	0	0	0	0	5.16
	L3	0.2195	0	0	0	0	0	0	0.03
	L4	24.5475	0	0	0	0	0	0	3.51
	Control	53.367	0	0	0	0	0	0	7.62
Nitrate Conc'n	Date	Sept. 29-05	Oct. 7-05	Oct. 14-05	Oct. 17-05	Oct. 20-05	Oct. 24-05	Oct. 26-05	
	L1	527.1165	259.034	389.081	123.889	228.438	166.396	26.645	245.80
	L2	12.659	28.446	34.367	5.978	12.995	48.884	76.232	31.37
	L3	4.342	138.503	497.554	130.15	3.599	51.104	56.871	126.02
	L4	0	30.366	53.143	32.927	5.062	37.434	60.696	31.38
	Control	0.109	168.8826	455.059	316.963	9.387	61.474	62.895	153.54
TKN	Date	Oct. 4-05	Oct. 15-05	Oct. 21-05					
	Control	586	613	643					614
	L1	527	555	462					515
	L2	415	379	486					427
	L3	510	538	575					541
	L4	481	574	631					562
VFA Analysis	Date	Sept. 28-05	Oct. 5-05	Oct. 27-05					
	L1	Straightline	Straightline	Straightline					0
	L2	Straightline	Straightline	Straightline					0
	L3	Straightline	Straightline	Straightline					0
	L4	Straightline	Straightline	Straightline					0
	Feed	Straightline	Straightline	Straightline					0

		Approaching SS-#4 - Digester Data				STEADY STATE-#4 - Digester Data								Overall
Parameter	Reactor	1	2	3	AVERAGE	1	2	3	4	5	6	7	AVERAGE	Average
Fecal (CFU/100 mL)	Date	Aug. 11-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 16-05	Oct. 19-05	Oct. 23-05		
	Control	3,977	52,000	84,000	46,659	184,000	4,000,000	2,700,000	530,000	40,000	110,000	57,000	1,088,714	776,098
	L1	3,239	52,000	110,000	55,080	95,000	28,000	1,500,000	1,720,000	920,000	760,000	120,000	737,571	532,824
	L2		2,600	800	1,700	1,500	11,000	185,000	51,000	8,000	13,500	4,200	36,457	28,733
	L3	39,983	99,000	55,000	61,994	28,000	325,000	2,100,000	240,000	15,000	8,000	14,500	390,071	291,648
	L4	62,065	51,724	8,050	40,613	1,700	560,000	720,000	340,000	60,000	49,000	6,000	248,100	185,854
E Coli (CFU/100 mL)	Date	Aug. 11-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 16-05	Oct. 19-05	Oct. 23-05		
	Control	9,721	119,000	110,000	79,574	195,000	3,500,000	5,000,000	630,000	80,000	266,000	91,000	1,394,571	1,000,072
	L1	6,477	98,000	155,000	86,826	132,000	68,000	5,200,000	4,260,000	1,720,000	1,390,000	8,400	1,827,629	1,305,388
	L2			1,200	1,200	1,900	17,000	280,000	83,000	84,000	250,000	40,000	107,986	94,638
	L3	68,719	158,000	52,000	89,573	60,000	280,000	4,000,000	310,000	130,000	86,000	820,000	812,286	595,472
	L4	100,104	34,000	7,600	47,235	9,000	580,000	640,000	450,000	200,000	81,000	24,000	283,429	212,570
Salmonella (CFU/100 mL)	Date	Aug. 11-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 16-05	Oct. 19-05	Oct. 23-05		
	Control	663	8,400	7,800	5,621	12,000	112,000	97,000	30,000	80,000	114,000	13,000	65,429	47,486
	L1		9,300	11,200	10,250	7,800	8,000	440,000	640,000	720,000	740,000	7,000	366,114	267,033
	L2		500	200	350	100	4,800	15,800	14,050	2,000	3,000	1,100	5,836	4,617
	L3	2,124	7,300	6,000	5,141	3,600	42,000	20,000	10,770	14,000	9,000	2,100	14,496	11,689
	L4	4,004	2,100	1,100	2,401	400	10,000	21,000	18,000	17,000	24,000	500	12,986	9,810
Clostridium Perfringens (CFU/100 mL)	Date	Aug. 11-05	Sept. 13-05	Sept. 15-05		Sept. 27-05	Oct. 3-05	Oct. 6-05	Oct. 12-05	Oct. 16-05	Oct. 19-05	Oct. 23-05		
	Control	288,561	3,333,333	3,250,000	2,277,298	3,250,000	1,666,667	2,625,000	1,875,000	2,375,000	2,375,000	1,250,000	2,202,381	2,224,855
	L1	2,159,113	3,833,333	4,125,000	3,372,482	4,875,000	2,125,000	4,000,000	2,833,333	4,250,000	4,166,667	1,666,667	3,416,667	3,408,411
	L2	3,859,847	3,625,000	2,500,000	3,328,282	2,750,000	1,750,000	1,500,000	875,000	750,000	2,000,000	1,666,667	1,613,095	2,127,651
	L3	1,858,470	4,666,667	2,125,000	2,883,379	3,000,000	3,000,000	2,875,000	1,875,000	2,000,000	1,500,000	750,000	2,142,857	2,365,014
	L4	1,251,305	4,000,000	2,875,000	2,708,768	5,125,000	1,875,000	3,000,000	3,125,000	3,125,000	1,750,000	2,333,333	2,904,762	2845,964

5) pH Values

January 8, 2005

		pH
Round 1	L1	6.7
	L2	6.63
	L3	7.08
	L4	6.55
Round 2	L1	6.68
	L2	6.7
	L3	7.12
	L4	6.63
Round 3	L1	6.67
	L2	6.7
	L3	7.15
	L4	6.61

January 14, 2005

		pH
Round 1	L1	6.71
	L2	6.79
	L3	6.84
	L4	6.45
Round 2	L1	6.75
	L2	6.73
	L3	6.77
	L4	6.42
Round 3	L1	6.75
	L2	6.57
	L3	6.82
	L4	6.4

January 28, 2005

		pH
Round 1	L1	6.82
	L2	6.4
	L3	6.64
	L4	5.81
Round 2	L1	6.86
	L2	6.35
	L3	6.5
	L4	6.19
Round 3	L1	6.78
	L2	6.37
	L3	6.63
	L4	5.88

February 4, 2005

		pH
Round 1	L1	6.9
	L2	7.24
	L3	6.87
	L4	6.51
Round 2	L1	7.1
	L2	7.23
	L3	7.09
	L4	6.54
Round 3	L1	7.03
	L2	7.24
	L3	6.88
	L4	6.51

February 10, 2005

		pH
Round 1	L1	5.92
	L2	6.3
	L3	6.03
	L4	5.88
Round 2	L1	5.98
	L2	6.99
	L3	6.05
	L4	6
Round 3	L1	6
	L2	6.99
	L3	6.05
	L4	5.99

6) Dissolved Oxygen Concentrations

January 8, 2005

		DO
Round 1	L1	7.89 ppm
	L2	2.43 ppm
	L3	14.15 ppb
	L4	8.36 ppb
Round 2	L1	9.05 ppm
	L2	3.33 ppm
	L3	13.29 ppb
	L4	7.75 ppb
Round 3	L1	8.97 ppm
	L2	3.43 ppm
	L3	12.85 ppb
	L4	7.87 ppb

January 14, 2005

		DO
Round 1	L1	9.57 ppm
	L2	1.514 ppm
	L3	0.471 ppm
	L4	19.6 ppb
Round 2	L1	9.51 ppm
	L2	1.124 ppm
	L3	0.363 ppm
	L4	16.15 ppb
Round 3	L1	9.62 ppm
	L2	1.340 ppm
	L3	0.398 ppm
	L4	15.43 ppb

February 4, 2005

		DO
Round 1	L1	29.01 ppm
	L2	0.974 ppm
	L3	0.269 ppm
	L4	32.1 ppb
Round 2	L2	0.707 ppm
	L3	80.9 ppb
	L4	48.6 ppb
Round 3	L2	1.040 ppm
	L3	102.3 ppb
	L4	29.4 ppb

February 10, 2005

		DO
Round 1	L1	A 30 ppm
	L2	1.083 ppm
	L3	84.2 ppb
	L4	43.1 ppb
Round 2	L1	
	L2	1.049 ppm
	L3	49.3 ppb
	L4	40.7 ppb
Round 3	L1	
	L2	1.065 ppm
	L3	55.3 ppb
	L4	36.2 ppb

7) Oxidation-Reduction Potential Measurements

January 8, 2005

		ORP (mV)
Round 1	L1	156.5
	L2	-181.7
	L3	-304.2
	L4	-359.2
Round 2	L1	122.3
	L2	-205.5
	L3	-373.3
	L4	-382.4
Round 3	L1	114.5
	L2	-219.5
	L3	-281.6
	L4	-339.4

January 14, 2005

		ORP (mV)
Round 1	L1	80.8
	L2	-251.3
	L3	-335.7
	L4	-393.9
Round 2	L1	84.8
	L2	-232.8
	L3	-334.6
	L4	-405.1
Round 3	L1	81.9
	L2	-214.9
	L3	-352.2
	L4	-398.3

January 28, 2005

		ORP (mV)
Round 1	L1	154.8
	L2	-228.1
	L3	-264.5
	L4	-299
Round 2	L1	156
	L2	-221.6
	L3	-266.7
	L4	-291.5
Round 3	L1	155.5
	L2	-232.4
	L3	-255.7
	L4	-297.6

February 4, 2005

		ORP (mV)
Round 1	L1	41.9
	L2	-224.1
	L3	-245.3
	L4	-259.4
Round 2	L1	47.8
	L2	-234.9
	L3	-262.6
	L4	-267.4
Round 3	L1	49.5
	L2	-218.7
	L3	-263.2
	L4	-267.6

February 10, 2005

		ORP (mV)
Round 1	L1	118.8
	L2	-199.9
	L3	-246.3
	L4	-253.2
Round 2	L1	161.7
	L2	-212.4
	L3	-247.2
	L4	-243.5
Round 3	L1	163
	L2	-205.6
	L3	-246.7
	L4	-245.9

8) Alkalinity and Total Volatile Fatty Acids Titration Results

January 8, 2005

		Alk (mg/L)	VFA (mg/L)	Ratio
Round 1	L1	38.3211	4.07055	0.10622
	L2	97.2118	-20.489	-0.2108
	L3	410.265	50.2189	0.12241
	L4	148.633	572.095	3.84905
Round 2	L1	83.9547	-19.177	-0.2284
	L2	119.307	-5.4327	-0.0455
	L3	422.174	50.2706	0.11908
	L4	144.953	608.108	4.1952

January 14, 2005

		Alk (mg/L)	VFA (mg/L)	Ratio
Round 1	L1	65.0796	1.14945	0.01766
	L2	126.525	-6.7264	-0.0532
	L3	362.23	17.9155	0.04946
	L4	146.759	483.774	3.29639
	Feed	270.821	360.48	1.33106
Round 2	L1	78.8225	-0.6927	-0.0088
	L2	130.591	1.84391	0.01412
	L3	338.84	75.336	0.22234
	L4	152.165	491.38	3.22926
	Feed	258.738	361.079	1.39554

January 28, 2005

		Alk (mg/L)	VFA (mg/L)	Ratio
Round 1	L1	85.7972	-1.7243	-0.0201
	L2	286.962	72.8943	0.25402
	L3	153.792	579.889	3.77061
	L4	240.754	696.945	2.89484
	Feed	254.753	424.163	1.66499
Round 2	L1	89.6621	7.05088	0.07864
	L2	288.957	90.1558	0.312
	L3	151.1	589.155	3.89912
	L4	145.462	709.892	4.88026
	Feed	250.983	441.728	1.75999

February 4, 2005

		Alk (mg/L)	VFA (mg/L)	Ratio
Round 1	L1	74.8743	-9.3958	-0.1255
	L2	187.905	4.85362	0.02583
	L3	139.901	510.853	3.65152
	L4	138.86	605.589	4.36117
	Feed			
Round 2	L1	72.5157	-0.3688	-0.0051
	L2	188.308	4.43117	0.02353
	L3	140.029	510.776	3.64763
	L4	144.003	624.126	4.33413
	Feed			

February 10, 2005

		Alk (mg/L)	VFA (mg/L)	Ratio
Round 1	L1	85.2979	-20.684	-0.2425
	L2	362.27	108.295	0.29893
	L3	154.57	534.665	3.45906
	L4	139.432	639.332	4.58525
	Feed			
Round 2	L1	84.3631	-19.634	-0.2327
	L2	372.153	71.8204	0.19299
	L3	132.708	572.111	4.31105
	L4	151.737	638.175	4.20579
	Feed			

9) Soluble COD Measurements and Calculated Concentrations

January 14, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	50%	0.01	28.04383	56.08766
L1	50%	0.009	25.23945	50.47889
L1	50%	0.015	42.06575	84.13149
L1	50%			
L2	50%	0.005	14.02192	28.04383
L2	50%	0.004	11.21753	22.43506
L2	50%	0.002	5.608766	11.21753
L2	50%	0.004	11.21753	22.43506
L3	50%	0.065	182.2849	364.5698
L3	50%	0.036	100.9578	201.9156
L3	50%	0.028		
L3	50%	0.062		
L4	50%	0.16	448.7013	897.4026
L4	50%	0.147	412.2443	824.4886
L4	50%	0.148	415.0487	830.0974
L4	50%	0.153	429.0706	858.1412
Feed	50%	0.135	378.5917	757.1834
Feed	50%	0.147	412.2443	824.4886
Feed	50%	0.141	395.418	790.836
Feed	50%	0.183	513.2021	1026.404

January 28, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	50%	0.01	28.04383	56.08766
L1	50%	0.042	117.7841	235.5682
L1	50%	0.041	114.9797	229.9594
L1	50%	0.044	123.3929	246.7857
L2	50%	0.095	266.4164	532.8328
L2	50%	0.109	305.6777	611.3555
L2	50%	0.075	210.3287	420.6575
L2	50%	0.055	154.2411	308.4821
L3	50%	0.2	560.8766	1121.753
L3	50%	0.198	555.2678	1110.536
L3	50%	0.199	558.0722	1116.144
L3	50%	0.191	535.6372	1071.274
L4	50%	0.282	790.836	1581.672
L4	50%	0.295	827.293	1654.586
L4	50%	0.263	737.5527	1475.105
L4	50%	0.265	743.1615	1486.323
Feed	50%	0.195	546.8547	1093.709
Feed	50%	0.135		
Feed	50%	0.173	485.1583	970.3165
Feed	50%	0.166	465.5276	931.0552

February 4, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	50%	0.01	28.04383	56.08766
L1	50%	0.027	75.71834	151.4367
L1	50%	0.03	84.13149	168.263
L1	50%	0.044	123.3929	246.7857
L2	50%	0.065	182.2849	364.5698
L2	50%	0.03	84.13149	168.263
L2	50%	0.024	67.30519	134.6104
L2	50%	0.033	92.54464	185.0893
L3	50%	0.166	465.5276	931.0552
L3	50%	0.174	487.9626	975.9253
L3	50%			
L3	50%			
L4	50%	0.214	600.138	1200.276
L4	50%	0.228	639.3993	1278.799
L4	50%	0.207	580.5073	1161.015
L4	50%	0.221	619.7686	1239.537
Feed	50%	0.116	325.3084	650.6169
Feed	50%	0.13	364.5698	729.1396
Feed	50%	0.135	378.5917	757.1834
Feed	50%	0.12	336.526	673.0519

February 10, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	0%	0.014	39.26136	39.26136
L1	0%	0	0	0
L1	0%	0	0	0
L1	0%	0	0	0
L2	0%	0.214	600.138	600.138
L2	0%	0.22	616.9643	616.9643
L2	0%	0.268	751.5746	751.5746
L2	0%	0.209	586.116	586.116
L3	50%	0.217	608.5511	1217.102
L3	50%	0.145	406.6355	813.2711
L3	50%	0.15	420.6575	841.3149
L3	50%	0.16	448.7013	897.4026
L4	50%	0.234	656.2256	1312.451
L4	50%	0.414		
L4	50%	0.24	673.0519	1346.104
L4	50%	0.245	687.0738	1374.148
Feed	50%	0.113	316.8953	633.7906
Feed	50%	0.039	109.3709	218.7419
Feed	50%	0.057	159.8498	319.6997
Feed	50%	0.297		

February 25, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	100%	-0.012	-33.6526	-33.6526
L1	100%	0.012	33.6526	33.6526
L1	100%	0.036	100.9578	100.9578
L1	100%	0.055	154.2411	154.2411
L2	100%	0.103	288.8514	288.8514
L2	100%	0.065	182.2849	182.2849
L2	100%	0.095	266.4164	266.4164
L2	100%	0.078	218.7419	218.7419
L3	50%	0.213	597.3336	1194.667
L3	50%	0.196	549.6591	1099.318
L3	50%	0.186	521.6152	1043.23
L3	50%	0.526	1475.105	2950.211
L4	50%	0.498	1396.583	2793.165
L4	50%	0.452	1267.581	2535.162
L4	50%	0.28	785.2272	1570.454
L4	50%	0.396	1110.536	2221.071
Feed	100%	0.281	788.0316	788.0316
Feed	100%	0.311	872.1631	872.1631
Feed	100%	0.32	897.4026	897.4026
Feed	100%	0.245	687.0738	687.0738

March 11, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	100%	0.017	47.67451	47.67451
L1	100%	0.01	28.04383	28.04383
L1	100%	0.047	131.806	131.806
L1	100%	0.08	224.3506	224.3506
L2	100%	0.024	67.30519	67.30519
L2	100%	0.031	86.93587	86.93587
L2	100%	0.021	58.89204	58.89204
L2	100%	0.018	50.47889	50.47889
L3	100%	0.099	277.6339	277.6339
L3	100%	0.118	330.9172	330.9172
L3	100%	0.091	255.1989	255.1989
L3	100%	0.091	255.1989	255.1989
L4	100%	0.276	774.0097	774.0097
L4	100%	0.28	785.2272	785.2272
L4	100%	0.287	804.8579	804.8579
L4	100%	0.286	802.0535	802.0535
Feed	100%	0.074	207.5243	207.5243
Feed	100%	0.099	277.6339	277.6339
Feed	100%	0.118	330.9172	330.9172
Feed	100%	0.069	193.5024	193.5024

March 23, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)
L1	100%	0.042	117.7841	117.7841
L1	100%	0.043	120.5885	120.5885
L1	100%	0.037	103.7622	103.7622
L1	100%	0.049	137.4148	137.4148
L2	100%	0.258	723.5308	723.5308
L2	100%	0.248	695.487	695.487
L2	100%	0.246	689.8782	689.8782
L2	100%	0.24	673.0519	673.0519
L3	50%	0.238	667.4432	1334.886
L3	50%	0.225	630.9862	1261.972
L3	50%	0.239	670.2475	1340.495
L3	50%	0.24	673.0519	1346.104
L4	50%	0.27	757.1834	1514.367
L4	50%	0.283	793.6404	1587.281
L4	50%	0.261	731.944	1463.888
L4	50%	0.27	757.1834	1514.367
Feed	100%	0.195	546.8547	546.8547
Feed	100%	0.206	577.7029	577.7029
Feed	100%	0.182	510.3977	510.3977
Feed	100%	0.192	538.4415	538.4415

May 19, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.019	53.28328	53.28328	62.39752
L1	100%	0.018	50.47889	50.47889	
L1	100%	0.021	58.89204	58.89204	
L1	100%	0.031	86.93587	86.93587	
L2	20%	0.036	100.9578	504.7889	396.1191
L2	20%	0.024	67.30519	336.526	
L2	20%	0.025	70.10958	350.5479	
L2	20%	0.028	78.52272	392.6136	
L3	20%	0.054	151.4367	757.1834	724.4656
L3	20%	0.049	137.4148	687.0738	
L3	20%	0.052	145.8279	729.1396	
L3	20%	N/A			
L4	20%	0.09	252.3945	1261.972	1170.83
L4	20%	0.091	255.1989	1275.994	
L4	20%	0.065	182.2849	911.4245	
L4	20%	0.088	246.7857	1233.929	
Feed	100%	0.055	154.2411	154.2411	138.817
Feed	100%	0.041	114.9797	114.9797	
Feed	100%	0.053	148.6323	148.6323	
Feed	100%	0.049	137.4148	137.4148	

May 12, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.041	114.9797	114.9797	98.15341
L1	100%	0.032	89.74026	89.74026	
L1	100%	0.033	92.54464	92.54464	
L1	100%	0.034	95.34902	95.34902	
L2	20%	0.058	162.6542	813.2711	560.8766
L2	20%	0.028	78.52272	392.6136	
L2	20%	0.038	106.5666	532.8328	
L2	20%	0.036	100.9578	504.7889	
L3	20%	0.13	364.5698	Discard	944.1423
L3	20%	0.068	190.698	953.4902	
L3	20%	0.067	187.8937	939.4683	
L3	20%	0.067	187.8937	939.4683	
L4	20%	0.11	308.4821	1542.411	1451.268
L4	20%	0.133	372.9829	1864.915	
L4	20%	0.083	232.7638	1163.819	
L4	20%	0.088	246.7857	1233.929	
Feed	100%	0.168	471.1363	471.1363	480.2506
Feed	100%	0.17	476.7451	476.7451	
Feed	100%	0.175	490.767	490.767	
Feed	100%	0.172	482.3539	482.3539	

May 5, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.042	117.7841	117.7841	108.6698
L1	100%	0.024	67.30519	67.30519	
L1	100%	0.05	140.2192	140.2192	
L1	100%	0.039	109.3709	109.3709	
L2	20%	0.269	754.379	Discard	836.6409
L2	20%	0.068	190.698	953.4902	
L2	20%	0.046	129.0016	645.0081	
L2	20%	0.065	182.2849	911.4245	
L3	20%	0.111	311.2865	1556.433	1461.785
L3	20%	0.108	302.8734	1514.367	
L3	20%	0.09	252.3945	1261.972	
L3	20%	0.108	302.8734	1514.367	
L4	20%	0.132	370.1786	1850.893	1945.541
L4	20%	0.164	459.9188	2299.594	
L4	20%	0.108	302.8734	1514.367	
L4	20%	0.151	423.4618	2117.309	
Feed	100%	0.28	785.2272	785.2272	797.847
Feed	100%	0.273	765.5966	765.5966	
Feed	100%	0.284	796.4448	796.4448	
Feed	100%	0.301	844.1193	844.1193	

May 3, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.154	431.875	431.875	480.9517
L1	100%	0.194	544.0503	544.0503	
L1	100%	0.158	443.0925	443.0925	
L1	100%	0.18	504.7889	504.7889	
L2	33%	0.352	987.1428	2964.393	2970.709
L2	33%	0.354	992.7516	2981.236	
L2	33%	0.35	981.5341	2947.55	
L2	33%	0.355	995.556	2989.658	
L3	33%	0.353	989.9472	2972.814	2953.866
L3	33%	0.357	1001.165	3006.501	
L3	33%	0.344	964.7078	2897.02	
L3	33%	0.349	978.7297	2939.128	
L4	33%	0.265	743.1615	2231.716	2318.037
L4	33%	0.293	821.6842	2467.52	
L4	33%	0.267	748.7703	2248.559	
L4	33%	0.276	774.0097	2324.353	
Feed	100%	0.06	168.263	168.263	197.709
Feed	100%	0.092	258.0032	258.0032	
Feed	100%	0.061	171.0674	171.0674	
Feed	100%	0.069	193.5024	193.5024	

April 28, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.138	387.0049	387.0049	379.2928
L1	100%	0.129	361.7654	361.7654	
L1	100%	0.132	370.1786	370.1786	
L1	100%	0.142	398.2224	398.2224	
L2	33%	0.237	664.6388	1995.912	1985.385
L2	33%	0.239	670.2475	2012.755	
L2	33%	0.226	633.7906	1903.275	
L2	33%	0.241	675.8563	2029.599	
L3	33%	0.217	608.5511	1827.481	1823.27
L3	33%	0.214	600.138	1802.216	
L3	33%	0.223	625.3774	1878.01	
L3	33%	0.212	594.5292	1785.373	
L4	33%	0.141	395.418	1187.441	1225.339
L4	33%	0.123	344.9391	1035.853	
L4	33%	0.139	389.8092	1170.598	
L4	33%	0.179	501.9846	1507.461	
Feed	50%	0.076	213.1331	426.2662	305.6777
Feed	50%	0.051	143.0235	286.0471	
Feed	50%	0.047	131.806	263.612	
Feed	50%	0.044	123.3929	246.7857	

April 21, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.078	218.7419	218.7419	206.8232
L1	100%	0.063	176.6761	176.6761	
L1	100%	0.079	221.5463	221.5463	
L1	100%	0.075	210.3287	210.3287	
L2	20%	0.17	476.7451	2383.726	2232.99
L2	20%	0.166	465.5276	2327.638	
L2	20%	0.162	454.31	2271.55	
L2	20%	0.139	389.8092	1949.046	
L3	20%	0.192	538.4415	2692.208	2786.856
L3	20%	0.195	546.8547	2734.273	
L3	20%	0.197	552.4635	2762.317	
L3	20%	0.211	591.7248	2958.624	
L4	20%	0.225	630.9862	3154.931	3414.336
L4	20%	0.22	616.9643	3084.821	
L4	20%	0.311	872.1631	4360.816	
L4	20%	0.218	611.3555	3056.777	
Feed	50%	0.159	445.8969	891.7938	950.6858
Feed	50%	0.149	417.8531	835.7061	
Feed	50%	0.206	577.7029	1155.406	
Feed	50%	0.164	459.9188	919.8376	

April 15, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.052	145.8279	145.8279	173.1707
L1	100%	0.079	221.5463	221.5463	
L1	100%	0.059	165.4586	165.4586	
L1	100%	0.057	159.8498	159.8498	
L2	50%	0.346	970.3165	1940.633	1937.829
L2	50%	0.34	953.4902	1906.98	
L2	50%	0.347	973.1209	1946.242	
L2	50%	0.349	978.7297	1957.459	
L3	50%	0.368	1032.013	2064.026	2090.668
L3	50%	0.424	1189.058	2378.117	
L3	50%	0.351	984.3384	1968.677	
L3	50%	0.348	975.9253	1951.851	
L4	50%	0.337	945.0771	1890.154	1925.209
L4	50%	0.346	970.3165	1940.633	
L4	50%	0.348	975.9253	1951.851	
L4	50%	0.342	959.099	1918.198	
Feed	100%	0.327	917.0332	917.0332	894.5982
Feed	100%	0.318	891.7938	891.7938	
Feed	100%	0.329	922.642	922.642	
Feed	100%	0.302	846.9237	846.9237	

August 12th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.085	230.1035	230.1035	196.2648
L1	100%	0.06	162.426	162.426	
L1			0		
L1			0		
L2	100%	0.352	952.8992	952.8992	886.5753
L2	100%	0.358	969.1418	969.1418	
L2	25%	0.082	221.9822	887.9288	
L2	25%	0.068	184.0828	736.3312	
L3	100%	0.051	138.0621	138.0621	196.2648
L3	100%	0.094	254.4674	254.4674	
L3			0		
L3			0		
L4	100%	0.244	660.5324	660.5324	681.5124
L4	100%	0.243	657.8253	657.8253	
L4	25%	0.063	170.5473	682.1892	
L4	25%	0.067	181.3757	725.5028	
Feed	100%	0.102	276.1242	276.1242	292.3668
Feed	100%	0.11	297.781	297.781	
Feed	25%	0.018	48.7278	194.9112	
Feed	25%	0.037	100.1627	400.6508	

August 9, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.028	84.0784	84.0784	75.07
L1	100%	0.022	66.0616	66.0616	
L1			0		
L1			0		
L2	100%	0.272	816.7616	816.7616	858.0501
L2	100%	0.275	825.77	825.77	
L2	25%	0.068	204.1904	816.7616	
L2	25%	0.081	243.2268	972.9072	
L3	100%	0.014	42.0392	42.0392	42.0392
L3	100%	0.014	42.0392	42.0392	
L3			0		
L3			0		
L4	100%	0.134	402.3752	402.3752	414.3864
L4	100%	0.142	426.3976	426.3976	
L4	25%	0.028	84.0784	336.3136	
L4	25%	0.041	123.1148	492.4592	
Feed	100%	0.149	447.4172	447.4172	399.3724
Feed	100%	0.13	390.364	390.364	
Feed	25%	0.03	90.084	360.336	
Feed	25%		0		

August 5, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.025	75.07	75.07	58.5546
L1	100%	0.014	42.0392	42.0392	
L1			0		
L1			0		
L2	100%	0.325	975.91	975.91	932.3694
L2	100%	0.296	888.8288	888.8288	
L2	25%	0.034	102.0952		
L2	25%	0.06	180.168		
L3	100%	0.039	117.1092	117.1092	162.1512
L3	100%	0.069	207.1932	207.1932	
L3			0		
L3			0		
L4	100%	0.17	510.476	510.476	500.7169
L4	100%	0.169	507.4732	507.4732	
L4	25%	0.037	111.1036	444.4144	
L4	25%	0.045	135.126	540.504	
Feed	100%	0.147	441.4116	441.4116	411.3836
Feed	100%	0.127	381.3556	381.3556	
Feed	25%	0.019	57.0532		
Feed	25%	0.019	57.0532		

July 25th, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.046	138.1288	138.1288	123.1148
L1	100%	0.036	108.1008	108.1008	
L1			0		
L1			0		
L2	100%	0.315	945.882	945.882	1315.226
L2	100%	0.297	891.8316	891.8316	
L2	50%	0.351	1053.983	2107.966	
L2			0		
L3	100%	0.037	111.1036	111.1036	115.6078
L3	100%	0.04	120.112	120.112	
L3			0		
L3			0		
L4	100%	0.259	777.7252	777.7252	785.7327
L4	100%	0.258	774.7224	774.7224	
L4	50%	0.134	402.3752	804.7504	
L4			0		
Feed	100%	0.113	339.3164	339.3164	285.266
Feed	100%	0.1	300.28	300.28	
Feed	50%	0.036	108.1008	216.2016	
Feed			0		

July 14th, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.034	95.34902	95.34902	126.1972
L1	100%	0.056	157.0454	157.0454	
L1			0		
L1			0		
L2	100%	0.294	824.4886	824.4886	869.125
L2	100%	0.309	866.5543	866.5543	
L2	50%	0.16	448.7013	897.4026	
L2	33%	0.1045	293.058	888.0546	
L3	100%	0.036	100.9578	100.9578	86.93587
L3	100%	0.026	72.91396	72.91396	
L3			0		
L3			0		
L4	100%	0.295	827.293	827.293	840.6563
L4	100%	0.31	869.3587	869.3587	
L4	50%	0.144	403.8312	807.6623	
L4	33%	0.101	283.2427	858.3112	
Feed	100%	0.109	305.6777	305.6777	311.2865
Feed	100%	0.101	283.2427	283.2427	
Feed	50%	0.055	154.2411	308.4821	
Feed	50%	0.062	173.8717	347.7435	

July 8th, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.062	173.8717	173.8717	182.2849
L1	100%	0.068	190.698	190.698	
L1			0		
L1			0		
L2	100%	0.336	942.2727		1200.276
L2	100%	0.333	933.8595		
L2	50%	0.206	577.7029	1155.406	
L2	50%	0.222	622.573	1245.146	
L3	100%	0.056	157.0454	157.0454	166.8608
L3	100%	0.063	176.6761	176.6761	
L3			0		
L3			0		
L4	100%	0.319	894.5982		1665.804
L4	100%	0.364	1020.795		
L4	50%	0.3	841.3149	1682.63	
L4	50%	0.294	824.4886	1648.977	
Feed	100%	0.235	659.03	659.03	691.2804
Feed	100%	0.258	723.5308	723.5308	
Feed			0		
Feed			0		

July 6, 2005

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.023	64.50081	64.50081	79.92492
L1	100%	0.034	95.34902	95.34902	
L1			0		
L1			0		
L2	100%	0.232	650.6169	650.6169	670.9486
L2	100%	0.22	616.9643	616.9643	
L2	40%	0.106	297.2646	743.1615	
L2	40%	0.096	269.2208	673.0519	
L3	100%	0.036	100.9578	100.9578	88.33806
L3	100%	0.027	75.71834	75.71834	
L3			0		
L3			0		
L4	100%	0.202	566.4854	566.4854	568.8224
L4	100%	0.184	516.0065	516.0065	
L4	40%	0.089	249.5901	623.9752	
L4			0		
Feed	100%	0.186	521.6152	521.6152	496.3758
Feed	100%	0.168	471.1363	471.1363	
Feed			0		
Feed			0		

August 5th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.033	89.3343	89.3343	87.98075
L1	100%	0.032	86.6272	86.6272	
L2	100%	0.034	92.0414	92.0414	100.1627
L2	100%	0.04	108.284	108.284	
L3	100%	0.014	37.8994	37.8994	6.76775
L3	100%	-0.009	-24.3639	-24.3639	
L4	100%	0.014	37.8994	37.8994	41.96005
L4	100%	0.017	46.0207	46.0207	
Control	100%	-0.007	-18.9497	-18.9497	29.7781
Control	100%	0.029	78.5059	78.5059	

September 8th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.027	73.0917	73.0917	83.9201
L1	100%	0.035	94.7485	94.7485	
L2	100%	0.02	54.142	54.142	59.5562
L2	100%	0.024	64.9704	64.9704	
L3	100%	0.024	64.9704	64.9704	58.20265
L3	100%	0.019	51.4349	51.4349	

L4	100%	0.02	54.142	54.142	51.4349
L4	100%	0.018	48.7278	48.7278	
Control	100%	0.057	154.3047	154.3047	120.466
Control	100%	0.032	86.6272	86.6272	

September 15th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.059	159.7189	159.7189	142.1228
L1	100%	0.046	124.5266	124.5266	
L2	100%	0.037	100.1627	100.1627	97.4556
L2	100%	0.035	94.7485	94.7485	
L3	100%	0.042	113.6982	113.6982	105.5769
L3	100%	0.036	97.4556	97.4556	
L4	100%	0.032	86.6272	86.6272	90.68785
L4	100%	0.035	94.7485	94.7485	
Control	100%	0.038	102.8698	102.8698	90.68785
Control	100%	0.029	78.5059	78.5059	

September 28th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.041	110.9911	110.9911	129.9408
L1	100%	0.055	148.8905	148.8905	
L2	100%	0.043	116.4053	116.4053	124.5266
L2	100%	0.049	132.6479	132.6479	
L3	100%	0.074	200.3254	200.3254	166.4867
L3	100%	0.049	132.6479	132.6479	
L4	100%	0.041	110.9911	110.9911	135.355
L4	100%	0.059	159.7189	159.7189	
Control	100%	0.052	140.7692	140.7692	121.8195
Control	100%	0.038	102.8698	102.8698	

Oct. 5th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.04	108.284	108.284	124.5266
L1	100%	0.052	140.7692	140.7692	
L2	100%	0.112	303.1952	303.1952	277.4778
L2	100%	0.093	251.7603	251.7603	
L3	100%	0.048	129.9408	129.9408	157.0118
L3	100%	0.068	184.0828	184.0828	
L4	100%	0.064	173.2544	173.2544	163.7796
L4	100%	0.057	154.3047	154.3047	
Control	100%	0.059	159.7189	159.7189	165.1331
Control	100%	0.063	170.5473	170.5473	

Oct. 14th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.06	162.426	162.426	151.5976
L1	100%	0.052	140.7692	140.7692	
L2	100%	0.068	184.0828	184.0828	200.3254
L2	100%	0.08	216.568	216.568	
L3	100%	0.051	138.0621	138.0621	146.1834
L3	100%	0.057	154.3047	154.3047	
L4	100%	0.059	159.7189	159.7189	221.9822
L4	100%	0.105	284.2455	284.2455	
Control	100%	0.064	173.2544	173.2544	186.7899
Control	100%	0.074	200.3254	200.3254	

Oct. 20th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.045	121.8195	121.8195	139.4157
L1	100%	0.058	157.0118	157.0118	
L2	100%	0.056	151.5976	151.5976	180.0222
L2	100%	0.077	208.4467	208.4467	
L3	100%	0.1	270.71	270.71	251.7603
L3	100%	0.086	232.8106	232.8106	
L4	100%	0.095	257.1745	257.1745	230.1035
L4	100%	0.075	203.0325	203.0325	
Control	100%	0.076	205.7396	205.7396	220.6287
Control	100%	0.087	235.5177	235.5177	

Oct. 24th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.042	113.6982	113.6982	101.5163
L1	100%	0.033	89.3343	89.3343	
L2	100%	0.042	113.6982	113.6982	104.2234
L2	100%	0.035	94.7485	94.7485	
L3	100%	0.056	151.5976	151.5976	181.3757
L3	100%	0.078	211.1538	211.1538	
L4	100%	0.059	159.7189	159.7189	148.8905
L4	100%	0.051	138.0621	138.0621	
Control	100%	0.167	452.0857	452.0857	489.9851
Control	100%	0.195	527.8845	527.8845	

Oct. 26th

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.046	124.5266	124.5266	135.355

L1	100%	0.054	146.1834	146.1834	
L2	100%	0.042	113.6982	113.6982	116.4053
L2	100%	0.044	119.1124	119.1124	
L3	100%	0.128	346.5088	346.5088	341.0946
L3	100%	0.124	335.6804	335.6804	
L4	100%	0.039	105.5769	105.5769	121.8195
L4	100%	0.051	138.0621	138.0621	
Control	100%	0.087	235.5177	235.5177	238.2248
Control	100%	0.089	240.9319	240.9319	

COD - PT Columns

Oct. 5-05

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.066	178.6686	178.6686	192.2041
L1	100%	0.076	205.7396	205.7396	
L2	50%	0.238	644.2898	1288.5796	1350.843
L2	50%	0.261	706.5531	1413.1062	
L3	100%	0.378	1023.284	1023.2838	1019.223
L3	100%	0.375	1015.163	1015.1625	
L4	50%	0.371	1004.334	2008.6682	2011.375
L4	50%	0.372	1007.041	2014.0824	
Feed	100%	0.37	1001.627	1001.627	1002.981
Feed	100%	0.371	1004.334	1004.3341	

COD - PT Columns

Oct. 14-05

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	20%	0.053	143.4763	143.4763	110.9911
L1	20%	0.029	78.5059	78.5059	
L2	20%	0.068	184.0828	920.414	1001.627
L2	20%	0.08	216.568	1082.84	
L3	20%	0.019	51.4349	257.1745	318.0843
L3	20%	0.028	75.7988	378.994	
L4	20%	0.064	173.2544	866.272	981.3238
L4	20%	0.081	219.2751	1096.3755	
Feed	20%	0.075	203.0325	1015.1625	1062.537
Feed	20%	0.082	221.9822	1109.911	

COD - PT Columns

Oct. 24-05

Sample	Dilution	Abs.	Measured COD (mg/L)	Actual COD (mg/L)	Average COD (mg/L)
L1	100%	0.023	62.2633	62.2633	75.7988
L1	100%	0.033	89.3343	89.3343	
L2	20%	0.042	113.6982	568.491	521.1168
L2	20%	0.035	94.7485	473.7425	
L3	100%	0.056	151.5976	151.5976	181.3757
L3	100%	0.078	211.1538	211.1538	
L4	20%	0.059	159.7189	798.5945	744.4525
L4	20%	0.051	138.0621	690.3105	
Feed	100%	0.167	452.0857	452.0857	489.9851
Feed	100%	0.195	527.8845	527.8845	

10) Volatile Fatty Acid Ion Chromatography Results

January 28, 2005

Sample	Formate	Acetate	Propionate	Butyrate
1.1		223.04		
2.1	0			
3.1		251.254		
4.1		171.52		
F.1		82.643		
1.2				
2.2				
3.2		159.279		
4.2		177.793		
F.2		91.507		

February 4, 2005

Sample	Formate	Acetate	Propionate	Butyrate
1.1	0			
2.1	0	0		
3.1		169.933		
4.1		232.942		
F.1		37.644		
1.2		0		2.575
2.2		2.756		
3.2		215.749	24.733	
4.2		140.494		
F.2		35.734		

11) Anion Column IC Results (Nitrite and Nitrate Nitrogen Concentrations)

January 8, 2005

Sample	Rep	Nitrite	Nitrate
SS1R1.001	1.1	23.144	19.031
0.002	2.1	28.764	34.311
0.003	3.1	21.944	70.4
0.004	4.1	1.053	3.546
0.005	DI	0.13	0.041
0.006	1.2	28.777	49.98
0.007	2.2	29.405	34.389
0.008	3.2	6.249	58.919
0.009	4.2	2.3	0.563

January 14, 2005

Sample	Rep	Nitrite	Nitrate
SS1R1.001	1.1	21.396	28.919
0.002	2.1	19.051	15.671
0.003	3.1	6.866	0.043
0.004	4.1	3.185	0.043
0.005	Feed.1	12.4	0.065
0.006	DI	0.185	0.053
0.007	1.2	21.664	30.305
0.008	2.2	19.16	16.03
0.009	3.2	8.347	0.087
0.01	4.2	3.252	0.036
0.011	Feed.2	12.799	0.042

January 28, 2005

Sample	Rep	Nitrite	Nitrate
SS1N3.001	1.1	0	41.33
0.002	2.1	0	0.057
0.003	3.1	1.823	0.043
0.004	4.1	3.959	0.498
0.005	Feed.1	3.636	0.091
0.006	DI	1.188	0.252
0.007	1.2	0	39.805
0.008	2.2	0	1.062
0.009	3.2	1.968	0.681
0.01	4.2	4.117	0.159
0.011	Feed.2	3.643	0.117

12) Aqueous Ammonia Data and Calculated Concentrations

January 8, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.59	1.1	130.9	0.5468
13.05	1.2	127.5	0.6275
12.33	2.1	126.2	0.6614
12.23	2.2	127.9	0.6174
12.92	3.1	31.2	31.0050
12.83	3.2	30.7	31.6393
12.52	4.1	39	22.6068
12.65	4.2	32.1	29.8952
13.03	F.1	34.1	27.5692
12.37	F.2	35.3	26.2614

January 14, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.63	1.1	77.3	4.7927
12.75	1.2	74.5	5.3682
12.68	2.1	81.2	4.0925
12.7	2.2	84.2	3.6243
12.7	3.1	22.3	44.4604
12.77	3.2	21.7	45.5540
12.77	4.1	15.8	57.8498
12.79	4.2	15.8	57.8498
12.46	F.1	24.4	40.8354
12.5	F.2	25.8	38.5845

January 28, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.3	1.1	82.5	3.8826
12.54	1.2	80.2	4.2616
12.41	2.1	26.4	37.6581
12.59	2.2	26.7	37.2034
12.42	3.1	13.6	63.2408
12.21	3.2	14.4	61.2246
12.48	4.1	10.9	70.5484
12.55	4.2	11	70.2633
12.47	F.1	27.9	35.4385
12.43	F.2	29.3	33.4851

February 4, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.24	1.1	86.3	3.3288
12.28	1.2	91.3	2.7186
12.51	2.1	49.3	14.8961
12.52	2.2	48.2	15.5747
12.48	3.1	13.6	63.2408
12.51	3.2	13.3	64.0138
12.4	4.1	12.8	65.3233
12.49	4.2	12.7	65.5884
12.42	F.1	41.9	20.1016
12.49	F.2	40.2	21.5344

February 10, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.11	1.1	90.3	2.8309
12.05	1.2	83.8	3.6834
12.17	2.1	11.6	68.5765
12.15	2.2	11.8	68.0232
12.31	3.1	9.4	74.9671
12.18	3.2	11.3	69.4147
12.31	4.1	7.6	80.6363
12.2	4.2	7.6	80.6363
12.35	F.1	43.1	19.1480
12.27	F.2	45.1	17.6582

March 3, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.17	1.1	67.9	7.0132
12.2	1.2	64.8	7.9514
12.47	2.1	15.1	59.5133
12.27	2.2	14.1	61.9730
12.49	3.1	8.8	76.8111
12.46	3.2	10.1	72.8716
12.24	4.1	-5	134.3233
12.1	4.2	-5.2	135.4157
12.61	F.1	24.1	41.3346
12.62	F.2	27.2	36.4576

March 24, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
13.15	1.1	81.3	4.0759
12.71	1.2	80.4	4.2272
12.45	2.1	26.8	37.0530
12.99	2.2	27.2	36.4576

12.97	3.1	17.4	54.2200
12.95	3.2	17.9	53.1331
12.78	4.1	12.7	65.5884
12.44	4.2	11.6	68.5765
13.46	F.1	54.2	12.2148
12.71	F.2	43.7	18.6883

May 17, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.73	1.1	92.8	2.5583	1.8838
12.76	1.2	111.3	1.2094	
13.03	2.1	-4	128.9919	134.1508
13.05	2.2	-5.9	139.3097	
12.7	3.1	-14.7	198.9591	204.3370
12.76	3.2	-16	209.7150	
12.69	4.1	-15.2	203.0291	202.6188
12.8	4.2	-15.1	202.2085	
12.5	F.1	43.5	18.8403	19.5938
12.34	F.2	41.6	20.3473	

May 12, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.19	1.1	98.6	2.0227	2.0393
12.51	1.2	98.2	2.0558	
12.43	2.1	-7.5	148.6359	146.5585
12.32	2.2	-6.8	144.4812	
12.55	3.1	-11	171.2714	169.8953
12.07	3.2	-10.6	168.5191	
12.57	4.1	-17.4	221.9494	212.4892
12.38	4.2	-15.2	203.0291	
12.44	F.1	10.9	70.5484	70.9796
12.04	F.2	10.6	71.4108	

May 10, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
13.05	1.1	82.4	3.8983	4.6771
13.34	1.2	74.1	5.4559	
28.89	2.1	-10.3	166.4840	150.4036
13.57	2.2	-5	134.3233	
13.63	3.1	-10.8	169.8897	174.8452
13.36	3.2	-12.2	179.8008	
12.45	4.1	-21.1	257.8297	232.5060
13.54	4.2	-15.7	207.1824	
12.41	F.1	41.1	20.7636	18.4910
13.64	F.2	47.2	16.2184	

May 6, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.74	1.1	86.7	3.2753	3.2753
	1.2			
14	2.1	9.6	74.3623	74.3623
	2.2			
12.37	3.1	-14.4	196.5564	196.5564
	3.2			
12.69	4.1	-18.2	229.2583	229.2583
	4.2			
12.42	F.1	12.9	65.0593	65.0593
	F.2			

April 29, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.22	1.1	64.8	7.9514	7.9514
	1.2			
12.9	2.1	22.9	43.3931	43.3931
	2.2			
12.88	3.1	13.8	62.7306	62.7306
	3.2			
13.36	4.1	23	43.2177	59.8592
12.8	4.2	8.9	76.5007	
13.24	F.1	50	14.4797	14.4797
	F.2			

April 22, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.15	1.1	87.1	3.2226	4.1270
13.02	1.2	76.1	5.0314	
12.73	2.1	16.5	56.2328	49.9894
12.97	2.2	22.7	43.7460	
12.62	3.1	-1.1	114.6976	103.6192
12.98	3.2	4.2	92.5408	
12.19	4.1	-4.2	130.0409	123.5424
12.88	4.2	-1.6	117.0439	
12.4	F.1	32.3	29.6541	26.1304
13.23	F.2	39	22.6068	

April 15, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.89	1.1	78.2	4.6212	5.6780
12.52	1.2	68.9	6.7349	
13.26	2.1	3.6	94.8171	99.0256

12.73	2.2	1.5	103.2341	
13.28	3.1	4.4	91.7942	99.2139
12.98	3.2	0.7	106.6337	
13.24	4.1	0.6	107.0664	112.2927
13.34	4.2	-1.7	117.5189	
13.34	F.1	31.6	30.5068	29.6077
13.11	F.2	33.1	28.7087	

August 11, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
13.35	1.1	50.6	14.1321	14.1321
	1.2			
13.2	2.1	-22.5	272.8711	272.8711
	2.2			
13.48	3.1	48.8	15.2008	15.2008
	3.2			
13.39	4.1	-10.6	168.5191	168.5191
	4.2			
13.37	F.1	26.3	37.8110	37.8110
	F.2			

August 9, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
13.42	1.1	89	2.9840	2.9840
	1.2			
13.39	2.1	-20.3	249.6099	249.6099
	2.2			
13.44	3.1	86.7	3.2753	3.2753
	3.2			
13.37	4.1	-6.7	143.8972	143.8972
	4.2			
13.42	F.1	43.9	18.5376	18.5376
	F.2			

August 2, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.55	1.1	65.7	7.6668	7.6668
	1.2			
12.73	2.1	-28.4	346.5231	346.5231
	2.2			
12.67	3.1	20.1	48.6037	48.6037
	3.2			
12.48	4.1	-20.2	248.6010	248.6010
	4.2			
12.53	F.1	13.2	64.2736	59.3568
12.75	F.2	17.3	54.4400	

July 25, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.35	1.1	25.5	39.0561	39.4556
12.34	1.2	25	39.8551	
12.41	2.1	-24	289.9619	289.9619
12.35	2.2	-24	289.9619	
12.29	3.1	91.1	2.7407	3.1678
12.52	3.2	84.4	3.5950	
12.44	4.1	-16.1	210.5660	208.0385
12.41	4.2	-15.5	205.5110	
12.4	F.1	22.3	44.4604	38.8377
12.3	F.2	29.5	33.2149	

July 22, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.71	1.1	16.7	55.7791	57.7669
12.5	1.2	15	59.7548	
12.5	2.1	-27.2	330.0847	292.4004
12.34	2.2	-20.8	254.7160	
12.41	3.1	128.6	0.6002	1.0316
12.41	3.2	106.6	1.4629	
12.33	4.1	-19.1	237.7689	236.8099
12.29	4.2	-18.9	235.8508	
12.24	F.1	19.4	50.0013	49.5001
12.59	F.2	19.9	48.9990	

July 8, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.22	1.1	-19.6	242.6328	240.2009
12.32	1.2	-19.1	237.7689	
12.14	2.1	-43.7	643.9360	658.6040
12.17	2.2	-44.8	673.2720	
12.35	3.1	6.9	82.9551	87.3747
12.55	3.2	4.4	91.7942	
12.3	4.1	-40.6	567.9591	586.9703
12.48	4.2	-42.2	605.9814	
	F.1		109.7000	109.7000
	F.2		109.7000	

July 6, 2005

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.27	1.1	1.1	104.9201	112.6649
12.58	1.2	-2.3	120.4096	
12.62	2.1	-37.3	496.9053	476.6480
12.26	2.2	-35.2	456.3908	
12.45	3.1	64.2	8.1470	8.7295
12.47	3.2	60.9	9.3120	
12.29	4.1	-15.3	203.8530	210.6766
12.48	4.2	-16.9	217.5001	
12.25	F.1	-0.3	111.0410	102.9290
12.35	F.2	3.6	94.8171	

Aug. 2-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.54	1.1	23.1	43.0430	42.7831
12.52	1.2	23.4	42.5232	
12.58	2.1	25.8	38.5845	45.1162
12.73	2.2	18.6	51.6479	
12.64	3.1	39.6	22.0640	22.8026
12.67	3.2	38	23.5411	
12.75	4.1	27.5	36.0173	36.9141
12.76	4.2	26.3	37.8110	
12.73	Control.1	13.8	62.7306	70.8752
12.7	Control.2	8.1	79.0199	

Aug. 9-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
13.37	1.1	58.7	10.1797	12.4480
13.37	1.2	49.6	14.7162	
13.42	2.1	31.1	31.1309	31.7087
13.45	2.2	30.2	32.2865	
13.45	3.1	64.2	8.1470	7.9538
13.46	3.2	65.4	7.7605	
13.33	4.1	33.7	28.0195	27.2472
13.25	4.2	35.1	26.4750	
13.43	Control.1	23	43.2177	42.7845
13.44	Control.2	23.5	42.3513	

Aug. 12-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
13.26	1.1	82.5	3.8826	3.8826
	1.2			
12.94	2.1	29.8	32.8138	32.8138

	2.2			
12.4	3.1	93.9	2.4468	2.4468
	3.2			
12.52	4.1	24.1	41.3346	41.3346
	4.2			
12.23	Control.1	31.9	30.1384	30.1384
	Control.2			

Sept. 8-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.18	1.1	71.7	6.0129	6.0129
	1.2			
12.42	2.1	22.7	43.7460	43.7460
	2.2			
12.35	3.1	40.9	20.9324	20.9324
	3.2			
12.42	4.1	10.9	70.5484	70.5484
	4.2			
12.31	Control.1	24.3	41.0011	41.0011
	Control.2			

Sept. 28-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.56	1.1	29.4	33.3497	32.7529
12.28	1.2	30.3	32.1560	
12.64	2.1	9	76.1915	75.1266
12.39	2.2	9.7	74.0618	
12.62	3.1	51	13.9050	14.6770
12.46	3.2	48.4	15.4491	
12.62	4.1	30.3	32.1560	34.1597
12.48	4.2	27.4	36.1635	
12.56	Control.1	66	7.5742	8.8770
12.34	Control.2	58.7	10.1797	

Sept. 30-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.26	1.1	24.1	41.3346	40.6757
12.37	1.2	24.9	40.0168	
12.31	2.1	0.9	105.7734	108.6325
12.39	2.2	-0.4	111.4916	
12.4	3.1	46	17.0261	16.9575
12.44	3.2	46.2	16.8888	
12.29	4.1	23.6	42.1801	43.6833
12.6	4.2	21.9	45.1865	
12.14	Control.1	70.8	6.2361	6.4855
12.67	Control.2	68.9	6.7349	

Oct. 12-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.89	1.1	99.1	1.9822	1.9822
	1.2			
12.71	2.1	-3.6	126.9190	126.9190
	2.2			
12.67	3.1	50.6	14.1321	14.1321
	3.2			
12.94	4.1	67.3	7.1857	7.1857
	4.2			
12.98	Control.1	66.5	7.4224	7.4224
	Control.2			

Oct. 14-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.81	1.1	85.8	3.3969	3.3969
	1.2			
12.97	2.1	-0.8	113.3125	113.3125
	2.2			
12.92	3.1	90.1	2.8539	2.8539
	3.2			
12.99	4.1	68.2	6.9285	6.9285
	4.2			
12.99	Control.1	60.9	9.3120	9.3120
	Control.2			

Oct. 18-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.95	1.1	86.8	3.2620	3.2620
	1.2			
12.9	2.1	-0.4	111.4916	111.4916
	2.2			
12.88	3.1	43.3	18.9935	18.9935
	3.2			
12.85	4.1	56.3	11.2189	11.2189
	4.2			
12.97	Control.1	49.3	14.8961	14.8961
	Control.2			

Oct. 21-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.84	1.1	61.6	9.0517	9.0517
	1.2			
12.86	2.1	7.1	82.2859	82.2859
	2.2			
12.87	3.1	14.4	61.2246	61.2246
	3.2			
12.82	4.1	48	15.7014	15.7014
	4.2			
12.84	Control.1	46.4	16.7525	16.7525
	Control.2			

Oct. 26-05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)	Ave. NH3 Conc'n Aqueous (mL/L)
12.77	1.1	34.5	27.1262	27.1262
	1.2			
12.86	2.1	9.8	73.7624	73.7624
	2.2			
12.83	3.1	9.3	75.2713	75.2713
	3.2			
12.87	4.1	32.4	29.5342	29.5342
	4.2			
12.61	Control.1	14.7	60.4852	60.4852
	Control.2			

Aqueous Ammonia - PT Columns
Sept. 30, 2005

ID	mV	NH3 Conc'n Aqueous (mL/L)
PT L1	68.2	6.9285
PT L2	-33.2	420.8807
PT L3	0	109.7000
PT L4	-21.6	263.1040
Feed	3.4	95.5882

Aqueous Ammonia - PT Columns
Oct.15/05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.76	PT L1	-22.8	276.2067
12.92	PT L2	-35.5	461.9697
12.81	PT L3	-12.9	184.9711
12.86	PT L4	-27.7	336.8371
13	Feed	8.8	76.8111

Aqueous Ammonia - PT Columns
Oct.21/05

pH	ID	mV	NH3 Conc'n Aqueous (mL/L)
12.9	PT L1	-21.7	264.1717
12.77	PT L2	-33.8	431.2334
12.84	PT L3	-9.4	160.5249
12.82	PT L4	-24.6	297.0942
12.95	Feed	21.8	45.3699

13) Total and Volatile Solids Data and Calculated Concentrations

January 14, 2005

Crucible	Rep	Clean/Dry	Solids	Volatile	Solids Conc'n (g/L)	Fixed Sol. Conc'n (g/L)	Fraction *
P2	1.1	66.8978	67.2893	67.04	15.66	9.972	0.3632
P3	1.2	58.3501	58.7459	58.4913	15.832	10.184	0.3567
P5	2.1	60.916	61.2848	61.0481	14.752	9.468	0.3582
P6	2.2	61.2051	61.5787	61.3374	14.944	9.652	0.3541
P7	3.1	61.4576	61.8252	61.585	14.704	9.608	0.3466
P8	3.2	64.7766	65.1547	64.9078	15.124	9.876	0.3470
P10	4.1	61.3103	61.7035	61.4438	15.728	10.388	0.3395
P13	4.2	61.736	62.1196	61.8671	15.344	10.1	0.3418
HCl	F.1	61.8109	62.2441	61.9547	17.328	11.576	0.3319
NaOH	F.2	58.7449	59.1305	58.8853	15.424	9.808	0.3641
Acc500	1.3	56.0328	56.4268	56.1741	15.76	10.108	0.3586
Blank	1.4	55.8047	56.1893	55.9441	15.384	9.808	0.3625
G2	2.3	63.7248	64.1013	63.8593	15.06	9.68	0.3572
Dig	2.4	57.0942	57.4628	57.2251	14.744	9.508	0.3551
S3	3.3	59.1369	59.5124	59.2668	15.02	9.824	0.3459
S7	3.4	56.6599	57.0427	56.7932	15.312	9.98	0.3482
K4	4.3	59.5022	59.892	59.6344	15.592	10.304	0.3391
K	4.4	57.7275	58.1165	57.8596	15.56	10.276	0.3396
F1, Raw	F.3	57.9717	58.4038	58.1141	17.284	11.588	0.3296
S13, Raw	F.4	58.3816	58.8009	58.5197	16.772	11.248	0.3294

* Fraction volatile solids on solids-only basis.
** Volatile solids loss by the Van Kleeck Equation.
*** Volatile solids loss by the mass balance equation.

January 25, 2005

Crucible	Rep	Clean/Dry	Solids	Volatile	Solids Conc'n (g/L)	Fixed Sol. Conc'n (g/L)
P7	1.1	61.4576	61.9288	61.6288	18.848	12
P8	1.2	64.7766	65.2302	64.9428	18.144	11.496
G-2	2.1	63.7248	64.2108	63.8923	19.44	12.74
Acc500	2.2	56.0328	56.498	56.196	18.608	12.08
S3	3.1	59.1369	59.6136	59.2989	19.068	12.588
S7	3.2	56.6599	57.1351	56.8232	19.008	12.476
K	4.1	57.7275	58.2264	57.8977	19.956	13.148
K4	4.2	59.5022	59.9989	59.6708	19.868	13.124
HCl	F.1	61.8109	62.2352	61.9545	16.972	11.228
P3	F.2	58.3501	58.7702	58.4913	16.804	11.156

February 4, 2005

Crucible	Rep	Clean/Dry	Solids	Volatile	Solids Conc'n (g/L)	Fixed Sol. Conc'n (g/L)
P7	1.1	61.4576	61.8238	61.5954	14.648	9.136
P8	1.2	64.7766	65.1526	64.916	15.04	9.464
G-2	2.1	63.7248	64.1295	63.8642	16.188	10.612
Acc500	2.2	56.0328	56.4184	56.1697	15.424	9.948
S3	3.1	59.1369	59.5392	59.2727	16.092	10.66
S7	3.2	56.6599	57.0656	56.7991	16.228	10.66
HCl	4.1	61.8109	62.2252	61.9568	16.572	10.736
P3	4.2	58.3501	58.7714	58.5003	16.852	10.844
K	F.1	57.7275	58.172	57.8759	17.78	11.844
K4	F.2	59.5022	59.9385	59.6479	17.452	11.624

	Feb 23 05	Feb 26 05	Mar 8 05	Mar 10 05	Mar 12 05	Mar 19 05	Mar 22 05	Mar 24 04
L11 - Label	O1	O1	O1	G1	G1	O1	O1	G1
Clean/Dry (g)	62.5052	62.5052	62.4959	54.9999	54.9999	62.4959	62.4959	54.9999
Solids (g)	62.9173	62.8876	62.737	55.2934	55.323	62.8513	62.8729	55.377
Fixed (g)			62.5752	55.0984	55.1182		62.6259	
Solids C (g/L)	20.605	19.12	12.055	14.675	16.155	17.77	18.85	18.855
Fixed C (g/L)			3.965	4.925	5.915		6.5	
L12 - Label	G1	G1	Dig	G2	G2	Dig	Dig	G2
Clean/Dry	55.002	55.002	57.0945	63.724	63.724	57.0945	57.0945	63.724
Solids	55.4034	55.3811	57.328	64.0159	64.0723	57.4574	57.4763	64.0976
Fixed (g)			57.1695	63.8214	63.8491		57.2263	
Solids C (g/L)	20.07	18.955	11.675	14.595	17.415	18.145	19.09	18.68
Fixed C (g/L)			3.75	4.87	6.255		6.59	
L21 - Label	4A0	4A0	P7	P5	P5	P7	P7	P5
Clean/Dry	59.5764	59.5764	61.4574	60.9153	60.9153	61.4574	61.4574	60.9153
Solids	60.0045	59.9734	61.6962	61.1957	61.258	61.8375	61.8514	61.2924
Fixed (g)			61.5365	61.0092	61.037		61.5851	
Solids C (g/L)	21.405	19.85	11.94	14.02	17.135	19.005	19.7	18.855
Fixed C (g/L)			3.955	4.695	6.085		6.385	
L22 - Label	7A0	7A0	P8	P10	P10	P8	P8	P10
Clean/Dry	60.1445	60.1445	64.777	61.3112	61.3112	64.777	64.777	61.3112
Solids	60.5797	60.5427	65.0213	61.5989	61.6542	65.159	65.1627	61.6869
Fixed (g)			64.8559	61.4074	61.432		64.9025	
Solids C (g/L)	21.76	19.91	12.215	14.385	17.15	19.1	19.285	18.785
Fixed C (g/L)			3.945	4.81	6.04		6.275	
L31 - Label	Dig	Dig	S3	P3	P3	S3	S3	P3
Clean/Dry	57.0974	57.0974	59.1372	58.3509	58.3509	59.1372	59.1372	58.3509
Solids	57.5107	57.4674	59.3819	58.6313	58.6943	59.5304	59.5455	58.7466
Fixed (g)			59.216	58.4407	58.4683		59.2688	
Solids C (g/L)	20.665	18.5	12.235	14.02	17.17	19.66	20.415	19.785
Fixed C (g/L)			3.94	4.49	5.87		6.58	
L32 - Label	P5	P5	S7	P13	P13	S7	S7	P13
Clean/Dry	60.9184	60.9184	56.6609	61.7409	61.7409	56.6609	56.6609	61.7409
Solids	61.3461	61.3042	56.9048	62.0285	62.0748	57.0435	57.0776	62.1285
Fixed (g)			56.739	61.8339	61.8589		56.7936	
Solids C (g/L)	21.385	19.29	12.195	14.38	16.695	19.13	20.835	19.38
Fixed C (g/L)			3.905	4.65	5.9		6.635	

	Feb 23 05	Feb 26 05	Mar 8 05	Mar 10 05	Mar 12 05	Mar 19 05	Mar 22 05	Mar 24 04
L41 - Label	P10	P10	K	4A0	4A0	K	K	4A0
Clean/Dry	61.3139	61.3139	57.7254	59.5724	59.5724	57.7254	57.7254	59.5724
Solids	61.7632	61.7297	57.9748	59.853	59.9254	58.1081	58.1229	59.9536
Fixed (g)			57.8038	59.6634	59.6896		57.8545	
Solids C (g/L)	22.465	20.79	12.47	14.03	17.65	19.135	19.875	19.06
Fixed C (g/L)			3.92	4.55	5.86		6.455	
L42 - Label	P13	P13	K4	7A0	7A0	K4	K4	7A0
Clean/Dry	61.7495	61.7495	59.5007	60.1432	60.1432	59.5007	59.5007	60.1432
Solids	62.1814	62.1563	59.7429	60.4258	60.4877	59.8775	59.908	60.5221
Fixed (g)			59.5755	60.235	60.2576		59.632	
Solids C (g/L)	21.595	20.34	12.11	14.13	17.225	18.84	20.365	18.945
Fixed C (g/L)			3.74	4.59	5.72		6.565	
F1 - Label	F2	F2	HCl	F2	F2	HCl	HCl	F2
Clean/Dry	59.9048	59.9048	61.8112	59.9008	59.9008	61.8112	61.8112	59.9008
Solids	60.2394	60.2649	62.1149	60.2893	60.234	62.1763	62.2177	60.2677
Fixed (g)			61.9069	60.0247	60.0089		61.9434	
Solids C (g/L)	16.73	18.005	15.185	19.425	16.66	18.255	20.325	18.345
Fixed C (g/L)			4.785	6.195	5.405		6.61	
F2 - Label	NaOH	NaOH	NaOH	Acc500	Acc500	NaOH	NaOH	Acc500
Clean/Dry	58.7514	58.7514	58.744	56.0326	56.0326	58.744	58.744	56.0326
Solids	59.0814	59.1174	59.0544	56.4247	56.3811	59.1079	59.1586	56.4172
Fixed (g)			58.8399	56.1562	56.1477		58.8789	
Solids C (g/L)	16.5	18.3	15.52	19.605	17.425	18.195	20.73	19.23
Fixed C (g/L)			4.795	6.18	5.755		6.745	

PHASE 2

M1 (g) Clean/dry crucible weight
M2 (g) Solids weight (incl. crucible)
M3 (g) Fixed solids weight (incl. crucible)
V (mL) Sample volume
C1 (g/L) Solids concentration
C2 (g/L) Fixed solids concentration

April 19, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	.O1	Dig	P7	P8	S3	S7	K	K4	HCl	NaOH
M1 (g)	62.4983	57.0972	61.4600	64.7794	59.1400	56.6638	57.7278	59.5051	61.8141	58.7479
M2 (g)	62.9279	57.5291	61.9285	65.2418	59.5952	57.1234	58.1880	59.9651	62.2566	59.1839
M3 (g)	62.6909	57.2906	61.6540	64.9704	59.3314	56.8566	57.9163	59.6928	61.9777	58.9122
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	21.48	21.595	23.425	23.12	22.76	22.98	23.01	23	22.125	21.8
C2 (g/L)	9.63	9.67	9.7	9.55	9.57	9.64	9.425	9.385	8.18	8.215
A C1	21.5375		23.2725		22.87		23.005		21.9625	
A C2	9.65		9.625		9.605		9.405		8.1975	

April 21, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	G1	G2	P5	P10	P3	P13	4AO	7AO	F2	Acc500
M1 (g)	55.0042	63.7271	60.9181	61.3131	58.3537	61.7428	59.5745	60.1454	59.9033	56.0355
M2 (g)	55.4486	64.1824	61.4400	61.8442	58.8427	62.2384	60.0743	60.6359	60.3497	56.4759
M3 (g)	55.2109	63.9363	61.1405	61.5387	58.5663	61.9569	59.7954	60.3628	60.0866	56.2158
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	22.22	22.765	26.095	26.555	24.45	24.78	24.99	24.525	22.32	22.02
C2 (g/L)	10.335	10.46	11.12	11.28	10.63	10.705	11.045	10.87	9.165	9.015
A C1	22.4925		26.325		24.615		24.7575		22.17	
A C2	10.3975		11.2		10.6675		10.9575		9.09	

April 23, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	.O1	Dig	P7	P8	S3	S7	K	K4	HCl	NaOH
M1 (g)	62.4979	57.0963	61.4597	64.7792	59.1409	56.6639	57.7279	59.5051	61.8142	58.7486
M2 (g)	62.9259	57.5175	61.9053	65.2200	59.5691	57.0921	58.1799	59.9719	62.2181	59.1510
M3 (g)	62.6748	57.2719	61.6323	64.9501	59.3088	56.8329	57.9025	59.6868	61.9656	58.8979
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	21.4	21.06	22.28	22.04	21.41	21.41	22.6	23.34	20.195	20.12
C2 (g/L)	8.845	8.78	8.63	8.545	8.395	8.45	8.73	9.085	7.57	7.465
A C1	21.23		22.16		21.41		22.97		20.1575	
A C2	8.8125		8.5875		8.4225		8.9075		7.5175	

April 25, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	.O1	Dig	P7	P8	S3	S7	K	K4	HCl	NaOH
M1 (g)	62.4995	57.0975	61.4604	64.7800	59.1418	66.6997	57.7289	59.5060	61.8153	58.7507
M2 (g)	62.9268	57.5195	61.8908	65.2190	59.5723	67.1329	58.1599	59.9406	62.2483	59.1920
M3 (g)	62.6775	57.2722	61.6262	64.9499	59.3082	66.8665	57.8986	59.6754	61.9738	58.9116
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	21.365	21.1	21.52	21.95	21.525	21.66	21.55	21.73	21.65	22.065
C2 (g/L)	8.9	8.735	8.29	8.495	8.32	8.34	8.485	8.47	7.925	8.045
A C1	21.2325		21.735		21.5925		21.64		21.8575	
A C2	8.8175		8.3925		8.33		8.4775		7.985	

April 27, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	G1	G2	P5	P10	P3	P13	4AO	7AO	F2	Acc500
M1 (g)	55.0037	63.7268	60.9178	61.3133	58.3539	61.7439	59.5761	60.1470	59.9038	56.0356
M2 (g)	55.4142	64.1376	61.3238	61.7235	58.7617	62.1595	59.9914	60.5630	60.2933	56.4255
M3 (g)	55.1752	63.8981	61.0761	61.4716	58.5133	61.9074	59.7367	60.3076	60.0513	56.1837
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	20.525	20.54	20.3	20.51	20.39	20.78	20.765	20.8	19.475	19.495
C2 (g/L)	8.575	8.565	7.915	7.915	7.97	8.175	8.03	8.03	7.375	7.405
A C1	20.5325		20.405		20.585		20.7825		19.485	
A C2	8.57		7.915		8.0725		8.03		7.39	

April 30, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	G1	G2	P5	P10	P3	P13	4AO	7AO	F2	Acc500
M1 (g)	55.0045	63.7279	60.9191	61.3140	58.3548	61.7446	59.5770	60.1478	59.9044	56.0360
M2 (g)	55.4689	64.1883	61.3841	61.7725	58.8130	62.2071	60.0636	60.6324	60.4158	56.5389
M3 (g)	55.1956	63.9175	61.1009	61.4942	58.5331	61.9242	59.7693	60.3392	60.0963	56.2243
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	23.22	23.02	23.25	22.925	22.91	23.125	24.33	24.23	25.57	25.145
C2 (g/L)	9.555	9.48	9.09	9.01	8.915	8.98	9.615	9.57	9.595	9.415
A C1	23.12		23.0875		23.0175		24.28		25.3575	
A C2	9.5175		9.05		8.9475		9.5925		9.505	

May 4, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	K4	D4	NaOH	Acc500
M1 (g)	62.4984	57.0973	63.7269	59.9043	62.7243	59.1400	59.5040	59.9478	58.7501	56.0371
M2 (g)	62.9247	57.5272	64.1836	60.3398	63.1439	59.5628	59.9398	60.4002	59.2261	56.5113
M3 (g)	62.6794	57.2773	63.9031	60.0749	62.8875	59.3065	59.6768	60.1223	58.9277	56.2163
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	21.315	21.495	22.835	21.775	20.98	21.14	21.79	22.62	23.8	23.71
C2 (g/L)	9.05	9	8.81	8.53	8.16	8.325	8.64	8.725	8.88	8.96
A C1	21.405		22.305		21.06		22.205		23.755	
A C2	9.025		8.67		8.2425		8.6825		8.92	

May 11, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	P5	P10	P7	P8	P3	P13	4AO	7AO	P38s	P16
M1 (g)	60.9186	61.3133	61.4600	64.7800	58.3595	61.7425	59.5762	60.1474	55.8627	61.8122
M2 (g)	61.2626	61.6632	61.8124	65.1296	58.7103	62.1006	59.9412	60.4945	56.1884	62.1462
M3 (g)	61.0624	61.4567	61.6024	64.9210	58.4938	61.8838	59.7207	60.2872	55.9904	61.9417
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	17.2	17.495	17.62	17.48	17.54	17.905	18.25	17.355	16.285	16.7
C2 (g/L)	7.19	7.17	7.12	7.05	6.715	7.065	7.225	6.99	6.385	6.475
A C1	17.3475		17.55		17.7225		17.8025		16.4925	
A C2	7.18		7.085		6.89		7.1075		6.43	

June 10, 2005												
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2	FEED - 1	FEED - 2
Label	0.1	Dig	G2	F3	S1	S3	K4	D4	NaOH	Acc500	P28s	P16
M1 (g)	62.4976	57.0958	63.7262	59.9024	62.7254	59.1399	59.5035	59.9464	58.7481	56.0347	55.8641	61.8129
M2 (g)	62.8594	57.4424	64.0203	60.1935	63.0076	59.4162	59.8787	60.3181	59.0390	56.3233	56.1660	62.1203
V (mL)	20	20	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.09	17.33	14.705	14.555	14.11	13.815	18.76	18.585	14.545	14.43	15.095	15.37
A C1	17.71		14.63		13.9625		18.6725		14.4875		15.2325	

PHASE 3 – Pre-treatment columns

July 5, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	D4	K4	Acc500	NaOH
M1 (g)	62.4966	57.0948	63.7249	59.9014	62.7252	59.1403	59.9462	59.5034	56.0344	58.7482
M2 (g)	62.7520	57.3685	63.9854	60.1603	62.9678	59.3832	60.5341	60.0878	56.2989	59.0136
M3 (g)	62.5956	57.2030	63.8262	60.0019	62.8169	59.2323	60.1621	59.7202	56.1203	58.8346
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	12.77	13.685	13.025	12.945	12.13	12.145	29.395	29.22	13.225	13.27
C2 (g/L)	4.95	5.41	5.065	5.025	4.585	4.6	10.795	10.84	4.295	4.32

July 7, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	P5	P10	P7	P8	P3	P13	4AO	7AO	P16	P38s
M1 (g)	60.9176	61.3127	61.4585	64.7787	58.3538	61.7418	59.5735	60.1459	61.8132	55.8655
M2 (g)	61.2066	61.6019	61.7372	65.0512	58.6572	62.0443	59.8308	60.4051	62.1608	56.2142
M3 (g)	61.0244	61.4198	61.5588	64.8776	58.4576	61.8465	59.6571	60.2295	61.9129	55.9657
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	14.45	14.46	13.935	13.625	15.17	15.125	12.865	12.96	17.38	17.435
C2 (g/L)	5.34	5.355	5.015	4.945	5.19	5.235	4.18	4.18	4.985	5.01

July 14, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	P5	P10	P7	P8	P3	P13	4AO	7AO	P16	P38s
M1 (g)	60.9162	61.3118	61.4573	64.7774	58.3537	61.7405	59.5719	60.1442	61.8166	55.8638
M2 (g)	61.1576	61.5554	61.6989	65.0213	58.6002	61.9874	59.7472	60.3210	62.1763	56.2388
M3 (g)	61.0029	61.3996	61.5435	64.8635	58.4372	61.8241	59.6297	60.2018	61.9248	55.9784
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	12.07	12.18	12.08	12.195	12.325	12.345	8.765	8.84	17.985	18.75
C2 (g/L)	4.335	4.39	4.31	4.305	4.175	4.18	2.89	2.88	5.41	5.73

July 26, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	D4	K4	Acc500	NaOH
M1 (g)	62.4976	57.0958	63.7253	59.9021	62.7263	59.1405	59.9473	59.5044	56.0345	58.7481
M2 (g)	62.7619	57.3614	63.9764	60.1546	62.9971	59.4115	60.2707	59.8213	56.4231	59.1326
M3 (g)	62.5974	57.1958	63.8211	59.9990	62.8297	59.2445	60.0676	59.6227	56.1703	58.8829
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	13.215	13.28	12.555	12.625	13.54	13.55	16.17	15.845	19.43	19.225
C2 (g/L)	4.99	5	4.79	4.845	5.17	5.2	6.015	5.915	6.79	6.74

August 1, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	D4	K4	Acc500	NaOH
M1 (g)	62.4985	57.0967	63.7257	59.9030	62.7275	59.1416	59.9478	59.5045	56.0361	58.7488
M2 (g)	62.8688	57.4523	64.1171	60.2986	63.1291	59.5383	60.3445	59.8957	56.4457	59.1764
M3 (g)	62.6334	57.2274	63.8819	60.0597	62.8719	59.2848	60.0902	59.6455	56.1756	58.8950
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.515	17.78	19.57	19.78	20.08	19.835	19.835	19.56	20.48	21.38
C2 (g/L)	6.745	6.535	7.81	7.835	7.22	7.16	7.12	7.05	6.975	7.31

August 8, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	4AO	7AO	Acc500	NaOH
M1 (g)	62.4989	57.0970	63.7257	59.9031	62.7271	59.1413	59.5751	60.1469	56.0357	58.7490
M2 (g)	62.8688	57.5694	64.0837	60.2588	63.1103	59.5093	59.9463	60.5125	56.4287	59.1407
M3 (g)	62.6399	57.2393	63.8593	60.0366	62.8702	59.2797	59.7090	60.2785	56.1747	58.8874
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.495	23.62	17.9	17.785	19.16	18.4	18.56	18.28	19.65	19.585
C2 (g/L)	7.05	7.115	6.68	6.675	7.155	6.92	6.695	6.58	6.95	6.92

August 11, 2005										
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	FEED - 1	FEED - 2
Label	O1	Dig	G2	F2	S1	S3	D4	K4	Acc500	NaOH
M1 (g)	62.4964	57.0955	63.7238	59.9032	62.7265	59.1408	59.9479	59.5042	56.0348	58.7475
M2 (g)	62.8712	57.4762	64.0718	60.2519	63.0833	59.4985	60.2917	59.8558	56.4321	59.1382
M3 (g)	62.6338	57.2358	63.8523	60.0307	62.8557	59.2691	60.0685	59.6272	56.1676	58.8794
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.74	19.035	17.4	17.435	17.84	17.885	17.19	17.58	19.865	19.535
C2 (g/L)	6.87	7.015	6.425	6.375	6.46	6.415	6.03	6.15	6.64	6.595

PHASE 3 – Digesters

August 8, 2005		
	Control - 1	Control - 2
Label	P7	P8
M1 (g)	61.4604	64.7803
M2 (g)	61.9185	65.1467
M3 (g)	61.6297	64.9155
V (mL)	20	20
C1 (g/L)	22.905	18.32
C2 (g/L)	8.465	6.76

August 11, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	P5	P10	P7	P8	P3	P13	4AO	7AO	P16	P38s
M1 (g)	60.9182	61.3150	61.4589	64.7797	58.3557	61.7426	59.5749	60.1456	61.8152	55.8660
M2 (g)	61.3136	61.6985	61.8384	65.1528	58.7069	62.0973	59.9141	60.4775	62.1795	56.2314
M3 (g)	61.0669	61.4588	61.6016	64.9190	58.4891	61.8787	59.7008	60.2699	61.9497	56.0002
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	19.77	19.175	18.975	18.655	17.56	17.735	16.96	16.595	18.215	18.27
C2 (g/L)	7.435	7.19	7.135	6.965	6.67	6.805	6.295	6.215	6.725	6.71

August 26, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	P7	P8	S1	S3	4AO	7AO	Acc500	NaOH
M1 (g)	62.5016	57.0985	61.4695	64.7861	62.7309	59.1419	59.5789	60.1504	56.0374	58.7509
M2 (g)	62.8392	57.4574	61.7459	65.0837	63.0753	59.4851	59.9007	60.4817	56.3257	59.0416
M3 (g)	62.6292	57.2334	61.5699	64.8975	62.8609	59.2725	59.6995	60.2757	56.1427	58.8566
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	16.88	17.945	13.82	14.88	17.22	17.16	16.09	16.565	14.415	14.535
C2 (g/L)	6.38	6.745	5.02	5.57	6.5	6.53	6.03	6.265	5.265	5.285
Ave. C1	17.4125		14.35		17.19		16.3275		14.475	
Ave. C2	6.5625		5.295		6.515		6.1475		5.275	

September 3, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	P5	P10	F2	G2	P3	P13	D4	K4	P16	P38s
M1 (g)	60.9219	61.3179	59.9042	63.7260	58.3588	61.7463	59.9481	59.5046	61.8200	55.8686
M2 (g)	61.2670	61.6538	60.1928	64.0110	58.6492	62.0431	60.2161	59.7763	62.0848	56.1334
M3 (g)	61.0630	61.4568	60.0193	63.8390	58.4773	61.8672	60.0567	59.6134	61.9195	55.9661
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	17.255	16.795	14.43	14.25	14.52	14.84	13.4	13.585	13.24	13.24
C2 (g/L)	7.055	6.945	5.755	5.65	5.925	6.045	5.43	5.44	4.975	4.875
Ave. C1	17.025		14.34		14.68		13.4925		13.24	
Ave. C2	7		5.7025		5.985		5.435		4.925	

September 13, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	P7	P8	S1	S3	4AO	7AO	Acc500	NaOH
M1 (g)	62.5036	57.1018	61.4676	64.7867	62.7322	59.1469	59.5806	60.1522	56.0383	58.7515
M2 (g)	62.9027	57.4981	61.8157	65.1338	63.0765	59.4924	59.9177	60.4900	56.3788	59.0895
M3 (g)	62.6487	57.2473	61.5870	64.9059	62.8527	59.2686	59.6976	60.2695	56.1461	58.8603
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	19.955	19.815	17.405	17.355	17.215	17.275	16.855	16.89	17.025	16.9
C2 (g/L)	7.255	7.275	5.97	5.96	6.025	6.085	5.85	5.865	5.39	5.44
Ave. C1	19.885		17.38		17.245		16.8725		16.9625	
Ave. C2	7.265		5.965		6.055		5.8575		5.415	

September 15, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	P5	P10	F2	G2	P3	P13	D4	K4	P16	P38s
M1 (g)	60.9236	61.3202	59.9055	63.7286	58.3585	61.7463	59.9497	59.5065	61.8180	55.8690
M2 (g)	61.2876	61.6870	60.2300	64.0500	58.6818	62.0638	60.2804	59.8136	62.1285	56.1859
M3 (g)	61.0666	61.4631	60.0249	63.8465	58.4794	61.8637	60.0724	59.6182	61.9235	55.9776
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.2	18.34	16.225	16.07	16.165	15.875	16.535	15.355	15.525	15.845
C2 (g/L)	7.15	7.145	5.97	5.895	6.045	5.87	6.135	5.585	5.275	5.43
Ave. C1	18.27		16.1475		16.02		15.945		15.685	
Ave. C2	7.1475		5.9325		5.9575		5.86		5.3525	

September 27, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	F2	G2	S1	S3	4AO	7AO	P16	P38s
M1 (g)	62.5073	57.1035	59.9080	63.7306	62.7333	59.1484	59.5815	60.1528	61.8193	55.8711
M2 (g)	62.8805	57.4645	60.2289	64.0474	63.0676	59.4783	59.8983	60.4613	62.1575	56.1979
M3 (g)	62.6420	57.2330	60.0204	63.8418	62.8490	59.2634	59.6920	60.2607	61.9293	55.9761
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.66	18.05	16.045	15.84	16.715	16.495	15.84	15.425	16.91	16.34
C2 (g/L)	6.735	6.475	5.62	5.56	5.785	5.75	5.525	5.395	5.5	5.25
Ave. C1	18.355		15.9425		16.605		15.6325		16.625	
Ave. C2	6.605		5.59		5.7675		5.46		5.375	

October 3, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	F2	G2	S1	S3	4AO	7AO	P16	P38s
M1 (g)	62.5122	57.1069	59.9120	63.7354	62.7352	59.1513	59.5857	60.1573	61.8231	55.8745
M2 (g)	62.8683	57.4723	60.1744	64.0092	63.0706	59.4806	59.9225	60.4909	62.1682	56.2120
M3 (g)	62.6377	57.2349	60.0036	63.8304	62.8481	59.2617	59.6988	60.2685	61.9338	55.9831
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	17.805	18.27	13.12	13.69	16.77	16.465	16.84	16.68	17.255	16.875
C2 (g/L)	6.275	6.4	4.58	4.75	5.645	5.52	5.655	5.56	5.535	5.43
Ave. C1	18.0375		13.405		16.6175		16.76		17.065	
Ave. C2	6.3375		4.665		5.5825		5.6075		5.4825	

October 6, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	P5	P10	Act1	Acc500	P3	P13	D4	K4	P8	NaOH
M1 (g)	61.0361	61.4291	57.4473	56.1493	58.4670	61.8539	60.1173	59.6847	64.8934	58.8564
M2 (g)	61.4147	61.7811	57.6835	56.3861	58.8112	62.2049	60.4444	60.0392	65.2255	59.1968
M3 (g)	61.1651	61.5483	57.5262	56.2288	58.5799	61.9684	60.2203	59.7932	64.9988	58.9638
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	18.93	17.6	11.81	11.84	17.21	17.55	16.355	17.725	16.605	17.02
C2 (g/L)	6.45	5.96	3.945	3.975	5.645	5.725	5.15	5.425	5.27	5.37
Ave. C1	18.265		11.825		17.38		17.04		16.8125	
Ave. C2	6.205		3.96		5.685		5.2875		5.32	

October 12, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	F2	G2	S1	S3	4AO	7AO	P16	P38s
M1 (g)	62.5113	57.1069	59.9099	63.7350	62.7295	59.1514	59.5846	60.1577	61.8226	55.8729
M2 (g)	62.8592	57.4713	60.1475	63.9771	63.0444	59.4635	59.9180	60.4895	62.1634	56.2069
M3 (g)	62.6427	57.2441	59.9937	63.8199	62.8430	59.2644	59.7033	60.2754	61.9384	55.9884
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	17.395	18.22	11.88	12.105	15.745	15.605	16.67	16.59	17.04	16.7
C2 (g/L)	6.57	6.86	4.19	4.245	5.675	5.65	5.935	5.885	5.79	5.775
Ave. C1	17.8075		11.9925		15.675		16.63		16.87	
Ave. C2	6.715		4.2175		5.6625		5.91		5.7825	

October 16, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	F2	G2	S1	S3	4AO	7AO	P16	P38s
M1 (g)	62.6427	57.2441	59.9937	63.8199	62.8430	59.2644	59.7033	60.2754	61.9384	55.9884
M2 (g)	63.0410	57.6463	60.2676	64.0887	63.1856	59.6096	60.0794	60.6494	62.3022	56.3554
M3 (g)	62.7795	57.3814	60.0838	63.9095	62.9538	59.3761	59.8262	60.3968	62.0524	56.1031
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	19.915	20.11	13.695	13.44	17.13	17.26	18.805	18.7	18.19	18.35
C2 (g/L)	6.84	6.865	4.505	4.48	5.54	5.585	6.145	6.07	5.7	5.735
Ave. C1	20.0125		13.5675		17.195		18.7525		18.27	
Ave. C2	6.8525		4.4925		5.5625		6.1075		5.7175	

October 19, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	P5	P10	Act1	Acc500	P3	P13	D4	K4	P8	NaOH
M1 (g)	61.0682	61.4611	57.4679	56.1745	58.4866	61.8707	60.1281	59.6795	64.9143	58.8787
M2 (g)	61.4577	61.8927	57.7520	56.4619	58.8032	62.1892	60.5131	60.0550	65.2809	59.2426
M3 (g)	61.1935	61.5998	57.5564	56.2625	58.5852	61.9698	60.2401	59.7913	65.0237	58.9852
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	19.475	21.58	14.205	14.37	15.83	15.925	19.25	18.775	18.33	18.195
C2 (g/L)	6.265	6.935	4.425	4.4	4.93	4.955	5.6	5.59	5.47	5.325
Ave. C1	20.5275		14.2875		15.8775		19.0125		18.2625	
Ave. C2	6.6		4.4125		4.9425		5.595		5.3975	

October 23, 2005										
	DL1 - 1	DL1 - 2	DL2 - 1	DL2 - 2	DL3 - 1	DL3 - 2	DL4 - 1	DL4 - 2	Control - 1	Control - 2
Label	O1	Dig	Act1	Acc500	S1	S3	4AO	7AO	P38s	NaOH
M1 (g)	62.6788	57.2712	57.4616	56.1525	62.8526	59.2699	59.6543	59.7374	56.0483	58.9275
M2 (g)	63.0255	57.6186	57.7458	56.4299	63.1060	59.5276	60.0704	60.6349	56.3789	59.2663
M3 (g)	62.8130	57.4043	57.5474	56.2453	62.9604	59.3790	59.7653	59.8483	56.1633	59.0435
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	17.335	17.37	14.21	13.87	12.67	12.885	20.805		16.53	16.94
C2 (g/L)	6.71	6.6571	4.29	4.64025	5.39	5.45615	5.55	5.54605	5.75	5.79895
Ave. C1	17.3525		14.04		12.7775		20.805		16.735	
Ave. C2	6.68355		4.465125		5.423075		5.548025		5.774475	

October 3, 2005	*Extra PT column results*									
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	Feed - 1	Feed - 2
Label	P5	P10	Act1	Acc500	P3	P13	D4	K4	P8	NaOH
M1 (g)	60.9274	61.3216	57.3370	56.0405	58.3617	61.7481	59.9507	59.5079	64.7888	58.7536
M2 (g)	61.2219	61.612	57.6348	56.3321	58.6744	62.0635	60.4613	60.0284	65.1063	59.0589
M3 (g)	61.0361	61.4291	57.4473	56.1493	58.4670	61.8539	60.1173	59.6847	64.8934	58.8564
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	14.725	14.52	14.89	14.58	15.635	15.77	25.53	26.025	15.875	15.265
C2 (g/L)	5.435	5.375	5.515	5.44	5.265	5.29	8.33	8.84	5.23	5.14
Ave. C1	14.6225		14.735		15.7025		25.7775		15.57	
Ave. C2	5.405		5.4775		5.2775		8.585		5.185	

October 12, 2005	*Extra PT column results*									
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	Feed - 1	Feed - 2
Label	P5	P10	Act1	Acc500	P3	P13	D4	K4	P8	NaOH
M1 (g)	60.9286	61.3215	57.3374	56.0416	58.3624	61.7481	59.9522	59.5097	64.7889	58.7541
M2 (g)	61.3099	61.7037	57.682	56.3892	58.7255	62.109	60.4537	59.9923	65.1949	59.1595
M3 (g)	61.0682	61.4611	57.4679	56.1745	58.4866	61.8707	60.1281	59.6795	64.9143	58.8787
V (mL)	20	20	20	20	20	20	20	20	20	20
C1 (g/L)	19.065	19.11	17.23	17.38	18.155	18.045	25.075	24.13	20.3	20.27
C2 (g/L)	6.98	6.98	6.525	6.645	6.21	6.13	8.795	8.49	6.27	6.23
Ave. C1	19.0875		17.305		18.1		24.6025		20.285	
Ave. C2	6.98		6.585		6.17		8.6425		6.25	

October 23, 2005	*Extra PT column results*									
	L1 - 1	L1 - 2	L2 - 1	L2 - 2	L3 - 1	L3 - 2	L4 - 1	L4 - 2	Feed - 1	Feed - 2
Label	P5	P10	F2	G2	P3	P13	D4	K4	P8	P16
M1 (g)	60.9286	61.3215	59.9099	63.735	58.3624	61.7481	59.9522	59.5097	61.82	61.8226
M2 (g)	61.3343	61.7475	60.3311	64.1446	58.7986	62.1598	60.813	59.9289	65.2786	62.3611
M3 (g)	60.9270	61.3199	59.9098	63.7319	58.3609	61.7475	59.9522	59.5089	64.7866	61.8239
V (mL)	25	25	25	25	25	25	25	25	25	25
C1 (g/L)	16.228	17.04	16.848	16.384	17.448	16.468	34.432	16.768	138.344	21.54
C2 (g/L)										
Ave. C1	16.634		16.616		16.958		25.6		21.54	
Ave. C2	6.2		6.03		5.72		8.6		5.71	

14) Fecal Coliform Data and Calculated Concentrations

February 27, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	41	5	D3	1,000	19.04	430.7288	362
L1 - 2	28	5	D3	1,000		294.1563	
L2 - 1	22	5	D4	10,000	19.88	2213.28	1,962
L2 - 2	17	5	D4	10,000		1710.262	
L3 - 1	34	5	D4	10,000	18.90	3598.836	2,752
L3 - 2	18	5	D4	10,000		1905.266	
L4 - 1	27	5	D4	10,000	20.57	2625.821	3,161
L4 - 2	38	5	D4	10,000		3695.599	
Feed - 1	32	5	D4	10,000	18.15	3525.685	3,911
Feed - 2	39	5	D4	10,000		4296.929	

March 9, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	35	5	D3	1,000	11.87	589.9705	573
L1 - 2	33	5	D3	1,000		556.2579	
L2 - 1	55	5	D3	1,000	12.08	910.7845	828
L2 - 2	45	5	D3	1,000		745.1873	
L3 - 1	116	5	D3	1,000	12.22	1899.304	1,785
L3 - 2	102	5	D3	1,000		1670.078	
L4 - 1	158	5	D3	1,000	12.29	2571.196	2,620
L4 - 2	164	5	D3	1,000		2668.836	
Feed - 1	276	5	D3	1,000	15.35	3595.506	3,198
Feed - 2	215	5	D3	1,000		2800.847	

March 11, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	65	5	D3	1,000	14.64	888.2815	765
L1 - 2	47	5	D3	1,000		642.2959	
L2 - 1	73	5	D3	1,000	14.20	1027.988	1,063
L2 - 2	78	5	D3	1,000		1098.398	
L3 - 1	100	5	D3	1,000	14.20	1408.451	1,690
L3 - 2	140	5	D3	1,000		1971.831	
L4 - 1	14	5	D4	10,000	14.08	1988.636	2,202
L4 - 2	17	5	D4	10,000		2414.773	
Feed - 1	39	5	D4	10,000	19.52	3996.925	3,433
Feed - 2	28	5	D4	10,000		2869.587	

March 13, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	30	5	D3	1,000	16.79	357.462	310
L1 - 2	22	5	D3	1,000		262.1388	
L2 - 1	29	5	D3	1,000	17.14	338.3404	169
L2 - 2	0	5	D3	1,000		0	
L3 - 1	50	5	D3	1,000	16.93	590.5802	632
L3 - 2	57	5	D3	1,000		673.2615	
L4 - 1	11	5	D4	10,000	17.44	1261.649	746
L4 - 2	2	5	D4	10,000		229.3907	
Feed - 1	0	5	D4	10,000	17.04	0	176
Feed - 2	3	5	D4	10,000		352.061	

March 20, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	1	5	D3	1,000	17.96	11.13741	17
L1 - 2	2	5	D3	1,000		22.27482	
L2 - 1	72	5	D3	1,000	19.05	755.8063	997
L2 - 2	118	5	D3	1,000		1238.683	
L3 - 1	16	5	D4	10,000	19.40	1649.91	1,959
L3 - 2	22	5	D4	10,000		2268.626	
L4 - 1	7	5	D4	10,000	18.99	737.3272	579
L4 - 2	4	5	D4	10,000		421.3298	
Feed - 1	2	5	D4	10,000	18.23	219.4787	604
Feed - 2	9	5	D4	10,000		987.6543	

March 23, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	2	5	D4	10,000	18.97	210.8593	211
L1 - 2	2	5	D4	10,000		210.8593	
L2 - 1	16	5	D4	10,000	19.49	1641.657	1,590
L2 - 2	15	5	D4	10,000		1539.053	
L3 - 1	13	5	D4	10,000	20.62	1260.606	1,406
L3 - 2	16	5	D4	10,000		1551.515	
L4 - 1	8	5	D4	10,000	20.12	795.2286	646
L4 - 2	5	5	D4	10,000		497.0179	
Feed - 1	3	5	D4	10,000	20.53	292.2908	146
Feed - 2	0	5	D4	10,000		0	

March 25, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	12	5	D4	10,000	18.77	1278.806	1,758
L1 - 2	21	5	D4	10,000		2237.911	
L2 - 1	67	5	D4	10,000	18.82	7120.085	5,420
L2 - 2	35	5	D4	10,000		3719.447	
L3 - 1	116	5	D4	10,000	19.58	11847.31	10,877
L3 - 2	97	5	D4	10,000		9906.805	
L4 - 1	113	5	D4	10,000	19.00	11893.17	11,209
L4 - 2	100	5	D4	10,000		10524.93	
Feed - 1	153	5	D4	10,000	18.79	16287.43	15,915
Feed - 2	146	5	D4	10,000		15542.25	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

	Date
Fecal (CFU/mL)	L1
	L2
	L3
	L4
	Feed

	Date
Fecal (CFU/100 mL)	L1
	L2
	L3
	L4
	Feed

PHASE 2

April 20, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	13	5	D4	10,000	21.54	1207.197	1,486
L1 - 2	19	5	D4	10,000		1764.364	
L2 - 1	103	5	D4	10,000	23.27	8851.649	9,754
L2 - 2	124	5	D4	10,000		10656.35	
L3 - 1	102	5	D4	10,000	22.87	8919.983	8,177
L3 - 2	85	5	D4	10,000		7433.319	
L4 - 1	540	5	D3	1,000	23.01	4694.632	4,130
L4 - 2	410	5	D3	1,000		3564.443	
Feed - 1	23	5	D4	10,000	21.96	2094.479	3,369
Feed - 2	51	5	D4	10,000		4644.28	

April 22, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	11	5	D4	10,000	22.49	978.1038	1,289
L1 - 2	18	5	D4	10,000		1600.534	
L2 - 1	70	5	D4	10,000	26.32	5318.139	5,508
L2 - 2	75	5	D4	10,000		5698.006	
L3 - 1	115	5	D4	10,000	24.61	9343.896	8,653
L3 - 2	98	5	D4	10,000		7962.624	
L4 - 1	50	5	D3	1,000	24.76	403.918	388
L4 - 2	46	5	D3	1,000		371.6046	
Feed - 1	63	5	D4	10,000	22.17	5683.356	6,044
Feed - 2	71	5	D4	10,000		6405.052	

April 28, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	10	5	D4	10,000	20.53	974.0655	1,169
L1 - 2	14	5	D4	10,000		1363.692	
L2 - 1	56	5	D4	10,000	20.41	5488.851	5,783
L2 - 2	62	5	D4	10,000		6076.942	
L3 - 1	47	5	D4	10,000	20.59	4566.432	4,858
L3 - 2	53	5	D4	10,000		5149.381	
L4 - 1	36	5	D3	1,000	20.78	346.4453	327
L4 - 2	32	5	D3	1,000		307.9514	
Feed - 1	58	5	D4	10,000	19.49	5953.297	5,851
Feed - 2	56	5	D4	10,000		5748.011	

May 1, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	5	5	D4	10,000	23.12	432.526	606
L1 - 2	9	5	D4	10,000		778.5467	
L2 - 1	37	5	D4	10,000	23.09	3205.198	3,465
L2 - 2	43	5	D4	10,000		3724.959	
L3 - 1	37	5	D4	10,000	23.02	3214.945	2,954
L3 - 2	31	5	D4	10,000		2693.603	
L4 - 1	23	5	D3	1,000	24.28	189.4563	181
L4 - 2	21	5	D3	1,000		172.9819	
Feed - 1	40	5	D4	10,000	25.36	3154.885	4,101
Feed - 2	64	5	D4	10,000		5047.816	

May 5, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	2	5	D4	10,000	21.41	186.8722	187
L1 - 2	N/A	5	D4	10,000			
L2 - 1	28	5	D4	10,000	22.30	2510.648	2,511
L2 - 2	N/A	5	D4	10,000			
L3 - 1	14	5	D4	10,000	21.06	1329.535	1,425
L3 - 2	16	5	D4	10,000		1519.468	
L4 - 1	20	5	D3	1,000	22.20	180.1396	180
L4 - 2	N/A	5	D3	1,000			
Feed - 1	90	5	D4	10,000	23.75	7577.352	7,577
Feed - 2	N/A	5	D4	10,000			

May 12, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	4	5	D4	10,000	17.35	461.1616	519
L1 - 2	5	5	D4	10,000		576.4519	
L2 - 1	19	5	D4	10,000	17.55	2165.242	2,279
L2 - 2	21	5	D4	10,000		2393.162	
L3 - 1	8	5	D4	10,000	17.72	902.8072	1,072
L3 - 2	11	5	D4	10,000		1241.36	
L4 - 1	9	5	D3	1,000	17.80	101.1094	90
L4 - 2	7	5	D3	1,000		78.64064	
Feed - 1	62	5	D4	10,000	16.49	7518.569	5,639
Feed - 2	31	5	D4	10,000		3759.285	

June 10, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	1	5	D4	10,000	17.71	112.9305	169
L1 - 2	2	5	D4	10,000		225.8611	
L2 - 1	40	5	D4	10,000	14.63	5468.216	5,400
L2 - 2	39	5	D4	10,000		5331.511	
L3 - 1	12	5	D4	10,000	13.96	1718.89	2,507
L3 - 2	23	5	D4	10,000		3294.539	
L4 - 1	26	5	D3	1,000	18.67	278.4844	359
L4 - 2	41	5	D3	1,000		439.1485	
Feed - 1	114	5	D4	10,000	14.86	15343.2	15,949
Feed - 2	123	5	D4	10,000		16554.51	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

April 20, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	13	5	10,000	26000	32,000
L1 - 2	19	5	10,000	38000	
L2 - 1	103	5	10,000	206000	227,000
L2 - 2	124	5	10,000	248000	
L3 - 1	102	5	10,000	204000	187,000
L3 - 2	85	5	10,000	170000	
L4 - 1	540	5	1,000	108000	95,000
L4 - 2	410	5	1,000	82000	
Feed - 1	23	5	10,000	46000	74,000
Feed - 2	51	5	10,000	102000	

April 22, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	11	5	10,000	22000	29,000
L1 - 2	18	5	10,000	36000	
L2 - 1	70	5	10,000	140000	145,000
L2 - 2	75	5	10,000	150000	
L3 - 1	115	5	10,000	230000	213,000
L3 - 2	98	5	10,000	196000	
L4 - 1	50	5	1,000	10000	9,600
L4 - 2	46	5	1,000	9200	
Feed - 1	63	5	10,000	126000	134,000
Feed - 2	71	5	10,000	142000	

April 28, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	10	5	10,000	20000	24,000
L1 - 2	14	5	10,000	28000	
L2 - 1	56	5	10,000	112000	118,000
L2 - 2	62	5	10,000	124000	
L3 - 1	47	5	10,000	94000	100,000
L3 - 2	53	5	10,000	106000	
L4 - 1	36	5	1,000	7200	6,800
L4 - 2	32	5	1,000	6400	
Feed - 1	58	5	10,000	116000	114,000
Feed - 2	56	5	10,000	112000	

May 1, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	5	5	10,000	10000	14,000
L1 - 2	9	5	10,000	18000	
L2 - 1	37	5	10,000	74000	80,000
L2 - 2	43	5	10,000	86000	
L3 - 1	37	5	10,000	74000	68,000
L3 - 2	31	5	10,000	62000	
L4 - 1	23	5	1,000	4600	4,400
L4 - 2	21	5	1,000	4200	
Feed - 1	40	5	10,000	80000	104,000
Feed - 2	64	5	10,000	128000	

May 5, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	2	5	10,000	4000	4,000
L1 - 2	N/A	5	10,000		
L2 - 1	28	5	10,000	56000	56,000
L2 - 2	N/A	5	10,000		
L3 - 1	14	5	10,000	28000	30,000
L3 - 2	16	5	10,000	32000	
L4 - 1	20	5	1,000	4000	4,000
L4 - 2	N/A	5	1,000		
Feed - 1	90	5	10,000	180000	180,000
Feed - 2	N/A	5	10,000		

May 12, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	4	5	10,000	8000	9,000
L1 - 2	5	5	10,000	10000	
L2 - 1	19	5	10,000	38000	40,000
L2 - 2	21	5	10,000	42000	
L3 - 1	8	5	10,000	16000	19,000
L3 - 2	11	5	10,000	22000	
L4 - 1	9	5	1,000	1800	1,600
L4 - 2	7	5	1,000	1400	
Feed - 1	62	5	10,000	124000	93,000
Feed - 2	31	5	10,000	62000	

June 10, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	1	5	10,000	2000	3,000
L1 - 2	2	5	10,000	4000	
L2 - 1	40	5	10,000	80000	79,000
L2 - 2	39	5	10,000	78000	
L3 - 1	12	5	10,000	24000	35,000
L3 - 2	23	5	10,000	46000	
L4 - 1	26	5	1,000	5200	6,700
L4 - 2	41	5	1,000	8200	
Feed - 1	114	5	10,000	228000	237,000
Feed - 2	123	5	10,000	246000	

PHASE 3 – Pre-treatment columns

July 5, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	17	5	D3	1,000	13.23	257.0403	287
L1 - 2	21	5	D3	1,000		317.5203	
L2 - 1	48	5	D3	1,000	12.98	739.3146	639
L2 - 2	35	5	D3	1,000		539.0836	
L3 - 1	49	5	D3	1,000	12.14	807.415	840
L3 - 2	53	5	D3	1,000		873.3265	
L4 - 1	17	5	D4	10,000	29.31	1160.113	1,194
L4 - 2	18	5	D4	10,000		1228.355	
Feed - 1	113	5	D4	10,000	13.25	17059.82	16,758
Feed - 2	109	5	D4	10,000		16455.94	

July 7, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	8	5	D3	1,000	14.46	110.6883	145
L1 - 2	13	5	D3	1,000		179.8686	
L2 - 1	39	5	D3	1,000	13.78	566.0377	530
L2 - 2	34	5	D3	1,000		493.4688	
L3 - 1	26	5	D3	1,000	15.15	343.291	390
L3 - 2	33	5	D3	1,000		435.7155	
L4 - 1	5	5	D3	1,000	12.91	77.44434	54
L4 - 2	2	5	D3	1,000		30.97773	
Feed - 1	120	5	D4	10,000	17.41	13787.16	13,155
Feed - 2	109	5	D4	10,000		12523.34	

July 14, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	39	5	D3	1,000	12.13	643.299	816
L1 - 2	60	5	D3	1,000		989.6907	
L2 - 1	12	5	D3	1,000	12.14	197.7343	239
L2 - 2	17	5	D3	1,000		280.1236	
L3 - 1	46	5	D3	1,000	12.34	745.8452	867
L3 - 2	61	5	D3	1,000		989.0555	
L4 - 1	2	5	D3	1,000	8.80	45.45455	68
L4 - 2	4	5	D3	1,000		90.90909	
Feed - 1	41	5	D4	10,000	18.37	4464.407	4,519
Feed - 2	42	5	D4	10,000		4573.295	

July 26, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	43	5	D3	1,000	13.25	649.1791	476
L1 - 2	20	5	D3	1,000		301.9438	
L2 - 1	27	5	D3	1,000	12.59	428.9118	326
L2 - 2	14	5	D3	1,000		222.3987	
L3 - 1	57	5	D3	1,000	13.54	841.639	753
L3 - 2	45	5	D3	1,000		664.4518	
L4 - 1	26	5	D3	1,000	16.01	324.8477	250
L4 - 2	14	5	D3	1,000		174.918	
Feed - 1	54	5	D4	10,000	19.33	5587.893	6,467
Feed - 2	71	5	D4	10,000		7347.044	

August 1, 2005 - August 2, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	14	5	D3	1,000	18.15	154.2912	160
L1 - 2	15	5	D3	1,000		165.312	
L2 - 1	8	5	D3	1,000	19.67	81.32147	91
L2 - 2	10	5	D3	1,000		101.6518	
L3 - 1	14	5	D3	1,000	19.96	140.2981	135
L3 - 2	13	5	D3	1,000		130.2768	
L4 - 1	7	5	D3	1,000	19.70	71.07501	61
L4 - 2	5	5	D3	1,000		50.76786	
Feed - 1	11	5	D4	10,000	20.93	1051.123	1,481
Feed - 2	20	5	D4	10,000		1911.132	

August 8, 2005 - August 9, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	67	5	D3	1,000	21.06	636.3528	465
L1 - 2	31	5	D3	1,000		294.4319	
L2 - 1	41	5	D3	1,000	17.84	459.5769	476
L2 - 2	44	5	D3	1,000		493.2044	
L3 - 1	90	5	D3	1,000	18.78	958.4665	927
L3 - 2	84	5	D3	1,000		894.5687	
L4 - 1	56	5	D3	1,000	18.42	608.0347	700
L4 - 2	73	5	D3	1,000		792.6167	
Feed - 1	47	5	D4	10,000	19.62	4791.64	4,486
Feed - 2	41	5	D4	10,000		4179.941	

August 12, 2005 - August 13, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L3 - 1	3	5	D3	1,000	17.86	33.58992	34
L3 - 2	3	5	D3	1,000		33.58992	
L4 - 1	4	5	D3	1,000	17.39	46.01668	52
L4 - 2	5	5	D3	1,000		57.52085	
Feed - 1	5	5	D4	10,000	19.70	507.6142	355
Feed - 2	2	5	D4	10,000		203.0457	

July 5, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	17	5	1,000	3400	3,800
L1 - 2	21	5	1,000	4200	
L2 - 1	48	5	1,000	9600	8,300
L2 - 2	35	5	1,000	7000	
L3 - 1	49	5	1,000	9800	10,200
L3 - 2	53	5	1,000	10600	
L4 - 1	17	5	10,000	34000	35,000
L4 - 2	18	5	10,000	36000	
Feed - 1	113	5	10,000	226000	222,000
Feed - 2	109	5	10,000	218000	

July 7, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	8	5	1,000	1600	2,100
L1 - 2	13	5	1,000	2600	
L2 - 1	39	5	1,000	7800	7,300
L2 - 2	34	5	1,000	6800	
L3 - 1	26	5	1,000	5200	5,900
L3 - 2	33	5	1,000	6600	
L4 - 1	5	5	1,000	1000	700
L4 - 2	2	5	1,000	400	
Feed - 1	120	5	10,000	240000	229,000
Feed - 2	109	5	10,000	218000	

July 14, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	39	5	1,000	7800	9,900
L1 - 2	60	5	1,000	12000	
L2 - 1	12	5	1,000	2400	2,900
L2 - 2	17	5	1,000	3400	
L3 - 1	46	5	1,000	9200	10,700
L3 - 2	61	5	1,000	12200	
L4 - 1	2	5	1,000	400	600
L4 - 2	4	5	1,000	800	
Feed - 1	41	5	10,000	82000	83,000
Feed - 2	42	5	10,000	84000	

July 26, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	43	5	1,000	8600	6,300
L1 - 2	20	5	1,000	4000	
L2 - 1	27	5	1,000	5400	4,100
L2 - 2	14	5	1,000	2800	
L3 - 1	57	5	1,000	11400	10,200
L3 - 2	45	5	1,000	9000	
L4 - 1	26	5	1,000	5200	4,000
L4 - 2	14	5	1,000	2800	
Feed - 1	54	5	10,000	108000	125,000
Feed - 2	71	5	10,000	142000	

August 1, 2005 - August 2, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	14	5	1,000	2800	2,900
L1 - 2	15	5	1,000	3000	
L2 - 1	8	5	1,000	1600	1,800
L2 - 2	10	5	1,000	2000	
L3 - 1	14	5	1,000	2800	2,700
L3 - 2	13	5	1,000	2600	
L4 - 1	7	5	1,000	1400	1,200
L4 - 2	5	5	1,000	1000	
Feed - 1	11	5	10,000	22000	31,000
Feed - 2	20	5	10,000	40000	

August 8, 2005 - August 9, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	67	5	1,000	13400	9,800
L1 - 2	31	5	1,000	6200	
L2 - 1	41	5	1,000	8200	8,500
L2 - 2	44	5	1,000	8800	
L3 - 1	90	5	1,000	18000	17,400
L3 - 2	84	5	1,000	16800	
L4 - 1	56	5	1,000	11200	12,900
L4 - 2	73	5	1,000	14600	
Feed - 1	47	5	10,000	94000	88,000
Feed - 2	41	5	10,000	82000	

August 12, 2005 - August 13, 2005

	Count	Volume	Factor	C/100mL	Average
L3 - 1	3	5	1,000	600	600
L3 - 2	3	5	1,000	600	
L4 - 1	4	5	1,000	800	900
L4 - 2	5	5	1,000	1000	
Feed - 1	5	5	10,000	10000	7,000
Feed - 2	2	5	10,000	4000	

Oct. 3-05

Fecal Coliforms

per 100 mL

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	[redacted]	5	D3	1,000	14.62	382971.4	376,133	2800000	2,750,000
L1 - 2		5	D3	1,000		369293.9		2700000	
L2 - 1	[redacted]	5	D3	1,000	14.73	366474.4	346,115	2700000	2,550,000
L2 - 2		5	D3	1,000		325755		2400000	
L3 - 1	20	5	D3	1,000	15.70	254736.5	248,368	2000000	1,950,000
L3 - 2	19	5	D3	1,000		241999.7		1900000	
L4 - 1	49	5	D3	1,000	25.78	380176.5	399,573	4900000	5,150,000
L4 - 2	54	5	D3	1,000		418970		5400000	
Feed - 1	[redacted]	5	D3	1,000	15.57	552344.3	526,654	4300000	4,100,000
Feed - 2		5	D3	1,000		500963.4		3900000	

Oct. 12-05

per 100 mL

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1		5	D3	1,000	19.09	639161.8	654,879	6100000	6,250,000
L1 - 2		5	D3	1,000		670595.9		6400000	
L2 - 1		5	D3	1,000	17.31	288933.8	283,155	2500000	2,450,000
L2 - 2		5	D3	1,000		277376.5		2400000	
L3 - 1		5	D3	1,000	18.10	486187.8	491,713	4400000	4,450,000
L3 - 2		5	D3	1,000		497237.6		4500000	
L4 - 1		5	D3	1,000	24.60	276394.7	288,589	3400000	3,550,000
L4 - 2		5	D3	1,000		300782.4		3700000	
Feed - 1		5	D3	1,000	20.29	1538082	1,690,905	15600000	17,150,000
Feed - 2		5	D3	1,000		1843727		18700000	

Oct. 23-05

per 100 mL

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	20	5	D4	10,000	16.63	24047132	33,665,985	2E+08	280,000,000
L1 - 2	36	5	D4	10,000		43284838		3.6E+08	
L2 - 1	30	5	D4	10,000	16.62	3610977	3,249,880	30000000	27,000,000
L2 - 2	24	5	D4	10,000		2888782		24000000	
L3 - 1	78	5	D4	10,000	16.96	9199198	7,842,906	78000000	66,500,000
L3 - 2	55	5	D4	10,000		6486614		55000000	
L4 - 1	38	5	D4	10,000	25.60	2968750	2,812,500	38000000	36,000,000
L4 - 2	34	5	D4	10,000		2656250		34000000	
Feed - 1	24	5	D5	100,000	21.54	22284123	21,355,617	2.4E+08	230,000,000
Feed - 2	22	5	D5	100,000		20427112		2.2E+08	

PHASE 3 – Digesters

August 9, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
Control-1	38	5	D2	100	20.61	36870.83	35,415
Control-2	35	5	D2	100		33959.98	
Control-1	5	5	D3	1,000	20.61	48514.25	38,811
Control-2	3	5	D3	1,000		29108.55	

August 11, 2005 - August 12, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	2	5	D2	100	18.04	2217.602	1,663
L1 - 2	1	5	D2	100		1108.801	
L2 - 1	0	5	D2	100	13.41	0	0
L2 - 2	0	5	D2	100		0	
L3 - 1	10	5	D2	100	16.62	12035.5	19,257
L3 - 2	22	5	D2	100		26478.11	
L4 - 1	33	5	D2	100	16.76	39379.47	36,993
L4 - 2	29	5	D2	100		34606.21	
Control-1	23	5	D2	100	165.13	2785.632	2,180
Control-2	13	5	D2	100		1574.487	

Sept. 13, 2005 - Sept. 14, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	26	5	D2	100	61.46	8461.104	8,461
L1 - 2	26	5	D2	100		8461.104	
L2 - 1	15	5	D1	10	57.75	519.4625	450
L2 - 2	11	5	D1	10		380.9392	
L3 - 1	40	5	D2	100	58.80	13604.7	16,836
L3 - 2	59	5	D2	100		20066.94	
L4 - 1	86.5	5	D1	10	60.51	2858.885	2,669
L4 - 2	7.5	5	D2	100		2478.802	
Control-1	37	5	D2	100	65.28	11335.63	7,966
Control-2	15	5	D2	100		4595.525	

September 15, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	51	5	D2	100	18.27	55829.23	60,208
L1 - 2	59	5	D2	100		64586.75	
L2 - 1	4	5	D1	10	16.15	495.4327	495
L2 - 2	4	5	D1	10		495.4327	
L3 - 1	23	5	D2	100	16.02	28714.11	33,084
L3 - 2	30	5	D2	100		37453.18	
L4 - 1	20.5	5	D1	10	15.95	2571.339	5,049
L4 - 2	6	5	D2	100		7525.87	
Control-1	43	5	D2	100	15.69	54829.45	53,554
Control-2	41	5	D2	100		52279.25	

Sept. 27-05

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	36	5	D2	100	18.36	39226.37	51,757
L1 - 2	59	5	D2	100		64287.66	
L2 - 1	18	10	D1	10	15.94	1129.058	941
L2 - 2	12	10	D1	10		752.705	
L3 - 1	19	5	D2	100	16.60	22884.67	16,862
L3 - 2	9	5	D2	100		10840.11	
L4 - 1	4	5	D1	10	15.63	511.7544	1,087
L4 - 2	13	5	D1	10		1663.202	
Feed - 1	100	5	D2	100	16.63	120300.8	110,677
Feed - 2	84	5	D2	100		101052.6	

October 3, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	[illegible]	[illegible]	[illegible]	[illegible]	18.04	31046.43	31,046
L1 - 2							
L2 - 1	[illegible]	[illegible]	[illegible]	[illegible]	13.41	16411.79	16,412
L2 - 2							
L3 - 1	[illegible]	[illegible]	[illegible]	[illegible]	16.62	391153.9	391,154
L3 - 2							
L4 - 1	[illegible]	[illegible]	[illegible]	[illegible]	16.76	668257.8	668,258
L4 - 2							
Feed - 1	[illegible]	[illegible]	[illegible]	[illegible]	17.07	4687958	4,687,958
Feed - 2							

October 6, 2005

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	75	5	D3	1,000	18.27	821242.8	821,243
L1 - 2		5	D3	1,000			
L2 - 1	86	5	D2	100	11.83	145454.5	140,381
L2 - 2	8	5	D3	1,000		135306.6	
L3 - 1	105	5	D3	1,000	17.38	1208285	1,208,285
L3 - 2		5	D3	1,000			
L4 - 1	36	5	D3	1,000	17.04	422535.2	422,535
L4 - 2		5	D3	1,000			
Feed - 1	135	5	D3	1,000	16.81	1605948	1,605,948
Feed - 2		5					

Oct. 12-05

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	99	5	D3	1,000	17.81	1111891	965,885
L1 - 2	73	5	D3	1,000		819879.3	
L2 - 1	29	5	D2	100	11.99	48363.56	42,527
L2 - 2	22	5	D2	100		36689.6	
L3 - 1	13	5	D3	1,000	15.68	165869.2	153,110
L3 - 2	11	5	D3	1,000		140350.9	
L4 - 1	23	5	D3	1,000	16.63	276608.5	204,450
L4 - 2	11	5	D3	1,000		132291	
Control-1	29	5	D3	1,000	16.87	343805.6	314,167
Control-2	24	5	D3	1,000		284528.7	

Oct. 16-05

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	41	5	D3	1,000	20.01	409743.9	459,713
L1 - 2	51	5	D3	1,000		509681.4	
L2 - 1	4	5	D2	100	13.57	5896.444	5,896
L2 - 2	4	5	D2	100		5896.444	
L3 - 1	7	5	D2	100	17.19	8141.902	8,723
L3 - 2	8	5	D2	100		9305.031	
L4 - 1	33	5	D2	100	18.75	35195.31	31,996
L4 - 2	27	5	D2	100		28796.16	
Control-1	3	5	D3	1,000	18.27	32840.72	21,894
Control-2	1	5	D3	1,000		10946.91	

Oct. 19-05

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	38	5	D3	1,000	20.53	370235.1	379,978
L1 - 2	40	5	D3	1,000		389721.1	
L2 - 1	12	10	D2	100	14.29	8398.95	9,449
L2 - 2	15	10	D2	100		10498.69	
L3 - 1	6	5	D2	100	15.88	7557.865	5,039
L3 - 2	2	5	D2	100		2519.288	
L4 - 1	24	5	D2	100	19.01	25246.55	25,773
L4 - 2	25	5	D2	100		26298.49	
Control-1	53	5	D2	100	18.26	58042.44	60,233
Control-2	57	5	D2	100		62423	

Oct. 23-05

Fecal Coliforms

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	4	5	D3	1,000	17.35	46102.87	69,154
L1 - 2	8	5	D3	1,000		92205.73	
L2 - 1	12	5	D1	10	14.04	1709.402	2,991
L2 - 2	30	5	D1	10		4273.504	
L3 - 1	11	10	D2	100	12.78	8608.883	11,348
L3 - 2	18	10	D2	100		14087.26	
L4 - 1	2	5	D2	100	20.81	1922.615	2,884
L4 - 2	4	5	D2	100		3845.23	
Control-1	26	5	D2	100	16.74	31072.6	34,060
Control-2	31	5	D2	100		37048.1	

15) *E. Coli* Data and Calculated Concentrations

February 27, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	45	5	D4	10,000	19.04	4727.511	4,517
L1 - 2	41	5	D4	10,000		4307.288	
L2 - 1	120	5	D4	10,000	19.88	12072.43	11,670
L2 - 2	112	5	D4	10,000		11267.61	
L3 - 1	96	5	D4	10,000	18.90	10161.42	10,373
L3 - 2	100	5	D4	10,000		10584.81	
L4 - 1	94	5	D4	10,000	20.57	9141.746	8,801
L4 - 2	87	5	D4	10,000		8460.977	
Feed - 1	172	5	D4	10,000	18.15	18950.56	18,951
Feed - 2	172	5	D4	10,000		18950.56	

March 9, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	10	5	D4	10,000	11.87	1685.63	2,444
L1 - 2	19	5	D4	10,000		3202.697	
L2 - 1	15	5	D4	10,000	12.08	2483.958	1,904
L2 - 2	8	5	D4	10,000		1324.777	
L3 - 1	82	5	D4	10,000	12.22	13426.12	14,900
L3 - 2	100	5	D4	10,000		16373.31	
L4 - 1	100	5	D4	10,000	12.29	16273.39	12,856
L4 - 2	58	5	D4	10,000		9438.568	
Feed - 1	167	5	D4	10,000	15.35	21755.41	22,342
Feed - 2	176	5	D4	10,000		22927.86	

March 11, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	16	5	D4	10,000	14.64	2186.539	1,708
L1 - 2	9	5	D4	10,000		1229.928	
L2 - 1	17	5	D4	10,000	14.20	2393.945	2,394
L2 - 2	17	5	D4	10,000		2393.945	
L3 - 1	61	5	D4	10,000	14.20	8591.549	9,437
L3 - 2	73	5	D4	10,000		10281.69	
L4 - 1	75	5	D4	10,000	14.08	10653.41	10,227
L4 - 2	69	5	D4	10,000		9801.136	
Feed - 1	234	5	D4	10,000	19.52	23981.55	24,135
Feed - 2	237	5	D4	10,000		24289.01	

March 13, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	15	5	D4	10,000	16.79	1787.31	2,085
L1 - 2	20	5	D4	10,000		2383.08	
L2 - 1	29	5	D4	10,000	17.14	3383.404	3,908
L2 - 2	38	5	D4	10,000		4433.426	
L3 - 1	57	5	D4	10,000	16.93	6732.615	6,674
L3 - 2	56	5	D4	10,000		6614.499	
L4 - 1	61	5	D4	10,000	17.44	6996.416	7,054
L4 - 2	62	5	D4	10,000		7111.111	
Feed - 1	97	5	D4	10,000	17.04	11383.31	13,906
Feed - 2	140	5	D4	10,000		16429.51	

March 20, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	7	5	D4	10,000	17.96	779.6185	668
L1 - 2	5	5	D4	10,000		556.8704	
L2 - 1	52	5	D4	10,000	19.05	5458.601	6,036
L2 - 2	63	5	D4	10,000		6613.305	
L3 - 1	69	5	D4	10,000	19.40	7115.236	6,754
L3 - 2	62	5	D4	10,000		6393.4	
L4 - 1	19	5	D4	10,000	18.99	2001.317	1,949
L4 - 2	18	5	D4	10,000		1895.984	
Feed - 1	81	5	D4	10,000	18.23	8888.889	7,407
Feed - 2	54	5	D4	10,000		5925.926	

March 23, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	48	5	D3	1,000	18.97	506.0622	485
L1 - 2	44	5	D3	1,000		463.8904	
L2 - 1	23	5	D4	10,000	19.49	2359.882	2,616
L2 - 2	28	5	D4	10,000		2872.9	
L3 - 1	38	5	D4	10,000	20.62	3684.848	3,345
L3 - 2	31	5	D4	10,000		3006.061	
L4 - 1	20	5	D4	10,000	20.12	1988.072	1,839
L4 - 2	17	5	D4	10,000		1689.861	
Feed - 1	21	5	D4	10,000	20.53	2046.036	2,387
Feed - 2	28	5	D4	10,000		2728.048	

March 25, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	23	5	D4	10,000	18.77	2451.046	2,664
L1 - 2	27	5	D4	10,000		2877.315	
L2 - 1	174	5	D4	10,000	18.82		16,684
L2 - 2	157	5	D4	10,000		16684.38	
L3 - 1	185	5	D4	10,000	19.58	18894.42	16,699
L3 - 2	142	5	D4	10,000		14502.74	
L4 - 1	117	5	D4	10,000	19.00		11,788
L4 - 2	112	5	D4	10,000		11787.92	
Feed - 1	230	5	D4	10,000	18.79	24484.36	20,865
Feed - 2	162	5	D4	10,000		17245.51	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

	Date	
E. Coli (CFU/mL)	L1	
	L2	
	L3	
	L4	
	Feed	

	Date	
E. Coli (CFU/100 mL)	L1	
	L2	
	L3	
	L4	
	Feed	

PHASE 2

April 20, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	36	5	D4	10,000	21.54	3343.006	2,786
L1 - 2	24	5	D4	10,000		2228.671	
L2 - 1	155	5	D4	10,000	23.27	13320.44	12,719
L2 - 2	141	5	D4	10,000		12117.31	
L3 - 1	127	5	D4	10,000	22.87	11106.25	11,019
L3 - 2	125	5	D4	10,000		10931.35	
L4 - 1	516	5	D3	1,000	23.01	4485.981	5,568
L4 - 2	765	5	D3	1,000		6650.728	
Feed - 1	101	5	D4	10,000	21.96	9197.496	11,429
Feed - 2	150	5	D4	10,000		13659.65	

April 22, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	11	5	D4	10,000	22.49	978.1038	1,512
L1 - 2	23	5	D4	10,000		2045.126	
L2 - 1	105	5	D4	10,000	26.32	7977.208	7,977
L2 - 2	N/A	5	D4	10,000			
L3 - 1	64	5	D4	10,000	24.61	5200.081	5,119
L3 - 2	62	5	D4	10,000		5037.579	
L4 - 1	35	5	D3	1,000	24.76	282.7426	283
L4 - 2	N/A	5	D3	1,000			
Feed - 1	55	5	D4	10,000	22.17	4961.66	5,368
Feed - 2	64	5	D4	10,000		5773.568	

April 28, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	12	5	D4	10,000	20.53	1168.879	1,899
L1 - 2	27	5	D4	10,000		2629.977	
L2 - 1	61	5	D4	10,000	20.41	5978.927	5,979
L2 - 2	69	5	D4	10,000			
L3 - 1	53	5	D4	10,000	20.59	5149.381	5,392
L3 - 2	58	5	D4	10,000		5635.171	
L4 - 1	29	5	D3	1,000	20.78	279.081	279
L4 - 2	30	5	D3	1,000			
Feed - 1	143	5	D4	10,000	19.49	14677.96	14,421
Feed - 2	138	5	D4	10,000		14164.74	

May 1, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	18	5	D4	10,000	23.12	1557.093	1,644
L1 - 2	20	5	D4	10,000		1730.104	
L2 - 1	74	5	D4	10,000	23.09	6410.395	6,021
L2 - 2	65	5	D4	10,000		5630.753	
L3 - 1	40	5	D4	10,000	23.02	3475.616	3,128
L3 - 2	32	5	D4	10,000		2780.493	
L4 - 1	18	5	D3	1,000	24.28	148.2702	144
L4 - 2	17	5	D3	1,000		140.0329	
Feed - 1	138	5	D4	10,000	25.36	10884.35	10,727
Feed - 2	134	5	D4	10,000		10568.87	

May 5, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	10	5	D4	10,000	21.41	934.3611	841
L1 - 2	8	5	D4	10,000		747.4889	
L2 - 1	73	5	D4	10,000	22.30	6545.618	6,546
L2 - 2	53	5	D4	10,000			
L3 - 1	41	5	D4	10,000	21.06	3893.637	3,181
L3 - 2	26	5	D4	10,000		2469.136	
L4 - 1	26	5	D3	1,000	22.20	234.1815	234
L4 - 2	25	5	D3	1,000			
Feed - 1	233	5	D4	10,000	23.75	19616.92	20,501
Feed - 2	254	5	D4	10,000		21384.97	

May 12, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	1	5	D4	10,000	17.35	115.2904	346
L1 - 2	5	5	D4	10,000		576.4519	
L2 - 1	N/A	5	D4	10,000	17.55		3,191
L2 - 2	28	5	D4	10,000		3190.883	
L3 - 1	17	5	D4	10,000	17.72	1918.465	2,144
L3 - 2	21	5	D4	10,000		2369.869	
L4 - 1	N/A	5	D3	1,000	17.80		146
L4 - 2	13	5	D3	1,000		146.0469	
Feed - 1	173	5	D4	10,000	16.49	20979.23	19,463
Feed - 2	148	5	D4	10,000		17947.55	

June 10, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	7	5	D4	10,000	17.71	790.5138	678
L1 - 2	5	5	D4	10,000		564.6527	
L2 - 1	81	5	D4	10,000	14.63	11073.14	11,005
L2 - 2	80	5	D4	10,000		10936.43	
L3 - 1	32	5	D4	10,000	13.96	4583.706	4,369
L3 - 2	29	5	D4	10,000		4153.984	
L4 - 1	34	5	D3	1,000	18.67	364.1719	455
L4 - 2	51	5	D3	1,000		546.2579	
Feed - 1	222	5	D4	10,000	14.86	29878.87	35,128
Feed - 2	300	5	D4	10,000		40376.85	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

April 20, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	36	5	10,000	72000	60,000
L1 - 2	24	5	10,000	48000	
L2 - 1	155	5	10,000	310000	296,000
L2 - 2	141	5	10,000	282000	
L3 - 1	127	5	10,000	254000	252,000
L3 - 2	125	5	10,000	250000	
L4 - 1	516	5	1,000	103200	128,100
L4 - 2	765	5	1,000	153000	
Feed - 1	101	5	10,000	202000	251,000
Feed - 2	150	5	10,000	300000	

April 22, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	11	5	10,000	22000	34,000
L1 - 2	23	5	10,000	46000	
L2 - 1	105	5	10,000	210000	210,000
L2 - 2	N/A	5	10,000		
L3 - 1	64	5	10,000	128000	126,000
L3 - 2	62	5	10,000	124000	
L4 - 1	35	5	1,000	7000	7,000
L4 - 2	N/A	5	1,000		
Feed - 1	55	5	10,000	110000	119,000
Feed - 2	64	5	10,000	128000	

April 28, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	12	5	10,000	24000	39,000
L1 - 2	27	5	10,000	54000	
L2 - 1	61	5	10,000	122000	130,000
L2 - 2	69	5	10,000	138000	
L3 - 1	53	5	10,000	106000	111,000
L3 - 2	58	5	10,000	116000	
L4 - 1	29	5	1,000	5800	5,900
L4 - 2	30	5	1,000	6000	
Feed - 1	143	5	10,000	286000	281,000
Feed - 2	138	5	10,000	276000	

May 1, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	18	5	10,000	36000	38,000
L1 - 2	20	5	10,000	40000	
L2 - 1	74	5	10,000	148000	139,000
L2 - 2	65	5	10,000	130000	
L3 - 1	40	5	10,000	80000	72,000
L3 - 2	32	5	10,000	64000	
L4 - 1	18	5	1,000	3600	3,500
L4 - 2	17	5	1,000	3400	
Feed - 1	138	5	10,000	276000	272,000
Feed - 2	134	5	10,000	268000	

May 5, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	10	5	10,000	20000	18,000
L1 - 2	8	5	10,000	16000	
L2 - 1	73	5	10,000	146000	126,000
L2 - 2	53	5	10,000	106000	
L3 - 1	41	5	10,000	82000	67,000
L3 - 2	26	5	10,000	52000	
L4 - 1	26	5	1,000	5200	5,100
L4 - 2	25	5	1,000	5000	
Feed - 1	233	5	10,000	466000	487,000
Feed - 2	254	5	10,000	508000	

May 12, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	1	5	10,000	2000	6,000
L1 - 2	5	5	10,000	10000	
L2 - 1	N/A	5	10,000		56,000
L2 - 2	28	5	10,000	56000	
L3 - 1	17	5	10,000	34000	38,000
L3 - 2	21	5	10,000	42000	
L4 - 1	N/A	5	1,000		2,600
L4 - 2	13	5	1,000	2600	
Feed - 1	173	5	10,000	346000	321,000
Feed - 2	148	5	10,000	296000	

June 10, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	7	5	10,000	14000	12,000
L1 - 2	5	5	10,000	10000	
L2 - 1	81	5	10,000	162000	161,000
L2 - 2	80	5	10,000	160000	
L3 - 1	32	5	10,000	64000	61,000
L3 - 2	29	5	10,000	58000	
L4 - 1	34	5	1,000	6800	8,500
L4 - 2	51	5	1,000	10200	
Feed - 1	222	5	10,000	444000	522,000
Feed - 2	300	5	10,000	600000	

PHASE 3 – Pre-treatment columns

July 5, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	38	5	D3	1,000	13.23	574.5606	446
L1 - 2	21	5	D3	1,000		317.5203	
L2 - 1	65	5	D3	1,000	12.98	1001.155	986
L2 - 2	63	5	D3	1,000		970.3504	
L3 - 1	66	5	D3	1,000	12.14	1087.539	1,022
L3 - 2	58	5	D3	1,000		955.7158	
L4 - 1	26	5	D4	10,000	29.31	1774.29	1,774
L4 - 2	26	5	D4	10,000		1774.29	
Feed - 1	166	5	D4	10,000	13.25	25061.33	24,306
Feed - 2	156	5	D4	10,000		23551.61	

July 7, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	27	5	D3	1,000	14.46	373.5732	387
L1 - 2	29	5	D3	1,000		401.2452	
L2 - 1	58	5	D3	1,000	13.78	841.7997	835
L2 - 2	57	5	D3	1,000		827.2859	
L3 - 1	40	5	D3	1,000	15.15	528.14	535
L3 - 2	41	5	D3	1,000		541.3435	
L4 - 1	9	5	D3	1,000	12.91	139.3998	155
L4 - 2	11	5	D3	1,000		170.3775	
Feed - 1	186	5	D4	10,000	17.41	21370.1	21,772
Feed - 2	193	5	D4	10,000		22174.35	

July 14, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	80	5	D3	1,000	12.13	1319.588	1,320
L1 - 2	80	5	D3	1,000		1319.588	
L2 - 1	32	5	D3	1,000	12.14	527.2915	560
L2 - 2	36	5	D3	1,000		593.2029	
L3 - 1	67	5	D3	1,000	12.34	1086.34	1,103
L3 - 2	69	5	D3	1,000		1118.768	
L4 - 1	8	5	D3	1,000	8.80	181.8182	182
L4 - 2	8	5	D3	1,000		181.8182	
Feed - 1	111	5	D4	10,000	18.37	12086.57	12,413
Feed - 2	117	5	D4	10,000		12739.89	

July 26, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	89	5	D3	1,000	13.25	1343.65	1,185
L1 - 2	68	5	D3	1,000		1026.609	
L2 - 1	48	5	D3	1,000	12.59	762.5099	755
L2 - 2	47	5	D3	1,000		746.6243	
L3 - 1	97	5	D3	1,000	13.54	1432.263	1,344
L3 - 2	85	5	D3	1,000		1255.076	
L4 - 1	26	5	D3	1,000	16.01	324.8477	412
L4 - 2	40	5	D3	1,000		499.7657	
Feed - 1	240	5	D4	10,000	19.33	24835.08	24,835
Feed - 2	240	5	D4	10,000		24835.08	

August 1, 2005 - August 2, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	25	5	D3	1,000	18.15	275.52	430
L1 - 2	53	5	D3	1,000		584.1025	
L2 - 1	27	5	D3	1,000	19.67	274.46	264
L2 - 2	25	5	D3	1,000		254.1296	
L3 - 1	35	5	D3	1,000	19.96	350.7453	436
L3 - 2	52	5	D3	1,000		521.1074	
L4 - 1	11	5	D3	1,000	19.70	111.6893	168
L4 - 2	22	5	D3	1,000		223.3786	
Feed - 1	44	5	D4	10,000	20.93	4204.491	4,730
Feed - 2	55	5	D4	10,000		5255.614	

August 8, 2005 - August 9, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	97	5	D3	1,000	21.06	921.287	917
L1 - 2	96	5	D3	1,000		911.7891	
L2 - 1	89	5	D3	1,000	17.84	997.618	947
L2 - 2	80	5	D3	1,000		896.7353	
L3 - 1	173	5	D3	1,000	18.78	1842.386	1,816
L3 - 2	168	5	D3	1,000		1789.137	
L4 - 1	108	5	D3	1,000	18.42	1172.638	1,292
L4 - 2	130	5	D3	1,000		1411.509	
Feed - 1	169	5	D4	10,000	19.62	17229.51	17,382
Feed - 2	172	5	D4	10,000		17535.36	

August 12, 2005 - August 13, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L3 - 1	127	7	D3	1,000	17.86	1015.695	777
L3 - 2	125	13	D3	1,000		538.3	
L4 - 1	516	8	D3	1,000	17.39	3710.095	9,189
L4 - 2	765	3	D3	1,000		14667.82	
Feed - 1	101	10	D4	10,000	19.70	5126.904	6,371
Feed - 2	150	10	D4	10,000		7614.213	

July 5, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	38	5	1,000	7600	5,900
L1 - 2	21	5	1,000	4200	
L2 - 1	65	5	1,000	13000	12,800
L2 - 2	63	5	1,000	12600	
L3 - 1	66	5	1,000	13200	12,400
L3 - 2	58	5	1,000	11600	
L4 - 1	26	5	10,000	52000	52,000
L4 - 2	26	5	10,000	52000	
Feed - 1	166	5	10,000	332000	322,000
Feed - 2	156	5	10,000	312000	

July 7, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	27	5	1,000	5400	5,600
L1 - 2	29	5	1,000	5800	
L2 - 1	58	5	1,000	11600	11,500
L2 - 2	57	5	1,000	11400	
L3 - 1	40	5	1,000	8000	8,100
L3 - 2	41	5	1,000	8200	
L4 - 1	9	5	1,000	1800	2,000
L4 - 2	11	5	1,000	2200	
Feed - 1	186	5	10,000	372000	379,000
Feed - 2	193	5	10,000	386000	

July 14, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	80	5	1,000	16000	16,000
L1 - 2	80	5	1,000	16000	
L2 - 1	32	5	1,000	6400	6,800
L2 - 2	36	5	1,000	7200	
L3 - 1	67	5	1,000	13400	13,600
L3 - 2	69	5	1,000	13800	
L4 - 1	8	5	1,000	1600	1,600
L4 - 2	8	5	1,000	1600	
Feed - 1	111	5	10,000	222000	228,000
Feed - 2	117	5	10,000	234000	

July 26, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	89	5	1,000	17800	15,700
L1 - 2	68	5	1,000	13600	
L2 - 1	48	5	1,000	9600	9,500
L2 - 2	47	5	1,000	9400	
L3 - 1	97	5	1,000	19400	18,200
L3 - 2	85	5	1,000	17000	
L4 - 1	26	5	1,000	5200	6,600
L4 - 2	40	5	1,000	8000	
Feed - 1	240	5	10,000	480000	480,000
Feed - 2	240	5	10,000	480000	

August 1, 2005 - August 2, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	25	5	1,000	5000	7,800
L1 - 2	53	5	1,000	10600	
L2 - 1	27	5	1,000	5400	5,200
L2 - 2	25	5	1,000	5000	
L3 - 1	35	5	1,000	7000	8,700
L3 - 2	52	5	1,000	10400	
L4 - 1	11	5	1,000	2200	3,300
L4 - 2	22	5	1,000	4400	
Feed - 1	44	5	10,000	88000	99,000
Feed - 2	55	5	10,000	110000	

August 8, 2005 - August 9, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	97	5	1,000	19400	19,300
L1 - 2	96	5	1,000	19200	
L2 - 1	89	5	1,000	17800	16,900
L2 - 2	80	5	1,000	16000	
L3 - 1	173	5	1,000	34600	34,100
L3 - 2	168	5	1,000	33600	
L4 - 1	108	5	1,000	21600	23,800
L4 - 2	130	5	1,000	26000	
Feed - 1	169	5	10,000	338000	341,000
Feed - 2	172	5	10,000	344000	

August 12, 2005 - August 13, 2005

	Count	Volume	Factor	C/100mL	Average
L3 - 1	127	7	1,000	18142.9	13,879
L3 - 2	125	13	1,000	9615.38	
L4 - 1	516	8	1,000	64500	159,750
L4 - 2	765	3	1,000	255000	
Feed - 1	101	10	10,000	101000	125,500
Feed - 2	150	10	10,000	150000	

Oct. 3-05

E. Coli

per 100 mL

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	9	5	D3	1,000	14.62	123098	198,324	900000	1,450,000
L1 - 2	20	5	D3	1,000		273551		2000000	
L2 - 1	[redacted]	5	D3	1,000	14.73	244316.3	223,957	1800000	1,650,000
L2 - 2	[redacted]	5	D3	1,000		203596.9		1500000	
L3 - 1	50	5	D3	1,000	15.70	636841.3	815,157	5000000	6,400,000
L3 - 2	78	5	D3	1,000		993472.4		7800000	
L4 - 1	84	5	D3	1,000	25.78	651731.2	752,594	8400000	9,700,000
L4 - 2	110	5	D3	1,000		853457.5		11000000	
Feed - 1	[redacted]	5	D3	1,000	15.57	1078998	1,123,956	8400000	8,750,000
Feed - 2	[redacted]	5	D3	1,000		1168915		9100000	

Oct. 12-05

per 100 ml

E. Coli

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	255	5	D3	1,000	19.09	2671906	2,619,515	25500000	25,000,000
L1 - 2	245	5	D3	1,000		2567125		24500000	
L2 - 1	215	5	D3	1,000	17.31	2484831	2,687,085	21500000	23,250,000
L2 - 2	250	5	D3	1,000		2889338		25000000	
L3 - 1		5	D3	1,000	18.10	961326	1,099,448	8700000	9,950,000
L3 - 2		5	D3	1,000		1237569		11200000	
L4 - 1	230	5	D3	1,000	24.60	1869729	1,707,144	23000000	21,000,000
L4 - 2	190	5	D3	1,000		1544558		19000000	
Feed - 1		5	D3	10,000	20.29	14986443	15,627,311	1.52E+08	158,500,000
Feed - 2		5	D3	10,000		16268178		1.65E+08	

Oct. 23-05

per 100 ml

E. Coli

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	41	5	D4	10,000	16.63	4929662	4,268,366	41000000	35,500,000
L1 - 2	30	5	D4	10,000		3607070		30000000	
L2 - 1	27	5	D4	10,000	16.62	3249880	3,610,977	27000000	30,000,000
L2 - 2	33	5	D4	10,000		3972075		33000000	
L3 - 1	86	5	D4	10,000	16.96	10142706	10,496,521	86000000	89,000,000
L3 - 2	92	5	D4	10,000		10850336		92000000	
L4 - 1	42	5	D4	10,000	25.60	3281250	3,320,313	42000000	42,500,000
L4 - 2	43	5	D4	10,000		3359375		43000000	
Feed - 1	48	5	D5	100,000	21.54	44568245	46,889,508	4.8E+08	505,000,000
Feed - 2	53	5	D5	100,000		49210771		5.3E+08	

PHASE 3 – Digesters

August 9, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
Control-1	TMTC	5	D2	100	20.61	#VALUE!	
Control-2	TMTC	5	D2	100		#VALUE!	
Control-1	20	5	D3	1,000	20.61	194057	184,354
Control-2	18	5	D3	1,000		174651.3	

August 11, 2005 - August 12, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	3	5	D2	100	18.04	3326.403	3,326
L1 - 2		5	D2	100			
L2 - 1	0	5	D2	100	13.41	0	0
L2 - 2		5	D2	100			
L3 - 1	30	5	D2	100	16.62	36106.51	36,107
L3 - 2		5	D2	100			
L4 - 1	50	5	D2	100	16.76	59665.87	59,666
L4 - 2		5	D2	100			
Control-1	44	5	D2	100	165.13	5329.035	5,329
Control-2		5	D2	100			

Sept. 13, 2005 - Sept. 14, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	56	5	D2	100	61.46	18223.92	15,946
L1 - 2	42	5	D2	100		13667.94	
L2 - 1		5	D1	10	57.75	0	0
L2 - 2		5	D1	10		0	
L3 - 1	86	5	D2	100	58.80	29250.11	26,019
L3 - 2	67	5	D2	100		22787.88	
L4 - 1	15	5	D2	100	60.51	4957.604	5,619
L4 - 2	19	5	D2	100		6279.632	
Control-1	60	5	D2	100	65.28	18382.1	18,229
Control-2	59	5	D2	100		18075.73	

September 15, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	83	5	D2	100	18.27	90859.33	85,386
L1 - 2	73	5	D2	100		79912.42	
L2 - 1	7	5	D1	10	16.15	867.0073	743
L2 - 2	5	5	D1	10		619.2909	
L3 - 1	29	5	D2	100	16.02	36204.74	32,459
L3 - 2	23	5	D2	100		28714.11	
L4 - 1	37	5	D1	10	15.95	4640.953	4,766
L4 - 2	39	5	D1	10		4891.816	
Control-1	56	5	D2	100	15.69	71405.8	70,131
Control-2	54	5	D2	100		68855.59	

Sept. 27-05

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	61	5	D2	100	18.36	66466.9	71,915
L1 - 2	71	5	D2	100		77363.12	
L2 - 1	9	5	D1	10	15.94	1129.058	1,192
L2 - 2	10	5	D1	10		1254.508	
L3 - 1	26	5	D2	100	16.60	31315.87	36,134
L3 - 2	34	5	D2	100		40951.52	
L4 - 1	5	5	D2	100	15.63	6396.929	5,757
L4 - 2	4	5	D2	100		5117.544	
Feed - 1	112	5	D2	100	16.63	134736.8	117,293
Feed - 2	83	5	D2	100		99849.62	

October 3, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	63	5	D2	100	18.04	69854.47	69,854
L1 - 2		5					
L2 - 1	17	5	D2	100	13.41	25363.67	25,364
L2 - 2		5					
L3 - 1	280	5	D2	100	16.62	336994.1	336,994
L3 - 2		5					
L4 - 1	58	5	D3	1,000	16.76	692124.1	692,124
L4 - 2		5					
Feed - 1	350	5	D3	1,000	17.07	4101963	4,101,963
Feed - 2		5					

October 6, 2005

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	260	5	D3	1,000	18.27	2846975	2,846,975
L1 - 2		5	D3	1,000			
L2 - 1	14	5	D3	1,000	11.83	236786.5	236,786
L2 - 2		5	D3	1,000			
L3 - 1	200	5	D3	1,000	17.38	2301496	2,301,496
L3 - 2		5	D3	1,000			
L4 - 1	32	5	D3	1,000	17.04	375586.9	375,587
L4 - 2		5	D3	1,000			
Feed - 1	250	5	D3	1,000	16.81	2973978	2,973,978
Feed - 2		5	D3	1,000			

Oct. 12-05

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	210	5	D3	1,000	17.81	2358557	2,403,482
L1 - 2	218	5	D3	1,000		2448407	
L2 - 1	32	5	D2	100	11.99	53366.69	69,210
L2 - 2	51	5	D2	100		85053.16	
L3 - 1	13	5	D3	1,000	15.68	165869.2	197,767
L3 - 2	18	5	D3	1,000		229665.1	
L4 - 1	20	5	D3	1,000	16.63	240529.2	270,595
L4 - 2	25	5	D3	1,000		300661.5	
Control-1	28	5	D3	1,000	16.87	331950.2	373,444
Control-2	35	5	D3	1,000		414937.8	

Oct. 16-05

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	97	5	D3	1,000	20.01	969394.1	859,463
L1 - 2	75	5	D3	1,000		749531.5	
L2 - 1	42	5	D2	100	13.57	61912.66	61,913
L2 - 2	42	5	D2	100		61912.66	
L3 - 1	9	5	D3	1,000	17.19	104681.6	75,603
L3 - 2	4	5	D3	1,000		46525.15	
L4 - 1	[redacted]	5	D2	100	18.75	106652.4	106,652
L4 - 2		5	D2	100		106652.4	
Control-1	4	5	D3	1,000	18.27	43787.63	43,788
Control-2	4	5	D3	1,000		43787.63	

Oct. 19-05

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	80	5	D3	1,000	20.53	779442.2	677,140
L1 - 2	59	5	D3	1,000		574838.6	
L2 - 1	125	5	D2	100	14.29	174978.1	174,978
L2 - 2		5	D2	100			
L3 - 1	48	5	D2	100	15.88	60462.92	54,165
L3 - 2	38	5	D2	100		47866.48	
L4 - 1	40	5	D2	100	19.01	42077.58	42,604
L4 - 2	41	5	D2	100		43129.52	
Control-1	134	5	D2	100	18.26	146748.8	145,654
Control-2	132	5	D2	100		144558.5	

Oct. 23-05

E. Coli

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	4.5	5	D2	100	17.35	5186.573	4,841
L1 - 2	39	5	D1	10		4495.03	
L2 - 1	23	5	D2	100	14.04	32763.53	28,490
L2 - 2	17	5	D2	100		24216.52	
L3 - 1	45	5	D3	1,000	12.78	704363.1	641,753
L3 - 2	37	5	D3	1,000		579143	
L4 - 1	13	5	D2	100	20.81	12497	11,536
L4 - 2	11	5	D2	100		10574.38	
Control-1	39	5	D2	100	16.74	46608.9	54,377
Control-2	52	5	D2	100		62145.2	

16) *Salmonella* spp. Data and Calculated Concentrations

February 27, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	3	5	D3	1,000	19.04	31.51674	42
L1 - 2	5	5	D3	1,000		52.52791	
L2 - 1	6	5	D3	1,000	19.88	60.36217	75
L2 - 2	9	5	D3	1,000		90.54326	
L3 - 1	15	5	D3	1,000	18.90	158.7722	164
L3 - 2	16	5	D3	1,000		169.357	
L4 - 1	10	5	D3	1,000	20.57	97.25261	112
L4 - 2	13	5	D3	1,000		126.4284	
Feed - 1	27	5	D3	1,000	18.15	297.4797	281
Feed - 2	24	5	D3	1,000		264.4264	

March 9, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	1	5	D3	1,000	11.87	16.8563	25
L1 - 2	2	5	D3	1,000		33.7126	
L2 - 1	2	5	D3	1,000	12.08	33.11944	33
L2 - 2	2	5	D3	1,000		33.11944	
L3 - 1	6	5	D3	1,000	12.22	98.23987	98
L3 - 2	6	5	D3	1,000		98.23987	
L4 - 1	7	5	D3	1,000	12.29	113.9138	114
L4 - 2	7	5	D3	1,000		113.9138	
Feed - 1	12	5	D3	1,000	15.35	156.3263	130
Feed - 2	8	5	D3	1,000		104.2176	

March 11, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	9	5	D3	1,000	14.64	122.9928	123
L1 - 2		5	D3	1,000			
L2 - 1	3	5	D3	1,000	14.20	42.24608	42
L2 - 2		5	D3	1,000			
L3 - 1	18	5	D3	1,000	14.20	253.5211	254
L3 - 2		5	D3	1,000			
L4 - 1	16	5	D3	1,000	14.08	227.2727	227
L4 - 2		5	D3	1,000			
Feed - 1	32	5	D3	1,000	19.52	327.9529	328
Feed - 2		5	D3	1,000			

March 13, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	4	5	D3	1,000	16.79	47.6616	71
L1 - 2	8	5	D3	1,000		95.32321	
L2 - 1	7	5	D3	1,000	17.14	81.66837	117
L2 - 2	13	5	D3	1,000		151.6698	
L3 - 1	14	5	D3	1,000	16.93	165.3625	224
L3 - 2	24	5	D3	1,000		283.4785	
L4 - 1	26	5	D3	1,000	17.44	298.2079	327
L4 - 2	31	5	D3	1,000		355.5556	
Feed - 1	35	5	D3	1,000	17.04	410.7379	440
Feed - 2	40	5	D3	1,000		469.4147	

March 20, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	41	5	D2	100	17.96	45.66337	68
L1 - 2	82	5	D2	100		91.32674	
L2 - 1	16	5	D3	1,000	19.05	167.957	194
L2 - 2	21	5	D3	1,000		220.4435	
L3 - 1	17	5	D3	1,000	19.40	175.3029	253
L3 - 2	32	5	D3	1,000		329.982	
L4 - 1	18	5	D3	1,000	18.99	189.5984	216
L4 - 2	23	5	D3	1,000		242.2646	
Feed - 1	50	5	D3	1,000	18.23	548.6968	494
Feed - 2	40	5	D3	1,000		438.9575	

March 23, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	43	5	D2	100	18.97	45.33474	33
L1 - 2	19	5	D2	100		20.03163	
L2 - 1	24	5	D3	1,000	19.49	246.2486	246
L2 - 2	24	5	D3	1,000		246.2486	
L3 - 1	30	5	D3	1,000	20.62	290.9091	281
L3 - 2	28	5	D3	1,000		271.5152	
L4 - 1	18	5	D3	1,000	20.12	178.9264	204
L4 - 2	23	5	D3	1,000		228.6282	
Feed - 1	25	5	D3	1,000	20.53	243.5757	234
Feed - 2	23	5	D3	1,000		224.0896	

March 25, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	12	5	D3	1,000	18.77	127.8806	117
L1 - 2	10	5	D3	1,000		106.5672	
L2 - 1	24	5	D3	1,000	18.82	255.0478	244
L2 - 2	22	5	D3	1,000		233.7938	
L3 - 1	30	5	D3	1,000	19.58	306.396	296
L3 - 2	28	5	D3	1,000		285.9696	
L4 - 1	29	5	D3	1,000	19.00	305.223	253
L4 - 2	19	5	D3	1,000		199.9737	
Feed - 1	35	5	D3	1,000	18.79	372.5882	415
Feed - 2	43	5	D3	1,000		457.7512	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

	Date	
Salmonella (CFU/mL)	L1	
	L2	
	L3	
	L4	
	Feed	

	Date	
Salmonella (CFU/100 mL)	L1	
	L2	
	L3	
	L4	
	Feed	

PHASE 2

April 20, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	6	5	D3	1,000	21.54	55.71677	51
L1 - 2	5	5	D3	1,000		46.43064	
L2 - 1	10	5	D3	1,000	23.27	85.93834	73
L2 - 2	7	5	D3	1,000		60.15684	
L3 - 1	12	5	D3	1,000	22.87	104.941	109
L3 - 2	13	5	D3	1,000		113.6861	
L4 - 1	15	5	D3	1,000	23.01	130.4064	152
L4 - 2	20	5	D3	1,000		173.8752	
Feed - 1	35	5	D3	1,000	21.96	318.7251	282
Feed - 2	27	5	D3	1,000		245.8736	

April 22, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	14	5	D3	1,000	22.49	124.4859	116
L1 - 2	12	5	D3	1,000		106.7022	
L2 - 1	18	5	D3	1,000	26.32	136.7521	144
L2 - 2	20	5	D3	1,000		151.9468	
L3 - 1	13	5	D3	1,000	24.61	105.6267	89
L3 - 2	9	5	D3	1,000		73.12614	
L4 - 1	12	5	D3	1,000	24.76	96.94032	109
L4 - 2	15	5	D3	1,000		121.1754	
Feed - 1	6	5	D3	1,000	22.17	54.1272	90
Feed - 2	14	5	D3	1,000		126.2968	

April 28, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	6	5	D3	1,000	20.53	58.44393	58
L1 - 2	6	5	D3	1,000		58.44393	
L2 - 1	8	5	D3	1,000	20.41	78.41215	103
L2 - 2	13	5	D3	1,000		127.4198	
L3 - 1	20	5	D3	1,000	20.59	194.3162	155
L3 - 2	12	5	D3	1,000		116.5897	
L4 - 1	8	5	D3	1,000	20.78	76.98785	77
L4 - 2	8	5	D3	1,000		76.98785	
Feed - 1	19	5	D3	1,000	19.49	195.0218	174
Feed - 2	15	5	D3	1,000		153.9646	

May 1, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	5	5	D3	1,000	23.12	43.2526	43
L1 - 2	5	5	D3	1,000		43.2526	
L2 - 1	7	5	D3	1,000	23.09	60.63887	35
L2 - 2	1	5	D3	1,000		8.662696	
L3 - 1	9	5	D3	1,000	23.02	78.20137	52
L3 - 2	3	5	D3	1,000		26.06712	
L4 - 1	4	5	D3	1,000	24.28	32.94893	33
L4 - 2	4	5	D3	1,000		32.94893	
Feed - 1	9	5	D3	1,000	25.36	70.98492	87
Feed - 2	13	5	D3	1,000		102.5338	

May 5, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	1	5	D3	1,000	21.41	9.343611	14
L1 - 2	2	5	D3	1,000		18.68722	
L2 - 1	14	5	D3	1,000	22.30	125.5324	103
L2 - 2	9	5	D3	1,000		80.69939	
L3 - 1	13	5	D3	1,000	21.06	123.4568	123
L3 - 2	13	5	D3	1,000		123.4568	
L4 - 1	11	5	D3	1,000	22.20	99.07678	77
L4 - 2	6	5	D3	1,000		54.04188	
Feed - 1	21	5	D3	1,000	23.75	176.8049	215
Feed - 2	30	5	D3	1,000		252.5784	

May 12, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	3	5	D3	1,000	17.35	34.58712	29
L1 - 2	2	5	D3	1,000		23.05808	
L2 - 1	2	5	D3	1,000	17.55	22.79202	46
L2 - 2	6	5	D3	1,000		68.37607	
L3 - 1	2	5	D3	1,000	17.72	22.57018	34
L3 - 2	4	5	D3	1,000		45.14036	
L4 - 1	5	5	D3	1,000	17.80	56.17189	45
L4 - 2	3	5	D3	1,000		33.70313	
Feed - 1	21	5	D3	1,000	16.49	254.6612	236
Feed - 2	18	5	D3	1,000		218.281	

June 10, 2005

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	3	5	D3	1,000	17.71	33.87916	40
L1 - 2	4	5	D3	1,000		45.17222	
L2 - 1	35	5	D3	1,000	14.63	478.4689	451
L2 - 2	31	5	D3	1,000		423.7867	
L3 - 1	13	5	D3	1,000	13.96	186.2131	236
L3 - 2	20	5	D3	1,000		286.4816	
L4 - 1	28	5	D3	1,000	18.67	299.9063	321
L4 - 2	32	5	D3	1,000		342.75	
Feed - 1	45	5	D3	1,000	14.86	605.6528	572
Feed - 2	40	5	D3	1,000		538.358	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

April 20, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	6	5	1,000	1200	1,100
L1 - 2	5	5	1,000	1000	
L2 - 1	10	5	1,000	2000	1,700
L2 - 2	7	5	1,000	1400	
L3 - 1	12	5	1,000	2400	2,500
L3 - 2	13	5	1,000	2600	
L4 - 1	15	5	1,000	3000	3,500
L4 - 2	20	5	1,000	4000	
Feed - 1	35	5	1,000	7000	6,200
Feed - 2	27	5	1,000	5400	

April 22, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	14	5	1,000	2800	2,600
L1 - 2	12	5	1,000	2400	
L2 - 1	18	5	1,000	3600	3,800
L2 - 2	20	5	1,000	4000	
L3 - 1	13	5	1,000	2600	2,200
L3 - 2	9	5	1,000	1800	
L4 - 1	12	5	1,000	2400	2,700
L4 - 2	15	5	1,000	3000	
Feed - 1	6	5	1,000	1200	2,000
Feed - 2	14	5	1,000	2800	

April 28, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	6	5	1,000	1200	1,200
L1 - 2	6	5	1,000	1200	
L2 - 1	8	5	1,000	1600	2,100
L2 - 2	13	5	1,000	2600	
L3 - 1	20	5	1,000	4000	3,200
L3 - 2	12	5	1,000	2400	
L4 - 1	8	5	1,000	1600	1,600
L4 - 2	8	5	1,000	1600	
Feed - 1	19	5	1,000	3800	3,400
Feed - 2	15	5	1,000	3000	

May 1, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	5	5	1,000	1000	1,000
L1 - 2	5	5	1,000	1000	
L2 - 1	7	5	1,000	1400	800
L2 - 2	1	5	1,000	200	
L3 - 1	9	5	1,000	1800	1,200
L3 - 2	3	5	1,000	600	
L4 - 1	4	5	1,000	800	800
L4 - 2	4	5	1,000	800	
Feed - 1	9	5	1,000	1800	2,200
Feed - 2	13	5	1,000	2600	

May 5, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	1	5	1,000	200	300
L1 - 2	2	5	1,000	400	
L2 - 1	14	5	1,000	2800	2,300
L2 - 2	9	5	1,000	1800	
L3 - 1	13	5	1,000	2600	2,600
L3 - 2	13	5	1,000	2600	
L4 - 1	11	5	1,000	2200	1,700
L4 - 2	6	5	1,000	1200	
Feed - 1	21	5	1,000	4200	5,100
Feed - 2	30	5	1,000	6000	

May 12, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	3	5	1,000	600	500
L1 - 2	2	5	1,000	400	
L2 - 1	2	5	1,000	400	800
L2 - 2	6	5	1,000	1200	
L3 - 1	2	5	1,000	400	600
L3 - 2	4	5	1,000	800	
L4 - 1	5	5	1,000	1000	800
L4 - 2	3	5	1,000	600	
Feed - 1	21	5	1,000	4200	3,900
Feed - 2	18	5	1,000	3600	

June 10, 2005

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	3	5	1,000	600	700
L1 - 2	4	5	1,000	800	
L2 - 1	35	5	1,000	7000	6,600
L2 - 2	31	5	1,000	6200	
L3 - 1	13	5	1,000	2600	3,300
L3 - 2	20	5	1,000	4000	
L4 - 1	28	5	1,000	5600	6,000
L4 - 2	32	5	1,000	6400	
Feed - 1	45	5	1,000	9000	8,500
Feed - 2	40	5	1,000	8000	

PHASE 3 – Pre-treatment columns

July 5, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	8	5	D2	100	13.23	12.09601	12
L1 - 2	8	5	D2	100		12.09601	
L2 - 1	26	5	D2	100	12.98	40.04621	35
L2 - 2	20	5	D2	100		30.80477	
L3 - 1	19	5	D2	100	12.14	31.30793	26
L3 - 2	12	5	D2	100		19.77343	
L4 - 1	38	5	D2	100	29.31	25.93193	24
L4 - 2	32	5	D2	100		21.83741	
Feed - 1	44	5	D3	1,000	13.25	664.2763	762
Feed - 2	57	5	D3	1,000		860.5397	

July 7, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	15	5	D2	100	14.46	20.75406	23
L1 - 2	18	5	D2	100		24.90488	
L2 - 1	11	5	D2	100	13.78	15.96517	11
L2 - 2	4	5	D2	100		5.805515	
L3 - 1	16	5	D2	100	15.15	21.1256	20
L3 - 2	14	5	D2	100		18.4849	
L4 - 1	10	5	D2	100	12.91	15.48887	11
L4 - 2	4	5	D2	100		6.195547	
Feed - 1	16	5	D3	1,000	17.41	183.8288	201
Feed - 2	19	5	D3	1,000		218.2967	

July 14, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	59	5	D2	100	12.13	97.31959	80
L1 - 2	38	5	D2	100		62.68041	
L2 - 1	54	5	D2	100	12.14	88.98043	88
L2 - 2	53	5	D2	100		87.33265	
L3 - 1	61	5	D2	100	12.34	98.90555	109
L3 - 2	73	5	D2	100		118.3624	
L4 - 1	9	5	D2	100	8.80	20.45455	34
L4 - 2	21	5	D2	100		47.72727	
Feed - 1	70	5	D3	1,000	18.37	762.2159	670
Feed - 2	53	5	D3	1,000		577.1063	

July 26, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	32	5	D2	100	13.25	48.311	54
L1 - 2	40	5	D2	100		60.38875	
L2 - 1	43	5	D2	100	12.59	68.30818	64
L2 - 2	38	5	D2	100		60.36537	
L3 - 1	49	5	D2	100	13.54	72.35142	72
L3 - 2	48	5	D2	100		70.87486	
L4 - 1	21	5	D2	100	16.01	26.2377	25
L4 - 2	19	5	D2	100		23.73887	
Feed - 1	72	5	D3	1,000	19.33	745.0524	745
Feed - 2	72	5	D3	1,000		745.0524	

August 1, 2005 - August 2, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	65	5	D2	100	18.15	71.63521	78
L1 - 2	76	5	D2	100		83.75809	
L2 - 1	5	5	D2	100	19.67	5.082592	4
L2 - 2	2	5	D2	100		2.033037	
L3 - 1	54	5	D2	100	19.96	54.11499	51
L3 - 2	47	5	D2	100		47.10009	
L4 - 1	13	5	D2	100	19.70	13.19964	12
L4 - 2	11	5	D2	100		11.16893	
Feed - 1	53	5	D3	1,000	20.93	506.4501	511
Feed - 2	54	5	D3	1,000		516.0057	

August 8, 2005 - August 9, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	31	5	D2	100	21.06	29.44319	29
L1 - 2	31	5	D2	100		29.44319	
L2 - 1	38	5	D2	100	17.84	42.59493	44
L2 - 2	40	5	D2	100		44.83677	
L3 - 1	39	5	D2	100	18.78	41.53355	42
L3 - 2		5	D2	100			
L4 - 1	24	5	D2	100	18.42	26.05863	29
L4 - 2	30	5	D2	100		32.57329	
Feed - 1	22	5	D3	1,000	19.62	224.2895	204
Feed - 2	18	5	D3	1,000		183.5096	

August 12, 2005 - August 13, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L3 - 1	2	5	D2	100	17.86	2.239328	4
L3 - 2	6	5	D2	100		6.717985	
L4 - 1	4	5	D2	100	17.39	4.601668	6
L4 - 2	7	5	D2	100		8.052919	
Feed - 1	6	5	D3	1,000	19.70	60.91371	61
Feed - 2	6	5	D3	1,000		60.91371	

July 5, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	8	5	100	160	160
L1 - 2	8	5	100	160	
L2 - 1	26	5	100	520	460
L2 - 2	20	5	100	400	
L3 - 1	19	5	100	380	310
L3 - 2	12	5	100	240	
L4 - 1	38	5	100	760	700
L4 - 2	32	5	100	640	
Feed - 1	44	5	1,000	8800	10,100
Feed - 2	57	5	1,000	11400	

July 7, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	15	5	100	300	330
L1 - 2	18	5	100	360	
L2 - 1	11	5	100	220	150
L2 - 2	4	5	100	80	
L3 - 1	16	5	100	320	300
L3 - 2	14	5	100	280	
L4 - 1	10	5	100	200	140
L4 - 2	4	5	100	80	
Feed - 1	16	5	1,000	3200	3,500
Feed - 2	19	5	1,000	3800	

July 14, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	59	5	100	1180	970
L1 - 2	38	5	100	760	
L2 - 1	54	5	100	1080	1,070
L2 - 2	53	5	100	1060	
L3 - 1	61	5	100	1220	1,340
L3 - 2	73	5	100	1460	
L4 - 1	9	5	100	180	300
L4 - 2	21	5	100	420	
Feed - 1	70	5	1,000	14000	12,300
Feed - 2	53	5	1,000	10600	

July 26, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	32	5	100	640	720
L1 - 2	40	5	100	800	
L2 - 1	43	5	100	860	810
L2 - 2	38	5	100	760	
L3 - 1	49	5	100	980	970
L3 - 2	48	5	100	960	
L4 - 1	21	5	100	420	400
L4 - 2	19	5	100	380	
Feed - 1	72	5	1,000	14400	14,400
Feed - 2	72	5	1,000	14400	

August 1, 2005 - August 2, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	65	5	100	1300	1,410
L1 - 2	76	5	100	1520	
L2 - 1	5	5	100	100	70
L2 - 2	2	5	100	40	
L3 - 1	54	5	100	1080	1,010
L3 - 2	47	5	100	940	
L4 - 1	13	5	100	260	240
L4 - 2	11	5	100	220	
Feed - 1	53	5	1,000	10600	10,700
Feed - 2	54	5	1,000	10800	

August 8, 2005 - August 9, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	31	5	100	620	620
L1 - 2	31	5	100	620	
L2 - 1	38	5	100	760	780
L2 - 2	40	5	100	800	
L3 - 1	39	5	100	780	390
L3 - 2		5	100	0	
L4 - 1	24	5	100	480	540
L4 - 2	30	5	100	600	
Feed - 1	22	5	1,000	4400	4,000
Feed - 2	18	5	1,000	3600	

August 12, 2005 - August 13, 2005

	Count	Volume	Factor	C/100mL	Average
L3 - 1	2	5	100	40	80
L3 - 2	6	5	100	120	
L4 - 1	4	5	100	80	110
L4 - 2	7	5	100	140	
Feed - 1	6	5	1,000	1200	1,200
Feed - 2	6	5	1,000	1200	

Oct. 3-05

Salmonella

per 100 mL

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	[redacted]	5	D3	1,000	14.62	123098	102,582	900000	750,000
L1 - 2		5	D3	1,000		82065.31		600000	
L2 - 1	[redacted]	5	D3	1,000	14.73	67865.63	95,012	500000	700,000
L2 - 2		5	D3	1,000		122158.1		900000	
L3 - 1	3	5	D3	1,000	15.70	38210.48	57,316	300000	450,000
L3 - 2	6	5	D3	1,000		76420.95		600000	
L4 - 1	20	5	D3	1,000	25.78	155174.1	128,019	2000000	1,650,000
L4 - 2	13	5	D3	1,000		100863.2		1300000	
Feed - 1	[redacted]	5	D4	10,000	15.57	642260.8	642,261	5000000	5,000,000
Feed - 2		5	D4	10,000		642260.8		5000000	

Oct. 12-05

[redacted] per 100 mL [redacted]

Salmonella

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	73	5	D3	1,000	19.09	764898.5	681,074	7300000	6,500,000
L1 - 2	57	5	D3	1,000		597249.5		5700000	
L2 - 1	13	5	D3	1,000	17.31	150245.6	150,246	1300000	1,300,000
L2 - 2	[redacted]	5	D3	1,000		150245.6		1300000	
L3 - 1	[redacted]	5	D3	1,000	18.10	99447.51	121,547	900000	1,100,000
L3 - 2	[redacted]	5	D3	1,000		143646.4		1300000	
L4 - 1	11	5	D3	1,000	24.60	89421.81	69,099	1100000	850,000
L4 - 2	6	5	D3	1,000		48775.53		600000	
Feed - 1	[redacted]	5	D3	1,000	20.29	335223.1	320,434	3400000	3,250,000
Feed - 2	[redacted]	5	D3	1,000		305644.6		3100000	

Oct. 23-05

[redacted] per 100 mL [redacted]

Salmonella

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	17	5	D3	1,000	16.63	204400.6	204,401	1700000	1,700,000
L1 - 2	17	5	D3	1,000		204400.6		1700000	
L2 - 1	14	5	D3	1,000	16.62	168512.3	228,695	1400000	1,900,000
L2 - 2	24	5	D3	1,000		288878.2		2400000	
L3 - 1	38	5	D3	1,000	16.96	448166.1	495,341	3800000	4,200,000
L3 - 2	46	5	D3	1,000		542516.8		4600000	
L4 - 1	22	5	D3	1,000	25.60	171875	152,344	2200000	1,950,000
L4 - 2	17	5	D3	1,000		132812.5		1700000	
Feed - 1	7	5	D4	10,000	21.54	649953.6	928,505	7000000	10,000,000
Feed - 2	13	5	D4	10,000		1207057		13000000	

PHASE 3 –Digesters

August 9, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
Control-1	TMTC	5	D1	10	20.61	#VALUE!	
Control-2	TMTC	5	D1	10		#VALUE!	
Control-1	18	5	D2	100	20.61	17465.13	13,099
Control-2	9	5	D2	100		8732.565	

August 11, 2005 - August 12, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	0	5	D2	100	18.04	0	0
L1 - 2	0	5	D2	100		0	
L2 - 1	0	5	D2	100	13.41	0	0
L2 - 2	0	5	D2	100		0	
L3 - 1	1	5	D2	100	16.62	1203.55	1,204
L3 - 2	1	5	D2	100		1203.55	
L4 - 1	2	5	D2	100	16.76	2386.635	2,387
L4 - 2	2	5	D2	100		2386.635	
Control-1	4	5	D2	100	165.13	484.4577	363
Control-2	2	5	D2	100		242.2288	

Sept. 13, 2005 - Sept. 14, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	55	5	D1	10	61.46	1789.849	1,513
L1 - 2	38	5	D1	10		1236.623	
L2 - 1	1	5	D1	10	57.75	34.63084	87
L2 - 2	4	5	D1	10		138.5233	
L3 - 1	49	5	D1	10	58.80	1666.576	1,241
L3 - 2	24	5	D1	10		816.2821	
L4 - 1	14	5	D1	10	60.51	462.7097	347
L4 - 2	7	5	D1	10		231.3549	
Control-1	30	5	D1	10	65.28	919.105	1,287
Control-2	54	5	D1	10		1654.389	

September 15, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	61	5	D1	10	18.27	6677.614	6,130
L1 - 2	51	5	D1	10		5582.923	
L2 - 1	1	5	D1	10	16.15	123.8582	124
L2 - 2	1	5	D1	10		123.8582	
L3 - 1	29	5	D1	10	16.02	3620.474	3,745
L3 - 2	31	5	D1	10		3870.162	
L4 - 1	6	5	D1	10	15.95	752.587	690
L4 - 2	5	5	D1	10		627.1558	
Control-1	35	5	D1	10	15.69	4462.863	4,973
Control-2	43	5	D1	10		5482.945	

Sept. 27-05

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	38	5	D1	10	18.36	4140.561	4,250
L1 - 2	40	5	D1	10		4358.485	
L2 - 1	1	5	D1	10	15.94	125.4508	63
L2 - 2	0	5	D1	10		0	
L3 - 1	18	5	D1	10	16.60	2168.022	2,168
L3 - 2	18	5	D1	10		2168.022	
L4 - 1	3	5	D1	10	15.63	383.8158	256
L4 - 2	1	5	D1	10		127.9386	
Feed - 1	63	5	D1	10	16.63	7578.947	7,218
Feed - 2	57	5	D1	10		6857.143	

October 3, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	4	5	D2	100	18.04	4435.204	4,435
L1 - 2		5	D2	100			
L2 - 1	24	5	D1	10	13.41	3580.753	3,581
L2 - 2		5	D2	100			
L3 - 1	21	5	D2	100	16.62	25274.56	25,275
L3 - 2		5	D2	100			
L4 - 1	5	5	D2	100	16.76	5966.587	5,967
L4 - 2		5	D2	100			
Feed - 1	56	5	D2	100	17.07	65631.41	65,631
Feed - 2		5	D3	1,000			

October 6, 2005

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	22	5	D3	1,000	18.27	240897.9	240,898
L1 - 2		5	D2	100			
L2 - 1	11	5	D2	100	11.83	18604.65	13,362
L2 - 2	48	5	D1	10		8118.393	
L3 - 1	17	5	D3	100	17.38	19562.72	11,507
L3 - 2	3	5	D2	100		3452.244	
L4 - 1	2	5	D3	1,000	17.04	23474.18	12,324
L4 - 2	1	5	D2	100		1173.709	
Feed - 1	7	5	D3	1,000	16.81	83271.38	57,695
Feed - 2	27	5	D2	100		32118.96	

Oct. 12-05

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	34	5	D3	1,000	17.81	381861.6	359,399
L1 - 2	30	5	D3	1,000		336936.7	
L2 - 1	30.5	5			11.99	5086.512	11,716
L2 - 2	11	5				18344.8	
L3 - 1		5	D1	10	15.68	0	0
L3 - 2		5	D1	10		0	
L4 - 1	7	5	D2	100	16.63	8418.521	10,824
L4 - 2	11	5	D2	100		13229.1	
Control-1	11	5	D2	100	16.87	13040.9	17,783
Control-2	19	5	D2	100		22525.19	

Oct. 16-05

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	36	5	D3	1,000	20.01	359775.1	359,775
L1 - 2	36	5	D3	1,000		359775.1	
L2 - 1	12	5	D1	10	13.57	1768.933	1,474
L2 - 2	8	5	D1	10		1179.289	
L3 - 1	7	5	D2	100	17.19	8141.902	8,142
L3 - 2	7	5	D2	100		8141.902	
L4 - 1	8	5	D2	100	18.75	8532.196	9,065
L4 - 2	9	5	D2	100		9598.72	
Control-1	35	5	D2	100	18.27	38314.18	43,788
Control-2	45	5	D2	100		49261.08	

Oct. 19-05

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	36	5	D3	1,000	20.53	350749	360,492
L1 - 2	38	5	D3	1,000		370235.1	
L2 - 1	1	5	D2	100	14.29	1399.825	2,100
L2 - 2	2	5	D2	100		2799.65	
L3 - 1	5	5	D2	100	15.88	6298.221	5,668
L3 - 2	4	5	D2	100		5038.577	
L4 - 1	14	5	D2	100	19.01	14727.15	12,623
L4 - 2	10	5	D2	100		10519.4	
Control-1	61	5	D2	100	18.26	66803.56	62,423
Control-2	53	5	D2	100		58042.44	

Oct. 23-05

Salmonella

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	2	5	D2	100	17.35	2305.143	4,034
L1 - 2	5	5	D2	100		5762.858	
L2 - 1	8	5	D1	10	14.04	1139.601	783
L2 - 2	3	5	D1	10		427.3504	
L3 - 1	6	5	D1	10	12.78	939.1509	1,644
L3 - 2	3	10	D2	100		2347.877	
L4 - 1	2	5	D1	10	20.81	192.2615	240
L4 - 2	3	5	D1	10		288.3922	
Control-1	9	5	D2	100	16.74	10755.9	7,768
Control-2	4	5	D2	100		4780.4	

17) Clostridium Perfringens Data and Calculated Concentrations

February 27, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	13	0.2	D3	1,000	19.04	3414.314	2,022
L1 - 2	6	0.5	D3	1,000		630.3349	
L2 - 1	12	0.5	D3	1,000	19.88	1207.243	1,207
L2 - 2		0.2	D3	1,000			
L3 - 1	10	0.2	D3	1,000	18.90	2646.203	2,382
L3 - 2	20	0.5	D3	1,000		2116.962	
L4 - 1	9	0.2	D3	1,000	20.57	2188.184	2,188
L4 - 2	12	0.2	D3	1,000			
Feed - 1	15	0.2	D3	1,000	18.15	4131.662	4,132
Feed - 2		0.2	D3	1,000			

March 9, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	4	0.2	D4	10,000	11.87	16,856	7,585
L1 - 2	0	0.2	D4	10,000		0	
L1 - 3	1	0.5	D4	10,000		1,686	
L1 - 4	7	0.5	D4	10,000		11,799	
L2 - 1	5	0.2	D4	10,000	12.08	20,700	10,557
L2 - 2	0	0.2	D4	10,000		0	
L2 - 3	4	0.5	D4	10,000		6,624	
L2 - 4	9	0.5	D4	10,000		14,904	
L3 - 1	1	0.2	D4	10,000	12.22	4,093	4,298
L3 - 2	0	0.2	D4	10,000		0	
L3 - 3	2	0.5	D4	10,000		3,275	
L3 - 4	6	0.5	D4	10,000		9,824	
L4 - 1	1	0.2	D4	10,000	12.29	4,068	5,899
L4 - 2	0	0.2	D4	10,000		0	
L4 - 3	5	0.5	D4	10,000		8,137	
L4 - 4	7	0.5	D4	10,000		11,391	
Feed - 1	15	0.2	D3	1,000	15.35	4,885	4,885
Feed - 2		0.2	D4	10,000			
Feed - 3		0.5	D4	10,000			
Feed - 4		0.5	D4	10,000			

March 11, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	8	0.2	D3	1,000		2,733	
L1 - 2	6	0.2	D3	1,000	14.64	2,050	5,466
L1 - 3	3	0.2	D4	10,000		10,249	
L1 - 4	2	0.2	D4	10,000		6,833	
L2 - 1	3	0.4	D4	10,000		5,281	
L2 - 2	1	0.4	D4	10,000	14.20	1,760	5,281
L2 - 3	2	0.2	D4	10,000		7,041	
L2 - 4	2	0.2	D4	10,000		7,041	
L3 - 1	0	0.4	D4	10,000		0	
L3 - 2	SBTM	0.4	D4	10,000	14.20		2,347
L3 - 3	1	0.2	D4	10,000		3,521	
L3 - 4	1	0.2	D4	10,000		3,521	
L4 - 1	SBTM	0.2	D3	1,000			
L4 - 2	9	0.2	D3	1,000	14.08	3,196	2,249
L4 - 3	1	0.4	D4	10,000		1,776	
L4 - 4	1	0.4	D4	10,000		1,776	
Feed - 1	3	0.2	D3	1,000		769	
Feed - 2	10	0.2	D3	1,000	19.52	2,562	4,035
Feed - 3	3	0.2	D4	10,000		7,686	
Feed - 4	2	0.2	D4	10,000		5,124	

March 13, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	3	0.1	D4	10,000		17,873	
L1 - 2	1	0.1	D4	10,000	16.79	5,958	10,426
L1 - 3	3	0.2	D4	10,000		8,937	
L1 - 4	3	0.2	D4	10,000		8,937	
L2 - 1	4	0.1	D4	10,000		23,334	
L2 - 2	4	0.1	D4	10,000	17.14	23,334	13,854
L2 - 3	2	0.2	D4	10,000		5,833	
L2 - 4	1	0.2	D4	10,000		2,917	
L3 - 1	4	0.1	D4	10,000		23,623	
L3 - 2	SBTM	0.1	D4	10,000	16.93		20,670
L3 - 3	6	0.2	D4	10,000		17,717	
L3 - 4	SBTM	0.2	D4	10,000			
L4 - 1	SBTM	0.1	D4	10,000			
L4 - 2	1	0.1	D4	10,000	17.44	5,735	11,470
L4 - 3	4	0.2	D4	10,000		11,470	
L4 - 4	6	0.2	D4	10,000		17,204	
Feed - 1	5	0.1	D4	10,000		29,338	
Feed - 2	4	0.1	D4	10,000	17.04	23,471	16,870
Feed - 3	3	0.2	D4	10,000		8,802	
Feed - 4	2	0.2	D4	10,000		5,868	

March 20, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	2	0.1	D4	10,000		11137.41	
L1 - 2	0	0.1	D4	10,000	17.96		8,353
L1 - 3	0	0.1	D4	10,000			
L1 - 4	1	0.1	D4	10,000		5568.704	
L2 - 1	1	0.1	D4	10,000		5248.655	
L2 - 2	1	0.1	D4	10,000	19.05	5248.655	5,249
L2 - 3	1	0.1	D4	10,000		5248.655	
L2 - 4	1	0.1	D4	10,000		5248.655	
L3 - 1	1	0.1	D4	10,000		5155.968	
L3 - 2	1	0.1	D4	10,000	19.40	5155.968	6,445
L3 - 3	2	0.1	D4	10,000		10311.94	
L3 - 4	1	0.1	D4	10,000		5155.968	
L4 - 1	1	0.1	D4	10,000		5266.623	
L4 - 2	0	0.1	D4	10,000	18.99		7,022
L4 - 3	1	0.1	D4	10,000		5266.623	
L4 - 4	2	0.1	D4	10,000		10533.25	
Feed - 1	0	0.1	D4	10,000			
Feed - 2	0	0.1	D4	10,000	18.23		10,974
Feed - 3	2	0.1	D4	10,000		10973.94	
Feed - 4	SB	0.1	D4	10,000			

March 23, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	8	0.1	D3	1,000		4217.185	
L1 - 2		0.1	D3	1,000	18.97		4,217
L1 - 3		0.1	D3	1,000			
L1 - 4		0.1	D3	1,000			
L2 - 1	6	0.1	D3	1,000		3078.107	
L2 - 2	7	0.1	D3	1,000	19.49	3591.125	3,335
L2 - 3		0.1	D3	1,000			
L2 - 4		0.1	D3	1,000			
L3 - 1	8	0.1	D3	1,000		3878.788	
L3 - 2	7	0.1	D3	1,000	20.62	3393.939	3,636
L3 - 3		0.1	D3	1,000			
L3 - 4		0.1	D3	1,000			
L4 - 1	10	0.1	D3	1,000		4970.179	
L4 - 2	5	0.1	D3	1,000	20.12	2485.089	3,728
L4 - 3		0.1	D3	1,000			
L4 - 4		0.1	D3	1,000			
Feed - 1	7	0.1	D3	1,000		3410.06	
Feed - 2		0.1	D3	1,000	20.53		3,410
Feed - 3		0.1	D3	1,000			
Feed - 4		0.1	D3	1,000			

March 25, 2005

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average
L1 - 1	1	0.1	D3	1,000		532.836	
L1 - 2	3	0.1	D3	1,000	18.77	1598.508	1,066
L1 - 3			D3	1,000			
L1 - 4			D3	1,000			
L2 - 1	4	0.1	D3	1,000		2125.399	
L2 - 2	SB		D3	1,000	18.82		2,125
L2 - 3			D3	1,000			
L2 - 4			D3	1,000			
L3 - 1	2	0.1	D3	1,000		1021.32	
L3 - 2	6	0.1	D3	1,000	19.58	3063.96	2,043
L3 - 3	SBTM		D3	1,000			
L3 - 4			D3	1,000			
L4 - 1	3	0.1	D3	1,000		1578.74	
L4 - 2	4	0.1	D3	1,000	19.00	2104.986	1,930
L4 - 3	4	0.1	D3	1,000		2104.986	
L4 - 4			D3	1,000			
Feed - 1	3	0.1	D3	1,000		1596.806	
Feed - 2	4	0.1	D3	1,000	18.79	2129.075	2,839
Feed - 3	9	0.1	D3	1,000		4790.419	
Feed - 4			D3	1,000			

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

	Date	
Clostridium Perfringens (CFU/mL)	L1	
	L2	
	L3	
	L4	
	Feed	

	Date	
Clostridium Perfringens (CFU/100 mL)	L1	
	L2	
	L3	
	L4	
	Feed	

PHASE 2

April 20, 2005 D3•V1

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	2	0.1	D3	1,000	21.54	928.6129	1,393
L1 - 2	4	0.1	D3	1,000		1857.226	
L2 - 1	0	0.1	D3	1,000	23.27	0	645
L2 - 2	3	0.1	D3	1,000		1289.075	
L3 - 1	4	0.1	D3	1,000	22.87	1749.016	1,530
L3 - 2	3	0.1	D3	1,000		1311.762	
L4 - 1	6	0.1	D3	1,000	23.01	2608.129	2,608
L4 - 2	N/A	0.1	D3	1,000			
Feed - 1	2	0.1	D3	1,000	21.96	910.6431	911
Feed - 2	2	0.1	D3	1,000		910.6431	

April 22, 2005 D3•V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	7	0.2	D3	1,000	22.49	1556.074	1,334
L1 - 2	5	0.2	D3	1,000		1111.482	
L1 - 3	6	0.2	D3	1,000		1333.778	
L1 - 4	N/A	0.2	D3	1,000			
L2 - 1	2	0.2	D3	1,000	26.32	379.867	1,456
L2 - 2	7	0.2	D3	1,000		1329.535	
L2 - 3	14	0.2	D3	1,000		2659.069	
L2 - 4	N/A	0.2	D3	1,000			
L3 - 1	6	0.2	D3	1,000	24.61	1218.769	1,354
L3 - 2	6	0.2	D3	1,000		1218.769	
L3 - 3	8	0.2	D3	1,000		1625.025	
L3 - 4	N/A	0.2	D3	1,000			
L4 - 1	14	0.2	D3	1,000	24.76	2827.426	1,952
L4 - 2	8	0.2	D3	1,000		1615.672	
L4 - 3	7	0.2	D3	1,000		1413.713	
L4 - 4	N/A	0.2	D3	1,000			
Feed - 1	2	0.2	D3	1,000	22.17	451.06	1,203
Feed - 2	10	0.2	D3	1,000		2255.3	
Feed - 3	4	0.2	D3	1,000		902.12	
Feed - 4	N/A	0.2	D3	1,000			

April 28, 2005 D3•V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	2	0.2	D3	1,000	20.53	487.0328	1,522
L1 - 2	5	0.2	D3	1,000		1217.582	
L1 - 3	8	0.2	D3	1,000		1948.131	
L1 - 4	10	0.2	D3	1,000		2435.164	
L2 - 1	11	0.2	D3	1,000	20.41	2695.418	2,450
L2 - 2	13	0.2	D3	1,000		3185.494	
L2 - 3	4	0.2	D3	1,000		980.1519	
L2 - 4	12	0.2	D3	1,000		2940.456	
L3 - 1	7	0.2	D3	1,000	20.59	1700.267	2,004
L3 - 2	9	0.2	D3	1,000		2186.058	
L3 - 3	8	0.2	D3	1,000		1943.162	
L3 - 4	9	0.2	D3	1,000		2186.058	
L4 - 1	7	0.2	D3	1,000	20.78	1684.109	2,707
L4 - 2	14	0.2	D3	1,000		3368.218	
L4 - 3	14	0.2	D3	1,000		3368.218	
L4 - 4	10	0.2	D3	1,000		2405.87	
Feed - 1	6	0.2	D3	1,000	19.49	1539.646	1,860
Feed - 2	8	0.2	D3	1,000		2052.861	
Feed - 3	6	0.2	D3	1,000		1539.646	
Feed - 4	9	0.2	D3	1,000		2309.469	

May 1, 2005 D3-V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	5	0.2	D3	1,000		1081.315	
L1 - 2	11	0.2	D3	1,000	23.12	2378.893	1,946
L1 - 3	15	0.2	D3	1,000		3243.945	
L1 - 4	5	0.2	D3	1,000		1081.315	
L2 - 1	8	0.2	D3	1,000		1732.539	
L2 - 2	7	0.2	D3	1,000	23.09	1515.972	1,678
L2 - 3	5	0.2	D3	1,000		1082.837	
L2 - 4	11	0.2	D3	1,000		2382.241	
L3 - 1	14	0.2	D3	1,000		3041.164	
L3 - 2	4	0.2	D3	1,000	23.02	868.9041	2,172
L3 - 3	12	0.2	D3	1,000		2606.712	
L3 - 4	N/A	0.2	D3	1,000			
L4 - 1	12	0.2	D3	1,000		2471.17	
L4 - 2	7	0.2	D3	1,000	24.28	1441.516	2,317
L4 - 3	13	0.2	D3	1,000		2677.1	
L4 - 4	13	0.2	D3	1,000		2677.1	
Feed - 1	13	0.2	D3	1,000		2563.344	
Feed - 2	8	0.2	D3	1,000	25.36	1577.443	1,873
Feed - 3	13	0.2	D3	1,000		2563.344	
Feed - 4	4	0.2	D3	1,000		788.7213	

May 5, 2005 D3-V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	10	0.2	D3	1,000		2335.903	
L1 - 2	7	0.2	D3	1,000	21.41	1635.132	1,810
L1 - 3	7	0.2	D3	1,000		1635.132	
L1 - 4	7	0.2	D3	1,000		1635.132	
L2 - 1	6	0.2	D3	1,000		1344.99	
L2 - 2	5	0.2	D3	1,000	22.30	1120.825	1,196
L2 - 3	5	0.2	D3	1,000		1120.825	
L2 - 4	N/A	0.2	D3	1,000			
L3 - 1	12	0.2	D3	1,000		2849.003	
L3 - 2	7	0.2	D3	1,000	21.06	1661.918	2,058
L3 - 3	7	0.2	D3	1,000		1661.918	
L3 - 4	N/A	0.2	D3	1,000			
L4 - 1	10	0.2	D3	1,000		2251.745	
L4 - 2	11	0.2	D3	1,000	22.20	2476.92	2,027
L4 - 3	7	0.2	D3	1,000		1576.222	
L4 - 4	8	0.2	D3	1,000		1801.396	
Feed - 1	12	0.2	D3	1,000		2525.784	
Feed - 2	4	0.2	D3	1,000	23.75	841.928	1,684
Feed - 3	8	0.2	D3	1,000		1683.856	
Feed - 4	N/A	0.2	D3	1,000			

May 12, 2005 D3-V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	7	0.2	D3	1,000		2017.582	
L1 - 2	3	0.2	D3	1,000	17.35	864.6779	1,873
L1 - 3	10	0.2	D3	1,000		2882.26	
L1 - 4	6	0.2	D3	1,000		1729.356	
L2 - 1	9	0.2	D3	1,000		2564.103	
L2 - 2	2	0.2	D3	1,000	17.55	569.8006	1,852
L2 - 3	11	0.2	D3	1,000		3133.903	
L2 - 4	4	0.2	D3	1,000		1139.601	
L3 - 1	8	0.2	D3	1,000		2257.018	
L3 - 2	8	0.2	D3	1,000	17.72	2257.018	1,763
L3 - 3	7	0.2	D3	1,000		1974.891	
L3 - 4	2	0.2	D3	1,000		564.2545	
L4 - 1	3	0.2	D3	1,000		842.5783	
L4 - 2	7	0.2	D3	1,000	17.80	1966.016	1,615
L4 - 3	7	0.2	D3	1,000		1966.016	
L4 - 4	6	0.2	D3	1,000		1685.157	
Feed - 1	6	0.2	D3	1,000		1819.009	
Feed - 2	3	0.2	D3	1,000	16.49	909.5043	1,819
Feed - 3	9	0.2	D3	1,000		2728.513	
Feed - 4	SB	0.2	D3	1,000			

June 10, 2005 D3-V2

	Count	Volume	Dilution	Factor	Solids	CFU/g solid	Average
L1 - 1	2	0.2	D3	1,000		564.6527	
L1 - 2	1	0.2	D3	1,000	17.71	282.3264	1,059
L1 - 3	8	0.2	D3	1,000		2258.611	
L1 - 4	4	0.2	D3	1,000		1129.305	
L2 - 1	7	0.2	D3	1,000		2392.344	
L2 - 2	6	0.2	D3	1,000	14.63	2050.581	2,136
L2 - 3	7	0.2	D3	1,000		2392.344	
L2 - 4	5	0.2	D3	1,000		1708.817	
L3 - 1	4	0.2	D3	1,000		1432.408	
L3 - 2	7	0.2	D3	1,000	13.96	2506.714	1,910
L3 - 3	5	0.2	D3	1,000		1790.51	
L3 - 4	SB	0.2	D3	1,000			
L4 - 1	14	0.2	D3	1,000		3748.828	
L4 - 2	3	0.2	D3	1,000	18.67	803.3204	1,607
L4 - 3	4	0.2	D3	1,000		1071.094	
L4 - 4	3	0.2	D3	1,000		803.3204	
Feed - 1	1	0.2	D3	1,000		336.4738	
Feed - 2	4	0.2	D3	1,000	14.86	1345.895	1,009
Feed - 3	6	0.2	D3	1,000		2018.843	
Feed - 4	1	0.2	D3	1,000		336.4738	

Concentrations were originally calculated in CFU/gram solids. Once significant solids destruction was observed across the entire process train, concentrations were then calculated in the units of CFU/100 mL of sample.

April 20, 2005 D3•V1

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	2	0.1	1,000	20000	30,000
L1 - 2	4	0.1	1,000	40000	
L2 - 1	0	0.1	1,000	0	15,000
L2 - 2	3	0.1	1,000	30000	
L3 - 1	4	0.1	1,000	40000	35,000
L3 - 2	3	0.1	1,000	30000	
L4 - 1	6	0.1	1,000	60000	60,000
L4 - 2	N/A	0.1	1,000		
Feed - 1	2	0.1	1,000	20000	20,000
Feed - 2	2	0.1	1,000	20000	

April 22, 2005 D3•V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	7	0.2	1,000	35000	30,000
L1 - 2	5	0.2	1,000	25000	
L1 - 3	6	0.2	1,000	30000	
L1 - 4	N/A	0.2	1,000		
L2 - 1	2	0.2	1,000	10000	38,333
L2 - 2	7	0.2	1,000	35000	
L2 - 3	14	0.2	1,000	70000	
L2 - 4	N/A	0.2	1,000		
L3 - 1	6	0.2	1,000	30000	33,333
L3 - 2	6	0.2	1,000	30000	
L3 - 3	8	0.2	1,000	40000	
L3 - 4	N/A	0.2	1,000		
L4 - 1	14	0.2	1,000	70000	48,333
L4 - 2	8	0.2	1,000	40000	
L4 - 3	7	0.2	1,000	35000	
L4 - 4	N/A	0.2	1,000		
Feed - 1	2	0.2	1,000	10000	26,667
Feed - 2	10	0.2	1,000	50000	
Feed - 3	4	0.2	1,000	20000	
Feed - 4	N/A	0.2	1,000		

April 28, 2005 D3•V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	2	0.2	1,000	10000	31,250
L1 - 2	5	0.2	1,000	25000	
L1 - 3	8	0.2	1,000	40000	
L1 - 4	10	0.2	1,000	50000	
L2 - 1	11	0.2	1,000	55000	50,000
L2 - 2	13	0.2	1,000	65000	
L2 - 3	4	0.2	1,000	20000	
L2 - 4	12	0.2	1,000	60000	
L3 - 1	7	0.2	1,000	35000	41,250
L3 - 2	9	0.2	1,000	45000	
L3 - 3	8	0.2	1,000	40000	
L3 - 4	9	0.2	1,000	45000	
L4 - 1	7	0.2	1,000	35000	56,250
L4 - 2	14	0.2	1,000	70000	
L4 - 3	14	0.2	1,000	70000	
L4 - 4	10	0.2	1,000	50000	
Feed - 1	6	0.2	1,000	30000	36,250
Feed - 2	8	0.2	1,000	40000	
Feed - 3	6	0.2	1,000	30000	
Feed - 4	9	0.2	1,000	45000	

May 1, 2005 D3-V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	5	0.2	1,000	25000	45,000
L1 - 2	11	0.2	1,000	55000	
L1 - 3	15	0.2	1,000	75000	
L1 - 4	5	0.2	1,000	25000	
L2 - 1	8	0.2	1,000	40000	38,750
L2 - 2	7	0.2	1,000	35000	
L2 - 3	5	0.2	1,000	25000	
L2 - 4	11	0.2	1,000	55000	
L3 - 1	14	0.2	1,000	70000	50,000
L3 - 2	4	0.2	1,000	20000	
L3 - 3	12	0.2	1,000	60000	
L3 - 4	N/A	0.2	1,000		
L4 - 1	12	0.2	1,000	60000	56,250
L4 - 2	7	0.2	1,000	35000	
L4 - 3	13	0.2	1,000	65000	
L4 - 4	13	0.2	1,000	65000	
Feed - 1	13	0.2	1,000	65000	47,500
Feed - 2	8	0.2	1,000	40000	
Feed - 3	13	0.2	1,000	65000	
Feed - 4	4	0.2	1,000	20000	

May 5, 2005 D3-V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	10	0.2	1,000	50000	38,750
L1 - 2	7	0.2	1,000	35000	
L1 - 3	7	0.2	1,000	35000	
L1 - 4	7	0.2	1,000	35000	
L2 - 1	6	0.2	1,000	30000	26,667
L2 - 2	5	0.2	1,000	25000	
L2 - 3	5	0.2	1,000	25000	
L2 - 4	N/A	0.2	1,000		
L3 - 1	12	0.2	1,000	60000	43,333
L3 - 2	7	0.2	1,000	35000	
L3 - 3	7	0.2	1,000	35000	
L3 - 4	N/A	0.2	1,000		
L4 - 1	10	0.2	1,000	50000	45,000
L4 - 2	11	0.2	1,000	55000	
L4 - 3	7	0.2	1,000	35000	
L4 - 4	8	0.2	1,000	40000	
Feed - 1	12	0.2	1,000	60000	40,000
Feed - 2	4	0.2	1,000	20000	
Feed - 3	8	0.2	1,000	40000	
Feed - 4	N/A	0.2	1,000		

May 12, 2005 D3:V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	7	0.2	1,000	35000	32,500
L1 - 2	3	0.2	1,000	15000	
L1 - 3	10	0.2	1,000	50000	
L1 - 4	6	0.2	1,000	30000	
L2 - 1	9	0.2	1,000	45000	32,500
L2 - 2	2	0.2	1,000	10000	
L2 - 3	11	0.2	1,000	55000	
L2 - 4	4	0.2	1,000	20000	
L3 - 1	8	0.2	1,000	40000	31,250
L3 - 2	8	0.2	1,000	40000	
L3 - 3	7	0.2	1,000	35000	
L3 - 4	2	0.2	1,000	10000	
L4 - 1	3	0.2	1,000	15000	28,750
L4 - 2	7	0.2	1,000	35000	
L4 - 3	7	0.2	1,000	35000	
L4 - 4	6	0.2	1,000	30000	
Feed - 1	6	0.2	1,000	30000	30,000
Feed - 2	3	0.2	1,000	15000	
Feed - 3	9	0.2	1,000	45000	
Feed - 4	SB	0.2	1,000		

June 10, 2005 D3:V2

	Count	Volume	Factor	C/100 mL	Average
L1 - 1	2	0.2	1,000	10000	18,750
L1 - 2	1	0.2	1,000	5000	
L1 - 3	8	0.2	1,000	40000	
L1 - 4	4	0.2	1,000	20000	
L2 - 1	7	0.2	1,000	35000	31,250
L2 - 2	6	0.2	1,000	30000	
L2 - 3	7	0.2	1,000	35000	
L2 - 4	5	0.2	1,000	25000	
L3 - 1	4	0.2	1,000	20000	26,667
L3 - 2	7	0.2	1,000	35000	
L3 - 3	5	0.2	1,000	25000	
L3 - 4	SB	0.2	1,000		
L4 - 1	14	0.2	1,000	70000	30,000
L4 - 2	3	0.2	1,000	15000	
L4 - 3	4	0.2	1,000	20000	
L4 - 4	3	0.2	1,000	15000	
Feed - 1	1	0.2	1,000	5000	15,000
Feed - 2	4	0.2	1,000	20000	
Feed - 3	6	0.2	1,000	30000	
Feed - 4	1	0.2	1,000	5000	

PHASE 3 – Pre-treatment columns

July 5, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	5	2	D3	1,000		189.0002	
L1 - 2	8	2	D3	1,000	13.23	302.4003	246
L1 - 3			D3	1,000			
L1 - 4			D3	1,000			
L2 - 1	6	2	D3	1,000		231.0358	
L2 - 2	2	2	D3	1,000	12.98	77.01194	128
L2 - 3	2	2	D3	1,000		77.01194	
L2 - 4			D3	1,000			
L3 - 1	0	2	D3	1,000		0	
L3 - 2	12	2	D3	1,000	12.14	494.3357	316
L3 - 3	11	2	D3	1,000		453.1411	
L3 - 4			D3	1,000			
L4 - 1	11	2	D3	1,000		187.6653	
L4 - 2	7	2	D3	1,000	29.31	119.4234	154
L4 - 3			D3	1,000			
L4 - 4			D3	1,000			
Feed - 1	5	2	D3	1,000		188.7149	
Feed - 2	6	2	D3	1,000	13.25	226.4578	189
Feed - 3	4	2	D3	1,000		150.9719	
Feed - 4			D3	1,000			

July 7, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	6	2.5	D4	10,000		1660.325	
L1 - 2	8	2.5	D4	10,000	14.46	2213.767	1,937
L1 - 3		2.5	D4	10,000			
L1 - 4		2.5	D4	10,000			
L2 - 1	10	2.5	D4	10,000		2902.758	
L2 - 2	7	2.5	D4	10,000	13.78	2031.93	2,419
L2 - 3	8	2.5	D4	10,000		2322.206	
L2 - 4		2.5	D4	10,000			
L3 - 1	13	2.5	D4	10,000		3432.91	
L3 - 2	7	2.5	D4	10,000	15.15	1848.49	2,729
L3 - 3	11	2.5	D4	10,000		2904.77	
L3 - 4		2.5	D4	10,000			
L4 - 1	8	2.5	D4	10,000		2478.219	
L4 - 2	4	2.5	D4	10,000	12.91	1239.109	2,168
L4 - 3	9	2.5	D4	10,000		2787.996	
L4 - 4		2.5	D4	10,000			
Feed - 1	9	2.5	D4	10,000		2068.074	
Feed - 2		2.5	D4	10,000	17.41		2,068
Feed - 3		2.5	D4	10,000			
Feed - 4		2.5	D4	10,000			

July 14, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	9	2.5	D4	10,000		2969.072	
L1 - 2	7	2.5	D4	10,000	12.13	2309.278	2,474
L1 - 3	5	2.5	D4	10,000		1649.485	
L1 - 4	9	2.5	D4	10,000		2969.072	
L2 - 1	7	2.5	D4	10,000		2306.9	
L2 - 2	11	2.5	D4	10,000	12.14	3625.129	2,472
L2 - 3	5	2.5	D4	10,000		1647.786	
L2 - 4	7	2.5	D4	10,000		2306.9	
L3 - 1	5	2.5	D4	10,000		1621.403	
L3 - 2	5	2.5	D4	10,000	12.34	1621.403	1,459
L3 - 3	3	2.5	D4	10,000		972.8415	
L3 - 4	5	2.5	D4	10,000		1621.403	
L4 - 1	6	2.5	D4	10,000		2727.273	
L4 - 2	2	2.5	D4	10,000	8.80	909.0909	1,818
L4 - 3	3	2.5	D4	10,000		1363.636	
L4 - 4	5	2.5	D4	10,000		2272.727	
Feed - 1	8	2.5	D4	10,000		1742.208	
Feed - 2	7	2.5	D4	10,000	18.37	1524.432	1,470
Feed - 3	6	2.5	D4	10,000		1306.656	
Feed - 4	6	2.5	D4	10,000		1306.656	

July 26, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	8	0.2	D3	1,000		3019.438	
L1 - 2	4	0.2	D3	1,000	13.25	1509.719	1,604
L1 - 3	2	0.2	D3	1,000		754.8594	
L1 - 4	3	0.2	D3	1,000		1132.289	
L2 - 1	2	0.2	D3	1,000		794.2812	
L2 - 2	3	0.2	D3	1,000	12.59	1191.422	1,489
L2 - 3	5	0.2	D3	1,000		1985.703	
L2 - 4	5	0.2	D3	1,000		1985.703	
L3 - 1	3	0.2	D3	1,000		1107.42	
L3 - 2	3	0.2	D3	1,000	13.54	1107.42	1,292
L3 - 3	3	0.2	D3	1,000		1107.42	
L3 - 4	5	0.2	D3	1,000		1845.7	
L4 - 1	4	0.2	D3	1,000		1249.414	
L4 - 2	5	0.2	D3	1,000	16.01	1561.768	1,562
L4 - 3	6	0.2	D3	1,000		1874.122	
L4 - 4		0.2	D3	1,000			
Feed - 1	1	0.2	D3	1,000		258.6987	
Feed - 2	1	0.2	D3	1,000	19.33	258.6987	517
Feed - 3	3	0.2	D3	1,000		776.0962	
Feed - 4	3	0.2	D3	1,000		776.0962	

August 1, 2005 - August 2, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	9	0.2	D3	1,000		2479.68	
L1 - 2	5	0.2	D3	1,000	18.15	1377.6	1,561
L1 - 3	3	0.2	D3	1,000		826.5601	
L1 - 4	SBTM	0.2	D3	1,000			
L2 - 1	7	0.2	D3	1,000		1778.907	
L2 - 2	11	0.2	D3	1,000	19.67	2795.426	2,160
L2 - 3	9	0.2	D3	1,000		2287.166	
L2 - 4	7	0.2	D3	1,000		1778.907	
L3 - 1	4	0.2	D3	1,000		1002.13	
L3 - 2	12	0.2	D3	1,000	19.96	3006.389	1,942
L3 - 3	7	0.2	D3	1,000		1753.727	
L3 - 4	8	0.2	D3	1,000		2004.259	
L4 - 1	6	0.2	D3	1,000		1523.036	
L4 - 2	4	0.2	D3	1,000	19.70	1015.357	1,269
L4 - 3	7	0.2	D3	1,000		1776.875	
L4 - 4	3	0.2	D3	1,000		761.518	
Feed - 1	3	0.2	D3	1,000		716.6746	
Feed - 2	10	0.2	D3	1,000	20.93	2388.915	1,354
Feed - 3	4	0.2	D3	1,000		955.5662	
Feed - 4	SBTM	0.2	D3	1,000			

August 8, 2005 - August 9, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	9	0.2	D3	1,000		2137.006	
L1 - 2	10	0.2	D3	1,000	21.06	2374.451	2,137
L1 - 3	8	0.2	D3	1,000		1899.561	
L1 - 4		0.2	D3	1,000			
L2 - 1	8	0.2	D3	1,000		2241.838	
L2 - 2	6	0.2	D3	1,000	17.84	1681.379	2,055
L2 - 3	8	0.2	D3	1,000		2241.838	
L2 - 4		0.2	D3	1,000			
L3 - 1	2	0.2	D3	1,000		532.4814	
L3 - 2	10	0.2	D3	1,000	18.78	2662.407	1,509
L3 - 3	5	0.2	D3	1,000		1331.203	
L3 - 4		0.2	D3	1,000			
L4 - 1	8	0.2	D3	1,000		2171.553	
L4 - 2	2	0.2	D3	1,000	18.42	542.8882	1,267
L4 - 3	4	0.2	D3	1,000		1085.776	
L4 - 4		0.2	D3	1,000			
Feed - 1	8	0.2	D3	1,000		2038.996	
Feed - 2	11	0.2	D3	1,000	19.62	2803.619	2,421
Feed - 3		0.2	D3	1,000			
Feed - 4		0.2	D3	1,000			

August 12, 2005 - August 13, 2005

	Count	Volume	Dilution	Factor	Solids	C/g solid	Average
L1 - 1	5	0.2	D3	1,000		1323.627	
L1 - 2	1	0.2	D3	1,000	18.89	264.7253	706
L1 - 3	2	0.2	D3	1,000		529.4507	
L1 - 4		0.2	D3	1,000			
L2 - 1	1	0.2	D3	1,000		287.0676	
L2 - 2	3	0.2	D3	1,000	17.42	861.2028	957
L2 - 3	6	0.2	D3	1,000		1722.406	
L2 - 4		0.2	D3	1,000			
L3 - 1	1	0.2	D3	1,000		279.916	
L3 - 2	0	0.2	D3	1,000	17.86	0	653
L3 - 3	6	0.2	D3	1,000		1679.496	
L3 - 4		0.2	D3	1,000			
L4 - 1	4	0.2	D3	1,000		1150.417	
L4 - 2	0	0.2	D3	1,000	17.39	0	767
L4 - 3	4	0.2	D3	1,000		1150.417	
L4 - 4		0.2	D3	1,000			
Feed - 1	7	0.2	D3	1,000		1776.65	
Feed - 2	6	0.2	D3	1,000	19.70	1522.843	2,115
Feed - 3	12	0.2	D3	1,000		3045.685	
Feed - 4		0.2	D3	1,000			

July 5, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	5	2	1,000	2500	
L1 - 2	8	2	1,000	4000	3,250
L1 - 3			1,000		
L1 - 4			1,000		
L2 - 1	6	2	1,000	3000	
L2 - 2	2	2	1,000	1000	1,667
L2 - 3	2	2	1,000	1000	
L2 - 4			1,000		
L3 - 1	0	2	1,000	0	
L3 - 2	12	2	1,000	6000	3,833
L3 - 3	11	2	1,000	5500	
L3 - 4			1,000		
L4 - 1	11	2	1,000	5500	
L4 - 2	7	2	1,000	3500	4,500
L4 - 3			1,000		
L4 - 4			1,000		
Feed - 1	5	2	1,000	2500	
Feed - 2	6	2	1,000	3000	2,500
Feed - 3	4	2	1,000	2000	
Feed - 4			1,000		

July 7, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	6	2.5	10,000	24000	28,000
L1 - 2	8	2.5	10,000	32000	
L1 - 3		2.5	10,000		
L1 - 4		2.5	10,000		
L2 - 1	10	2.5	10,000	40000	33,333
L2 - 2	7	2.5	10,000	28000	
L2 - 3	8	2.5	10,000	32000	
L2 - 4		2.5	10,000		
L3 - 1	13	2.5	10,000	52000	41,333
L3 - 2	7	2.5	10,000	28000	
L3 - 3	11	2.5	10,000	44000	
L3 - 4		2.5	10,000		
L4 - 1	8	2.5	10,000	32000	28,000
L4 - 2	4	2.5	10,000	16000	
L4 - 3	9	2.5	10,000	36000	
L4 - 4		2.5	10,000		
Feed - 1	9	2.5	10,000	36000	36,000
Feed - 2		2.5	10,000		
Feed - 3		2.5	10,000		
Feed - 4		2.5	10,000		

July 14, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	9	2.5	10,000	36000	30,000
L1 - 2	7	2.5	10,000	28000	
L1 - 3	5	2.5	10,000	20000	
L1 - 4	9	2.5	10,000	36000	
L2 - 1	7	2.5	10,000	28000	30,000
L2 - 2	11	2.5	10,000	44000	
L2 - 3	5	2.5	10,000	20000	
L2 - 4	7	2.5	10,000	28000	
L3 - 1	5	2.5	10,000	20000	18,000
L3 - 2	5	2.5	10,000	20000	
L3 - 3	3	2.5	10,000	12000	
L3 - 4	5	2.5	10,000	20000	
L4 - 1	6	2.5	10,000	24000	14,667
L4 - 2	2	2.5	10,000	8000	
L4 - 3	3	2.5	10,000	12000	
L4 - 4	5	2.5	10,000		
Feed - 1	8	2.5	10,000	32000	27,000
Feed - 2	7	2.5	10,000	28000	
Feed - 3	6	2.5	10,000	24000	
Feed - 4	6	2.5	10,000	24000	

July 26, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	8	0.2	1,000	40000	21,250
L1 - 2	4	0.2	1,000	20000	
L1 - 3	2	0.2	1,000	10000	
L1 - 4	3	0.2	1,000	15000	
L2 - 1	2	0.2	1,000	10000	18,750
L2 - 2	3	0.2	1,000	15000	
L2 - 3	5	0.2	1,000	25000	
L2 - 4	5	0.2	1,000	25000	
L3 - 1	3	0.2	1,000	15000	17,500
L3 - 2	3	0.2	1,000	15000	
L3 - 3	3	0.2	1,000	15000	
L3 - 4	5	0.2	1,000	25000	
L4 - 1	4	0.2	1,000	20000	25,000
L4 - 2	5	0.2	1,000	25000	
L4 - 3	6	0.2	1,000	30000	
L4 - 4		0.2	1,000		
Feed - 1	1	0.2	1,000	5000	10,000
Feed - 2	1	0.2	1,000	5000	
Feed - 3	3	0.2	1,000	15000	
Feed - 4	3	0.2	1,000	15000	

August 1, 2005 - August 2, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	9	0.2	1,000	45000	28,333
L1 - 2	5	0.2	1,000	25000	
L1 - 3	3	0.2	1,000	15000	
L1 - 4	SBTM	0.2	1,000		
L2 - 1	7	0.2	1,000	35000	42,500
L2 - 2	11	0.2	1,000	55000	
L2 - 3	9	0.2	1,000	45000	
L2 - 4	7	0.2	1,000	35000	
L3 - 1	4	0.2	1,000	20000	38,750
L3 - 2	12	0.2	1,000	60000	
L3 - 3	7	0.2	1,000	35000	
L3 - 4	8	0.2	1,000	40000	
L4 - 1	6	0.2	1,000	30000	25,000
L4 - 2	4	0.2	1,000	20000	
L4 - 3	7	0.2	1,000	35000	
L4 - 4	3	0.2	1,000	15000	
Feed - 1	3	0.2	1,000	15000	28,333
Feed - 2	10	0.2	1,000	50000	
Feed - 3	4	0.2	1,000	20000	
Feed - 4	SBTM	0.2	1,000		

August 8, 2005 - August 9, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	9	0.2	1,000	45000	
L1 - 2	10	0.2	1,000	50000	45,000
L1 - 3	8	0.2	1,000	40000	
L1 - 4		0.2	1,000		
L2 - 1	8	0.2	1,000	40000	
L2 - 2	6	0.2	1,000	30000	36,667
L2 - 3	8	0.2	1,000	40000	
L2 - 4		0.2	1,000		
L3 - 1	2	0.2	1,000	10000	
L3 - 2	10	0.2	1,000	50000	28,333
L3 - 3	5	0.2	1,000	25000	
L3 - 4		0.2	1,000		
L4 - 1	8	0.2	1,000	40000	
L4 - 2	2	0.2	1,000	10000	23,333
L4 - 3	4	0.2	1,000	20000	
L4 - 4		0.2	1,000		
Feed - 1	8	0.2	1,000	40000	
Feed - 2	11	0.2	1,000	55000	47,500
Feed - 3		0.2	1,000		
Feed - 4		0.2	1,000		

August 12, 2005 - August 13, 2005

	Count	Volume	Factor	C/100mL	Average
L1 - 1	5	0.2	1,000	25000	
L1 - 2	1	0.2	1,000	5000	13,333
L1 - 3	2	0.2	1,000	10000	
L1 - 4		0.2	1,000		
L2 - 1	1	0.2	1,000	5000	
L2 - 2	3	0.2	1,000	15000	16,667
L2 - 3	6	0.2	1,000	30000	
L2 - 4		0.2	1,000		
L3 - 1	1	0.2	1,000	5000	
L3 - 2	0	0.2	1,000	0	11,667
L3 - 3	6	0.2	1,000	30000	
L3 - 4		0.2	1,000		
L4 - 1	4	0.2	1,000	20000	
L4 - 2	0	0.2	1,000		20,000
L4 - 3	4	0.2	1,000	20000	
L4 - 4		0.2	1,000		
Feed - 1	7	0.2	1,000	35000	
Feed - 2	6	0.2	1,000	30000	41,667
Feed - 3	12	0.2	1,000	60000	
Feed - 4		0.2	1,000		

Oct. 3-05 per 100 mL

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	9	0.2	D3	1,000		3077449		900000	
L1 - 2	3	0.2	D3	1,000	14.62	1025816	2,051,633	300000	600,000
L1 - 3	7	0.2	D3	1,000		2393572		700000	
L1 - 4	5	0.2	D3	1,000		1709694		500000	
L2 - 1	7	0.2	D3	1,000		2375297		700000	
L2 - 2	5	0.2	D3	1,000	14.73	1696641	1,922,859	500000	566,667
L2 - 3	5	0.2	D3	1,000		1696641		500000	
L2 - 4		0.2	D3	1,000					
L3 - 1	3	0.2	D3	1,000		955261.9		300000	
L3 - 2	4	0.2	D3	1,000	15.70	1273683	1,273,683	400000	400,000
L3 - 3	2	0.2	D3	1,000		636841.3		200000	
L3 - 4	7	0.2	D3	1,000		2228944		700000	
L4 - 1	4	0.2	D3	1,000		775870.4		400000	
L4 - 2	2	0.2	D3	1,000	25.78	387935.2	1,066,822	200000	550,000
L4 - 3	6	0.2	D3	1,000		1163806		600000	
L4 - 4	10	0.2	D3	1,000		1939676		1000000	
Feed - 1	3	0.2	D3	1,000		963391.1		300000	
Feed - 2	4	0.2	D3	1,000	15.57	1284522	1,177,478	400000	366,667
Feed - 3	4	0.2	D3	1,000		1284522		400000	
Feed - 4		0.2	D3	1,000					

Oct. 12-05 per 100 mL

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	4	0.2	D3	1,000		1047669		400000	
L1 - 2	4	0.2	D3	1,000	19.09	1047669	916,710	400000	350,000
L1 - 3	2	0.2	D3	1,000		523834.5		200000	
L1 - 4	4	0.2	D3	1,000		1047669		400000	
L2 - 1	2	0.2	D3	1,000		577700.8		200000	
L2 - 2	6	0.2	D3	1,000	17.31	1733102	1,372,039	600000	475,000
L2 - 3	5	0.2	D3	1,000		1444252		500000	
L2 - 4	6	0.2	D3	1,000		1733102		600000	
L3 - 1	2	0.2	D3	1,000		552486.2		200000	
L3 - 2	5	0.2	D3	1,000	18.10	1381215	1,381,215	500000	500,000
L3 - 3	8	0.2	D3	1,000		2209945		800000	
L3 - 4	5	0.2	D3	1,000		1381215		500000	
L4 - 1	3	0.2	D3	1,000		609756.1		300000	
L4 - 2	8	0.2	D3	1,000	24.60	1626016	1,219,512	800000	600,000
L4 - 3	10	0.2	D3	1,000		2032520		1000000	
L4 - 4	3	0.2	D3	1,000		609756.1		300000	
Feed - 1	8	0.2	D3	1,000		1971414		800000	
Feed - 2	7	0.2	D3	1,000	20.29	1724988	1,416,954	700000	575,000
Feed - 3	6	0.2	D3	1,000		1478561		600000	
Feed - 4	2	0.2	D3	1,000		492853.6		200000	

Oct. 23-05 per 100 mL

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	Conc'n	Average	Conc'n	Average
L1 - 1	9	0.2	D3	1,000		2705953		900000	
L1 - 2	6	0.2	D3	1,000	16.63	1803969	2,330,126	600000	775,000
L1 - 3	3	0.2	D3	1,000		901984.4		300000	
L1 - 4	13	0.2	D3	1,000		3908599		1300000	
L2 - 1	4	0.2	D3	1,000		1203369		400000	
L2 - 2	8	0.2	D3	1,000	16.62	2406739	1,729,844	800000	575,000
L2 - 3	7	0.2	D3	1,000		2105897		700000	
L2 - 4	4	0.2	D3	1,000		1203369		400000	
L3 - 1	0	0.2	D3	1,000		0		0	
L3 - 2	8	0.2	D3	1,000	16.96	2358491	1,326,651	800000	450,000
L3 - 3	4	0.2	D3	1,000		1179245		400000	
L3 - 4	6	0.2	D3	1,000		1768868		600000	
L4 - 1	1	0.2	D3	1,000		195312.5		100000	
L4 - 2	3	0.2	D3	1,000	25.60	585937.5	781,250	300000	400,000
L4 - 3	5	0.2	D3	1,000		976562.5		500000	
L4 - 4	7	0.2	D3	1,000		1367188		700000	
Feed - 1	4	0.2	D3	1,000		928505.1		400000	
Feed - 2	4	0.2	D3	1,000	21.54	928505.1	986,537	400000	425,000
Feed - 3	4	0.2	D3	1,000		928505.1		400000	
Feed - 4	5	0.2	D3	1,000		1160631		500000	

PHASE 3 – Digesters

August 9, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
Control - 1	62	0.2	D2	100		1503942	
Control - 2	9	0.2	D3	1,000	20.61	2183141	2,073,984
Control - 3	10	0.2	D3	1,000		2425713	
Control - 4	9	0.2	D3	1,000		2183141	

August 11, 2005 - August 12, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	5	0.2	D3	1,000		1386001	
L1 - 2	3	0.2	D3	1,000	18.04	831600.8	1,108,801
L1 - 3		0.2	D3	1,000			
L1 - 4		0.2	D3	1,000			
L2 - 1	7	0.2	D3	1,000		2610966	
L2 - 2	4	0.2	D3	1,000	13.41	1491981	2,051,473
L2 - 3		0.2	D3	1,000			
L2 - 4		0.2	D3	1,000			
L3 - 1	3	0.2	D3	1,000		902662.9	
L3 - 2	4	0.2	D3	1,000	16.62	1203550	1,053,107
L3 - 3		0.2	D3	1,000			
L3 - 4		0.2	D3	1,000			
L4 - 1	3	0.2	D3	1,000		894988.1	
L4 - 2	2	0.2	D3	1,000	16.76	596658.7	745,823
L4 - 3		0.2	D3	1,000			
L4 - 4		0.2	D3	1,000			
Control - 1	5	0.2	D3	1,000		151393	
Control - 2	4	0.2	D3	1,000	165.13	121114.4	136,254
Control - 3		0.2	D3	1,000			
Control - 4		0.2	D3	1,000			

Sept. 13, 2005 - Sept. 14, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	9	0.2	D3	1,000		732210.9	
L1 - 2	6	0.2	D3	1,000	61.46	488140.6	623,735
L1 - 3	8	0.2	D3	1,000		650854.2	
L1 - 4	BB	0.2	D3	1,000			
L2 - 1	12	0.2	D3	1,000		1038925	
L2 - 2	8	0.2	D3	1,000	57.75	692616.7	627,684
L2 - 3	4	0.2	D3	1,000		346308.4	
L2 - 4	5	0.2	D3	1,000		432885.4	
L3 - 1	7	0.2	D3	1,000		595205.7	
L3 - 2	12	0.2	D3	1,000	58.80	1020353	793,608
L3 - 3	9	0.2	D3	1,000		765264.5	
L3 - 4	BB	0.2	D3	1,000			
L4 - 1	5	0.2	D3	1,000		413133.7	
L4 - 2	13	0.2	D3	1,000	60.51	1074148	661,014
L4 - 3	7	0.2	D3	1,000		578387.2	
L4 - 4	7	0.2	D3	1,000		578387.2	
Control - 1	6	0.2	D3	1,000		459552.5	
Control - 2	10	0.2	D3	1,000	65.28	765920.8	510,614
Control - 3	4	0.2	D3	1,000		306368.3	
Control - 4	BB	0.2	D3	1,000			

September 15, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	14	0.2	D3	1,000		3831418	
L1 - 2	7	0.2	D3	1,000	18.27	1915709	2,257,800
L1 - 3	3	0.2	D3	1,000		821018.1	
L1 - 4	9	0.2	D3	1,000		2463054	
L2 - 1	4	0.2	D3	1,000		1238582	
L2 - 2	4	0.2	D3	1,000	16.15	1238582	1,548,227
L2 - 3	4	0.2	D3	1,000		1238582	
L2 - 4	8	0.2	D3	1,000		2477164	
L3 - 1	2	0.2	D3	1,000		624219.7	
L3 - 2	7	0.2	D3	1,000	16.02	2184769	1,326,467
L3 - 3	4	0.2	D3	1,000		1248439	
L3 - 4	4	0.2	D3	1,000		1248439	
L4 - 1	8	0.2	D3	1,000		2508623	
L4 - 2	8	0.2	D3	1,000	15.95	2508623	1,803,073
L4 - 3	5	0.2	D3	1,000		1567890	
L4 - 4	2	0.2	D3	1,000		627155.8	
Control - 1	12	0.2	D3	1,000		3825311	
Control - 2	6	0.2	D3	1,000	15.69	1912655	2,072,043
Control - 3	5	0.2	D3	1,000		1593880	
Control - 4	3	0.2	D3	1,000		956327.7	

Sept. 27-05

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	12	0.2	D3	1,000		3268864	
L1 - 2	8	0.2	D3	1,000	18.36	2179243	2,655,952
L1 - 3	10	0.2	D3	1,000		2724053	
L1 - 4	9	0.2	D3	1,000		2451648	
L2 - 1	12	0.2	D3	1,000		3763525	
L2 - 2	2	0.2	D3	1,000	15.94	627254.2	1,724,949
L2 - 3	5	0.2	D3	1,000		1568135	
L2 - 4	3	0.2	D3	1,000		940881.3	
L3 - 1	5	0.2	D3	1,000		1505571	
L3 - 2	6	0.2	D3	1,000	16.60	1806685	1,806,685
L3 - 3	4	0.2	D3	1,000		1204456	
L3 - 4	9	0.2	D3	1,000		2710027	
L4 - 1	8	0.2	D3	1,000		2558772	
L4 - 2	9	0.2	D3	1,000	15.63	2878618	3,278,426
L4 - 3	5	0.2	D3	1,000		1599232	
L4 - 4	19	0.2	D3	1,000		6077083	
Feed - 1	7	0.2	D3	1,000		2105263	
Feed - 2	7	0.2	D3	1,000	16.63	2105263	1,954,887
Feed - 3	7	0.2	D3	1,000		2105263	
Feed - 4	5	0.2	D3	1,000		1503759	

October 3, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	1	0.2	D3	1,000		277200.3	
L1 - 2	5	0.2	D3	1,000	18.04	1386001	1,178,101
L1 - 3	8	0.2	D3	1,000		2217602	
L1 - 4	3	0.2	D3	1,000		831600.8	
L2 - 1	2	0.2	D3	1,000		745990.3	
L2 - 2	3	0.2	D3	1,000	13.41	1118985	1,305,483
L2 - 3	5	0.2	D3	1,000		1864976	
L2 - 4	4	0.2	D3	1,000		1491981	
L3 - 1	4	0.2	D3	1,000		1203550	
L3 - 2	9	0.2	D3	1,000	16.62	2707989	1,805,326
L3 - 3	6	0.2	D3	1,000		1805326	
L3 - 4	5	0.2	D3	1,000		1504438	
L4 - 1	3	0.2	D3	1,000		894988.1	
L4 - 2	4	0.2	D3	1,000	16.76	1193317	1,118,735
L4 - 3	6	0.2	D3	1,000		1789976	
L4 - 4	2	0.2	D3	1,000		596658.7	
Feed - 1	4	0.2	D3	1,000		1171989	
Feed - 2	1	0.2	D3	1,000	17.07	292997.4	976,658
Feed - 3	5	0.2	D3	1,000		1464987	
Feed - 4		0.2	D3	1,000			

October 6, 2005

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	8	0.2	D3	1,000		2189981	
L1 - 2	8	0.2	D3	1,000	18.27	2189981	2,189,981
L1 - 3	7	0.2	D3	1,000		1916233	
L1 - 4	9	0.2	D3	1,000		2463728	
L2 - 1	1	0.2	D3	1,000		422833	
L2 - 2	1	0.2	D3	1,000	11.83	422833	1,268,499
L2 - 3	4	0.2	D3	1,000		1691332	
L2 - 4	6	0.2	D3	1,000		2536998	
L3 - 1	3	0.2	D3	1,000		863061	
L3 - 2	9	0.2	D3	1,000	17.38	2589183	1,654,200
L3 - 3	2	0.2	D3	1,000		575374	
L3 - 4	9	0.2	D3	1,000		2589183	
L4 - 1	9	0.2	D3	1,000		2640845	
L4 - 2	6	0.2	D3	1,000	17.04	1760563	1,760,563
L4 - 3	4	0.2	D3	1,000		1173709	
L4 - 4	5	0.2	D3	1,000		1467136	
Feed - 1	6	0.2	D3	1,000		1784387	
Feed - 2	3	0.2	D3	1,000	16.81	892193.3	1,561,338
Feed - 3	7	0.2	D3	1,000		2081784	
Feed - 4	5	0.2	D3	1,000		1486989	

Oct. 12-05

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	5	0.2	D3	1,000		1403903	
L1 - 2	8	0.2	D3	1,000	17.81	2246245	1,591,090
L1 - 3	4	0.2	D3	1,000		1123122	
L1 - 4		0.2	D3	1,000			
L2 - 1	1	0.2	D3	1,000		416927.2	
L2 - 2	2	0.2	D3	1,000	11.99	833854.5	729,623
L2 - 3	3	0.2	D3	1,000		1250782	
L2 - 4	1	0.2	D3	1,000		416927.2	
L3 - 1	4	0.2	D3	1,000		1275917	
L3 - 2	3	0.2	D3	1,000	15.68	956937.8	1,196,172
L3 - 3	5	0.2	D3	1,000		1594896	
L3 - 4	3	0.2	D3	1,000		956937.8	
L4 - 1	5	0.2	D3	1,000		1503307	
L4 - 2	7	0.2	D3	1,000	16.63	2104630	1,879,134
L4 - 3	6	0.2	D3	1,000		1803969	
L4 - 4	7	0.2	D3	1,000		2104630	
Control - 1	1	0.2	D3	1,000		296384.1	
Control - 2	3	0.2	D3	1,000	16.87	889152.3	1,111,440
Control - 3	4	0.2	D3	1,000		1185536	
Control - 4	7	0.2	D3	1,000		2074689	

Oct. 16-05

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	10	0.2	D3	1,000		2498438	
L1 - 2	7	0.2	D3	1,000	20.01	1748907	2,123,673
L1 - 3	8	0.2	D3	1,000		1998751	
L1 - 4	9	0.2	D3	1,000		2248595	
L2 - 1	3	0.2	D3	1,000		1105583	
L2 - 2	2	0.2	D3	1,000	13.57	737055.5	552,792
L2 - 3	1	0.2	D3	1,000		368527.7	
L2 - 4	0	0.2	D3	1,000		0	
L3 - 1	2	0.2	D3	1,000		581564.4	
L3 - 2	3	0.2	D3	1,000	17.19	872346.6	1,163,129
L3 - 3	5	0.2	D3	1,000		1453911	
L3 - 4	6	0.2	D3	1,000		1744693	
L4 - 1	6	0.2	D3	1,000		1599787	
L4 - 2	9	0.2	D3	1,000	18.75	2399680	1,666,444
L4 - 3	4	0.2	D3	1,000		1066524	
L4 - 4	6	0.2	D3	1,000		1599787	
Control - 1	6	0.2	D3	1,000		1642036	
Control - 2	5	0.2	D3	1,000	18.27	1368363	1,299,945
Control - 3	3	0.2	D3	1,000		821018.1	
Control - 4	5	0.2	D3	1,000		1368363	

Oct. 19-05

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	5	0.2	D3	1,000		1217878	
L1 - 2	8	0.2	D3	1,000	20.53	1948606	2,029,797
L1 - 3	12	0.2	D3	1,000		2922908	
L1 - 4		0.2	D3	1,000			
L2 - 1	5	0.2	D3	1,000		1749781	
L2 - 2	4	0.2	D3	1,000	14.29	1399825	1,399,825
L2 - 3	4	0.2	D3	1,000		1399825	
L2 - 4	3	0.2	D3	1,000		1049869	
L3 - 1	3	0.2	D3	1,000		944733.1	
L3 - 2	3	0.2	D3	1,000	15.88	944733.1	944,733
L3 - 3	2	0.2	D3	1,000		629822.1	
L3 - 4	4	0.2	D3	1,000		1259644	
L4 - 1	5	0.2	D3	1,000		1314924	
L4 - 2	2	0.2	D3	1,000	19.01	525969.8	920,447
L4 - 3	6	0.2	D3	1,000		1577909	
L4 - 4	1	0.2	D3	1,000		262984.9	
Control - 1	5	0.2	D3	1,000		1368925	
Control - 2	5	0.2	D3	1,000	18.26	1368925	1,300,479
Control - 3	5	0.2	D3	1,000		1368925	
Control - 4	4	0.2	D3	1,000		1095140	

Oct. 23-05

Clostridium Perfringens

	Count	Volume	Dilution	Factor	Solids	C/g solids	Average
L1 - 1	6	0.2	D3	1,000		1728858	
L1 - 2	1	0.2	D3	1,000	17.35	288142.9	960,476
L1 - 3	3	0.2	D3	1,000		864428.8	
L1 - 4		0.2	D3	1,000			
L2 - 1	2	0.2	D3	1,000		712250.7	
L2 - 2	4	0.2	D3	1,000	14.04	1424501	1,187,085
L2 - 3	4	0.2	D3	1,000		1424501	
L2 - 4		0.2	D3	1,000			
L3 - 1	1	0.2	D3	1,000		391312.9	
L3 - 2	3	0.2	D3	1,000	12.78	1173939	586,969
L3 - 3	1	0.2	D3	1,000		391312.9	
L3 - 4	1	0.2	D3	1,000		391312.9	
L4 - 1	6	0.2	D3	1,000		1441961	
L4 - 2	6	0.2	D3	1,000	20.81	1441961	1,121,525
L4 - 3	2	0.2	D3	1,000		480653.7	
L4 - 4		0.2	D3	1,000			
Control - 1	2	0.2	D3	1,000		597550	
Control - 2	6	0.2	D3	1,000	16.74	1792650	746,938
Control - 3	0	0.2	D3	1,000		0	
Control - 4	2	0.2	D3	1,000		597550	