# ANAEROBIC DIGESTION OPTIMIZATION FOR ENHANCED RENEWABLE BIOMETHANE PRODUCTION


By

TED ROSS STOVER

Bachelor of Science in Zoology
Oklahoma State University
Stillwater, Oklahoma
2008

Master of Science in Environmental Engineering
Oklahoma State University
Stillwater, OK
2009



Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2011

ANAEROBIC DIGESTION OPTIMIZATION FOR

ENHANCED RENEWABLE BIOMETHANE

PRODUCTION

Dissertation Approved:

Dr. Enos L. Stover

Dissertation Adviser

Dr. William F. McTernan

Dr. Gregory G. Wilber

Dr. Dee Ann Sanders

Dr. Douglas Hamilton

Outside Committee Member

Dr. Mark E. Payton

Dean of the Graduate College

# ACKNOWLEDGMENTS

I would like to sincerely thank my father, Dr. Enos L. Stover, for serving as my thesis advisor and providing direct oversight throughout the course of this research study. I would also like to thank Dr. Stover for giving me motivation to pursue higher education at Oklahoma State University and providing learning experiences and opportunities that most aspiring engineers will never have the chance to encounter.

I would like to thank Dr. William F. McTernan for serving as my committee chairman, and Dr. Dee Ann Sanders and Dr. Gregory G. Wilber for serving as committee members. All three instructors have provided great insight and a fun and memorable learning experience at Oklahoma State University that I will remember for the rest of my life. I would also like to thank Dr. Douglas Hamilton for his willingness to serve as a committee member.

Special thanks to my wife, Abby, for her understanding and support through the extensive timeframe of this project, and for encouraging me to succeed in everything I do.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

# CHAPTER I

# INTRODUCTION

With petroleum-based fuel prices at all-time record highs and growing public interest in environmentally conscious products, alternative fuel sources are receiving more attention than ever. Universities, private and public corporations, and government agencies are spending millions of dollars each year to further research towards production of effective and feasible alternative fuels that are renewable, clean burning, and more economical to produce compared to the long-established fossil fuels. One alternative fuel that has been received with great success in Europe and Asia, and is showing increased interest in the United States, is biomethane (biogas). Biogas has been evaluated as one of the most energy-efficient and environmentally beneficial technologies for bioenergy production (Fehrenbach *et al.*, 2008)

Biogas is a biologically-produced, renewable fuel that can be used for any combustion process that utilizes methane as a fuel source, such as heat, transportation, electricity, and combined heat and power (CHP) generation. Biogas can also be scrubbed and upgraded to meet pipeline gas quality standards for transmission. Biogas is comprised of methane, carbon dioxide, hydrogen sulfide and other trace gases, and is generated by biological anaerobic digestion of organic compounds and materials, such as agricultural wastes, including animal and crop wastes, food wastes, energy crops, industrial wastes, and municipal wastes.

With the success of biogas as a fuel source in Europe and Asia, and the prospective future of biogas as a fuel source in the United States, research studies were performed to evaluate anaerobic digester operations from an alternative fuels production standpoint.

The scope of this research study was to operate suspended growth, continuous stirred tank reactor (CSTR) anaerobic digesters at the bench-scale level to evaluate improved operation techniques/methods and develop biokinetic relationships. Multiple digester reactors were operated simultaneously for approximately fourteen months to obtain data that were used to develop improved operational processes and biokinetic relationships, along with evaluation of treatment performance under various operating conditions.

The ultimate goal of this study was to develop biokinetic constants and a database of anaerobic digester operating parameters using manual operating techniques at the bench-scale level that could be applied for automation of full-scale biogas/bioenergy production facilities for the purpose of enhanced biogas production. The purpose of automating full-scale biogas/bioenergy production facilities is to improve digester operations and enhance biogas production by producing the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume while maintaining stabile digester operating conditions.

Considering technology currently available for on-line monitoring and process control of biogas production facilities and waste treatment facilities, facilities could ultimately implement automated monitoring of key analytical parameters and biokinetic constants along with a means for adjusting selected variables through the use of programmable logic controllers (PLCs) to optimize for biogas production and treatment performance while maintaining adequate pH and alkalinity requirements.

Feedstocks used for this research project consisted of combined agricultural waste feedstocks, such as laying hen litter, swine manure, corn husklage, thin stillage from fuel alcohol production, and sweet corn silage juice. Feedstocks were chosen based on availability and reasonable trucking distance within a specific region of the United States based on the concept of regional waste biogas production facilities. Individual feedstocks were characterized for chemical oxygen demand (COD), nutrient value, and pH and alkalinity. Individual feedstocks were blended together to provide a co-digestion process based on individual feedstock characterization to control COD to nutrient ratios, pH and alkalinity demands in the digesters, manage ammonia inhibition/toxicity, and provide macronutrients (nitrogen and phosphorus) and micronutrients without requiring additional nutrient supplementation. Trace elements like iron, nickel, cobalt, selenium, molybdenum, and tungsten are important for the growth rate of microorganisms and often must be added for biogas production if single feedstocks such as energy crops are used (Abdoun and Weiland, 2009; Jarvis *et al.*, 1997). Feedstocks were provided by outside suppliers and shipped to laboratory facilities in Stillwater, Oklahoma, and stored at 4$^{o}$C in a walk-in refrigerator prior to use.

Multiple bench-scale anaerobic digesters were operated in a semi-continuous fed, CSTR mode. Feed was pumped into the digesters via peristaltic pumps controlled by electronic timers. Once daily, digester lids were removed to allow for wasting of digester contents to maintain digester operating volumes. All digesters were operated under mesophilic conditions. Digesters were operated in a temperature controlled room and air temperature was maintained between 33$^{o}$C to 36$^{o}$C throughout the course of the research study period. Digesters were operated in a once-through CSTR mode similar to full-scale operations at conventional anaerobic digestion facilities. However; one digester was operated in a biomass recycle CSTR mode to evaluate the impacts of sludge recycle on treatment performance and biogas quality and quantity. To accomplish biomass recycle, digester contents were removed once daily to maintain a standard digester operating volume. The digester contents removed from the biomass recycle digester were placed into a laboratory centrifuge. After centrifugation, the centrate was wasted and sampled as effluent, while the concentrated biomass was returned to the digester. Excess centrate remaining after effluent sampling was discarded. The biomass recycle digester was operated under the same maintenance and sampling programs as the other digesters. All digesters were routinely sampled for key analytical parameters and monitored for biogas production quantity and quality.

Biokinetic relationships were developed from data obtained during the course of the research study for specific biogas production rate, specific methane production rate, and specific substrate utilization rate, or substrate removal, in terms of COD. Biokinetic constants were developed according to the Stover-Kincannon Model (Stover & Kincannon, 1982, 1983, and 1984).

# CHAPTER II

# REVIEW OF LITERATURE

## CURRENT STATE

Many European and Asian countries have already turned to biogas as a major fuel source for electricity production, transportation fuel, and heating fuel. Biogas currently accounts for 2/3 of the renewable energy in Europe and is typically produced from agricultural wastes, including animal and crop wastes, energy crops, industrial wastes, and municipal wastes (European Biomass Association, 2009). Germany has become the world's largest biogas producing country with approximately 4,000 on-farm biogas production plants in operation at the end of 2008 (Fachverband Biogas, 2009) The most common digester reactor configuration is the vertical CSTR which is applied in nearly 90% of the modern biogas production facilities in Germany (Gemmeke *et al.*, 2009). An estimated six to eight million family-sized, low-technology digesters are used in the Far East (China and India) to provide biogas for cooking and lighting. Over 1,000 high-rate anaerobic digesters are operated world-wide to treat organic polluted industrial waste streams including beverage, food, meat, pulp and paper, and milk processors (IEA Bioenergy, 1999).

**BACKGROUND**

Biogas is a biological product that occurs as a result of anaerobic digestion of organic compounds and materials, both in soluble waste constituents, or in particulate suspended solid matter that serves as a food or fuel source for anaerobic microorganisms. The three main components of biogas are methane, carbon dioxide, and hydrogen sulfide. The fractional composition of biogas, as well as methane yield, varies based on waste source quality, sulfur content, type of digestion system used, and hydraulic retention time (HRT) (Braun 2007).

Methane is a colorless, odorless, combustible gas and the principal component of natural gas and biogas. Methane typically comprises 65 to 85 percent of biogas, depending on waste source quality. Methane production can be estimated based on substrate removal efficiency in terms of COD. For each gram of COD removed/converted under anaerobic conditions, 0.35 liters of methane is produced at standard conditions ($0^{o}C$ and 1 atm) (Metcalf and Eddy, Inc., 2003). Methane from biogas can be used as a fuel source for a variety of operations, such as heat fuel, engine fuel for transportation, engine fuel for electricity generation, and engine fuel for CHP, which is the process of electricity generation and waste heat recovery. Biogas is usually used to fuel reciprocal engine CHP processes where electricity generating efficiencies can reach up to 43%. An alternative to reciprocal engine CHP processes is the microgas turbine. Microgas turbines result in lower electricity generation efficiencies between 25%-31%, but provide long maintenance intervals. The big advantage of microgas turbines compared to reciprocal engines is the high exhaust temperatures of 270 $^{o}$C or higher which provides excellent heat for steam production (Schmid *et al.*, 2005). Biogas can also be merged with natural gas in pipelines, but must be conditioned prior to injection. To be used for fuel purposes, biogas must first be cleaned and separated as many gas utility providers require 98% methane content and a minimum heating value of 990 British thermal units per standard cubic foot (Burns & McDonnell, 2010). Waste heat produced by combustion of biogas can also be collected and used to return heat to maintain digester temperature, or supply heat for water or air heating demands.

Combustion of methane results in reduced emissions when compared to fossil fuels. Concentrations of greenhouse gases in the atmosphere are rising rapidly as a result of fossil fuel carbon dioxide emissions. In order to minimize global climate impacts as a result of greenhouse gas emissions, a report by the Intergovernmental Panel on Climate Change (IPCC) indicated that greenhouse gas emissions must be reduced to less than half of the global emissions from the year 1990 (2000). Combustion of methane, compared to oil and coal, resulted in greatly reduced carbon dioxide, nitrogen oxide, sulfur dioxide, particulate, and mercury emissions as demonstrated in a recent study performed by the United States Environmental Protection Agency (NaturalGas.org, 2010).

Carbon dioxide is a colorless, odorless gas which typically comprises 10 to 35 percent of biogas composition. Carbon dioxide removal is not required for combustion of biogas. However; if the biogas produced is to be blended in with natural gas pipelines or used for transportation fuel, carbon dioxide must be removed since it dilutes the energy content of the biogas, but is considered to have no significant environmental impact (IEA Bioenergy, 1999).

Hydrogen sulfide is an odorous and toxic gas produced during decomposition of sulfur-containing residues by sulfate-reducing bacteria that compete with methanogenic bacteria for substrate. The lethal concentration for 50% ($LC_{50}$) of humans for 5 minutes of exposure is 800 ppm hydrogen sulfide (Speece, 2008). The characteristic rotten egg odor of hydrogen sulfide is a nuisance, but hydrogen sulfide can also be of major concern for plant operations due to its corrosive nature. Hydrogen sulfide has been found to be corrosive to cast iron, steel, ferric stainless steel, 300 series stainless steels, copper nickel alloys, high nickel molybdenum alloys, copper, copper-based alloys (brass and some bronzes), Monel metal, and silver (Speece, 2008). For this reason, hydrogen sulfide can have detrimental effects on reactor/digester surfaces, piping, and electrical components. Several methods for hydrogen sulfide removal exist. The most common commercially practiced methods are air/oxygen dosing to biogas, iron chloride dosing to the digester contents, iron sponges, iron oxide pellets, activated carbon, water scrubbing, sodium hydroxide scrubbing, biological removal on a filter bed, and air stripping and recovery (IEA Bioenergy, 1999).

## Anaerobic Digestion Process

Anaerobic digestion consists of three major processes: hydrolysis, fermentation, and methanogenesis. First, solid particulate matter must be hydrolyzed to soluble compounds, such as carbohydrates, proteins, and lipids that can be transported across the microorganism cell wall before it can be used as a food or fuel source. The hydrolysis process can be assisted using mechanical methods, such as grinders/choppers to decrease particle sizes, to reduce the time required to achieve biochemical hydrolyzation. To increase the degradation rate of substrates, pretreatment processes using mechanical, thermal, chemical, or enzymatic processes can be applied (Müller *et al.*, 2003). Mshandete *et al.* noted that the degradation process is faster with decreasing particle size, but does not necessarily result in improved methane yield (2006). However; it should be noted that depending on waste characteristics, not all digestion processes will require the hydrolysis step. The second major process in anaerobic digestion is the fermentation process. The fermentation process is facilitated by facultative and obligate anaerobes and is also referred to as acetogenesis (Speece, 2008). During the fermentation process, complex soluble compounds are further broken down into simple compounds such as acetate, hydrogen, carbon dioxide, and occasionally propionate, and butyrate. In low pH conditions, acetate is found in the acidic form ($CH_3COOH$). At higher pHs, acetate exists in the acetate salt forms of sodium acetate ($NaCH_3COO$), potassium acetate ($KCH_3COO$) and calcium acetate ($CaCH_3COO$) (Stover, 1998). Although acetate is usually present in higher concentrations than other volatile fatty acids (VFAs), propionate and butyrate were found to cause more inhibition to methanogens (Wang *et al.*, 1999; Mösche and Jördening, 1999). The inhibition was found to be a result of the undissociated forms, resulting in increased VFA inhibition in low pH systems. Studies performed by Cohen indicate that propionic acid is predominant during unstable digester conditions, is difficult to degrade, is not a known methanogenic substrate, and must first pass through acetogenesis before being converted to methane (1983). By-products from the fermentation process are the precursors for the final process of methane production, methanogenesis.  In this process, the fermentation by-products are converted to biogas by select bacterial genres known as methanogens.  The methanogens can be divided into two groups, one group known as aceticlastic methanogens, which physically split acetate into methane and carbon dioxide, and the other group known as hydrogen-utilizing methanogens, which use hydrogen as an electron donor and carbon dioxide as the electron acceptor to form methane (Metcalf and Eddy, Inc., 2003).  A diagram of the basic anaerobic processes previously described can be viewed in Figure 1.

When acetic acid is converted to methane and carbon dioxide, the carbon dioxide reacts to produce both methane and carbonic acid.  The carbonic acid represents the majority of the acidity produced by anaerobic treatment.  The major requirement for alkalinity in anaerobic systems is neutralization of high carbonic acid which results from the high partial pressure of carbon dioxide in the system.  The alkalinity requirement for VFA neutralization is small compared to that for carbonic acid.  If acetate is present as sodium and potassium acetate salts, sodium and potassium acetate get converted to methane, sodium bicarbonate, and potassium bicarbonate.  No carbon dioxide is produced in this process (Stover, 1998).  Sodium and potassium bicarbonate are referred to as generated alkalinity.  Calcium acetate gets converted to methane, carbon dioxide, and calcium carbonate.  The carbon dioxide produced prevents an excessive increase in system alkalinity and pH.  Methanogenesis is typically considered to be the rate limiting step in anaerobic treatment with upset conditions usually accompanied by an increase in VFAs and a decrease in process efficiency (Stover, 2009).  McCarty stated that methane fermentation of fatty acids is the ultimate step that determines the maximum loading rate in treatment of readily degradable organic materials and that failure of methane-formers

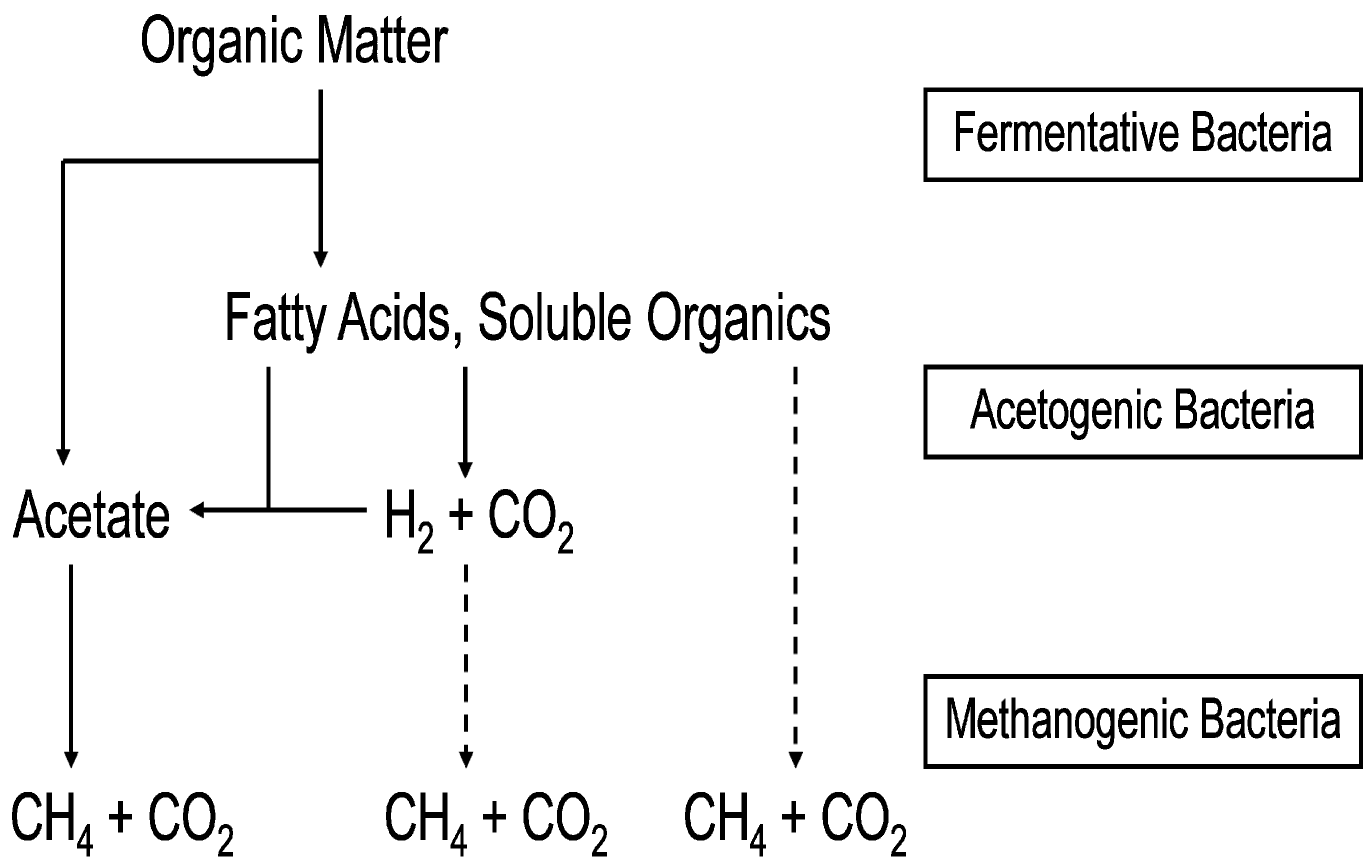



Figure 1. Basic Diagram of Anaerobic Digestion Processes

to utilize the volatile acids at approximately the same rate as they are produced can result in a build-up in volatile acids and a drop in pH (1966). However; the rate-limiting step can vary based on organic loading rate and substrate characteristics. Studies performed using high-solids swine waste concluded that hydrolysis was the rate limiting step at high organic loading rates, while acetogenesis was the rate-limiting step at lower organic loading rates (Barber, 1987). Studies using municipal wastewater and refuse sludges determined hydrolysis to be the rate-limiting step due to slow degradation of lipids (O'Rourke, 1968). Temperature impact studies have determined that temperature affects the rate of conversion of acetate to methane. Studies by Stover *et al.* and Speece have both shown methanogenesis rates to be dependent on temperature (1994 and 1970, respectively). As temperature decreases, methanogenesis rates decrease and cause methanogenesis to become the rate-limiting step.

**<u>Advantages of Anaerobic Digestion</u>**

Anaerobic digestion provides several advantages over conventional activated sludge treatment processes when treating high-strength wastes, such as agricultural wastes. Anaerobic digestion processes typically require no nutrient addition, have lower alkalinity demands when compared to aerobic treatment processes, and can produce a high quality effluent that can be recycled back for reuse, used for irrigation purposes, or discharged (Stover *et al.*, 1984). Anaerobic processes also have lower sludge yields; typically 6 to 8 times less sludge is produced for anaerobic processes compared to aerobic processes, which requires less cost expenditures for sludge handling operations (Metcalf and Eddy. Inc., 2003). Anaerobic digesters can also handle higher organic loading rates in the range of 3.2 to 32 kg COD/$m^3$/day compared to aerobic processes which may be limited to 0.5 to 3.2 kg COD/$m^3$/day (Speece, 1996).

Healthy anaerobic digestate can be a quality fertilizer source. Anaerobic treatment minimizes the survival of pathogens which is important for using digested residue as fertilizer (Weiland, 2010). The anaerobic digestion process is capable of inactivation of weed seeds, bacteria, viruses, fungi, and parasites (Sahlström, 2003; Strauch and Philipp, 2000).

Another economical benefit to anaerobic digestion can be the possible occurrence of ammonium magnesium phosphate (struvite) precipitation. Struvite is a high-quality, high-value fertilizer that can be harvested from anaerobic processes and sold to offset operating costs. Struvite can form in anaerobic systems when the waste streams contain high concentrations of orthophosphates, ammonia and magnesium (Loewethal *et al*, 1994). It has been observed that reducing the partial pressure of carbon dioxide triggers struvite precipitation (Speece, 2008). Although struvite formation can serve as a financial return for plant operations through fertilizer sales, it is often considered a nuisance by operating staff. The precipitant typically forms in pipe elbows and pump inlets, or on surfaces close to inlets and outlets of secondary clarifiers following CSTR reactors (Speece, 2008).

## PREVIOUS STUDIES

Studies were performed by Takamura to evaluate the performance of anaerobic CSTR and packed bed reactors using centrifuged thin stillage from fuel alcohol production as substrate from a waste treatment standpoint (1983). Takamura observed better substrate removal efficiency and stability at lower substrate loading rates using packed bed reactors operated at HRTs below 15 days. However; he found that the CSTR systems were capable of handling higher loading rates with hydraulic retention times of 20 days or longer. Takamura also monitored methane production for both systems and found that both systems produced nearly identical volumes of methane per mass of substrate fed.

Research studies performed by Dutt expanded on Takamura's work by evaluating higher substrate loading rates on anaerobic packed bed reactors and conventional and modified CSTRs (1985). Dutt's studies demonstrated pH and alkalinity problems as a result of high loading rates and low HRTs of 6 days, requiring calcium carbonate addition to supplement alkalinity and maintain pH levels.

Pilot-scale treatability studies were performed by Lanting and Gross by feeding thin stillage from fuel alcohol production to an Upflow Anaerobic Sludge Blanket (UASB) digester at HRTs of 10 hours (1985). The system managed to achieve COD removal efficiencies of 76%. Nitrogen and phosphorus addition were required along with caustic addition to maintain proper pH levels.

Extensive bench-scale studies were performed by Stover *et al.* using thin stillage from fuel alcohol production to evaluate anaerobic suspended growth and anaerobic fixed-film reactors to evaluate the effects of substrate loading rates on substrate removal kinetics (1983, 1984). Substrate removal kinetic constants were shown to be a function of mass substrate loading rates. These studies showed that pH and alkalinity requirements decreased significantly with increasing solids retention time (SRT) and substrate strength. It was also observed that substrate removal efficiencies remained between 98% - 99%

with SRTs of 10 days or greater. Below the limiting SRT of 4 days, VFA accumulation resulted in significantly decreased treatment performance, with negligible treatment performance observed at SRTs of 2 days.

Waste sludge from the Stover *et al.* studies was used to perform batch anaerobic studies to directly compare continuous feed systems with batch feed systems (1983, 1984). Fair comparison of the two systems was prevented due to high substrate loading in the batch feed systems causing VFA accumulation and methanogen inhibition/toxicity not experienced in the continuous fed systems. When substrate loading rates were lowered for batch feed systems to minimize VFA issues, the batch feed system kinetics approached those determined during the continuous feed studies.

Suspended growth studies were performed by Ganapathi to investigate the treatability of thin stillage from fuel alcohol production from a waste treatment standpoint (1984). Ganapathi operated both aerobic and anaerobic treatability studies and concluded that thin stillage from fuel alcohol production was susceptible to anaerobic digestion treatment processes with COD removal efficiencies of 98% or greater at organic loading rates up to three times higher than that of the aerobic systems. Ganapathi operated anaerobic systems at several different flow rates and influent substrate concentrations and determined that specific substrate utilization rate was a function of specific substrate loading rate according to the Stover-Kincannon Model. Ganapathi also stated that extreme caution should be used when incorporating anaerobic batch treatment kinetics into those of continuous systems as batch system kinetics appear different from the continuous feed kinetics due to build up of VFAs above certain specific substrate loading rates, resulting in methanogen inhibition/toxicity.

Fixed-film up-flow anaerobic digestion studies were performed for a period of two years using thin stillage from fuel alcohol production from a waste treatment standpoint (González, 1987). González developed biokinetic constants relative to fixed-film systems for the purpose of reliable full-scale fixed-film anaerobic system design and operation. Biokinetic constants were developed for specific substrate utilization rate, specific biogas production rate, and specific methane production rate as a function of mass specific substrate loading rate according to the Stover-Kincannon Model. González experienced decreasing substrate removal efficiencies, decreasing biogas methane content, and increasing biogas carbon dioxide content as specific substrate loading rates increased above determined optimum loading rates. González also attributed this decrease in digester performance to VFA accumulation, resulting in methanogen inhibition/toxicity. González concluded that development of biokinetic constants for specific substrate utilization rate, specific biogas production rate, and specific methane production rate allowed for prediction of digester operations and the ability to maintain stable digester operating conditions with varying substrate COD concentrations.

Hansen *et al.* performed anaerobic studies to evaluate ammonia inhibition using batch feed and CSTR experiments (1998). Swine manure was used as the sole substrate for CSTR experiments while batch feed studies used various blend ratios of swine and cattle manure. CSTR experiments were performed at mesophilic and thermophilic conditions while batch studies were only performed at thermophilic conditions. Hansen *et al.* observed stable CSTR digester operations with ammonia concentrations as high as 6,000 mg/L for both mesophilic and thermophilic conditions. Batch feed studies exhibited toxicity at free ammonia concentrations of 1,100 mg/L and higher with digester pHs of

8.0. Batch feed digesters exhibited toxicity through reduced biogas production with reduced methane yield. These batch feed studies demonstrated the ability of methanogens to tolerate free ammonia concentrations 7-10 times higher than that reported earlier by Braun *et al.* and De Baere *et al.* and even higher than the 700 mg/L threshold reported by Angelidaki and Ahring (1981, 1984, and 1993, respectively). A study performed by Kroiss found process inhibition by undissociated ammonia at concentrations of 80 mg/L and higher (1985).

Studies by Angelidaki *et al.* and Dornack demonstrated increased ammonia toxicity with increased temperature (2003 and 2009, respectively). Nielsen and Angelidaki performed studies to evaluate strategies for digester recovery following ammonia inhibition (2008). Nielsen and Angelidaki found that the most stable digester recovery process was accomplished by diluting digester biomass with recycled digester effluent.

# CHAPTER III

# METHODOLOGY

Anaerobic digestion research optimization studies were initially performed using five bench-scale, semi-continuous flow, anaerobic digester CSTRs with liquid volumes of 12.0 liters and headspace volumes of 1.25 liters. An additional single reactor was later operated at a liquid volume of 11.0 liters and headspace volume of 2.25 liters due to increased feed rate (decreased hydraulic retention time) and digester reactor size limitations. The anaerobic digesters were operated at various HRTs and loading rates over the course of approximately fourteen months. The purpose of this study was to perform research simulation treatment studies for evaluations of operations and performance capabilities of full-scale bio-energy anaerobic digesters for enhanced and optimized biogas (methane) production.

## FEEDSTOCKS

Feedstocks used for the anaerobic digestion research studies consisted of laying hen litter, swine manure, corn husklage, thin stillage from fuel alcohol production, and sweet corn silage juice. Feedstocks were chosen for this study based on availability within a specific region of the United States based on the concept of regional waste biogas production facilities. The feedstocks were evaluated for regional availability and reasonable trucking distance to centrally located biogas production facilities. Feedstocks were provided by outside suppliers and delivered to the laboratory facilities located in Stillwater, Oklahoma. All feedstocks were stored at $4^{o}C$ prior to use. Feedstocks were blended together based on individual feedstock characterization data. Individual feedstocks were characterized for pH, total COD (tCOD), soluble COD (sCOD), total solids (TS), volatile solids (VS), total suspended solids (TSS), volatile suspended solids (VSS), total Kjeldahl nitrogen (TKN), ammonia-nitrogen ($NH_3$-N), total phosphorus (T-P), and ortho-phosphate ($PO_4$-P) as viewed in Table 1. Individual feedstocks were blended together based on individual characteristics to manage desired COD to nutrient ratios, pH and alkalinity demands in the digesters, manage ammonia inhibition/toxicity, and provide macronutrients (nitrogen and phosphorus) and micronutrients without requiring additional nutrient supplementation.

Feed blends consisted of 0.2 grams sweet corn silage juice, 1.0 gram husklage, 11.4 grams hen litter, 38 mL swine manure, and 942 mL thin stillage. All masses and volumes of individual feedstocks listed were per liter of feed. Feed blends were typically made in 15 to 18 liter batches. All feed blends were stored at $4^{o}C$ prior to use. Swine manure was screened using a screen with 1 millimeter pore sizes. Hen litter was weighed in 110 gram batches or less. The hen litter was then placed in a beaker and diluted with de-ionized water to a final volume of 1 liter. This mixture was then placed in a household kitchen-style blender to break up the large chunks. The mixture was then poured into an Imhoff cone and allowed to settle for a minimum of 20 minutes. The supernatant layer and litter

**TABLE 1**
**Analytical Testing Program**

| Parameter | Individual Feedstocks | Digester Feed | Digester Contents | Effluent |
|---|---|---|---|---|
| Temp | | | X | |
| pH | X | X | X | X |
| tCOD | X | X | X | |
| sCOD | X | X | X | X |
| TS | X | X | X | X |
| VS | X | X | X | X |
| TSS | X | X | X | X |
| VSS | X | X | X | X |
| TKN | X | X | X | X |
| $NH_3$-N | X | X | X | X |
| Total P | X | X | X | X |
| $PO_4$-P | X | X | X | X |
| VFA | | | X | |
| T-Alk | | | X | |
| P-Alk | | | X | |
| Biogas $CO_2$ | | | X | |
| Biogas $H_2S$ | | | X | |

solids were collected and placed into the feed blend, while the grit that collected in the bottom portion of the Imhoff cone was discarded. Grit was discarded as most of the grit material was considered non-biodegradable and would settle and collect in the bottom of the digester reactors and build up reducing, effective digester working volumes. Feed blends were prepared according to the previous volumes and masses throughout the course of the entire study. Feed blend preparation routines were consistent throughout the course of the study. Digester influent feed blends were characterized for pH, COD, solids, nitrogen, and phosphorus content as viewed in Table 1.

## DIGESTER OPERATIONS

The anaerobic digesters were initially seeded with anaerobic sludge collected from the Oklahoma State University Swine Production Facility anaerobic digester, as well as anaerobic granular sludge from an industrial wastewater treatment plant located in Oklahoma. Digester mixing was accomplished via magnetic stir bar and variable speed magnetic mixer. Additional mixing was provided through biogas production due to methane insolubility and the mixing action provided as biogas rises to the liquid surface.

The initial seed and start-up of the digesters was followed by an acclimation/stabilization period to ensure proper sludge acclimation to the feed blend. The initial acclimation/stabilization period was performed by manually introducing small amounts of feed to the digesters and gradually increasing feed volume with time. Acclimation period feed rates started at approximately 50 mL of feed per day and gradually increased until the first desired HRT operating condition was achieved. Feed rate increase intervals were determined by monitoring pH, volatile fatty acids (VFAs), partial alkalinity (P-Alk), total alkalinity (T-Alk), and COD. Upon reaching the desired HRT operating condition, digesters were allowed a stabilization period of typically 2-4 weeks for pH, VFA, P-Alk, T-Alk, and COD stabilization. Stabilization periods were followed by 2-4 week detailed data collection periods. During stabilization periods, samples for digester content and digester effluent characterization, as seen in Table 1, were typically collected three times per week. During data collection periods, samples for digester content and digester effluent characterization, as seen in Table 1, were typically collected daily. Digesters were allowed a stabilization period following each increase in feed loading rate.

Daily digester feed volumes were contained in beakers and pumped into the digester reactors via peristaltic pumps. Feeds were replenished daily. The flow rates of the feed pumps were controlled with variable speed pump controllers that were operated via electronic timer, feeding approximately one minute out of every 4 hours for 24 hours per day operation. Each feed beaker was mixed via magnetic stir bar and variable speed magnetic mixer. The digesters were sealed with gas-tight lids with two bulkhead fittings that provided outside connections. These two fittings provided feed line access and biogas collection line access. The feed lines were connected to the peristaltic pumps and transferred feed to one of the bulkhead fittings in each digester, which had tubes connected on the inside of the reactors, so that feed was introduced three-quarters of the way to the bottom of each reactor. The biogas collection fittings were maintained in the head space of each digester. Effluent was removed once daily to maintain digester operating volumes.

Daily digester maintenance consisted of scraping digester walls daily to remove sludge buildup and checking all fittings and lines for plugging and leaks. Feed pumps, pump tubing, and all magnetic mixers were checked daily for proper operation, and pump tubing was replaced as needed. Table 2 outlines these and other daily maintenance duties performed throughout the course of the study.

All digesters were operated in a once-through, semi-continuous fed, CSTR mode except for one digester. The once-through digesters operated in a CSTR mode were numbered Digesters 1-4. One digester, numbered Digester 5, was operated in a biomass recycle CSTR mode to evaluate the impacts of sludge recycle on treatment performance and biogas quality and quantity. To accomplish biomass recycle, digester contents were removed once daily to maintain a standard digester operating volume. The digester contents removed from Digester 5 were placed into a Fisher Scientific Marathon 3200 centrifuge and centrifuged for 15 minutes at 4,000 rpm. After centrifugation, the centrate was wasted and sampled as effluent, while the concentrated biomass was returned to the digester. Remaining centrate after effluent sampling was discarded. Digester 5 was operated under the same maintenance and sampling programs as the other digesters. However; due to decreased HRT, increased feed loading rate, and digester size limitations, it was required to reduce the liquid operating volume of Digester 5 to 11.0 liters to maintain adequate headspace for biogas collection and analysis. Digester contents were monitored daily for pH, temperature, VFA, P-Alk, and T-Alk. Digester contents and treated effluent were routinely characterized for pH, tCOD, sCOD, TS, VS, TSS, VSS, TKN, $NH_3$-N, T-P, and $PO_4$-P throughout the course of the research optimization studies as viewed in Table 1. Digester reactors were operated in a vented,

**TABLE 2**
**Research Study – Daily Duties**
**(System Maintenance)**

| Morning | Afternoon |
|---|---|
| • Reactor Maintenance (Scrape and clean reactors, brush outlets) | • Check Mechanical Mixers (Mixing) |
| • Check Mechanical Mixers (Mixing) | • Check Feed Pumps, Tubing, Etc. (Insure working properly) |
| • Check Feed Pumps, Tubing, Etc. (Insure working properly) | |
| • Measure Influent Flow Rate | |
| • Measure pH, VFA, T-Alk, P-Alk | |
| • Measure Temperature | |
| • Add Feed | |
| • Collect Samples (See Table 1) | |
| • Waste Mixed Liquor (Use for lab sample) (Measure volume) | |

temperature controlled room. Air temperature in the room was maintained at $33^{o}C$ to $36^{o}C$ throughout the course of the research study period to maintain digester reactor temperatures, instead of using heated water baths. Bench-scale digester photographs can be viewed in Appendix A.

**BIOGAS MONITORING**

Digester biogas production rates were initially monitored using a gas collection chamber consisting of an inverted one-liter graduated cylinder with the open end of the cylinder submerged in a water bath. The upper portion of the cylinder was supported with a ring stand. A gas line connected to the gas collection bulkhead fitting on the digester lid transferred biogas to the inverted cylinder where the biogas produced was collected. Water was drawn up into the cylinder under vacuum. Biogas production then forced the water out of the cylinder and was monitored with time to determine biogas production rates. An Automatic Methane Potential Test System (AMPTS) unit from Bioprocess Control AB of Sweden (BioProcess Control) was obtained towards the end of the study and later used to measure biogas production rates from the digesters by plumbing biogas produced in the digesters directly to the gas cell plate of the AMPTS unit. The AMPTS unit consists of a cell plate which is submerged in a water bath. The cell plate contains 15 individual gas collection cells. Each cell is individually calibrated by Bioprocess Control to one-hundredth of a milliliter of gas volume. The cell has a pivot at one end and a magnetic tip at the other which closes a circuit. The water bath ensures the biogas produced is trapped in the cell. When the cell is filled with biogas produced from the digester, the cell lifts, breaking or opening the circuit on the cell plate and the biogas is vented to the atmosphere. The cell plate is connected to a laptop computer with application-specific software developed by Bioprocess Control. The computer software counts the number of circuit breaks and produces an average gas production rate as well as a total accumulated gas production volume.

The AMPTS unit can measure biogas production rate in terms of biogas or in terms of methane. To measure gas production rate in terms of biogas, biogas produced in the digester is plumbed directly to the gas cell plate. To measure gas production rate in terms of methane, biogas produced in the digester is first passed through a small biogas scrubbing bottle containing a 3.0 molar sodium hydroxide solution and Alizarin Yellow R color indicator to indicate when the solution is spent. When biogas is passed through the scrubber bottle, carbon dioxide and hydrogen sulfide are scrubbed or removed from the biogas, filling the gas cell with methane instead of biogas. The biogas scrubbing feature of the AMPTS unit was not used with the bench-scale digesters due to the large volume of biogas produced by the bench-scale digesters and the limited scrubbing capacity of the scrubber bottles due to small volumes of scrubbing solution.

Biogas quality was monitored by plumbing biogas produced in the digesters to a gas collection chamber previously mentioned. A sample line was also placed into the inverted cylinder so the biogas could be sampled for carbon dioxide and hydrogen sulfide. Sampling and analysis for carbon dioxide was performed using a Bacharach Fyrite® Classic Gas Analyzer model no. 10-5032 capable of measuring gas carbon dioxide concentrations from 0% to 60%. Sampling and analysis for hydrogen sulfide was performed using a Sensidyne AP-20S Gas Detection Pump and hydrogen sulfide detection tubes. Hydrogen sulfide detection tubes used during the course of the study were capable of measuring 25 ppm to 12,500 ppm $H_2S$. Biogas collection lines were switched daily between the AMPTS unit and the gas collection chamber towards the end of the bench-scale digester portion of the study during detailed data collection periods to obtain both biogas production rate and biogas quality data.

## ANALYTICAL TESTING

Analytical testing was performed using a combination of methods from Standard Methods for the Examination of Water & Wastewater 21$^{st}$ Edition (Standard Methods), as well as several spectrophotometric methods from Hach Company, Inc (Hach). However; VFA, P-Alk, and T-Alk data was generated using the titration method developed by Ripley *et al.* (1986) with contributions from Jenkins *et al.* (1983). The titration method developed by Ripley *et al.* involves titration to two pH end points using sulfuric acid. The first titration end point occurs at pH 5.75 which correlates to the P-Alk parameter which corresponds roughly to the bicarbonate alkalinity as determined by Jenkins *et al.* (1983). The second titration end point occurs at pH 4.3 which correlates to the T-Alk parameter. The difference in titrant volume between the two end points correlates to the VFA parameter or intermediate alkalinity as referred to by Ripley *et al.* (1986) which approximates the volatile acid alkalinity. The following equations are used to calculate the three previously mentioned parameters:

$$P - Alk = \frac{T_1 * N * 50{,}000}{S}$$

$$T - Alk = \frac{T_2 * N * 50{,}000}{S}$$

$$VFA = \frac{(T_2 - T_1) * N * 50{,}000}{S}$$

Where:

P-Alk = partial alkalinity, mg/L as $CaCO_3$

T-Alk = total alkalinity, mg/L as $CaCO_3$

VFA = volatile acids, mg/L as $CH_3COOH$

$T_1$ = volume of titrant used to reach pH 5.75 end point, mL

$T_2$ = volume of titrant used to reach pH 4.3 end point, mL

N = normality of acid used

S = sample volume used, mL

Digester pH testing and all sample pH testing were performed using an Oakton pHTestr 10 meter. The pH meter was calibrated once per week using a three-point calibration with pH buffer solution standards of pH 4.0, 7.0, and 10.0. Digester ORP testing was performed using an Oakton ORPTestr 20 meter. The ORP meter was calibrated before use with an ORP standard solution of +200 mv. All COD, TKN, NH3-N, T-P, and PO4-P analytical testing was performed using a Hach DR2800 spectrophotometer and Hach spectrophotometric methods. All TS, VS, TSS, and VSS analytical testing was performed according to methods described in Standard Methods. All analytical tests performed and the detailed test method numbers can be viewed in Table 3.

**KINETICS DEVELOPMENT**

Data obtained from the digester reactor portion of the study was used to develop kinetics

**TABLE 3**
**Analytical Test Parameters and Methods**

| **Parameter** | **Method** |
|---|---|
| pH | Electrode Method |
| Oxidation Reduction Potential | Electrode Method |
| Volatile Fatty Acids (VFA) | Titration Method |
| Partial Alkalinity (P-Alk) | Titration Method |
| Total Alkalinity (T-Alk) | Titration Method |
| Total Chemical Oxygen Demand (tCOD) | Hach Method 8000 |
| Soluble Chemical Oxygen Demand (sCOD) | Hach Method 8000 |
| Total Solids (TS) | Standard Method 2540 B |
| Volatile Solids (VS) | Standard Method 2540 E |
| Total Suspended Solids (TSS) | Standard Method 2540 D |
| Volatile Suspended Solids (VSS) | Standard Method 2540 E |
| Total Kjeldahl Nitrogen (TKN) | Hach Method Simplified TKN |
| Ammonia-Nitrogen ($NH_3$-N) | Hach Method 10205 |
| Total Phosphorus (T-P) | Hach Method 10210 |
| Ortho Phosphorus ($PO_4$-P) | Hach Method 10209 |

relationships using the Stover-Kincannon Model (Stover & Kincannon, 1982, 1983, and 1984). Data obtained from digester reactors was used to develop a mass balance of substrate into and out of the digesters as follows:

$$mass\ of\ substrate\ into\ the\ reactor = mass\ of\ substrate\ out\ of\ the\ reactor + mass\ of\ substrate\ consumed\ biologically$$

Since CSTR suspended growth systems were modeled with the research performed, the resultant mass balance equation follows:

$$FS_i = FS_e + \left(\frac{dS}{dt}\right)_G V$$

Where:

F= flow rate, L/day

$S_i$ = influent substrate concentration, mg/L

$S_e$ = effluent substrate concentration, mg/L

V = reactor volume, L

$(dS/dt)_G$ = ((dS/dt)/X) = specific substrate utilization rate, g COD Removed/day/ g VSS

The specific substrate utilization rate from the previous equation is mathematically described as a function of the substrate loading rate or food-to-microorganism (F/M) ratio based on monomolecular kinetics as follows:

$$\left(\frac{dS}{dt}\right)_G = U = \frac{U_{max}\left(X * \frac{FS_i}{XV}\right)}{(K_B + \frac{FS_i}{VX})}$$

Where:

$FS_i/XV$ = F/M = food-to-microorganism ratio, g/g day

X = reactor mixed liquor volatile suspended solids, mg/L

U = specific substrate utilization rate, g COD Removed/day/g VSS

$U_{max}$ = maximum specific substrate utilization rate, g COD Removed/day/g VSS

$K_B$ = proportionality constant or specific substrate loading rate where the rate of substrate utilization is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $U_{max}$ and $K_B$ were determined from the data obtained during the research portion of this study. The specific substrate utilization rate was plotted as a function of the F/M ratio in terms of COD. The reciprocal of U was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship. In linearized form, $U_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $K_B/U_{max}$.

The specific biogas production rate is mathematically described as a function of the mass substrate loading rate as follows:

$$G = \frac{G_{max}\left(X * \frac{FS_i}{XV}\right)}{(G_B + \frac{FS_i}{VX})}$$

Where:

G = specific methane production rate, L/day/L Reactor Volume

$G_{max}$ = maximum specific methane production rate, L/day/L Reactor Volume

$G_B$ = proportionality constant or specific substrate loading rate where the rate of biogas production is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $G_{max}$ and $G_B$ were determined from the data obtained during the research portion of this study. The specific biogas production rate was plotted as a function of the F/M ratio in terms of COD. The reciprocal of G was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship. In linearized form, $G_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $G_B/G_{max}$.

The specific methane production rate is mathematically described as a function of the mass substrate loading rate as follows:

$$M = \frac{M_{max}\left(X * \frac{FS_i}{XV}\right)}{(M_B + \frac{FS_i}{VX})}$$

Where:

M = specific methane production rate, L/day/L Reactor Volume

$M_{max}$ = maximum specific methane production rate, L/day/L Reactor Volume

$M_B$ = proportionality constant or specific substrate loading rate where the rate of methane production is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $M_{max}$ and $M_B$ were determined from the data obtained during the research portion of this study. The specific methane production rate was plotted as a function of the F/M ratio in terms of COD. The reciprocal of M was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship. In linearized form, $M_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $M_B/M_{max}$.

**AMPTS KINETICS EVALUATION**

AMPTS studies were also conducted for development of biokinetic constants by performing batch feed studies using small reactors. The purpose of the AMPTS kinetics studies was to evaluate the potential for developing a quick and simple method/procedure to determine kinetic relationships for full-scale applications without the long-term bench-scale operations. Since substantial data were obtained during the course of the bench-scale digester portion of the research, kinetics data obtained during the AMPTS studies could be directly compared and contrasted with the kinetics data developed from the digester reactors. For the AMPTS portion of the study, small 500 mL digesters were set up in a batch reactor mode at multiple food-to-microorganism (F/M) ratios. Digesters were set up with 300 mLs of seed sludge and various feed volumes. Seed sludge used for the AMPTS kinetics relationship studies was supplied from an operating digester from the previously mentioned bench-scale digester studies. Digesters were set up in duplicates with one set of digesters providing unscrubbed biogas to the AMPTS cell plate and another set of digesters providing scrubbed biogas (methane) to the AMPTS cell plate. A control digester was operated for each study. The control digester received no feed addition. Air temperature in the room was maintained at 34$^{o}$C through the course of the study period and used to provide and maintain digester reactor temperature instead of using water baths. Seed sludge was characterized for tCOD, sCOD, TSS, VSS, TKN, $NH_3$-N, T-P, and $PO_4$-P before initiating the studies. Study completion was determined by calculating a theoretical maximum gas production based on COD loading. Once the digester(s) with the lowest COD load (lowest F/M ratio) approached the theoretical maximum gas production volume and gas production rate substantially decreased, the study period was determined to be complete and all digesters were immediately sampled and analyzed for sCOD, TSS, VSS, VFA, P-Alk, and T-Alk.  AMPTS digester photographs can be viewed in Appendix B.

# CHAPTER IV

# RESULTS

Anaerobic digestion research optimization studies were performed using five bench-scale, semi-continuous flow, anaerobic digester CSTRs. The anaerobic digesters were operated at various HRTs, SRTs, F/M ratios, and loading rates over the course of approximately fourteen months to obtain data necessary to determine biokinetic constants for specific substrate utilization rate, specific biogas production rate, and specific methane production rate in terms of specific substrate loading rate. Biokinetic constants were developed according to the Stover-Kincannon Model (Stover & Kincannon, 1982, 1983, 1984).

## SUBSTRATE CHARACTERIZATION

Individual feedstocks were characterized for pH, TS, VS, TSS, VSS, tCOD, sCOD, $NH_3$-N, T-P, and $PO_4$-P. Results for individual feedstock characterization can be viewed in Table 4. Individual feedstocks were blended together to provide a co-digestion process based on individual feedstock characterization to control COD to nutrient ratios, pH and alkalinity demands in the digesters, manage ammonia inhibition/toxicity, and provide

**TABLE 4**
**Individual Feedstock Characterization**

| Sample Description | pH (s.u.) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | tCOD (mg/L) | sCOD (mg/L) | $NH_3$-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hen Litter | --- | 75.95 | 46.97 | | | | | | | |
| Swine Manure | 8.2 | 2.71 | 1.68 | 10,800 | 8,200 | 35,200 | 13,700 | 27,900 | 395 | 17 |
| Husklage | --- | 91.19 | 87.56 | | | | | | | |
| Silage Juice | 4.0 | 7.49 | 7.11 | 32,200 | 31,600 | 133,400 | 91,400 | 67 | 385 | 367 |
| Thin Stillage #1 | 4.6 | 5.59 | 4.91 | 27,600 | 26,600 | 93,600 | 59,300 | 89 | 1,090 | 422 |
| Thin Stillage #2 | 4.2 | 6.69 | 6.01 | 25,800 | 25,600 | 118,300 | 57,450 | 46 | 1,170 | 575 |
| Thin Stillage #3 | 4.2 | 6.22 | 5.48 | 28,600 | 28,400 | 118,400 | 63,400 | 22 | 1,315 | 600 |
| Thin Stillage #4 | 4.5 | 6.11 | 5.34 | 28,000 | 28,000 | 120,200 | 59,300 | 20 | 1,325 | 570 |
| Thin Stillage #5 | 4.5 | 5.37 | 4.56 | 20,900 | 20,500 | 104,500 | 61,600 | 14 | 1,375 | 525 |
| Thin Stillage #6 | 4.4 | 5.06 | 4.26 | 17,400 | 17,300 | 104,000 | 65,000 | 24 | 1,365 | 570 |
| Thin Stillage #7 | 3.4 | 6.24 | 5.62 | 30,800 | 30,550 | 117,300 | 61,750 | 15 | 1,165 | 730 |
| Thin Stillage #8 | 3.8 | 6.08 | 5.33 | 26,000 | 25,600 | 115,200 | 55,700 | 35 | 1,135 | 688 |

macronutrients and micronutrients without requiring additional nutrient supplementation. Influent feed blends consisted of 0.2 grams sweet corn silage juice, 1.0 gram husklage, 11.4 grams hen litter, 38 mL swine manure, and 942 mL thin stillage from fuel alcohol production. All masses and volumes of individual feedstocks listed were per liter of feed. Influent feed batches were characterized for pH, tCOD, sCOD, TS, VS, TSS, VSS, TKN, $NH_3$-N, T-P, and PO4-P. The research project was broken down into four data collection phases for ease of data analysis and interpretation. Phase I occurred from November 14, 2009 to January 29, 2010. Phase II occurred from February 28, 2010 to April 16, 2010. Phase III occurred from April 22, 2010 to June 16, 2010. Phase IV occurred from June 17, 2010 to December 10, 2010. Average influent feed characteristics for each phase can be viewed in Table 5.

## BENCH-SCALE DIGESTER STUDIES

### Digester Characterization

Digester contents were routinely monitored for pH, temperature, tCOD, sCOD, TS, VS, TSS, VSS, TKN, $NH_3$-N, T-P, $PO_4$-P, VFA, P-Alk, and T-Alk throughout the course of the research optimization studies. Average digester feed conditions, digester content characterization, and COD utilization/removal data can be viewed in Tables 6 through 9 for Phase I, Phase II, Phase III, and Phase IV data collection periods, respectively. Since Digesters 1-4 were operated in a once-through CSTR mode, the effluent pH, tCOD, sCOD, TS, VS, TSS, VSS, TKN, $NH_3$-N, T-P, $PO_4$-P, VFA, P-Alk, and T-Alk concentrations determined from the digester contents are equivalent to the digester effluent concentrations. However; Digester 5 was operated in a biomass recycle CSTR

**TABLE 5**
**Average Influent Feed Characterization Data**

| Parameter | Study Phase Period<br>Phase I (11/14/09 – 01/29/10) | Phase II (02/28/10 – 04/16/10) | Phase III (04/22/10 – 06/16/10) | Phase IV (06/17/10 – 12/10/10) |
|---|---|---|---|---|
| pH (s.u.) | 5.2 | 5.5 | 4.6 | 4.3 |
| tCOD (mg/L) | 104,590 | 108,709 | 102,830 | 96,386 |
| sCOD (mg/L) | 55,808 | 57,138 | 59,694 | 48,520 |
| TS (%) | 6.12 | 5.94 | 4.64 | 4.26 |
| VS (%) | 5.41 | 5.07 | 3.76 | 3.43 |
| TSS (mg/L) | 28,039 | 26,109 | 20,804 | 21,113 |
| VSS (mg/L) | 27,639 | 25,247 | 20,354 | 20,801 |
| TKN (mg/L) | 1,600 | 1,888 | 1,418 | 1,616 |
| $NH_3$-N (mg/L) | 209 | 196 | 230 | 229 |
| T-P (mg/L) | 1,291 | 1,367 | 1,314 | 1,441 |
| $PO_4$-P (mg/L) | 509 | 576 | 625 | 721 |

**TABLE 6**
**Average Anaerobic Digester Characterization**
**Phase I (November 14, 2009 - January 29, 2010)**

| **Parameter** | **Once-Through Digester #** 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Feed (L/day) | 0.405 | 0.365 | 0.346 | 0.373 |
| COD Fed (g/day) | 42.542 | 44.383 | 35.941 | 38.835 |
| F/M (g COD/day/g VSS) | 0.223 | 0.240 | 0.180 | 0.181 |
| U (g COD R/day/g VSS) | 0.218 | 0.236 | 0.177 | 0.177 |
| COD Removed (%)* | 97.6 | 97.7 | 97.8 | 97.6 |
| HRT (days) | 28.9 | 27.4 | 35.0 | 34.0 |
| SRT (days) | 28.9 | 27.4 | 35.0 | 34.0 |
| pH (s.u.) | 7.2 | 7.3 | 7.2 | 7.2 |
| Temperature ($^oC$) | 35.5 | 35.3 | 34.9 | 35.4 |
| tCOD (mg/L) | 28,222 | 24,710 | 28,748 | 29.874 |
| sCOD (mg/L) | 3,037 | 2,633 | 2,882 | 3,112 |
| TS (%) | 2.68 | 2.51 | 2.64 | 2.76 |
| VS (%) | 1.89 | 1.77 | 1.91 | 1.98 |
| TSS (mg/L) | 20,083 | 18,265 | 19,817 | 17,170 |
| VSS (mg/L) | 17,091 | 15,767 | 17,135 | 18,246 |
| TKN (mg/L) | 1,845 | 1,963 | 2,064 | 2,183 |
| $NH_3$-N (mg/L) | 868 | 868 | 845 | 807 |
| T-P (mg/L) | 674 | 506 | 643 | 742 |
| $PO_4$-P (mg/L) | 187 | 185 | 178 | 186 |
| VFA (mg/L) | 1,565 | 1,514 | 1,409 | 1,472 |
| P-Alk (mg/L) | 5,622 | 5,536 | 5,624 | 5,570 |
| T-Alk (mg/L) | 6,231 | 6,019 | 6,134 | 6,214 |
| VFA/P-Alk | 0.279 | 0.270 | 0.251 | 0.265 |

* Based on influent mass tCOD minus effluent mass sCOD

**TABLE 7**
**Average Anaerobic Digester Characterization**
**Phase II (February 28, 2010 - March 26,2010)**

| | Once-Through Digester # | | |
|---|---|---|---|
| **Parameter** | **1** | **2** | **3** |
| Feed (L/day) | 0.356 | 0.364 | 0.342 |
| COD Fed (g/day) | 39.838 | 40.663 | 36.720 |
| F/M (g COD/day/g VSS) | 0.276 | 0.288 | 0.249 |
| U (g COD R/day/g VSS) | 0.264 | 0.275 | 0.238 |
| COD Removed (%)* | 95.6 | 95.2 | 95.7 |
| HRT (days) | 32.2 | 31.3 | 30.2 |
| SRT (days) | 32.2 | 31.3 | 30.2 |
| pH (s.u.) | 7.5 | 7.5 | 7.6 |
| Temperature ($^oC$) | 35.2 | 35.2 | 34.9 |
| tCOD (mg/L) | 23,972 | 23,151 | 26,186 |
| sCOD (mg/L) | 5,972 | 5,636 | 5,630 |
| TS (%) | 2.56 | 2.45 | 2.60 |
| VS (%) | 1.5 | 1.43 | 1.58 |
| TSS (mg/L) | 16,834 | 15,982 | 17,703 |
| VSS (mg/L) | 12,247 | 11,745 | 13,350 |
| TKN (mg/L) | 2,820 | 2,719 | 3,440 |
| $NH_3$-N (mg/L) | 1,462 | 1,367 | 1,462 |
| T-P (mg/L) | 858 | 705 | 860 |
| $PO_4$-P (mg/L) | 291 | 281 | 297 |
| VFA (mg/L) | 1,688 | 1,517 | 1,770 |
| P-Alk (mg/L) | 7,217 | 6,659 | 7,173 |
| T-Alk (mg/L) | 8,883 | 8,176 | 8,944 |
| VFA/P-Alk | 0.236 | 0.230 | 0.248 |

* Based on influent mass tCOD minus effluent mass sCOD

**TABLE 8**
**Average Anaerobic Digester Characterization**
**Phase III (April 22, 2010 - June 16, 2010)**

| Parameter | Once-Through Digester #1 | Biomass Recycle Digester #5 |
|---|---|---|
| Feed (L/day) | 0.514 | 0.586 |
| COD Fed (g/day) | 25.889 | 60.287 |
| F/M (g COD/day/g VSS) | 0.446 | 0.298 |
| U (g COD R/day/g VSS) | 0.428 | 0.297 |
| COD Removed (%)* | 95.9 | 99.7 |
| HRT (days) | 23.3 | 21.4 |
| SRT (days) | 23.3 | 239 |
| pH (s.u.) | 7.4 | 7.4 |
| Temperature ($^{o}$C) | 35.5 | 34.7 |
| tCOD (mg/L) | 20,616 | 32,344 |
| sCOD (mg/L) | 4,484 | 5,317 |
| TS (%) | 2.53 | 3.49 |
| VS (%) | 1.29 | 2.04 |
| TSS (mg/L) | 15,770 | 25,233 |
| VSS (mg/L) | 10,621 | 17,255 |
| TKN (mg/L) | 1,795 | 3,988 |
| $NH_3$-N (mg/L) | 863 | 1,025 |
| T-P (mg/L) | 688 | 1,411 |
| $PO_4$-P (mg/L) | 371 | 382 |
| VFA (mg/L) | 1,311 | 1,227 |
| P-Alk (mg/L) | 5,230 | 5,296 |
| T-Alk (mg/L) | 6,558 | 6,539 |
| VFA/P-Alk | 0.251 | 0.235 |

* Based on influent mass tCOD minus effluent mass sCOD

**TABLE 9**
**Average Anaerobic Digester Characterization**
**Phase IV (June 17, 2010 - December 10, 2010)**

| Parameter | Once-Through Digester #1 | Biomass Recycle Digester #5 |
|---|---|---|
| Feed (L/day) | 0.660 | 1.032 |
| COD Fed (g/day) | 63.722 | 98.907 |
| F/M (g COD/day/g VSS) | 0.620 | 0.307 |
| U (g COD R/day/g VSS) | 0.592 | 0.306 |
| COD Removed (%)* | 95.7 | 99.8 |
| HRT (days) | 19.6 | 12.6 |
| SRT (days) | 19.6 | 124 |
| pH (s.u.) | 7.2 | 7.2 |
| Temperature ($^oC$) | 35.9 | 35.2 |
| tCOD (mg/L) | 20,910 | 47,363 |
| sCOD (mg/L) | 5,199 | 4,333 |
| TS (%) | 2.19 | 4.89 |
| VS (%) | 1.16 | 2.97 |
| TSS (mg/L) | 12,716 | 41,624 |
| VSS (mg/L) | 9,074 | 27,533 |
| TKN (mg/L) | 1,979 | 5,367 |
| $NH_3$-N (mg/L) | 578 | 668 |
| T-P (mg/L) | 949 | 2,546 |
| $PO_4$-P (mg/L) | 396 | 394 |
| VFA (mg/L) | 1,565 | 1,057 |
| P-Alk (mg/L) | 4,133 | 4,188 |
| T-Alk (mg/L) | 5,659 | 5,246 |
| VFA/P-Alk | 0.410 | 0.259 |

* Based on influent mass tCOD minus effluent mass sCOD

mode.  To accomplish biomass recycle, digester contents were removed from Digester 5 and placed into a Fisher Scientific Marathon 3200 centrifuge and centrifuged for 15 minutes at 4,000 rpm.  After centrifugation, the centrate was wasted and sampled as effluent, while the concentrated biomass was returned to the digester.  Digester 5 effluent was characterized for sCOD, TS, VS, TSS, and VSS.  Digester 5 average effluent characterization data for Phase III and Phase IV data can be viewed in Table 10.

Digester reactors were operated in a vented, temperature controlled room.  Air temperature in the room was maintained at $33^{o}C$ to $36^{o}C$ throughout the course of the research study period to maintain digester reactor temperatures, instead of using heated water baths.

Individual feedstocks were blended together to provide a co-digestion process based on individual feedstock characterization to control COD to nutrient ratios, manage ammonia inhibition/toxicity, and provide macronutrients and micronutrients without requiring additional nutrient supplementation.  Nutrient concentrations were monitored throughout the course of the study to ensure that the digesters did not operate under nutrient deficient conditions.  As seen in Tables 6 through 9, $NH_3$-N concentrations averaged between 578 mg/L and 1,462 mg/L for the once-through CSTR digesters and between 668 mg/L and 1,025 for the biomass recycle CSTR digester.  $PO_4$-P concentrations averaged between 178 mg/L and 396 mg/L for the once-through CSTR digesters and between 382 mg/L and 394 for the biomass recycle CSTR digester.  Adequate $NH_3$-N and $PO_4$-P concentrations were maintained at all times throughout the course of this research project and no manual nutrient additions were performed at any time.  Micronutrient analyses were performed on digester effluents to confirm adequate micronutrients were available from the

**TABLE 10**
**Average Digester 5 Effluent Characterization**

| Parameter | Phase III (04/22/10 - 6/16/2010) | Phase IV (06/17/10 - 12/10/10) |
|---|---|---|
| sCOD (mg/L) | 5,317 | 4,333 |
| TS (%) | 1.17 | 0.95 |
| VS(%) | 0.23 | 0.18 |
| TSS (mg/L) | 441 | 472 |
| VSS (mg/L) | 326 | 373 |

co-substrate feed mixture.

VFA to P-Alk ratios (VFA/P-Alk) are an important operational parameter for anaerobic digesters in relation to pH buffering capacity. It can be observed in Tables 6 through 9 that the average VFA/P-Alk ratios ranged from 0.230 to 0.410 throughout the course of the study. As long as the VFA/P-Alk ratio remains below 0.5, anaerobic digestion systems should be able to tolerate moderate variations in VFA concentrations, with little fluctuation in pH, while a rise above 0.5 is an indication of possible concern with a lack of pH buffering capacity. If the VFA/P-Alk ratio increases above 0.8, the system is likely to experience a severe drop in pH from small changes in VFA concentrations (González, 1987). It should be noted that digester pHs were maintained between 7.2 and 7.6 throughout the course of this research project and that no manual pH adjustments were performed at any time.

Tables 6 through 9 also present the average U values in terms of g COD Removed/day/g VSS in the digester, and percent COD removal. Percent COD removal was calculated on a mass basis of grams per day using the following equation:

$$\% \, COD \ Removal = \frac{(Influent \ tCOD \ \left(\frac{g}{day}\right) - Effluent \ sCOD \ \left(\frac{g}{day}\right)) * 100}{Influent \ tCOD \ (\frac{g}{day})}$$

The once-through CSTR digesters attained high COD removal efficiencies throughout the course of this research study with average COD removal efficiencies between 95.2% and 97.8%. The biomass recycle digester attained excellent COD removal efficiencies between 99.7% and 99.8%. Effluent soluble COD trend plots for Phase I, Phase II, Phase III, and Phase IV can be viewed in Figures 2 through 5, respectively. Data points

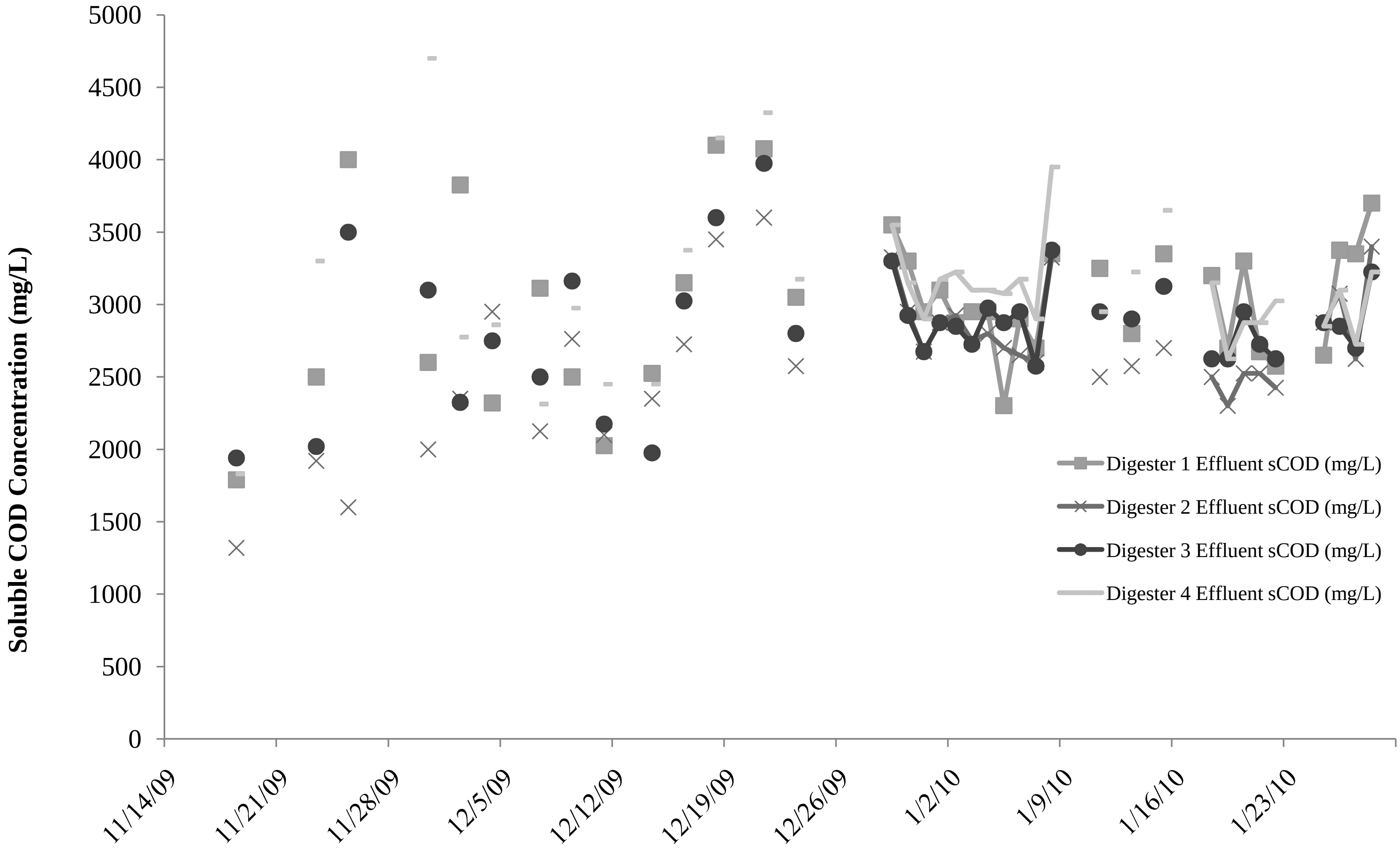



Figure 2. Phase I Effluent Soluble COD Trend Plot

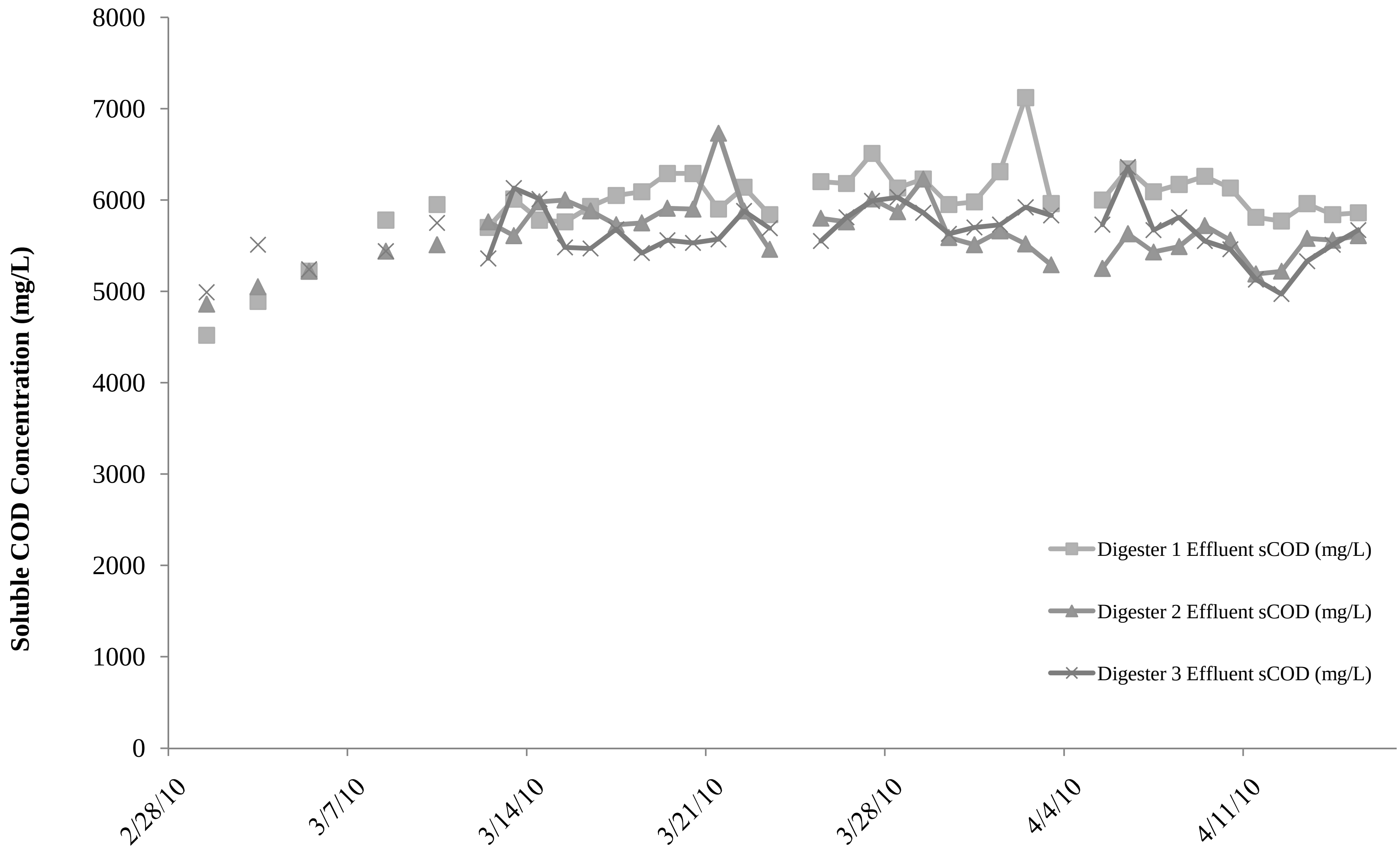



Figure 3. Phase II Effluent SolubleCOD Trend Plot

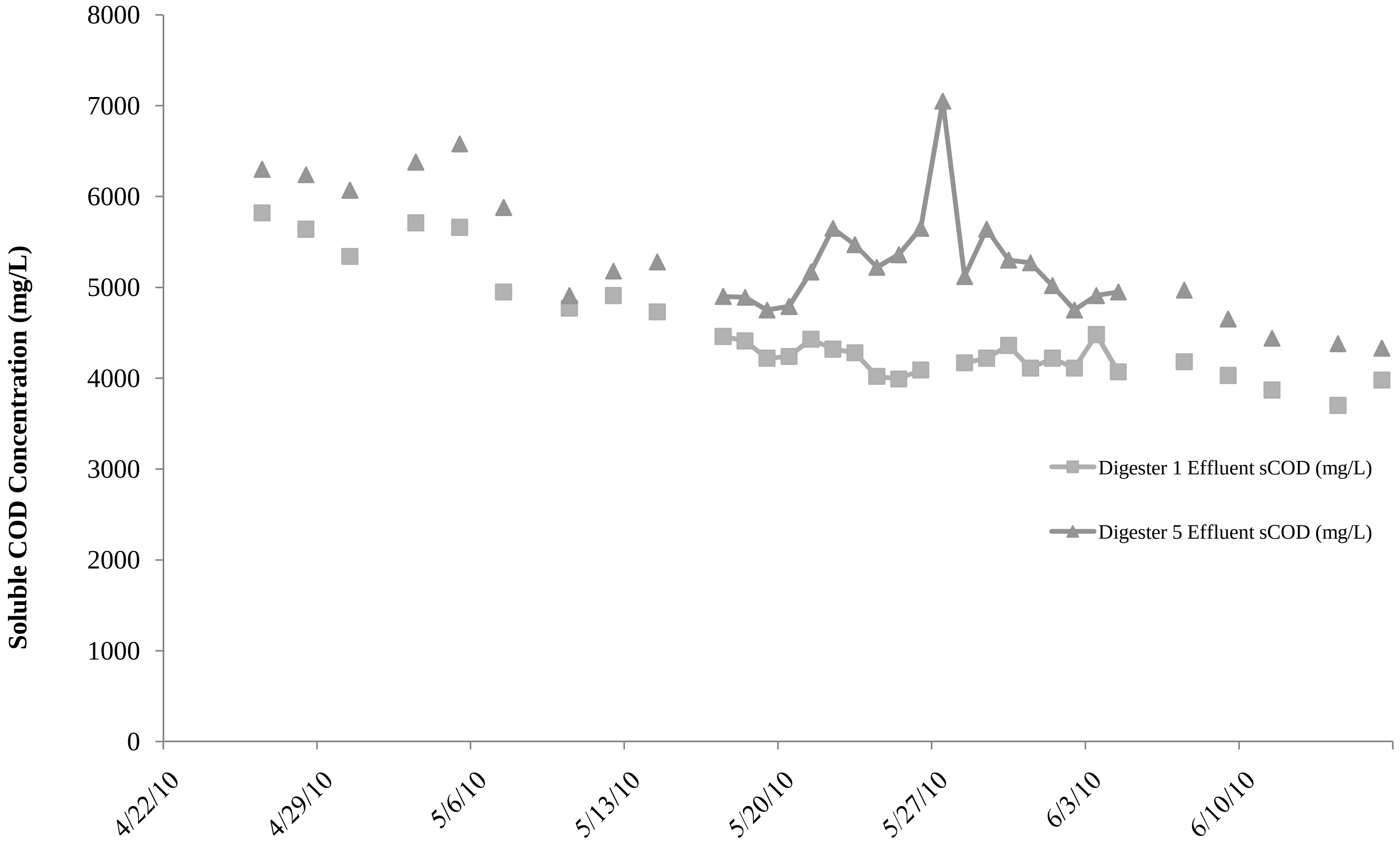



Figure 4. Phase III Effluent Soluble COD Trend Plot

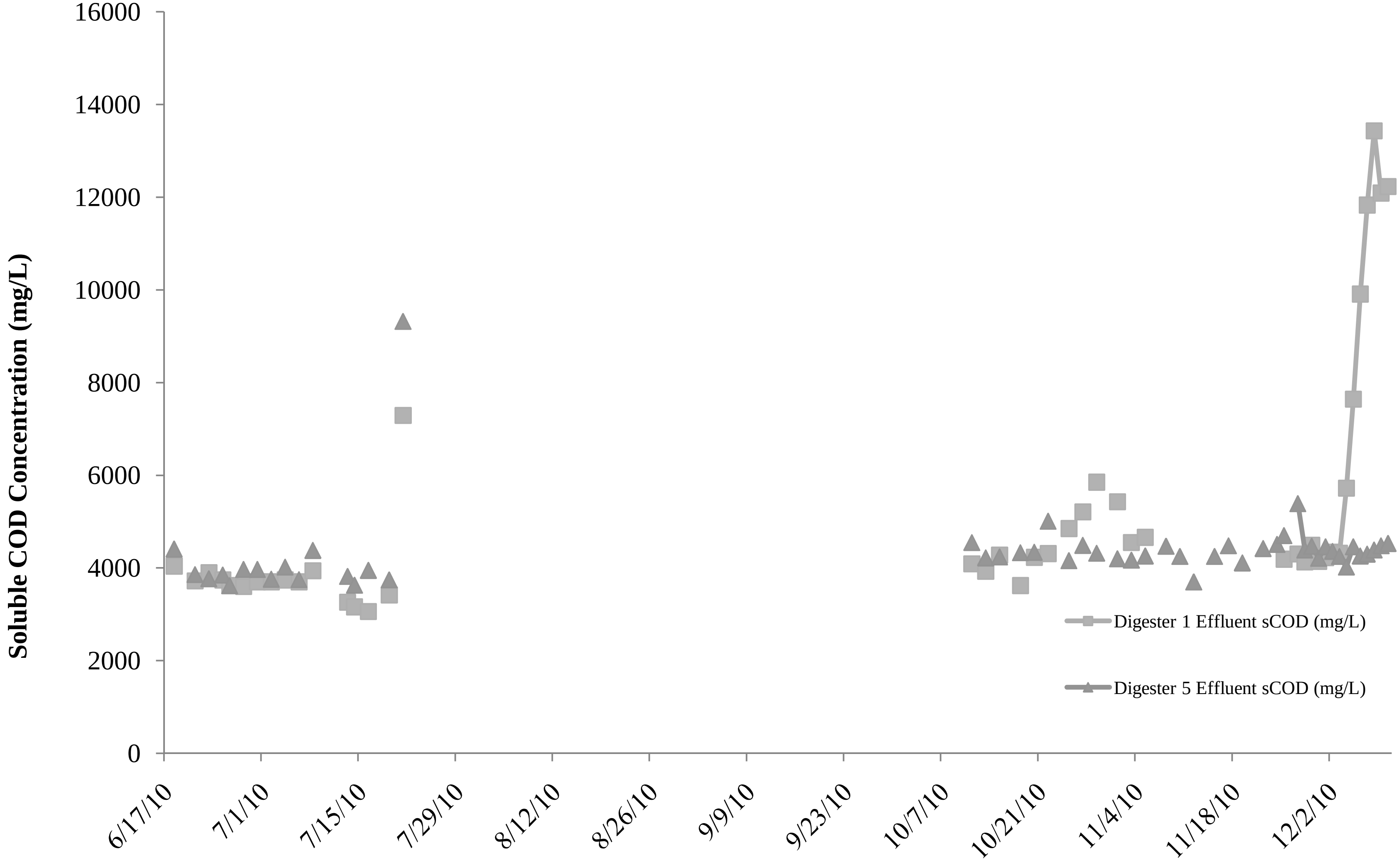



Figure 5. Phase IV Effluent Soluble COD Trend Plot

connected by lines as observed in Figures 2 through 5 indicate data collection periods used for determining digester kinetics. Data points not connected by lines in Figures 1 through 4 indicate acclimation/stabilization data points that were not used for determining digester kinetics. Phase I, Phase II, Phase III, and Phase IV raw data obtained during the bench-scale digester study period can be viewed in Appendix C, D, E, and F, respectively.

**<u>Digester Substrate Kinetics</u>**

Digester substrate kinetics were developed in terms of COD according to the Stover-Kincannon Model (Stover & Kincannon, 1982, 1983, an 1984). Data obtained from digester reactors was used to develop a mass balance of substrate into and out of the digesters as follows:

$$mass\ of\ substrate\ into\ the\ reactor = mass\ of\ substrate\ out\ of\ the\ reactor + mass\ of\ substrate\ consumed\ biologically$$

Since CSTR suspended growth systems were modeled with the research performed, the resultant mass balance equation follows:

$$FS_i = FS_e + \left(\frac{dS}{dt}\right)_G V$$

Where:

F= flow rate, L/day

$S_i$ = influent substrate concentration, mg/L

$S_e$ = effluent substrate concentration, mg/L

V = reactor volume, L

$(dS/dt)_G$ = ((dS/dt)/X) = specific substrate utilization rate, g COD Removed/day/ g VSS

The specific substrate utilization rate from the previous equation is mathematically described as a function of the specific substrate loading rate or food-to-microorganism (F/M) ratio based on monomolecular kinetics as follows:

$$\left(\frac{dS}{dt}\right)_G = U = \frac{U_{max}\left(X * \frac{FS_i}{XV}\right)}{\left(K_B + \frac{FS_i}{VX}\right)}$$

Where:

$FS_i/XV$ = F/M = food-to-microorganism ratio (specific substrate loading rate), g COD Applied/day/g VSS

X = reactor mixed liquor volatile suspended solids, mg/L

U = specific substrate utilization rate, g COD Removed/day/g VSS

$U_{max}$ = maximum specific substrate utilization rate, g COD Removed/day/g VSS

$K_B$ = proportionality constant or specific substrate loading rate where the rate of substrate utilization is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $U_{max}$ and $K_B$ were determined from the data obtained during the research portion of this study. The average U values from each data collection phase were plotted as a function of the average F/M ratios in terms of COD as seen in Figure 6. The reciprocals of the average U values from each data collection phase were plotted as a function of the reciprocals of the average F/M ratios to achieve a linear monomolecular kinetic relationship as seen in Figure 7. In linearized form, $U_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $K_B/U_{max}$. $U_{max}$ is determined from

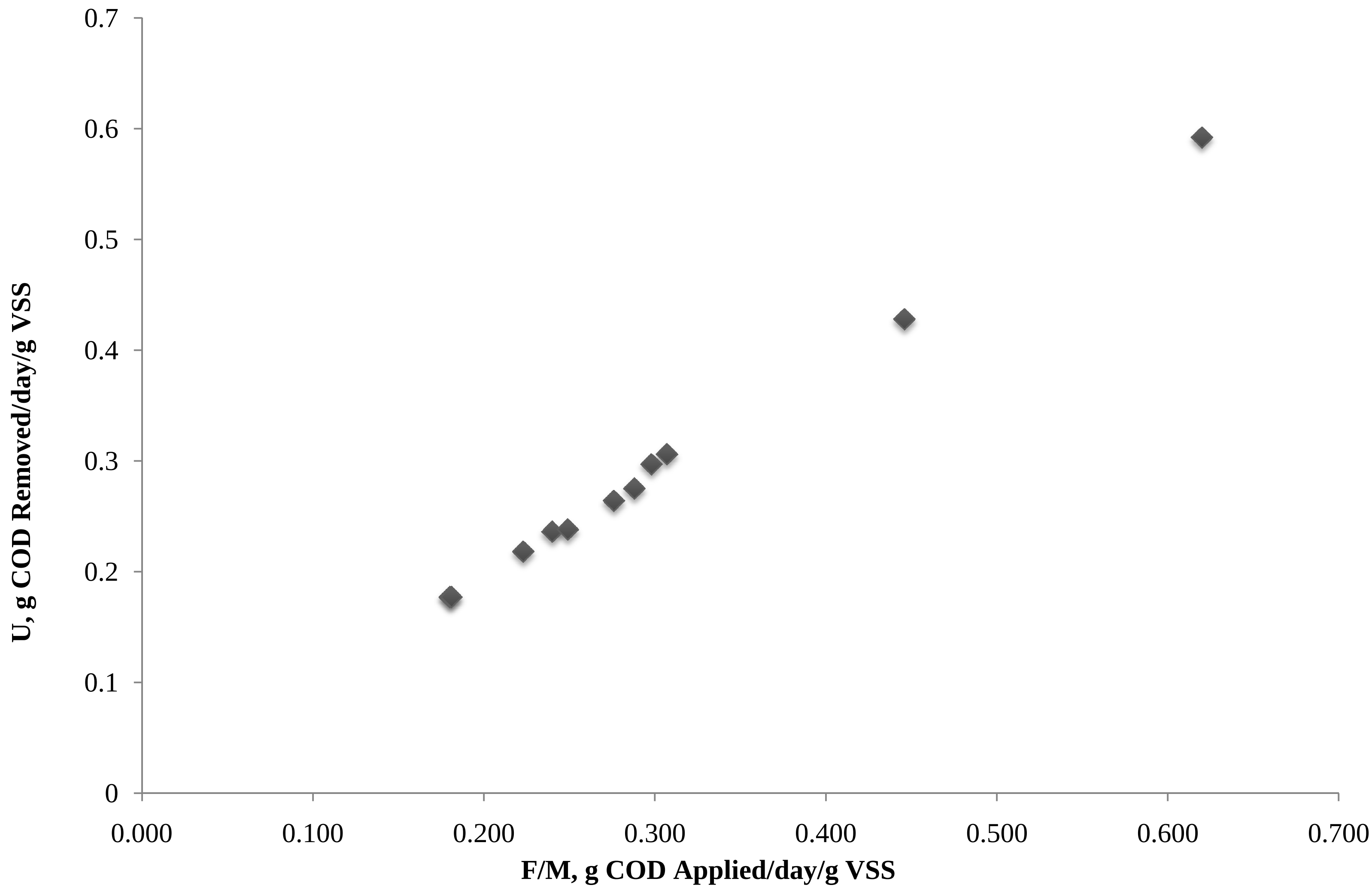



Figure 6. Substrate Utilization as a Function of Mass Specific Substrate Loading Rate in Terms of COD

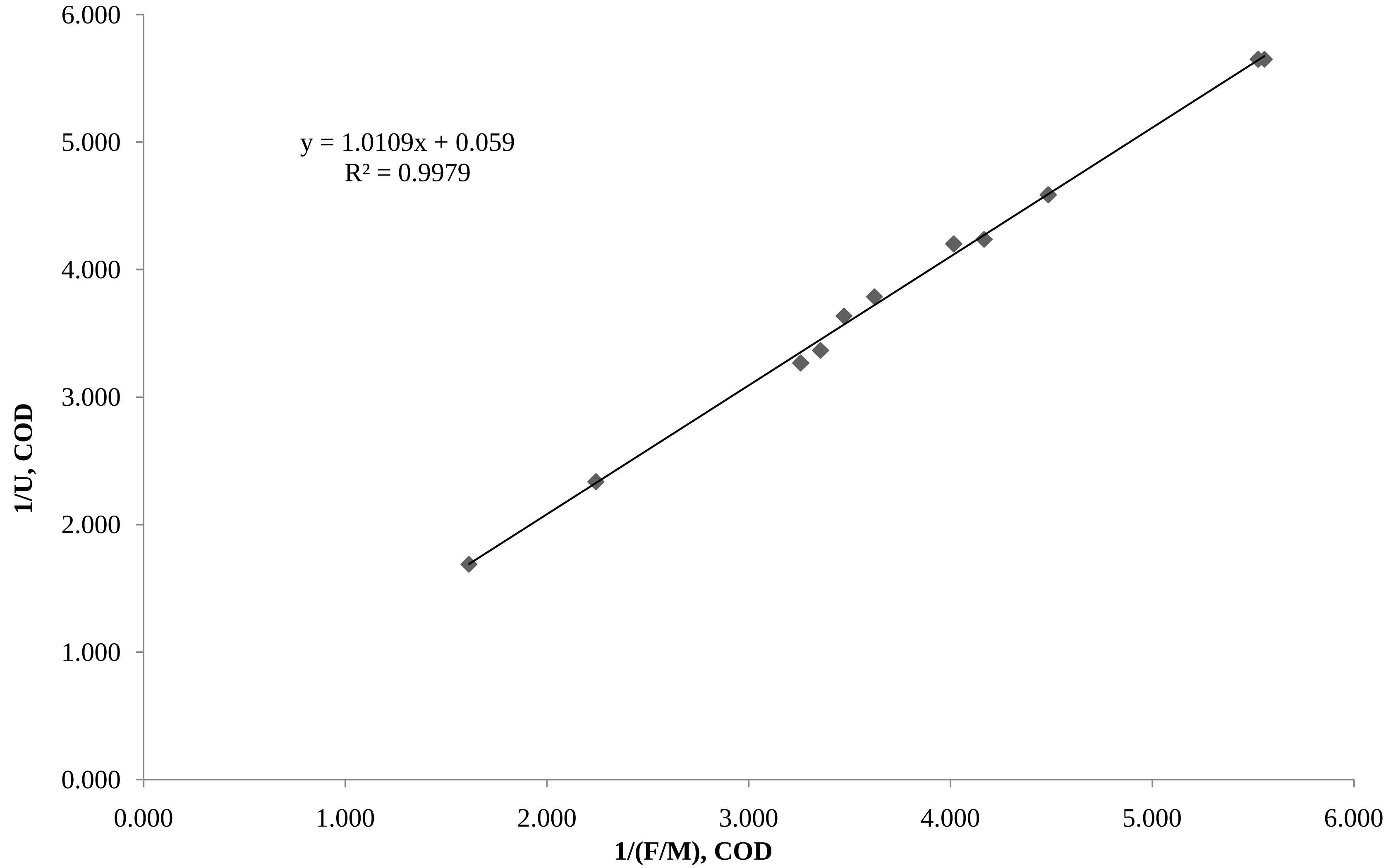



Figure 7. Graphical Determination of $U_{max}$ and $K_B$ in Terms of COD

Figure 7 to be 16.95 g COD Removed/day/g VSS with a $K_B$ value of 17.13 g COD Applied/day/g VSS.

**Digester Biogas Production**

Digester biogas production rates were initially monitored using a gas collection chamber consisting of an inverted one-liter graduated cylinder with the open end of the cylinder submerged in a water bath. Water was drawn up into the cylinder under vacuum. Biogas production then forced the water out of the cylinder and was monitored with time to determine biogas production rates. The AMPTS unit from Bioprocess Control was obtained towards the end of the bench-scale digester portion of the study and later used to measure biogas production rate. Biogas collection lines were switched daily between the AMPTS unit and the gas collection chamber to obtain both biogas production rate and biogas quality data. Biogas quality was monitored by plumbing biogas from the digesters to the gas collection chamber. A sample line was placed into the inverted cylinder so the biogas could be sampled for carbon dioxide and hydrogen sulfide. Sampling and analysis for carbon dioxide were performed using a Bacharach Fyrite® Classic Gas Analyzer model no. 10-5032 capable of measuring gas carbon dioxide concentrations from 0% to 60%. Sampling and analysis for hydrogen sulfide were performed using a Sensidyne AP-20S Gas Detection Pump and hydrogen sulfide detection tubes. Hydrogen sulfide detection tubes used during the course of the study were capable of measuring 25 ppm to 12,500 ppm $H_2S$. Biogas collection lines were switched daily between the AMPTS unit and the gas collection chamber during detailed data collection periods to obtain both biogas production rate and biogas quality data. Average biogas characterization data for each digester during each data collection phase can be viewed in Tables 11 through 14.

**TABLE 11**
**Average Biogas Characterization Data**
**Phase I (November 14, 2009 - January 29, 2010)**

| | Once-Through Digester # | | | |
|---|---|---|---|---|
| **Parameter** | **1** | **2** | **3** | **4** |
| Feed (L/day) | 0.405 | 0.365 | 0.346 | 0.373 |
| COD Fed (g/day) | 42.542 | 44.383 | 35.941 | 38.835 |
| F/M (g COD/day/g VSS) | 0.223 | 0.240 | 0.180 | 0.181 |
| U (g COD R/day/g VSS) | 0.218 | 0.236 | 0.177 | 0.177 |
| COD Removed (%)* | 97.6 | 97.7 | 97.8 | 97.6 |
| HRT (days) | 28.9 | 27.4 | 35.0 | 34.0 |
| SRT (days) | 28.9 | 27.4 | 35.0 | 34.0 |
| Biogas (L/day) | 18.700 | 24.667 | 17.800 | 17.125 |
| Biogas (L/day/L)** | 1.558 | 2.056 | 1.483 | 1.427 |
| Biogas (L/day/g COD R)* | 0.347 | 0.453 | 0.448 | 0.403 |
| Methane (L/day) | 12.348 | 17.064 | 11.748 | 11.292 |
| Methane (L/day/L)** | 1.029 | 1.422 | 0.979 | 0.941 |
| Methane (L/day/g COD R)* | 0.229 | 0.311 | 0.295 | 0.266 |
| Biogas CO2 (%) | 33.3 | 33.7 | 33.6 | 33.9 |
| Biogas H2S (ppm) | 1,390 | 1,588 | 1,440 | 1,333 |

* Based on influent mass tCOD minus effluent mass sCOD
** Biogas produced per liter of reactor volume

**TABLE 12**
**Average Biogas Characterization Data**
**Phase II (February 28, 2010 - March 26,2010)**

| **Parameter** | **Once-Through Digester #** 1 | 2 | 3 |
|---|---|---|---|
| Feed (L/day) | 0.356 | 0.364 | 0.342 |
| COD Fed (g/day) | 39.838 | 40.663 | 36.720 |
| F/M (g COD/day/g VSS) | 0.276 | 0.288 | 0.249 |
| U (g COD R/day/g VSS) | 0.264 | 0.275 | 0.238 |
| COD Removed (%)* | 95.6 | 95.2 | 95.7 |
| HRT (days) | 32.2 | 31.3 | 30.2 |
| SRT (days) | 32.2 | 31.3 | 30.2 |
| Biogas (L/day) | 17.152 | 18.442 | 14.558 |
| Biogas (L/day/L)** | 1.429 | 1.537 | 1.213 |
| Biogas (L/day/g COD R)* | 0.429 | 0.466 | 0.371 |
| Methane (L/day) | 12.144 | 12.948 | 9.972 |
| Methane (L/day/L)** | 1.012 | 1.079 | 0.831 |
| Methane (L/day/g COD R)* | 0.305 | 0.332 | 0.257 |
| Biogas CO2 (%) | 29.2 | 29.5 | 31.2 |
| Biogas H2S (ppm) | 1,769 | 1,638 | 1,579 |

* Based on influent mass tCOD minus effluent mass sCOD
** Biogas produced per liter of reactor volume

**TABLE 13**
**Average Biogas Characterization Data**
**Phase III (April 22, 2010 - June 16, 2010)**

| | Digester # | |
|---|---|---|
| **Parameter** | **1** | **5** |
| Feed (L/day) | 0.514 | 0.586 |
| COD Fed (g/day) | 25.889 | 60.287 |
| F/M (g COD/day/g VSS) | 0.446 | 0.298 |
| U (g COD R/day/g VSS) | 0.428 | 0.297 |
| COD Removed (%)* | 95.9 | 99.7 |
| HRT (days) | 23.3 | 21.4 |
| SRT (days) | 23.3 | 239.1 |
| Biogas (L/day) | 25.560 | 28.479 |
| Biogas (L/day/L)** | 2.130 | 2.373 |
| Biogas (L/day/g COD R)* | 0.422 | 0.457 |
| Methane (L/day) | 15.744 | 17.532 |
| Methane (L/day/L)** | 1.312 | 1.461 |
| Methane (L/day/g COD R)* | 0.262 | 0.285 |
| Biogas CO2 (%) | 33.6 | 34.0 |
| Biogas H2S (ppm) | 2,000 | 2,000 |

* Based on influent mass tCOD minus effluent mass sCOD
** Biogas produced per liter of reactor volume

**TABLE 14**
**Average Biogas Characterization Data**
**Phase IV (June 17, 2010 - December 10, 2010)**

| | Digester # | |
|---|---|---|
| **Parameter** | **1** | **5** |
| Feed (L/day) | 0.660 | 1.032 |
| COD Fed (g/day) | 63.722 | 98.907 |
| F/M (g COD/day/g VSS) | 0.620 | 0.307 |
| U (g COD R/day/g VSS) | 0.592 | 0.306 |
| COD Removed (%)* | 95.7 | 99.8 |
| HRT (days) | 19.6 | 12.6 |
| SRT (days) | 19.6 | 124.1 |
| Biogas (L/day) | 18.658 | 38.279 |
| Biogas (L/day/L) | 1.555 | 3.274 |
| Biogas (L/day/g COD R)* | 0.310 | 0.384 |
| Methane (L/day) | 12.024 | 23.309 |
| Methane (L/day/L) | 1.002 | 2.119 |
| Methane (L/day/g COD R)* | 0.160 | 0.252 |
| Biogas CO2 (%) | 31.2 | 33.7 |
| Biogas H2S (ppm) | 2,850 | 2,028 |

* Based on influent mass tCOD minus effluent mass sCOD
**Biogas produced per liter of reactor volume

A biogas trend plot of average biogas composition as a function of F/M based on average biogas composition values and F/M ratios for all digesters for the entire course of the research study can be viewed in Figure 8. As viewed in Figure 8, at an F/M ratios greater than 0.460 g COD Applied/g VSS and higher, biogas production and biogas quality decreases, most likely as a result of VFA accumulation resulting in methanogen inhibition/toxicity.

**Digester Biogas Kinetics**

The specific biogas production rate is mathematically described as a function of the mass specific substrate loading rate as follows:

$$G = \frac{G_{max}\left(X * \frac{FS_i}{XV}\right)}{(G_B + \frac{FS_i}{VX})}$$

Where:

G = specific methane production rate, L/day/L Reactor Volume

$G_{max}$ = maximum specific methane production rate, L/day/L Reactor Volume

$G_B$ = proportionality constant or specific substrate loading where the rate of biogas production is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $G_{max}$ and $G_B$ were determined from the data obtained during the bench-scale digester portion of this study. A comparison of average F/M ratios and average G values for each data collection phase can be viewed in Table 15. However, it should be noted that the Phase I, Digester 2 G value was not used to determine biogas kinetics due to limited data as a result of gas leaks during the Phase I data collection period. The Phase IV, Digester 1 G value was not used to determine biogas kinetics due

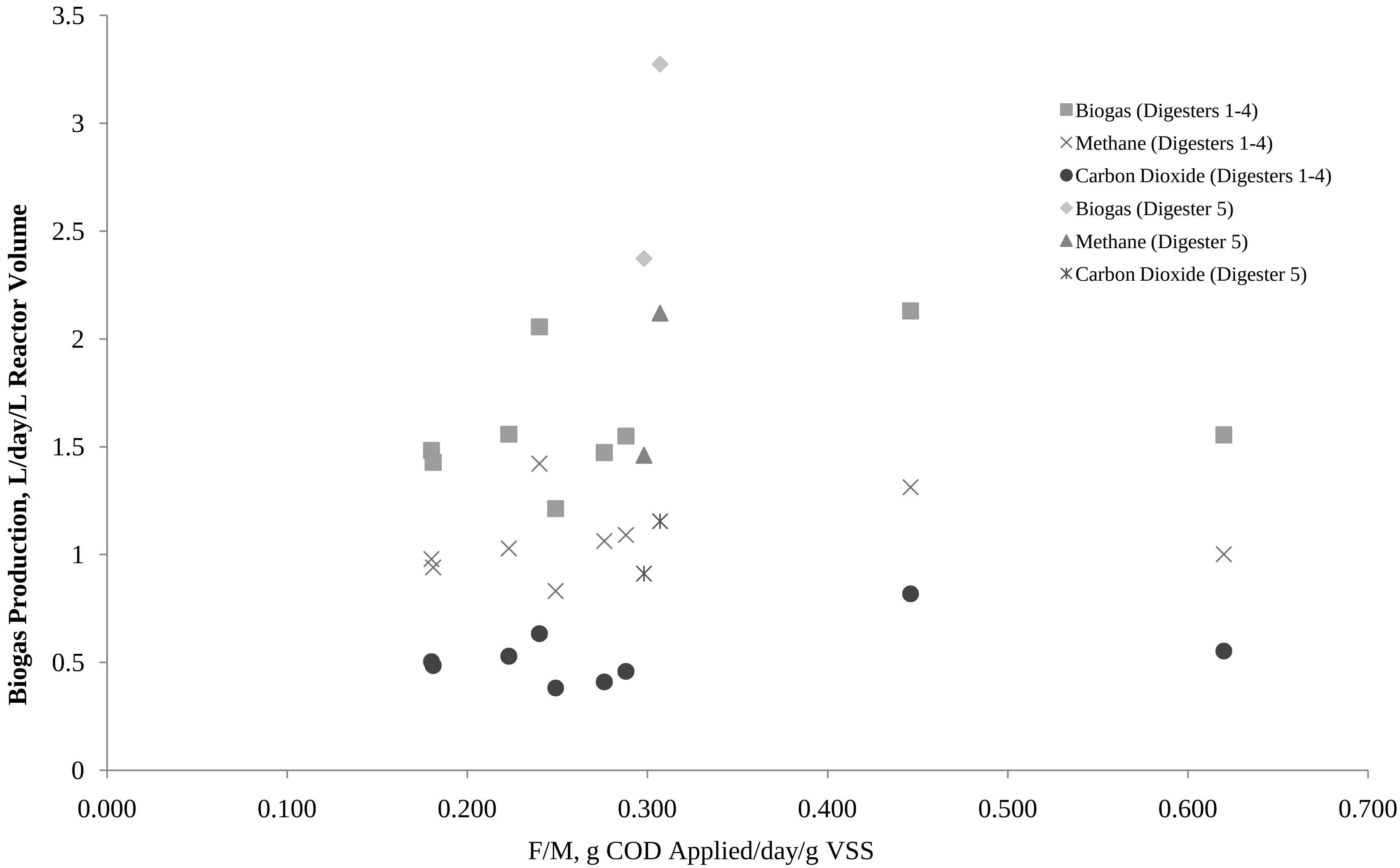



Figure 8. Biogas Production Composition as a Function of Mass Specific Substrate Loading Rate in Terms of COD

**TABLE 15**
**Average Biogas and Methane Production Rates**

| Digester | F/M (g COD/ day/g VSS) | G (L Biogas/ Day/L) | M (L Methane/ Day/L) |
|---|---|---|---|
| **Phase I (November 14, 2009 - January 29, 2010)** | | | |
| 1 | 0.223 | 1.558 | 1.029 |
| 2 | 0.240 | 2.056 | 1.422 |
| 3 | 0.180 | 1.483 | 0.979 |
| 4 | 0.181 | 1.427 | 0.941 |
| **Phase II (February 28, 2010 - March 26, 2010)** | | | |
| 1 | 0.276 | 1.473 | 1.064 |
| 2 | 0.288 | 1.550 | 1.091 |
| 3 | 0.249 | 1.371 | 0.940 |
| **Phase III (April 22, 2010 - June 16, 2010)** | | | |
| 1 | 0.446 | 2.215 | 1.392 |
| 5 | 0.298 | 2.373 | 1.461 |
| **Phase IV (June 16, 2010 - December 10, 2010)** | | | |
| 1 | 0.620 | 1.555 | 1.002 |
| 5 | 0.307 | 3.274 | 2.119 |

to reduced average biogas production compared to the lower F/M ratios as seen in Table 15. This decreased biogas production rate most likely indicates VFA inhibition/toxicity, resulting in decreased COD utilization/removal and poor biogas production. Biomass recycle G values were not used to determine biogas kinetics due to significantly higher biogas production rates as a result of increased COD volumetric and mass loading rates. Biomass recycle digester biogas kinetics would be different than the once-through digester biogas kinetics and would have to be developed as a separate set of kinetic relationships. Biomass recycle digesters can be substrate loaded at higher volumetric substrate loading rates (kg/day/$m^3$) than once-through systems. The average G values from the once-through digesters for each data collection phase were plotted as a function of the average F/M ratios in terms of COD as seen in Figure 9. The reciprocals of the average G values from each data collection phase were plotted as a function of the reciprocals of the average F/M ratios to achieve a linear monomolecular kinetic relationship as seen in Figure 10. In linearized form, $G_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $G_B/G_{max}$. $G_{max}$ is determined from Figure 10 to be 2.38 L Biogas/day/L Reactor Volume with a $G_B$ value of 0.13 g COD Applied/day/g VSS.

**Digester Methane Kinetics**

The specific methane production rate is mathematically described as a function of the specific mass substrate loading rate as follows:

$$M = \frac{M_{max}\left(X * \frac{FS_i}{XV}\right)}{(M_B + \frac{FS_i}{VX})}$$

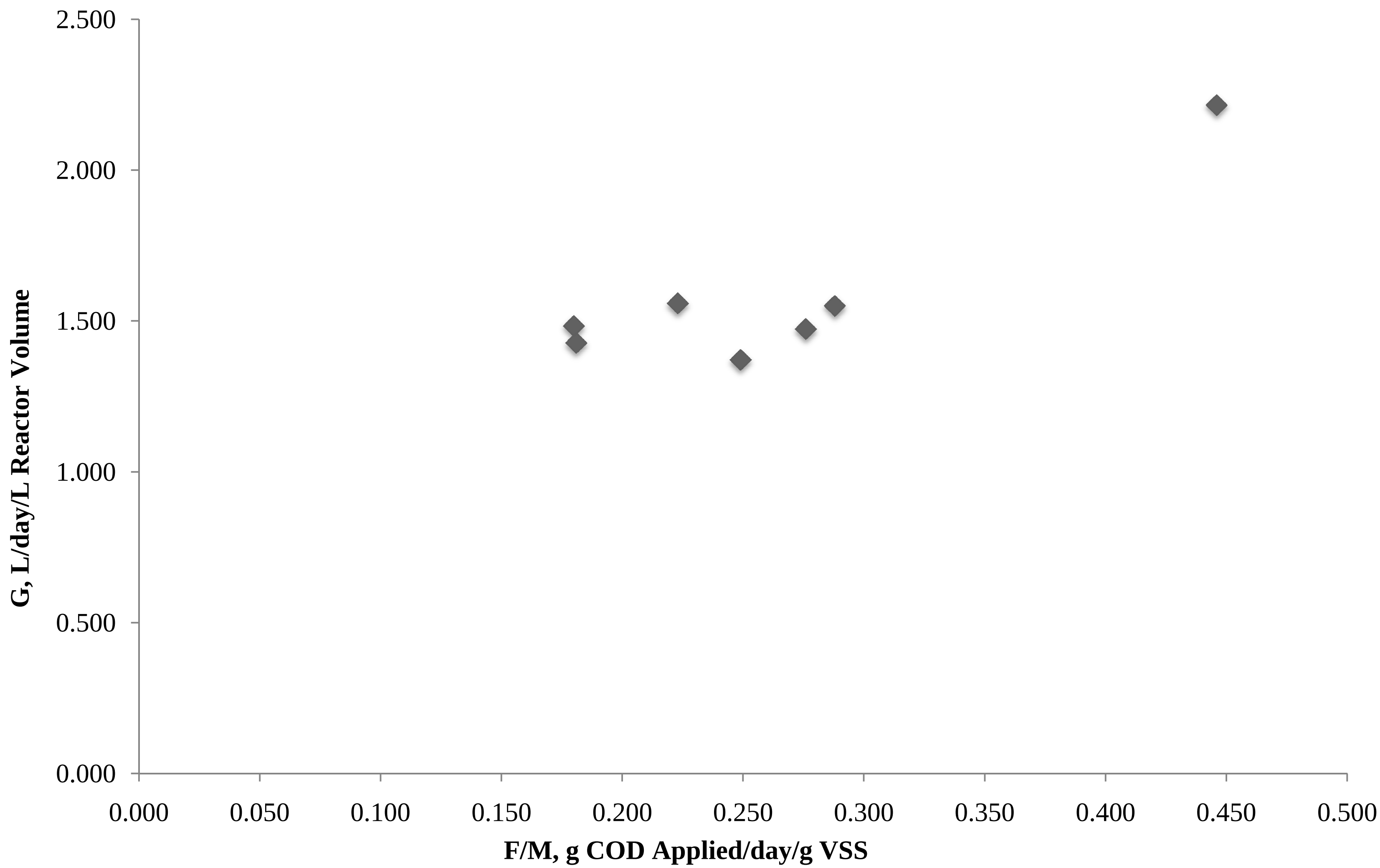



Figure 9. Specific Biogas Production Rate as a Function of Mass Specific Substrate Loading Rate in Terms of COD (Digester 1-4)

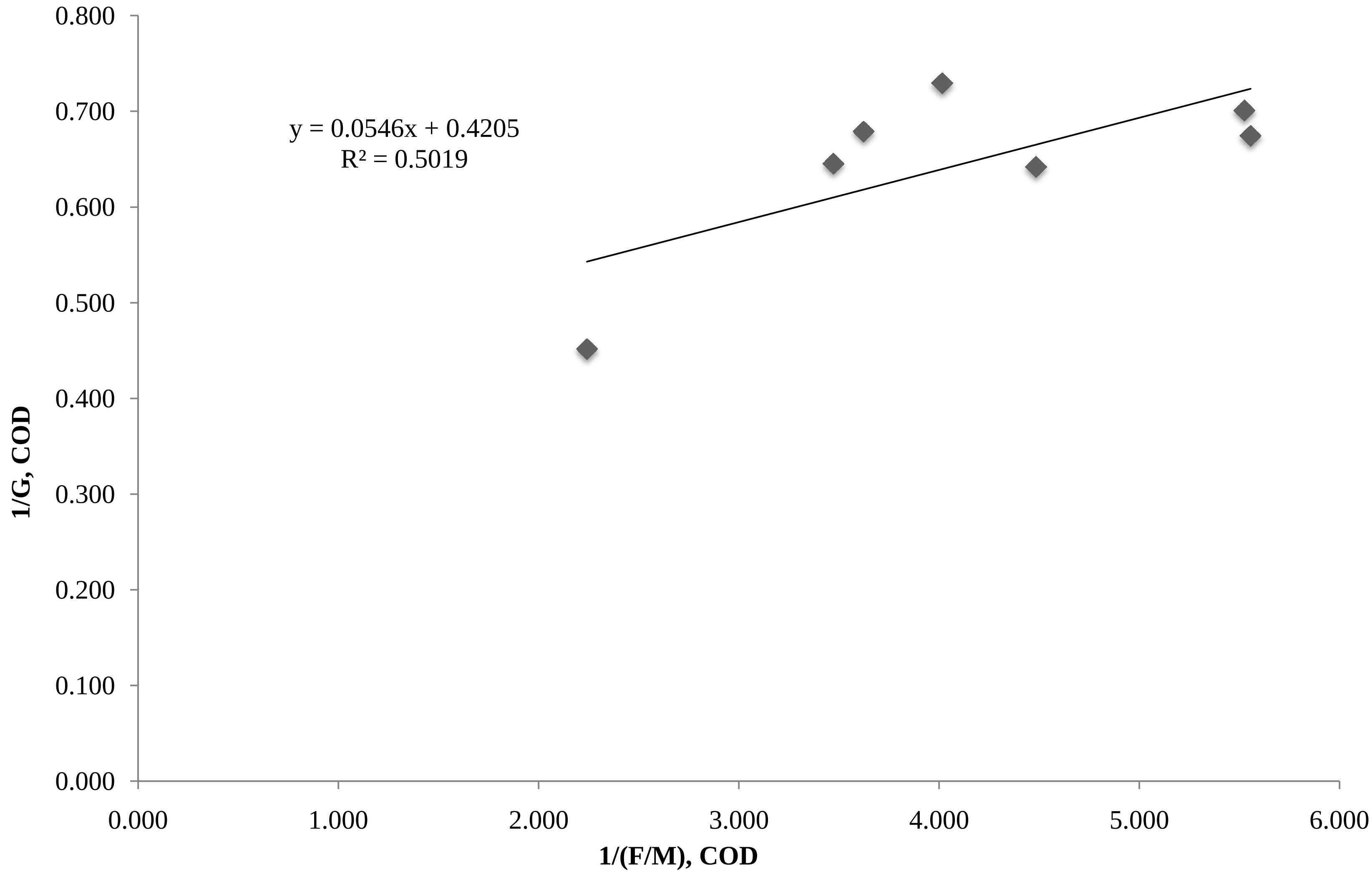



Figure 10. Graphical Determination of $G_{max}$ and $G_B$ in Terms of COD (Digester 1-4)

Where:

$M$ = specific methane production rate, L/day/L Reactor Volume

$M_{max}$ = maximum specific methane production rate, L/day/L Reactor Volume

$M_B$ = proportionality constant or specific substrate loading rate where the rate of methane production is one-half the maximum rate, g COD Applied/day/g VSS

The biokinetic constants $M_{max}$ and $M_B$ were determined from the data obtained during the bench-scale digester portion of this study. A comparison of average F/M ratios and M values for each data collection phase can be viewed in Table 15. However, it should be noted that the Phase I, Digester 2 M value was not used to determine methane kinetics due to limited data as a result of gas leaks during the Phase I data collection period. The Phase IV, Digester 1 M value was not used to determine methane kinetics due to reduced average methane production compared to the lower F/M ratios as seen in Table 15. This decreased methane production rate most likely indicates VFA accumulation and inhibition/toxicity to the methanogens, resulting in decreased COD utilization/removal and poor methane production. Biomass recycle M values were not used to determine methane kinetics due to significantly higher methane production as a result of increased COD volumetric and mass loading rates. Biomass recycle digester methane kinetics would be different than the once-through digester methane kinetics and would have to be developed as a separate set of kinetic relationships. Biomass recycle digesters can be substrate loaded at higher volumetric substrate loading rates (kg/day/$m^3$) than once-through systems. The average M values from the once-through digesters for each data collection phase were plotted as a function of the average F/M ratios in terms of COD as seen in Figure 11. The reciprocals of the average M values were plotted as a function of

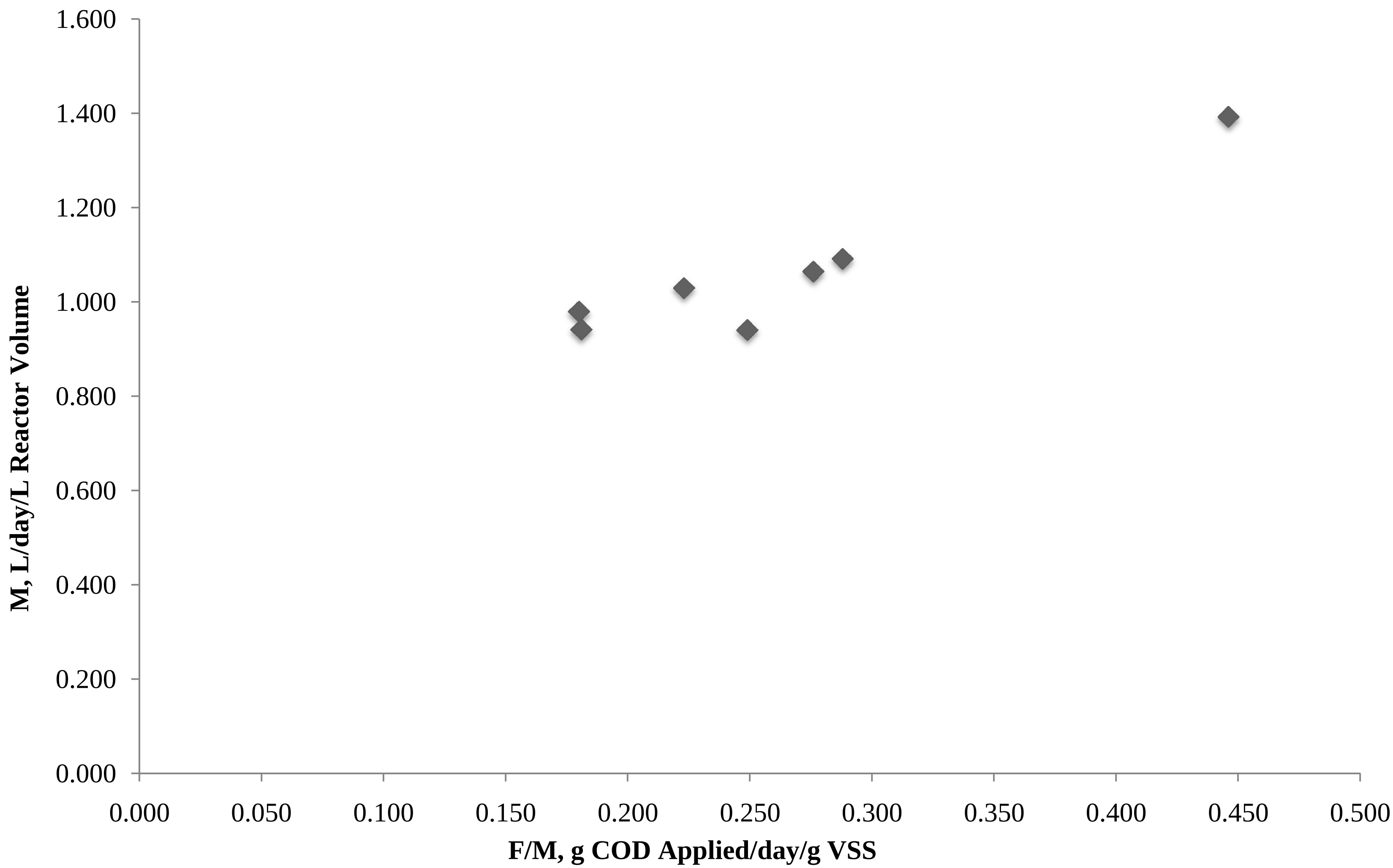



Figure 11. Specific Methane Production Rate as a Function of Mass Specific Substrate Loading Rate in Terms of COD (Digester 1-4)

the reciprocals of the average F/M ratios to achieve a linear monomolecular kinetic relationship as seen in Figure 12. In linearized form, $M_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $M_B/M_{max}$. $M_{max}$ is determined from Figure 12 to be 1.66 L Methane/day/L Reactor Volume with an $M_B$ value of 0.14 g COD Applied/day/g VSS. A summary table of the digester substrate, biogas, and methane biokinetic constants can be viewed in Table 16.

## AMPTS STUDIES

### AMPTS Substrate Characterization

AMPTS studies were also conducted for evaluation of potential development of biokinetic constants by performing batch feed studies using small reactors. The purpose of the AMPTS kinetics studies was to evaluate the potential for developing a quick and simple method/procedure to determine biokinetic relationships for full-scale applications without performing the long-term bench-scale operations. Since substantial data was obtained during the course of the bench-sale digester reactor portion of the research, kinetics data obtained during the AMPTS studies could be directly compared and contrasted with the kinetics data developed from the digester reactors. AMPTS studies were performed using a feed blend identical to that used during the bench-scale digester portion of the study. Influent feed was characterized for tCOD and sCOD. Influent feed characteristics can be viewed in Table 17. Seed sludge used for the AMPTS kinetics relationship studies was supplied from an operating digester from the previously mentioned digester studies. Seed sludge was characterized for tCOD, sCOD, TSS, VSS, TKN, $NH_3$-N, T-P, and $PO_4$-P.

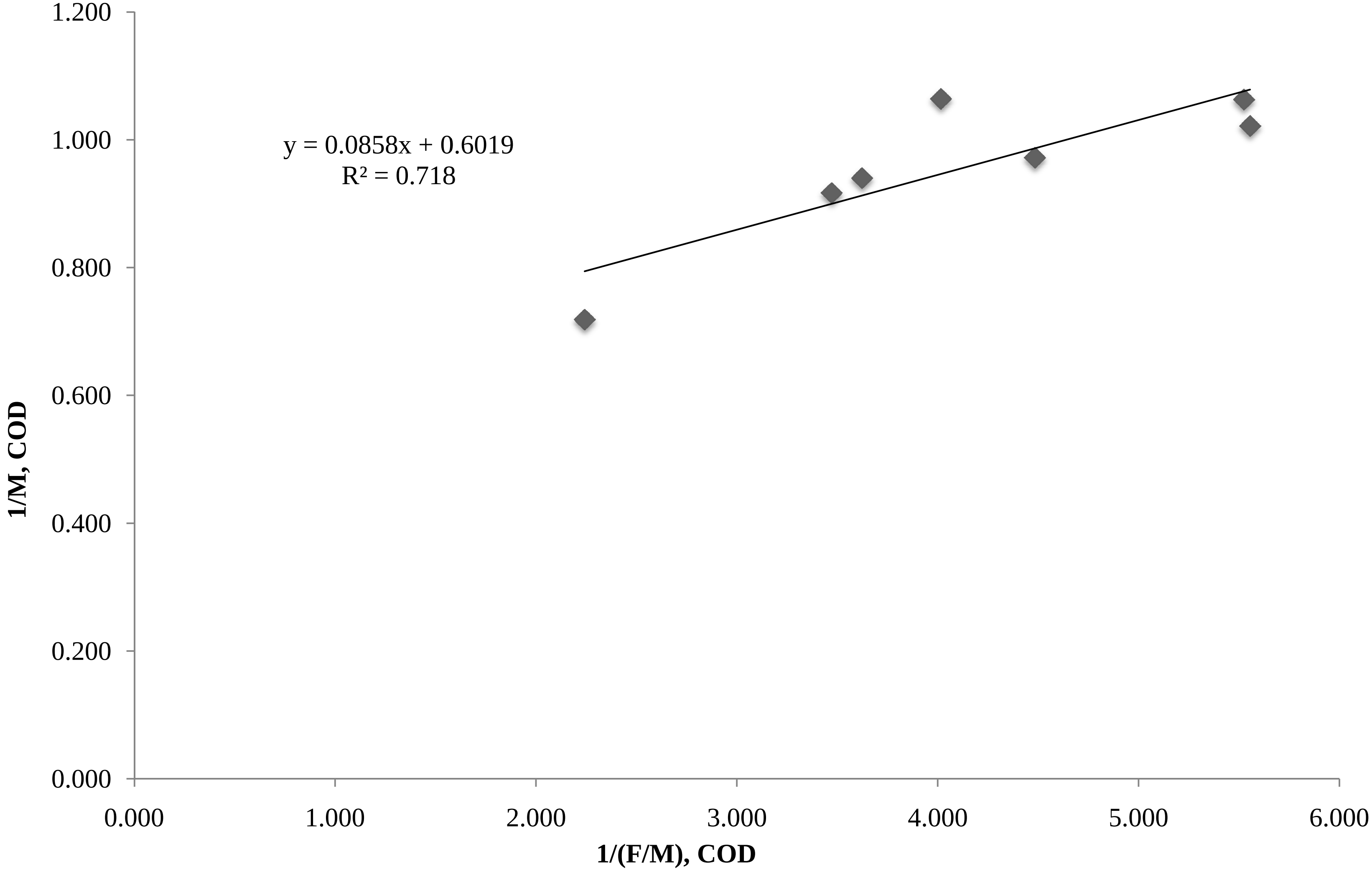



Figure 12. Graphical Determination of $M_{max}$ and $M_B$ in Terms of COD (Digester 1-4)

**TABLE 16**
**Bench-Scale Digester Biokinetic Constants**

| Parameter | Value |
|---|---|
| $U_{max}$ (g COD R/day/g VSS) | 16.95 |
| $K_B$ (g COD/day/g VSS) | 17.13 |
| $G_{max}$ (L/day/L Reactor Volume) | 2.38 |
| $G_B$ (g COD/day/g VSS) | 0.13 |
| $M_{max}$ (L/day/L Reactor Volume) | 1.66 |
| $M_B$ (g COD/day/g VSS) | 0.14 |

**TABLE 17**
**AMPTS Influent Feed Characterization Data**

| Parameter | Influent Feed |
|---|---|
| tCOD (mg/L) | 103,150 |
| sCOD (mg/L) | 56,450 |

Seed sludge characterization data can be viewed in Table 18. For the AMPTS portion of the study, small 500 mL digesters were set up in a batch reactor mode at multiple food-to-microorganism (F/M) ratios. Digesters were set up with 300 mLs of seed sludge and various feed volumes. Air temperature in the room was maintained at 33$^{o}$C to 36$^{o}$C throughout the course of the study period to maintain digester reactor temperatures, instead of using heated water baths. Once the digester(s) with the lowest COD load (lowest F/M ratio) approached the theoretical maximum gas production volume and the gas production rate substantially decreased, the study period was determined to be complete and all digesters were immediately sampled and analyzed for sCOD, TSS, VSS, VFA, P-Alk, and T-Alk. AMPTS digester effluent data can be viewed in Table 19. It should be noted that Table 19 includes two columns containing F/M ratios. One F/M column is labeled Initial F/M column and represents the initial F/M ratio in terms of g COD/g VSS at the onset of the study. The other F/M column represents F/M ratio in terms of g COD/day/g VSS with respect to the HRT of the study period.

**AMPTS Digester Substrate Kinetics**

Table 20 presents the U values in terms of g COD Removed/day/g VSS in each digester, and percent COD removal for each digester. Biokinetic constants $U_{max}$ and $K_B$ were determined from the data obtained during the AMPTS research portion of this study. The specific substrate utilization rate was plotted as a function of the F/M ratio in terms of COD as seen in Figure 13. The reciprocal of U was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship as seen in Figure 14. In linearized form, $U_{max}$ is the reciprocal of the y-axis intercept, and the slope of the

**TABLE 18**
**AMPTS Seed Sludge Characterization Data**

| Parameter | Seed Sludge |
|---|---|
| tCOD | 40,150 |
| sCOD | 11,310 |
| TSS | 32,800 |
| VSS | 19,900 |
| TKN | 6,550 |
| $NH_3$-N | 1,790 |
| T-P | 4,160 |
| $PO_4$-P | 740 |

**TABLE 19**
**AMPTS Digester Data**

| Digester | Feed (L) | tCOD Fed (g) | Initial F/M (g COD/ g VSS) | F/M (g COD/ g VSS) | HRT (days) | SRT (days) | sCOD (mg/L) | TSS (mg/L) | VSS (mg/L) | VFA (mg/L) | P-Alk (mg/L) | VFA/ P-Alk |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000 | 0.000 | 0.568 | 0.202 | 2.81 | 2.81 | 6,650 | 29,600 | 19,700 | 3,900 | 10,450 | 0.373 |
| 2 | 0.000 | 0.000 | 0.568 | 0.156 | 3.65 | 3.65 | 6,920 | 28,900 | 19,400 | 3,400 | 8,800 | 0.386 |
| 3 | 0.012 | 1.238 | 0.776 | 0.276 | 2.81 | 2.81 | 8,560 | 26,000 | 18,200 | 3,700 | 8,625 | 0.429 |
| 4 | 0.012 | 1.238 | 0.776 | 0.276 | 2.81 | 2.81 | 6,900 | 26,000 | 18,600 | 3,875 | 8,900 | 0.435 |
| 5 | 0.015 | 1.547 | 0.828 | 0.227 | 3.65 | 3.65 | 8,960 | 25,900 | 18,400 | 3,875 | 7,200 | 0.538 |
| 6 | 0.015 | 1.547 | 0.828 | 0.227 | 3.65 | 3.65 | 8,000 | 27,100 | 19,000 | 3,325 | 7,275 | 0.457 |
| 7 | 0.024 | 2.476 | 0.983 | 0.350 | 2.81 | 2.81 | 11,220 | 25,000 | 17,800 | 4,325 | 7,150 | 0.605 |
| 8 | 0.024 | 2.476 | 0.983 | 0.350 | 2.81 | 2.81 | 8,940 | 24,300 | 18,000 | 4,175 | 7,100 | 0.588 |
| 9 | 0.030 | 3.095 | 1.087 | 0.298 | 3.65 | 3.65 | 11,620 | 25,700 | 18,100 | 4,750 | 5,925 | 0.802 |
| 10 | 0.030 | 3.095 | 1.087 | 0.298 | 3.65 | 3.65 | 12,060 | 26,900 | 18,800 | 5,175 | 5,775 | 0.896 |
| 11 | 0.036 | 3.713 | 1.190 | 0.424 | 2.81 | 2.81 | 12,540 | 23,800 | 17,000 | 5,625 | 5,900 | 0.953 |
| 12 | 0.036 | 3.713 | 1.190 | 0.424 | 2.81 | 2.81 | 10,840 | 23,300 | 17,200 | 4,975 | 5,425 | 0.917 |
| 13 | 0.048 | 4.951 | 1.398 | 0.497 | 2.81 | 2.81 | 15,280 | 24,000 | 17,700 | 5,750 | 5,075 | 1.133 |
| 14 | 0.048 | 4.951 | 1.398 | 0.497 | 2.81 | 2.81 | 13,900 | 25,100 | 18,200 | 6,600 | 5,250 | 1.257 |
| 15 | 0.060 | 6.189 | 1.605 | 0.571 | 2.81 | 2.81 | 16,320 | 24,000 | 17,600 | 6,675 | 4,475 | 1.492 |
| 16 | 0.060 | 6.189 | 1.605 | 0.571 | 2.81 | 2.81 | 12,960 | 25,000 | 19,100 | 6,025 | 4,425 | 1.362 |
| 17 | 0.060 | 6.189 | 1.605 | 0.440 | 3.65 | 3.65 | 16,840 | 27,100 | 18,900 | 7,000 | 4,075 | 1.718 |
| 18 | 0.060 | 6.189 | 1.605 | 0.440 | 3.65 | 3.65 | 16,360 | 25,400 | 17,900 | 7,125 | 4,125 | 1.727 |
| 19 | 0.090 | 9.284 | 2.123 | 0.582 | 3.65 | 3.65 | 20,100 | 23,800 | 17,900 | 6,475 | 3,175 | 2.039 |
| 20 | 0.090 | 9.284 | 2.123 | 0.582 | 3.65 | 3.65 | 20,680 | 23,400 | 17,400 | 6,525 | 2,950 | 2.212 |
| 21 | 0.120 | 12.378 | 2.642 | 0.724 | 3.65 | 3.65 | 21,540 | 26,800 | 19,300 | 7,400 | 2,625 | 2.819 |
| 22 | 0.120 | 12.378 | 2.642 | 0.724 | 3.65 | 3.65 | 21,960 | 24,800 | 18,300 | 7,025 | 2,000 | 3.513 |

**TABLE 20**
**AMPTS Digester Effluent Data**

| Digester | Feed (L) | tCOD Fed (g) | Initial F/M (g COD/ g VSS) | F/M (g COD/ g VSS) | U (g COD/ day/g VSS) | COD Removed (%) | HRT (days) | SRT (days) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.000 | 0.000 | 0.568 | 0.202 | 0.083 | 41.2 | 2.81 | 2.81 |
| 2 | 0.000 | 0.000 | 0.568 | 0.156 | 0.060 | 38.8 | 3.65 | 3.65 |
| 3 | 0.012 | 1.238 | 0.776 | 0.276 | 0.117 | 42.3 | 2.81 | 2.81 |
| 4 | 0.012 | 1.238 | 0.776 | 0.276 | 0.148 | 53.5 | 2.81 | 2.81 |
| 5 | 0.015 | 1.547 | 0.828 | 0.227 | 0.097 | 42.9 | 3.65 | 3.65 |
| 6 | 0.015 | 1.547 | 0.828 | 0.227 | 0.111 | 49.0 | 3.65 | 3.65 |
| 7 | 0.024 | 2.476 | 0.983 | 0.350 | 0.133 | 38.1 | 2.81 | 2.81 |
| 8 | 0.024 | 2.476 | 0.983 | 0.350 | 0.177 | 50.6 | 2.81 | 2.81 |
| 9 | 0.030 | 3.095 | 1.087 | 0.298 | 0.122 | 40.9 | 3.65 | 3.65 |
| 10 | 0.030 | 3.095 | 1.087 | 0.298 | 0.115 | 38.7 | 3.65 | 3.65 |
| 11 | 0.036 | 3.713 | 1.190 | 0.424 | 0.172 | 40.7 | 2.81 | 2.81 |
| 12 | 0.036 | 3.713 | 1.190 | 0.424 | 0.206 | 48.7 | 2.81 | 2.81 |
| 13 | 0.048 | 4.951 | 1.398 | 0.497 | 0.180 | 36.3 | 2.81 | 2.81 |
| 14 | 0.048 | 4.951 | 1.398 | 0.497 | 0.209 | 42.0 | 2.81 | 2.81 |
| 15 | 0.060 | 6.189 | 1.605 | 0.571 | 0.221 | 38.7 | 2.81 | 2.81 |
| 16 | 0.060 | 6.189 | 1.605 | 0.571 | 0.293 | 51.3 | 2.81 | 2.81 |
| 17 | 0.060 | 6.189 | 1.605 | 0.440 | 0.162 | 36.7 | 3.65 | 3.65 |
| 18 | 0.060 | 6.189 | 1.605 | 0.440 | 0.169 | 38.5 | 3.65 | 3.65 |
| 19 | 0.090 | 9.284 | 2.123 | 0.582 | 0.222 | 38.2 | 3.65 | 3.65 |
| 20 | 0.090 | 9.284 | 2.123 | 0.582 | 0.212 | 36.4 | 3.65 | 3.65 |
| 21 | 0.120 | 12.378 | 2.642 | 0.724 | 0.309 | 42.6 | 3.65 | 3.65 |
| 22 | 0.120 | 12.378 | 2.642 | 0.724 | 0.300 | 41.5 | 3.65 | 3.65 |

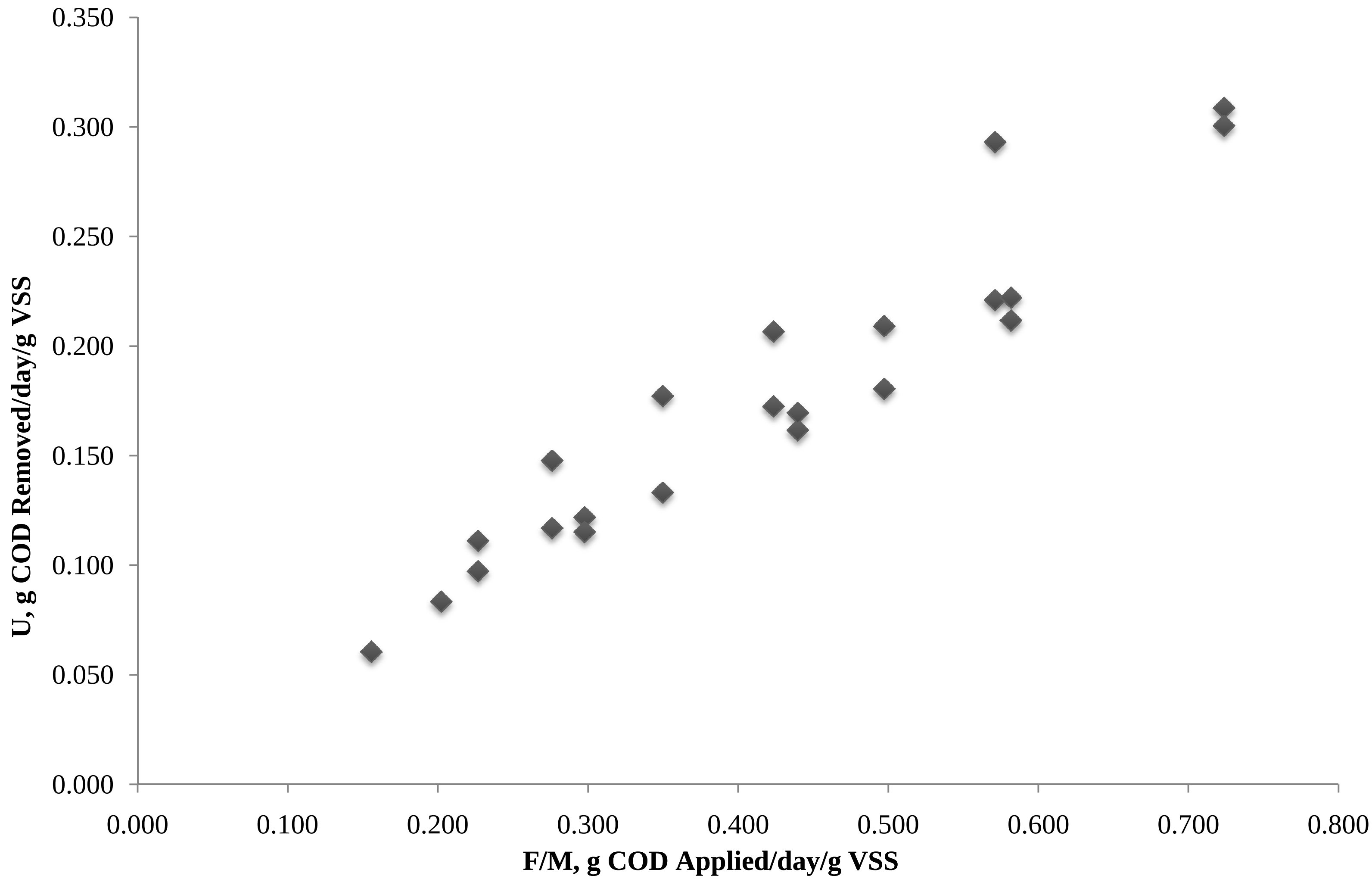



Figure 13. Specific Substrate Utilization Rate as a Function of Mass Specific Substrate Loading Rate in Terms of COD (AMPTS)

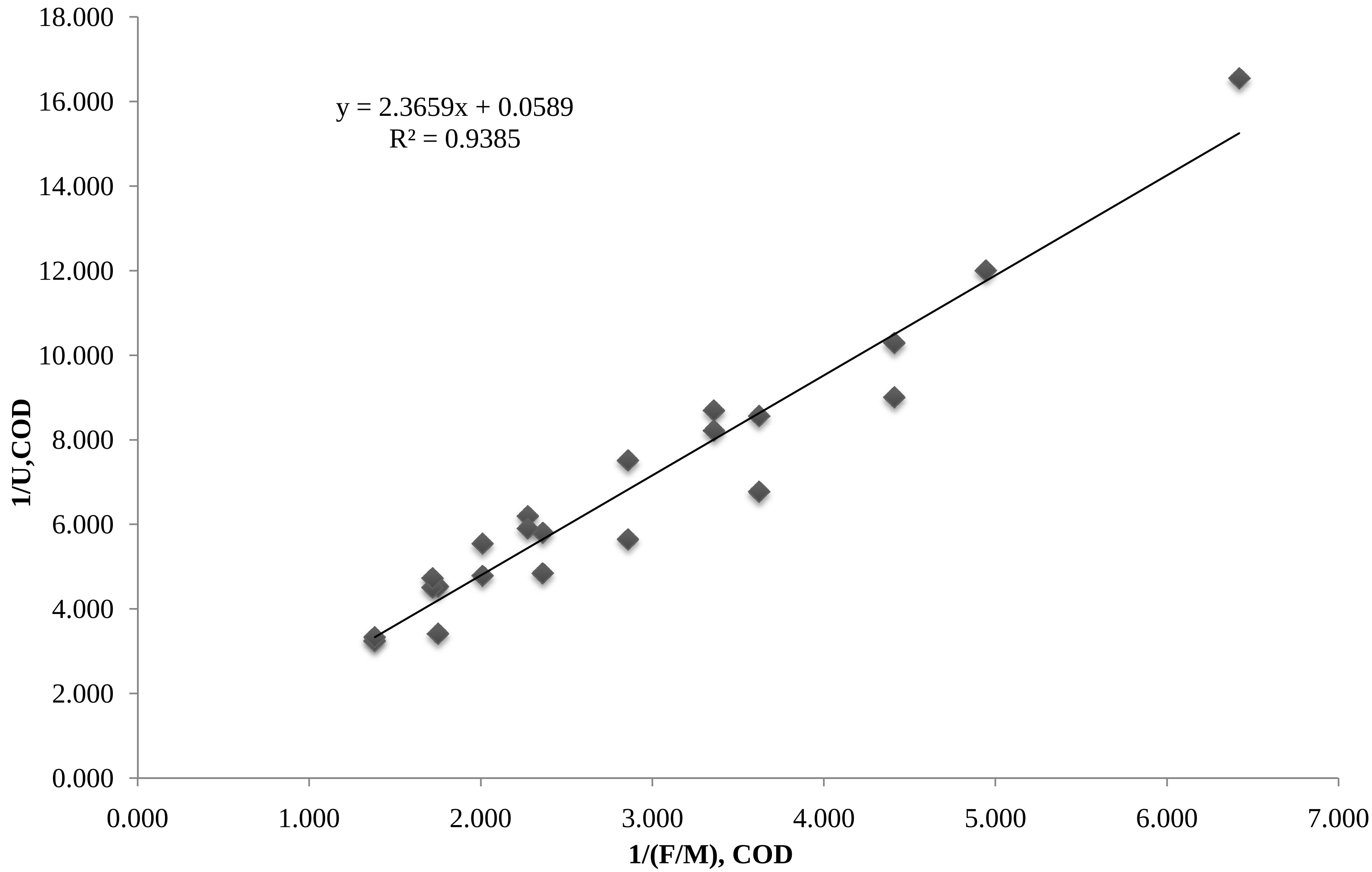



Figure 14. Graphical Determination of $U_{max}$ and $K_B$ in Terms of COD (AMPTS)

line is equal to $K_B/U_{max}$. $U_{max}$ was determined from Figure 14 to be 16.98 g COD Removed/day/g VSS with a $K_B$ value of 40.168 g COD Applied/day/g VSS.

**AMPTS Digester Biogas Kinetics**

Digesters were set up in duplicates with one set of digesters providing unscrubbed biogas to the AMPTS cell plate and another set of digesters providing scrubbed biogas (methane) to the AMPTS cell plate.

Biokinetic constants $G_{max}$ and $G_B$ were determined from the data obtained during the AMPTS research portion of this study. AMPTS digester biogas production rates can be viewed in Table 21. The specific biogas production rates were plotted as a function of the F/M ratio in terms of COD as seen in Figure 15. The reciprocal of G was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship as seen in Figure 16. In linearized form, $G_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $G_B/G_{max}$. $G_{max}$ was determined from Figure 16 to be 1.29 L Biogas/day/L Reactor Volume with a $G_B$ value of 0.262 g COD Applied/day/g VSS. Specific biogas production rates for the initial F/M ratios of 1.398 g COD Applied/g VSS and higher F/M ratios were not included in Figure 15 and 16 for biogas kinetics determination due to decreasing biogas production rates most likely resulting from VFA inhibition/toxicity. A biogas trend plot of average biogas composition as a function of initial F/M based on average biogas composition values and F/M ratios for the AMPTS digesters can be viewed in Figure 17. As viewed in Figure 17 at the initial F/M ratio of 1.398 g COD Applied/g VSS and higher, biogas production rate and biogas quality decreases most likely as a result of VFA inhibition/toxicity.

**TABLE 21**
**AMPTS Digester Biogas Data**

| Digester | Feed (L) | tCOD Fed (g) | Initial F/M (g COD/ g VSS) | F/M (g COD/ g VSS) | HRT (days) | SRT (days) | G (L/day/L) | M (L/day/L) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.000 | 0.000 | 0.568 | 0.202 | 2.81 | 2.81 | 0.261 | |
| 2 | 0.000 | 0.000 | 0.568 | 0.156 | 3.65 | 3.65 | 0.292 | |
| 3 | 0.012 | 1.238 | 0.776 | 0.276 | 2.81 | 2.81 | 0.639 | |
| 4 | 0.012 | 1.238 | 0.776 | 0.276 | 2.81 | 2.81 | | 0.456 |
| 5 | 0.015 | 1.547 | 0.828 | 0.227 | 3.65 | 3.65 | 0.618 | |
| 6 | 0.015 | 1.547 | 0.828 | 0.227 | 3.65 | 3.65 | | 0.435 |
| 7 | 0.024 | 2.476 | 0.983 | 0.350 | 2.81 | 2.81 | 0.769 | |
| 8 | 0.024 | 2.476 | 0.983 | 0.350 | 2.81 | 2.81 | | 0.648 |
| 9 | 0.030 | 3.095 | 1.087 | 0.298 | 3.65 | 3.65 | 0.664 | |
| 10 | 0.030 | 3.095 | 1.087 | 0.298 | 3.65 | 3.65 | | 0.531 |
| 11 | 0.036 | 3.713 | 1.190 | 0.424 | 2.81 | 2.81 | 0.805 | |
| 12 | 0.036 | 3.713 | 1.190 | 0.424 | 2.81 | 2.81 | | 0.625 |
| 13 | 0.048 | 4.951 | 1.398 | 0.497 | 2.81 | 2.81 | 0.634 | |
| 14 | 0.048 | 4.951 | 1.398 | 0.497 | 2.81 | 2.81 | | 0.491 |
| 15 | 0.060 | 6.189 | 1.605 | 0.571 | 2.81 | 2.81 | 0.593 | |
| 16 | 0.060 | 6.189 | 1.605 | 0.571 | 2.81 | 2.81 | | 0.405 |
| 17 | 0.060 | 6.189 | 1.605 | 0.440 | 3.65 | 3.65 | 0.457 | |
| 18 | 0.060 | 6.189 | 1.605 | 0.440 | 3.65 | 3.65 | | 0.312 |
| 19 | 0.090 | 9.284 | 2.123 | 0.582 | 3.65 | 3.65 | 0.597 | |
| 20 | 0.090 | 9.284 | 2.123 | 0.582 | 3.65 | 3.65 | | 0.393 |
| 21 | 0.120 | 12.378 | 2.642 | 0.724 | 3.65 | 3.65 | 0.639 | |
| 22 | 0.120 | 12.378 | 2.642 | 0.724 | 3.65 | 3.65 | | 0.352 |

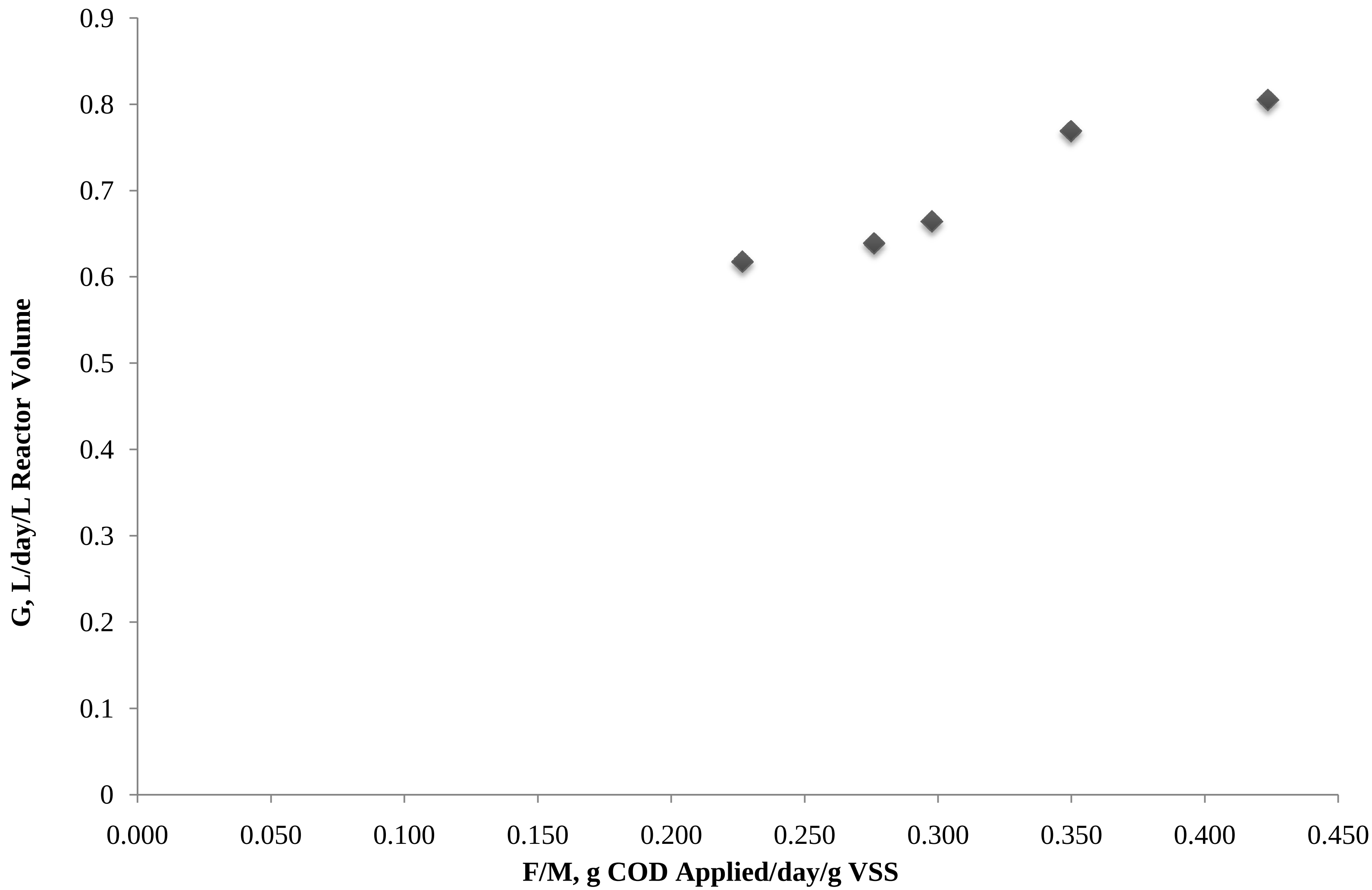



Figure 15. Specific Biogas Production Rate as a Function of Mass Specific Substrate Loading Rate in Terms of COD (AMPTS)

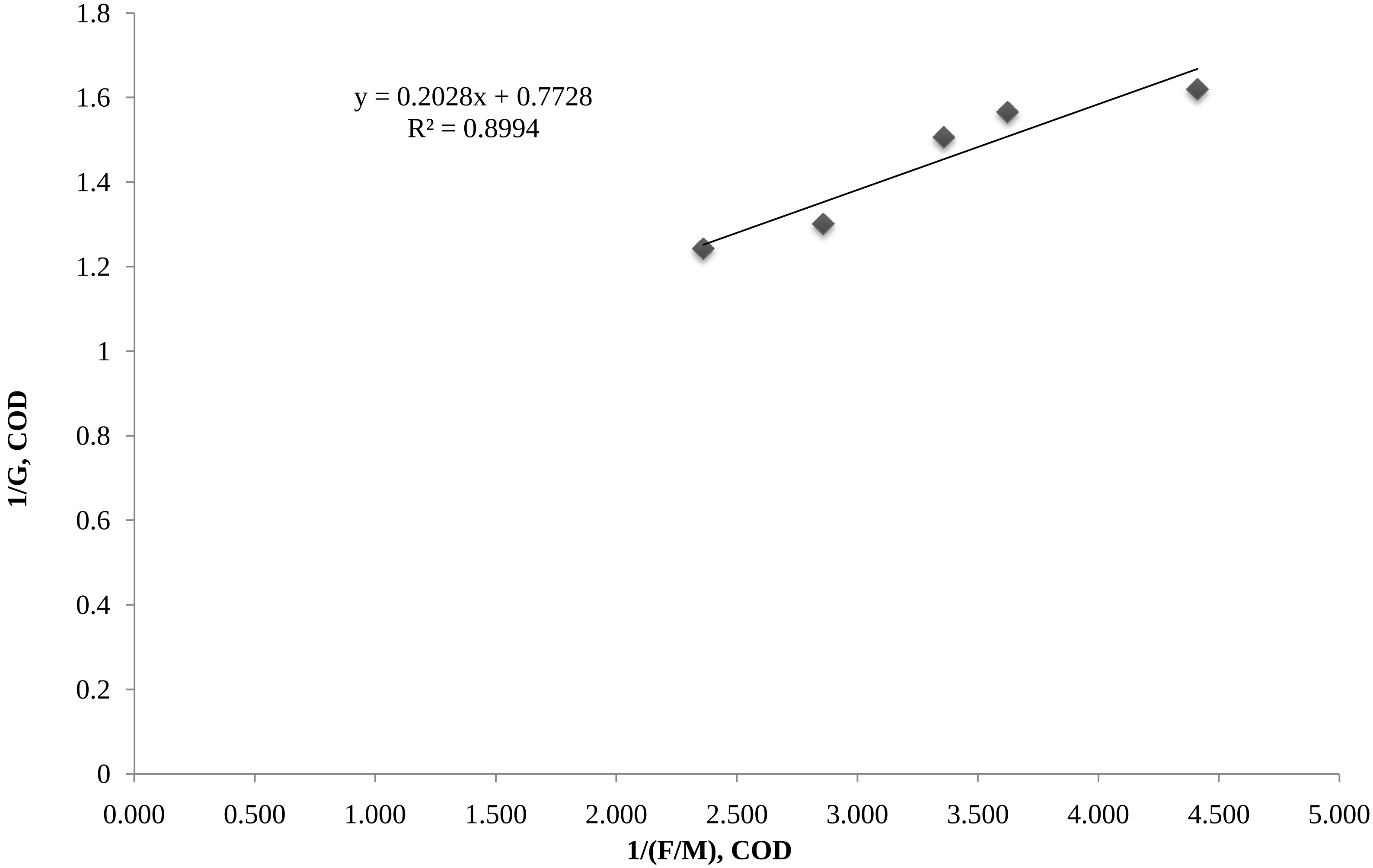



Figure 16. Graphical Determination of $G_{max}$ and $G_B$ in Terms of COD (AMPTS)

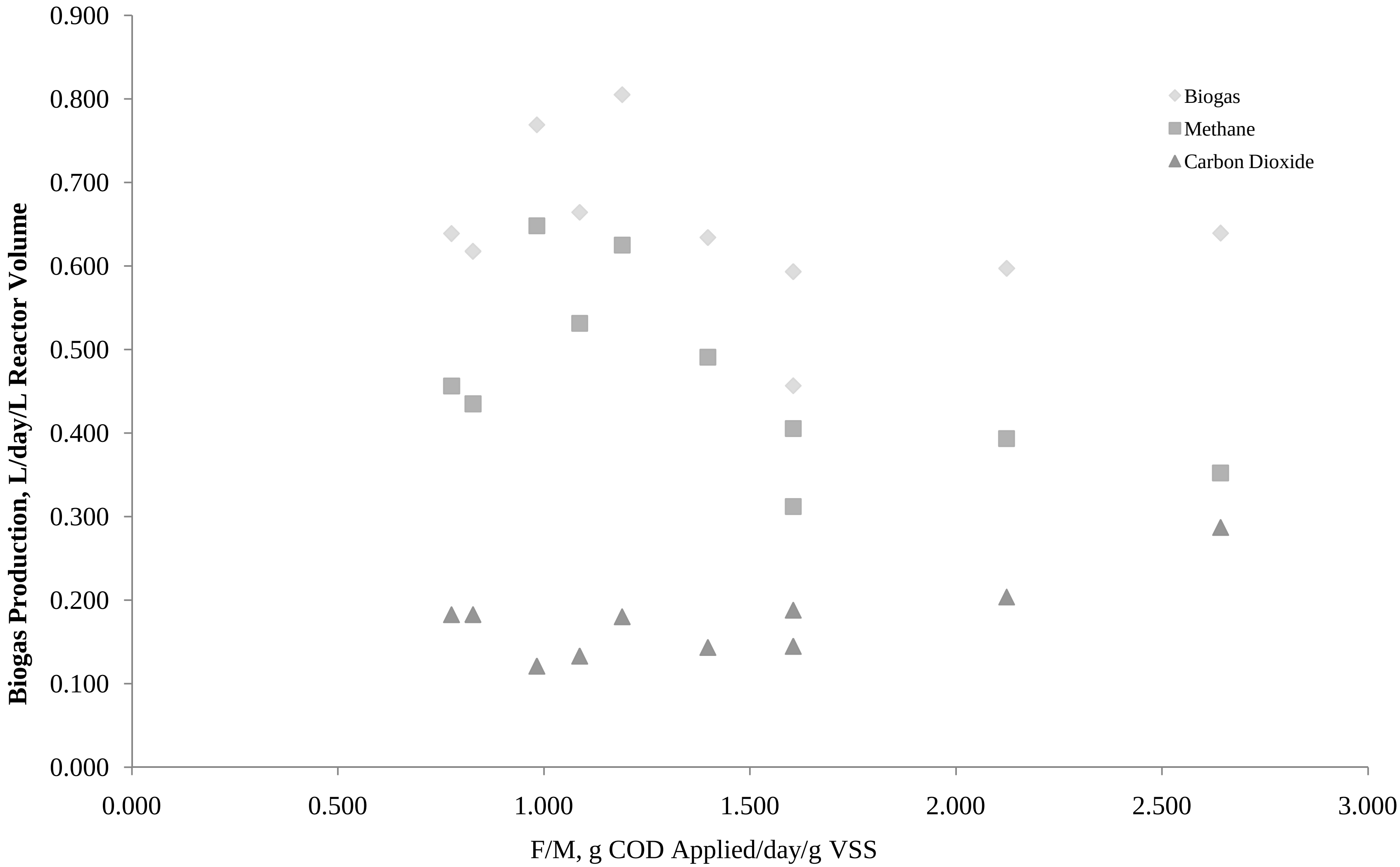



Figure 17. Biogas Production Composition as a Function of Mass Specific Substrate Loading Rate in Terms of COD (AMPTS)

## AMPTS Digester Methane Kinetics

Biokinetic constants $M_{max}$ and $M_B$ were determined from the data obtained during the AMPTS research portion of this study. AMPTS digester methane production rates can be viewed in Table 21. The specific methane production rates were plotted as a function of the F/M ratio in terms of COD as seen in Figure 18. The reciprocal of M was plotted as a function of the reciprocal of the F/M ratio to achieve a linear monomolecular kinetic relationship as seen in Figure 19. In linearized form, $M_{max}$ is the reciprocal of the y-axis intercept, and the slope of the line is equal to $M_B/M_{max}$. $M_{max}$ was determined from Figure 19 to be 0.71 L Methane/day/L Reactor Volume with a $M_B$ value of 0.135 g COD Applied/day/g VSS. Specific methane production rates for the initial F/M ratios of 1.398 g COD Applied/g VSS and higher F/M ratios were not included in Figure 18 and 19 for methane kinetics determination due to decreasing methane production rates most likely resulting from VFA inhibition/toxicity. A summary table of the AMPTS digester substrate, biogas, and methane biokinetic constants can be viewed in Table 22. As viewed in Figure 17 at the initial F/M ratio of 1.398 g COD Applied/g VSS and higher, methane production rate decreases most likely as a result of VFA inhibition/toxicity.

# BENCH-SCALE DIGESTER KINETICS VS. AMPTS DIGESTER KINETICS

## Substrate Kinetics Comparison

Since substantial data was obtained during the course of the digester reactor portion of the research, kinetics data obtained during the AMPTS studies could be directly compared and contrasted with the kinetics data developed from the bench-scale digesters.

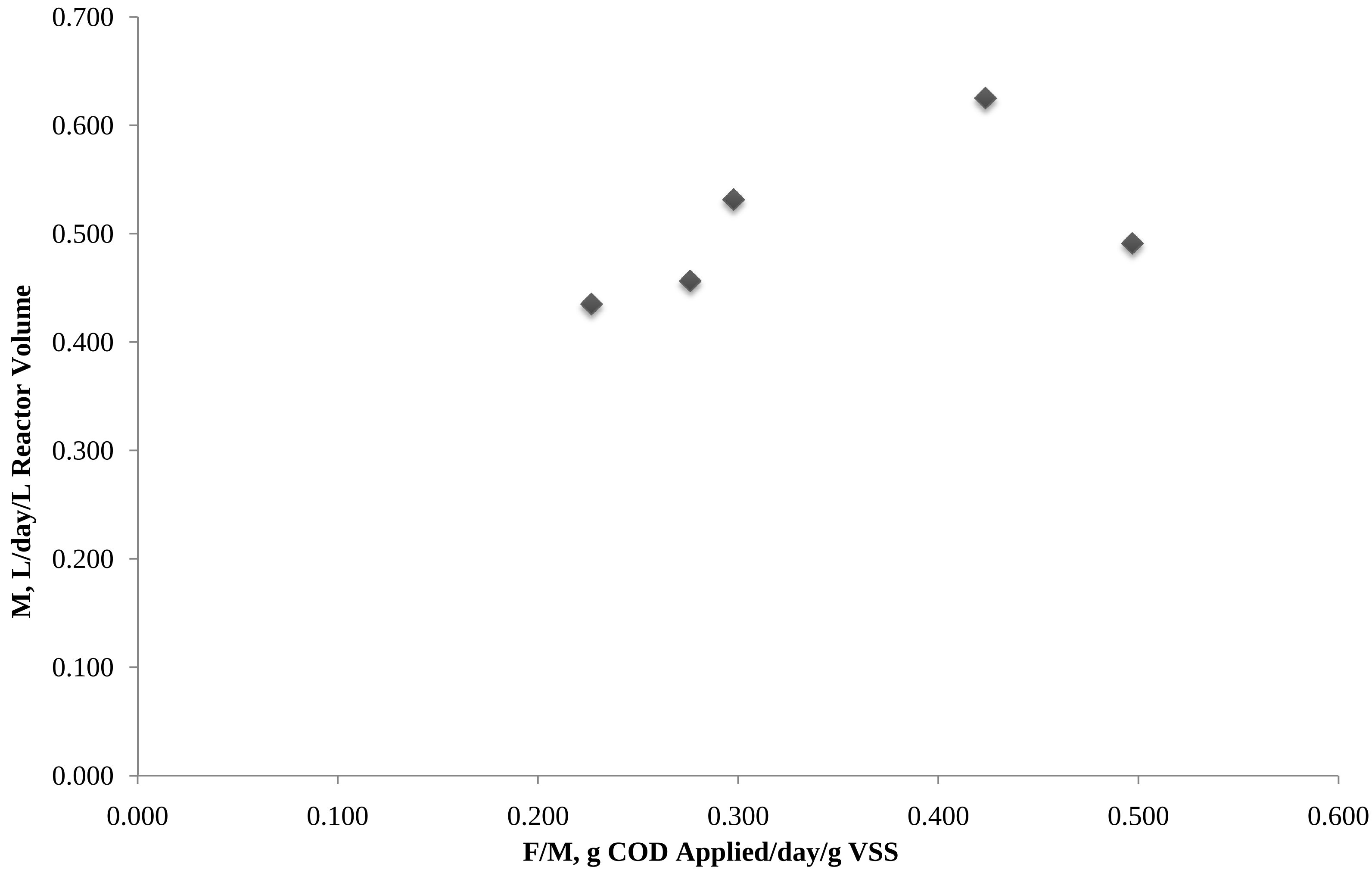



Figure 18. Specific Methane Production Rate as a Function of Mass Specific Substrate Loading Rate in Terms of COD (AMPTS)

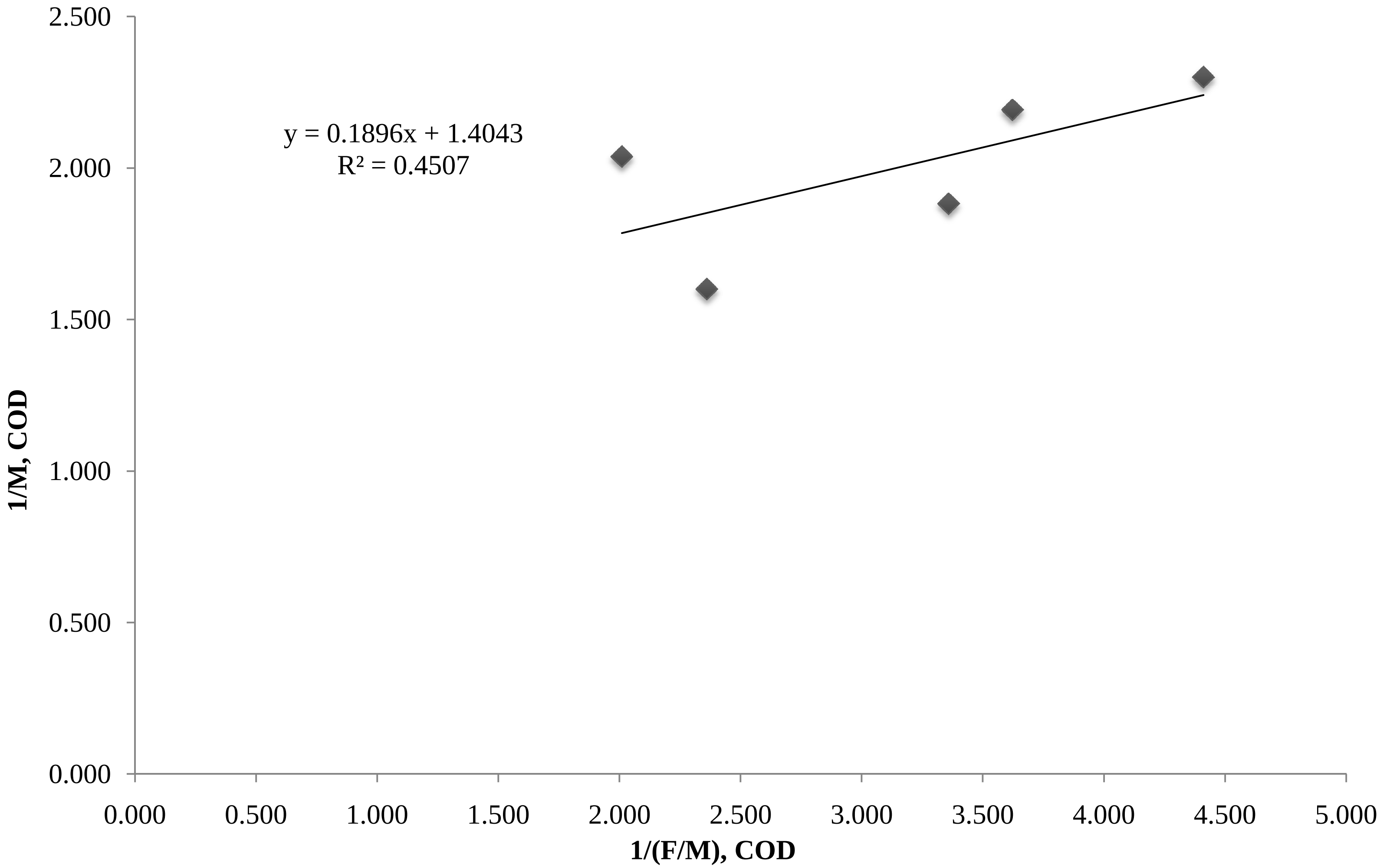



Figure 19. Graphical Determination of $M_{max}$ and $M_B$ in Terms of COD (AMPTS)

**TABLE 22**
**AMPTS Digester Biokinetic Constants**

| Parameter | Value |
|---|---|
| $U_{max}$ (g COD R/day/g VSS) | 16.98 |
| $K_B$ (g COD/day/g VSS) | 40.17 |
| $G_{max}$ (L/day/L Reactor Volume) | 1.29 |
| $G_B$ (g COD/day/g VSS) | 0.26 |
| $M_{max}$ (L/day/L Reactor Volume) | 0.71 |
| $M_B$ (g COD/day/g VSS) | 0.14 |

Bench-scale digesters were operated in a semi-continuous fed, CSTR mode, while AMPTS digesters were operated in a batch mode. Both studies were performed using the same feed blend throughout the course of the studies. The AMPTS digesters were seeded with sludge from one of the operating bench-scale digesters. Both studies were performed using vented, temperature controlled rooms with air temperatures maintained between 33$^{o}$C to 36$^{o}$C throughout the course of the studies to maintain digester operating temperatures. Biokinetic constants were developed for both studies based on mass specific substrate loading rate according to the Stover-Kincannon Model (Stover & Kincannon, 1982, Stover & Kincannon, 1983, and Stover & Kincannon, 1984). A summary table comparing the biokinetic constants developed from data obtained from the bench-scale digester studies and from the AMPTS digester studies can be viewed in Table 23.

The biokinetic constants $U_{max}$ and $K_B$ obtained from the bench-scale digester studies and the AMPTS studies were used to calculate U values as a function of F/M using the following equation:

$$U = \frac{U_{max}(X)\left(\frac{F}{M}\right)}{K_B + \left(\frac{F}{M}\right)}$$

Where:

X = reactor VSS, g/L

An X value of 10 g/L (10,000 mg/L) was chosen based on average once-through digester VSS concentrations throughout the course of the bench-scale digester studies. A series of F/M ratios were chosen to calculate U value data points to produce U vs. F/M curves

**TABLE 23**
**Comparison of Biokinetic Constants**

| Parameter | Bench-Scale Digester Constants | AMPTS Digester Constants |
|---|---|---|
| $U_{max}$ (g COD R/day/g VSS) | 16.95 | 16.98 |
| $K_B$ (g COD/day/g VSS) | 17.13 | 40.17 |
| $G_{max}$ (L/day/L Reactor Volume) | 2.28 | 1.29 |
| $G_B$ (g COD/day/g VSS) | 0.11 | 0.26 |
| $M_{max}$ (L/day/L Reactor Volume) | 1.55 | 0.71 |
| $M_B$ (g COD/day/g VSS) | 0.11 | 0.14 |

based on the biokinetic constants $U_{max}$ and $K_B$ obtained from both the bench-scale digester studies and the AMPTS studies.  The generated curves from both digester studies were plotted together for direct comparison and can be viewed in Figure 20.  As seen in Figure 20, the calculated U values plotted according to the bench-scale digester $U_{max}$ and $K_B$ values follow an initial rapid increase and then start to level off as the calculated U values approach $U_{max}$ according to monomolecular kinetics.  However; the calculated U values plotted according to the AMPTS digester $U_{max}$ and $K_B$ values produced a significantly different U response curve with much lower specific substrate utilization rates for the same specific substrate loading rates as the bench-scale digesters; as a result of the high determined $K_B$ value.  The significantly higher $K_B$ value determined from the AMPTS studies is a direct result of the high initial F/M ratio VFA inhibition/toxicity impacts, as a result of the batch operating mode of the AMPTS digesters compared to the semi-continuous feed mode of the bench-scale digesters.  The high initial F/M ratios in the AMPTS digesters resulted in VFA inhibition/toxicity and poor treatment performance in terms of COD removal compared to the bench-scale digesters that did not experience VFA inhibition/toxicity.

**Biogas Kinetics Comparison**

The biokinetic constants $G_{max}$ and $G_B$ obtained from the bench-scale digester studies and the AMPTS studies were used to calculate G values as a function of F/M using the following equation:

$$G = \frac{G_{max}(X)\left(\frac{F}{M}\right)}{G_B + \left(\frac{F}{M}\right)}$$

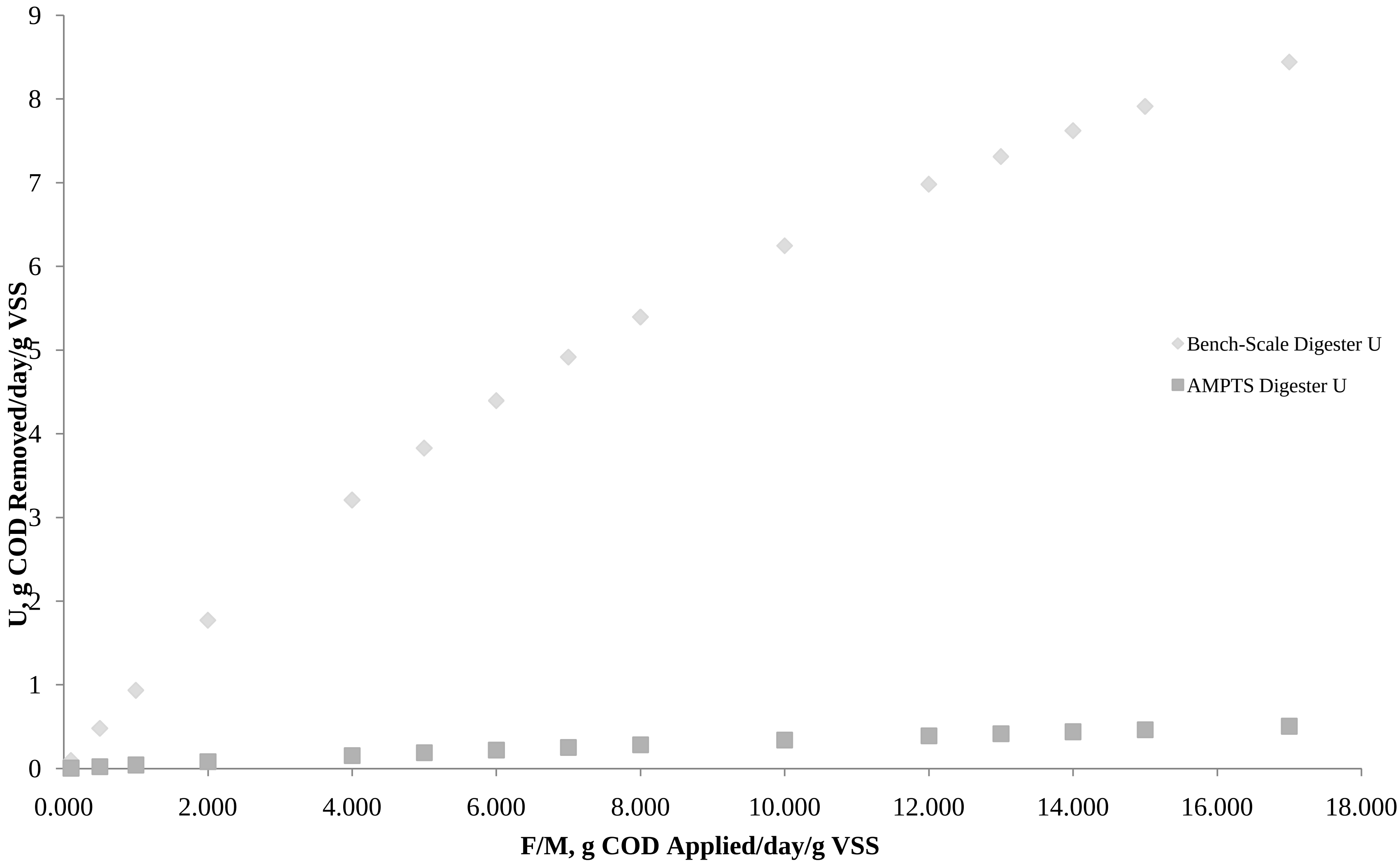



Figure 20. U vs. F/M Comparison Plot of Bench-Scale Digester and AMPTS Digester U Values with Respect to F/M

An X value of 10 g/L (10,000 mg/L) was chosen based on average once-through digester VSS concentrations throughout the course of the bench-scale digester studies. A series of F/M ratios were chosen to calculate G value data points to produce G vs. F/M curves based on the biokinetic constants $G_{max}$ and $G_B$ obtained from both the bench-scale digester studies and the AMPTS studies. The generated curves from both digester studies were plotted together for direct comparison and can be viewed in Figure 21. As seen in Figure 21, the plotted G values calculated according to the bench-scale digester $G_{max}$ and $G_B$ values follow an initial rapid increase and then start to level off as the calculated G values approach $G_{max}$ according to monomolecular kinetics. However; the calculated G values plotted according to the AMPTS digester $G_{max}$ and $G_B$ values produced a significantly different G response curve with much lower specific biogas production rates for the same specific substrate loading rates as the bench-scale digesters; as a result of the high determined $G_B$ value. The significantly higher $G_B$ value determined from the AMPTS studies is a direct result of the high initial F/M ratio VFA inhibition/toxicity impacts as a result of the batch operating mode of the AMPTS digesters compared to the semi-continuous feed mode of the bench-scale digesters. The high initial F/M ratios in the AMPTS digesters resulted in VFA inhibition/toxicity and poor biogas production performance compared to the bench-scale digesters that did not experience VFA inhibition/toxicity.

**Methane Kinetics Comparison**

The biokinetic constants $M_{max}$ and $M_B$ obtained from the bench-scale digester studies and the AMPTS studies were used to calculate M values as a function of F/M using the

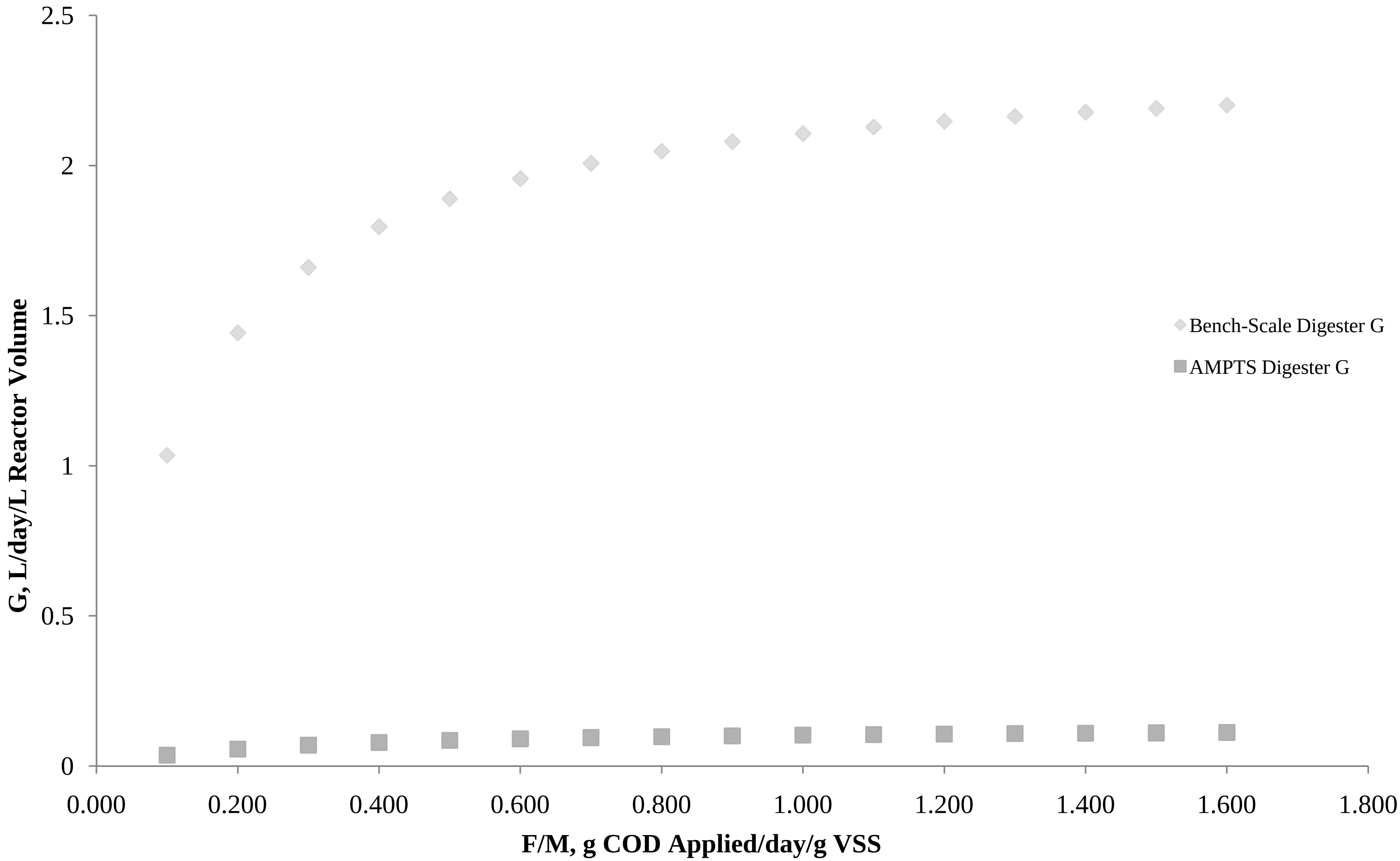



Figure 21. G vs. F/M Comparison Plot of Bench-Scale Digester and AMPTS Digester G Values with Respect to F/M

following equation:

$$M = \frac{M_{max}(X)\left(\frac{F}{M}\right)}{M_B + \left(\frac{F}{M}\right)}$$

An X value of 10 g/L (10,000 mg/L) was chosen based on average once-through digester VSS concentrations throughout the course of the bench-scale digester studies. A series of F/M ratios were chosen to calculate M value data points to produce M vs. F/M curves based on the biokinetic constants $M_{max}$ and $M_B$ obtained from both the bench-scale digester studies and the AMPTS studies. The generated curves from both digester studies were plotted together for direct comparison and can be viewed in Figure 22. As seen in Figure 22, the calculated M values plotted according to the bench-scale digester $M_{max}$ and $M_B$ values follow an initial rapid increase and then start to level off as the calculated M values approach $M_{max}$ according to monomolecular kinetics. However; the plotted M values calculated according to the AMPTS digester $M_{max}$ and $M_B$ values produced a significantly different M response curve with much lower specific methane production rates for the same specific substrate loading rates as the bench-scale digesters; as a result of the high determined $M_B$ value. The significantly higher $M_B$ value determined from the AMPTS studies is a direct result of the high initial F/M ratio inhibition/toxicity impacts as a result of the batch operating mode of the AMPTS digesters compared to the semi-continuous feed mode of the bench-scale digesters. The high initial F/M ratios in the AMPTS digesters most likely resulted in VFA inhibition/toxicity and poor methane production performance compared to the bench-scale digesters which did not experience VFA inhibition/toxicity. AMPTS study raw data can be viewed in Appendix G

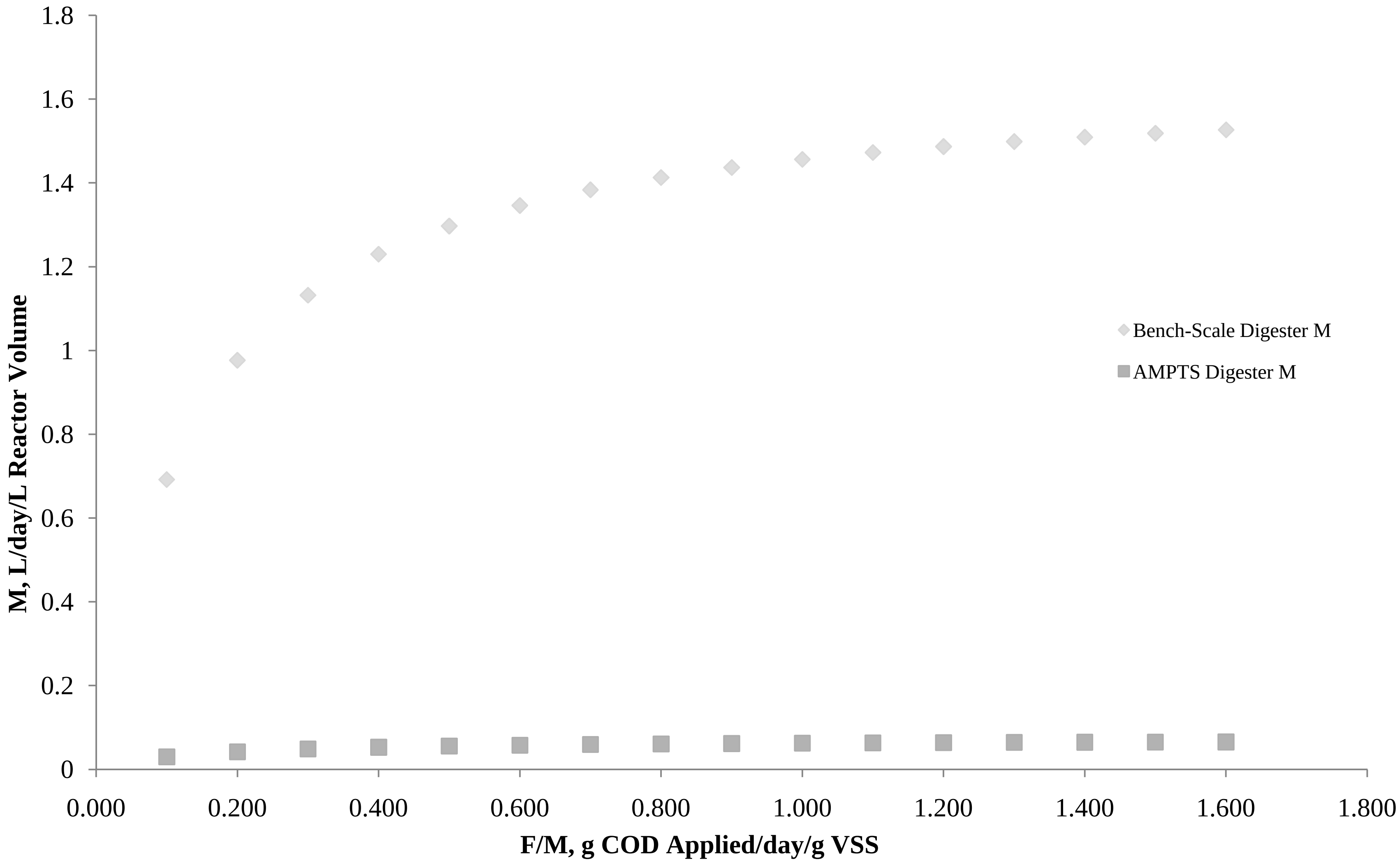



Figure 22. M vs. F/M Comparison Plot of Bench-Scale Digester and AMPTS Digester M Values with Respect to F/M

# CHAPTER V

# DISCUSSION

The scope of this research project was to operate suspended growth, CSTR anaerobic digesters at the bench-scale level to evaluate improved operation techniques/methods and develop biokinetic relationships. Multiple digester reactors were operated simultaneously for approximately fourteen months to obtain data that were used to develop improved operational processes and biokinetic relationships, along with evaluation of treatment performance under various operating conditions. Biokinetic relationships were developed for specific substrate utilization rate, specific biogas production rate, and specific methane production rate in terms of specific substrate loading rates.

The goal for developing improved operational processes and biokinetic relationships at the bench-scale level is to apply the improved techniques and relationships to full-scale biogas/bioenergy production facilities for improved digester operations and enhanced biogas production by producing the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume.

Considering technology currently available, the purpose of this research project is to use the biokinetic constants developed from the bench-scale digesters to develop a PLC algorithm to automate digester operations with input of key analytical parameters to control injection of substrate, and on-line monitoring of key digester operating parameters to optimize digester operating conditions and provide enhanced biogas production with improved methane content while maintaining good digester health, (pH, alkalinity, and nutrient requirements).

When performing anaerobic digestion processes from a waste treatment standpoint, waste treatment plants have little to no control over substrate selection and are forced to accept and treat whatever waste flows and loads are provided. As a result, flow and loading conditions often vary due to changing waste stream characteristics, resulting in unstable digester operation. Unstable operating conditions often result in digester unpredictability, poor substrate removal, poor biogas production, poor biogas quality, and even digester failure. An example of digester failure can be observed in the AMPTS studies previously mentioned where high initial F/M ratios (high COD loading conditions) in several of the digesters resulted in VFA accumulation and inhibition/toxicity to the methanogens, resulting in poor COD removal, poor biogas production, and poor biogas quality. Substrate overdosing as a result of insufficient substrate monitoring and digester monitoring is a common reason for digester failure. Low feed rates are also of concern and do not provide maximum biogas production per reactor volume available (this is of particular concern relative to biogas/bioenergy applications). It is important to select high-strength (high COD) waste sources to avoid limiting substrate injection as a result of low HRT to avoid digester solids dilution and allow proper time for methanogen growth.

When performing anaerobic digestion processes from an alternative fuels/energy production standpoint, it is important to select a quality substrate(s) that is readily available and amenable to anaerobic digestion processes. It may also be important to have a variety of quality substrates to choose from due to possible seasonal variation and availability. Substrates must be routinely monitored and characterized for COD and nutrient value. The PLC algorithm must be able to adjust at least a selected one of the rate of the various feedstocks based on substrate COD and nutrient data input obtained through analytical laboratory testing to optimize the digester reactor for biogas production, treatment performance, and pH and alkalinity control. The purpose for input of substrate COD data into the PLC is to adjust flow rates according to substrate COD concentrations to maintain stable substrate mass loading rates (F/M ratios) in the digester reactor to minimize specific substrate loading rate peaks and valleys associated with unstable operating conditions and lack of full use of anaerobic reactor volume biogas production capabilities.

On-line digester monitoring for key parameters is a critical part of the full-scale digester optimization process. Key on-line monitoring parameters include digester pH, temperature, biogas flow rate, biogas methane, carbon dioxide, and hydrogen sulfide content. Important digester parameters to monitor through laboratory analytical practices include VFAs, alkalinity, COD (same as effluent COD for once-through systems), TS, VS, TSS, VSS, $NH_3$-N, and $PO_4$-P. The PLC algorithm needs to be able to read and interpret the key digester parameters for both on-line monitoring and analytical data entry and adjust specific substrate loading rates accordingly. For example, decreasing pH and alkalinity and increasing VFAs and effluent CODs with decreasing biogas production rate and methane content would be cause for concern and reason to reduce substrate loading to the digester. With an automated PLC system with specific parameter setpoints, an upset condition with one or a combination of the key parameters would automatically reduce substrate loading rates, allow for digester recovery, and significantly reduce the risk of digester failure. On the other hand, inadequate use of anaerobic digester volume could also be determined and the specific substrate loading rate increased for increased biogas production.

By determining biokinetic constants for the substrates, a PLC algorithm can be created to monitor the critical on-line monitoring parameters previously mentioned and receive data input from laboratory analytical testing for full-scale digester operations. The biokinetic constants, when combined with proper on-line monitoring and laboratory analytical testing, can be used to predict and maximize treatment performance and ultimately enhance biogas production with the highest methane content possible.

The biokinetic constants developed during the course of this research project do not necessarily apply to different substrates. The biokinetic constants will be substrate specific, and the biokinetic constants will have to be determined for each application. Different substrates may require different operating techniques/methodologies. All digesters operated during the course of this study were operated under mesophilic conditions. However; the key operating parameters for consistent anaerobic digester operation and optimization remain the same for thermophilic operating conditions as well.

Biomass recycle was proven during the course of this research project to be an excellent option for increased biogas production and enhanced COD removal. Biomass recycle for full-scale applications can be accomplished by a solids/liquid separation device, such as a centrifuge, dissolved air or gas flotation system (Stover, 1987), gravity belt thickener, ultrafilter membranes, etc. The effluent produced after the solids/liquid separation process is of high quality for recycle or reuse such as direct irrigation, and the majority of the separated solids/biomass are recycled back to the digester reactor to increase and maintain high biomass inventory. The biomass solids returned to the digester reactor provide significant advantages for operations compared to the currently used once-through operating systems. Biomass recycle provides biomass management and control and allows increased substrate loading while maintaining low, stable operating F/M ratios with decreased inhibition as a result of increased biomass inventory. Biomass recycle provides process stability and performance enhancement with nutrient and alkalinity recycle for enhanced pH control, and enhanced and optimized biomethane production by enhanced COD removal. A portion of the biomass solids can also be wasted from an operating system as concentrated solids with high fertilizer nutrient value.

The data obtained during this research project has proven through proper laboratory analytical testing and monitoring of key digester operating parameters that this approach to digester optimization can be applied to full-scale anaerobic digestion processes for the purpose of enhanced biogas production with maximum possible methane content. This research project has also proven through proper laboratory analytical testing and monitoring of key digester operating parameters that it is possible to push digester operating conditions towards the maximum specific methane production rate per unit of digester reactor volume while maintaining operational stability and reliability.  Operating anaerobic digestion systems for the primary purpose of biogas/bioenergy production, rather than for waste treatment, will place greater emphasis on obtaining the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume.

# CHAPTER VI

# SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The scope of this research project was to operate suspended growth, CSTR anaerobic digesters at the bench-scale level to evaluate improved operation techniques/methods and develop biokinetic relationships. Multiple digester reactors were operated simultaneously for approximately fourteen months to obtain data that was used to develop improved operational processes and biokinetic relationships, along with evaluation of treatment performance under various operating conditions. Biokinetic relationships were developed for specific substrate utilization rate, specific biogas production rate, and specific methane production rate in terms of specific substrate loading rates.

The ultimate goal of this study was to develop biokinetic constants and a database of anaerobic digester operating parameters using manual operating techniques at the bench-scale level that could be applied for automation of full-scale biogas/bioenergy production facilities for the purpose of enhanced biogas production. The purpose of automating full-scale biogas/bioenergy production facilities is to improve digester operations and enhance biogas production by producing the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume while maintaining stabile digester operating conditions.

Considering technology currently available, the purpose of this research project is to use the biokinetic constants developed from the bench-scale digesters to develop a PLC algorithm to automate digester operations with input of key analytical parameters to control injection of substrate, and on-line monitoring of key digester operating parameters to optimize digester operating conditions and provide enhanced biogas production with improved methane content while maintaining good digester health, (pH, alkalinity, and nutrient requirements).

The following conclusions can be drawn from this research study:

1. Individual feedstocks chosen for this study when combined to form a co-digestion substrate proved to be highly biodegradable and can be successfully converted to biogas with consistent average methane content between 65% - 70% using anaerobic digestion processes.

2. Substrate utilization kinetics were found to be predictable as a function of mass specific substrate loading rates.  Substrate utilization can be accurately predicted using the Stover-Kincannon Model.

3. Specific biogas and methane production rates were found to be predictable as a function of mass specific substrate loading rates.  Specific biogas and methane production rates can be described by monomolecular kinetics, the same as specific substrate utilization rates.  Biokinetic constants were developed to be used in full-scale anaerobic digester operations to predict specific substrate utilization, specific biogas

production, and specific methane production rates at various specific substrate loading rates.

4. Substrates must be routinely monitored and characterized for COD and nutrient value. Full-scale anaerobic digestion plants, for the purpose of alternative fuel/energy production, should have the ability to adjust at least a selected one of the rate of the various feedstocks based on substrate COD and nutrient data input obtained through analytical laboratory testing to optimize the digester reactor(s) for biogas production, substrate removal, and pH and alkalinity control. Influent flow rates should be adjusted according to substrate COD concentrations to maintain stable substrate mass loading rates (F/M ratios) in the digester reactor to minimize specific substrate loading rate peaks and valleys associated with unstable operating conditions and lack of full use of anaerobic reactor volume for biogas production capabilities.

5. The biokinetic constants, when combined with proper on-line monitoring and laboratory analytical testing, can be used to predict and maximize treatment performance and ultimately enhance biogas production with the highest methane content possible while maintaining operational stability and reliability.

6. Improper monitoring and correlation of substrate loading and key digester operating parameters can lead to unstable operating conditions with digester unpredictability, poor substrate utilization rates, poor biogas production, poor biogas quality, and even digester failure.

7. Substrate overdosing as a result of insufficient substrate monitoring and digester monitoring is a common reason for digester failure. Low feed rates are also of concern

and do not provide maximum biogas production per reactor volume available. It is important to select high-strength (high COD) waste sources to avoid limiting substrate injection as a result of low HRT to avoid digester solids dilution and allow proper time for methanogen growth.

8. Operating anaerobic digestion systems for the primary purpose of biogas/bioenergy production, rather than for waste treatment, places greater emphasis on obtaining the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume.

9. Biomass recycle is an excellent option for increased biogas production and enhanced COD utilization. Biomass recycle provides biomass management and control and allows increased digester substrate loading rates while maintaining low, stable operating F/M ratios with decreased inhibition as a result of increased biomass inventory. Biomass recycle provides process stability and enhanced performance with nutrient and alkalinity recycle for enhanced pH control, and enhanced and optimized biomethane production by enhanced COD utilization.

10. AMPTS studies show potential for developing a quick and simple method/procedure to determine biokinetic relationships for full-scale applications without performing the long-term bench-scale operations. However; biokinetic constants developed using the AMPTS studies were different than those determined form the bench-scale digesters. AMPTS study biokinetic constants differed due to batch feeding compared to semi-continuous feeding, resulting in initial high F/M ratios in the digesters causing VFA

accumulation and methanogen inhibition/toxicity resulting in poor substrate removal, poor biogas production, and poor biogas quality.

From the research study conclusions presented, it is recommended to pursue the following:

1. Develop PLC algorithms for full-scale anaerobic digestion alternative fuels/energy production plants using the co-digestion process of combined feedstocks and/or individual feedstocks according to the key laboratory analytical testing parameters and key on-line digester monitoring parameters previously mentioned in correlation with the biokinetic constants developed to maximize biogas and methane production rates based on substrate loading rates.

2. Develop laboratory analytical testing and on-line digester monitoring programs for key operating parameters for full-scale anaerobic digestion biogas/bioenergy production plants. Important digester parameters to monitor through laboratory analytical practices include VFAs, alkalinity, COD, TS, VS, TSS, VSS, $NH_3$-N, and $PO_4$-P. Key on-line monitoring parameters include digester pH, temperature, biogas flow rate, biogas methane, carbon dioxide, and hydrogen sulfide content. Key digester parameters for both on-line monitoring and analytical data entry should be used to adjust specific substrate loading rates accordingly.

3. Continue investigation in AMPTS study methodologies to overcome the problems associated with batch feeding and initial high F/M ratios that result in VFA accumulation and methanogen inhibition/toxicity ultimately resulting in poor substrate removal, poor biogas production, and poor biogas quality.

REFERENCES


Abdoun, E. and Weiland, P. "Optimization of Monofermentation From Renewable Raw Materials by the Addition of Trace Elements." Bornimer Agrartechnische Berichte (Bornimer Agricultural Technical Reports) 68 (2009): 69-78

Angelidaki, I. and Ahring, B.K. "Thermophilic Anaerobic Digestion of Livestock Waste: Effect of Ammonia." Applied Microbiology and Biotechnology 38 (1993): 560-564

Angelidaki, I., Ellegaard, L., and Ahring, B.K. "Application of the Anaerobic Digestion Process." Advances in Biochemical Engineering/Biotechnology. 82 (2003): 2-33.

Barber, J. "A Comprehensive Evaluation of the Design and Operation of Anaerobic Filters." Diss. Oklahoma State University 1987.

Braun, R. "Anaerobic Digestion: A Multi-Faceted Process for Energy, Environmental Management and Rural Development." Ranalli, P., ed. Improvement of Crop Plants for Industrial End Uses. Springer (2007): 335-416

Braun, R., Huber P., and Meyrath, J. "Ammonia Toxicity in Liquid Piggery Manure Digestion." Biotechnology Letters 3 (1981): 159-164

Burns & McDonnell. Biogas to Pipeline-Quality Gas Using Pressure-Swing Adsorption. 2010.http://www.burnsmcd.com/portal/page/portal/Internet/Content_Admin/Complete%20Issues%20Link%20Repository/TB2010v2.pdf 28 Nov. 2010.

Cohen, A. "Two-Phase Digestion of Liquid and Solid Wastes." Third International Symposium on Anaerobic Digestion, Boston, Massachusetts, 14-19 August 1983.

De Baere, L.A., Devocht, M. and van Assche, P. "Influence of High NaCl and $NH_4Cl$ Salt Levels on Methanogenic Associations." Water Research 18 (1984): 543-548.

Dornack, C. "Stickstoff in Biogasanlagen." (Nitrogen in Biogas Plants). VDI—Ber 2057 (2009): 155-171.

Dutt, A. "Anaerobic Treatment of a Sorghum-Based Alcohol Production Wastewater." Diss. University of Texas at Austin 1985.

European Biomass Association. "A Biogas Road Map for Europe." Oct 2009. http://www.aebiom.org/IMG/pdf/Brochure_BiogasRoadmap_WEB.pdf. 30 Oct. 2010.

Fachverband Biogas. "Biogas Dezentral Erzeugen, Regional Profitieren, International Gewinnen." (Biogas Distributed Generation, Regional Benefit, International Profits.) Jahrestagung des Fachverbandes Biogas. Hannover, Germany. 2009.

Fehrenbach, H. *et al.* "Kriteerien Einer Nachhaltigen Bioenergienutzung im Globalen Maßstab." (Criteria for Sustainable Bioenergy Use in the Global Scale). UBA-Forschungsbericht. 206 (2008): 41-112.

Ganapathi, G. "A Comprehensive Treatability Study on Alcohol Stillage Using Aerobic and Anaerobic Suspended Growth Systems." Diss. Oklahoma State University, 1984.

Gemmeke, B., Rieger, C., and Weiland, P. "Biogas-Messprogramm II." (Biogas Measurement Program). 61 Biogasanlagen im Vergleich. FNR, Gülzow, Germany. 2009.

González, R. "Kinetic Studies and Performance Evaluation of an Anaerobic Fixed-Film Reactor Treating Fuel Alcohol Wastewater." Diss. Oklahoma State University, 1987.

Hansen, K.H., Angelidaki, I., and Ahring, B.K. "Anaerobic Digestion of Swine Manure: Inhibition by Ammonia." Water Research 32 (1998): 5-12

IEA Bioenergy. "Task 24: Energy from biological conversion of organic waste." 1999 http://www.iea-biogas.net/Dokumente/Biogas%20upgrading.pdf 28 Nov. 2010.

IPCC. "IPCC Special Report Emissions Scenarios." Intergovernmental Panel on Climate Change. 2000

Jarvis, A., Nordberg, A., Jarlsvik, T., Mathisen, B., and Svensson, B.H. "Improvement of a Grass-Clover Silage-Fed Biogas Process by the Addition of Cobalt." Biomass & Bioenergy. 12 (1997): 453-460.

Jenkins, S.R., Morgan, J.M., and Sawyer, C.L. "Measuring Anaerobic Sludge Digestion and Growth by a Simple Alkalimetric Titration." Water Pollution Control Federation 55 (1983): 448-453.

Lanting, J. and Gross, R.L. "Anaerobic Pretreatment of Corn Ethanol Production Wastewaters." 40th Annual Purdue Industrial Waste Conference 14-16 May 1985.

Loewenthal, R.E., Kornmüller, U.R.C., and van Heerden, E.P. " Modeling Struvite Precipitation in Anaerobic Treatment Systems." Water Science and Technology. 30 (1994): 107-116

McCarty, P.L. "Kinetics of Waste Assimilation in Anaerobic Treatment." Developments in Industrial Microbiology, Washington, D.C. 144 (1966)

Metcalf and Eddy, Inc. Wastewater Engineering Treatment and Reuse. Boston: McGraw Hill, 2003.

Mösche, M., and Jördening, H.J. "Comparison of Different Models of Substrate and Product Inhibition in Anaerobic Digestion." Water Research. 33 (1999): 2545-2554.

Mshandete, A., Bjornsson, L., Kivaisi, A.K., Rubindamayugi, M.S.T., and Matthiasson, B. "Effect of Particle Size on Biogas Yield From Sisal Fibre Waste." Renewable Energy. 31 (2006): 2385-2392.

Müller, J. *et al.* "Thermische, Chemische, und Biochemische Desintegratiosverfahren." (Thermal, Chemical, and Biochemical Disintegration Process). Korrespondenz Abwasser. 50 (2003): 796-804

NaturalGas.org. Natural Gas and the Environment. 2010. http://www.naturalgas.org/environment/naturalgas.asp#emission. 28 Nov. 2010.

Nielsen, H.B., and Angelidaki, I. "Strategies for Optimizing Recovery of the Biogas Process Following Ammonia Inhibition." Bioresource Technology. 99 (2008): 7995-8001.

O'Rourke, J.T. "Kinetics of Anaerobic Treatment at Reduced Temperature." Diss. Stanford University 1968.

Ripley, L.E., Boyle, W.C., and Converse, J.C. "Improved Alkalimetric Monitoring for Anaerobic Digestion of High-Strength Wastes." Water Pollution Control Federation 58 (1986): 406-411.

Sahlström, L. "A Review of Survival of Pathogenic Bacteria in Organic Waste Used in Biogas Plants." Bioresource Technology. 87 (2003): 161-166.

Schmid, J., Krautkremer, B., and Müller, J. "Biogas Powered Microgas-Turbine." Expo World Conference on Wind Energy, Renewable Energy and Fuel Cells. Hamamatsu, Japan. 7-10 June 2005.

Speeece, R.E. and Kem, J. "The Effects of Short-Term Temperature Variations on Methane Production." Water Pollution Control Federation 42 (1970): 1990-1997

Speece, R.E., Anaerobic Biotechonology for Industrial Wastewaters. Nashville: Archae Press, 1996.

Speece, R.E., Anaerobic Biotechnology and Odor/Corrosion Control for Municipalities and Industries. Nashville: Archae Press, 2008.

Stover, E.L. "Impacts of Dissolved Oxygen on Anaerobic Recycle Sludge Viability During Sludge Thickening." Industrial Wastes Symposia, 60th Annual Water Pollution Control Federation Conference. Philadelphia, Pennsylvania. October 1987.

Stover, E.L. "Anaerobic Treatment: Troubleshooting." WEFTEC®98 Workshop: Industrial Waste Treatment Operations. 4 October 1998.

Stover, E.L. Lecture. Oklahoma State University, Stillwater. 13 April 2009.

Stover, E.L., Brooks, S., and Munirathinam, K. "Control of Biogas $H_2S$ Concentrations During Anaerobic Treatment." AIChE Symposium Series No. 300. 90 1994

Stover, E.L. and Kincannon, D.F. "Rotating Biological Contactor Scale-Up and Design." First International Conference on Fixed-Film Biological Processes, Kings Island, Ohio. 20-23 April 1982.

Stover, E.L. and Kincannon, D.F. "Design Methodology for Fixed-Film Reactors – RBC's and Biological Towers." Civil Engineering for Practicing and Design Engineers 2 (1983): 107-124.

Stover, E.L. and Kincannon, D.F. "Biological Treatability Data Analysis of Industrial Wastewaters." 39th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana. 8-10 May 1984.

Stover, E.L., Ganapathi, G., and González, R., "Anaerobic Treatment of Fuel Alcohol Wastewater by Suspended Growth Activated Sludge." 38th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana. 10-12 May 1983.

Stover, E.L., Ganapathi, G., and González, R., "Use of Methane Gas from Anaerobic Treatment of Stillage for Fuel Alcohol Production." 39th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana. 8-10 May 1984.

Stover, E.L., González, R., and Ganapathi, G. "Anaerobic Fixed-Film Biological Treatment Kinetics of Fuel Alcohol Production Wastewaters." Second International Conference on Fixed-Film Biological Processes, Arlington, Virginia. July 1984.

Strauch, D., and Philipp, W. "Hygieneaspekte der Biologischen Abfallbehandlung und-Verwertung." (Hygiene Aspects of Biological Waste Treatment and Recycling). Bidlingnaier, W. ed. Biologische Abfallbehandlung. Eugen Ulmer. (2000): 155-208

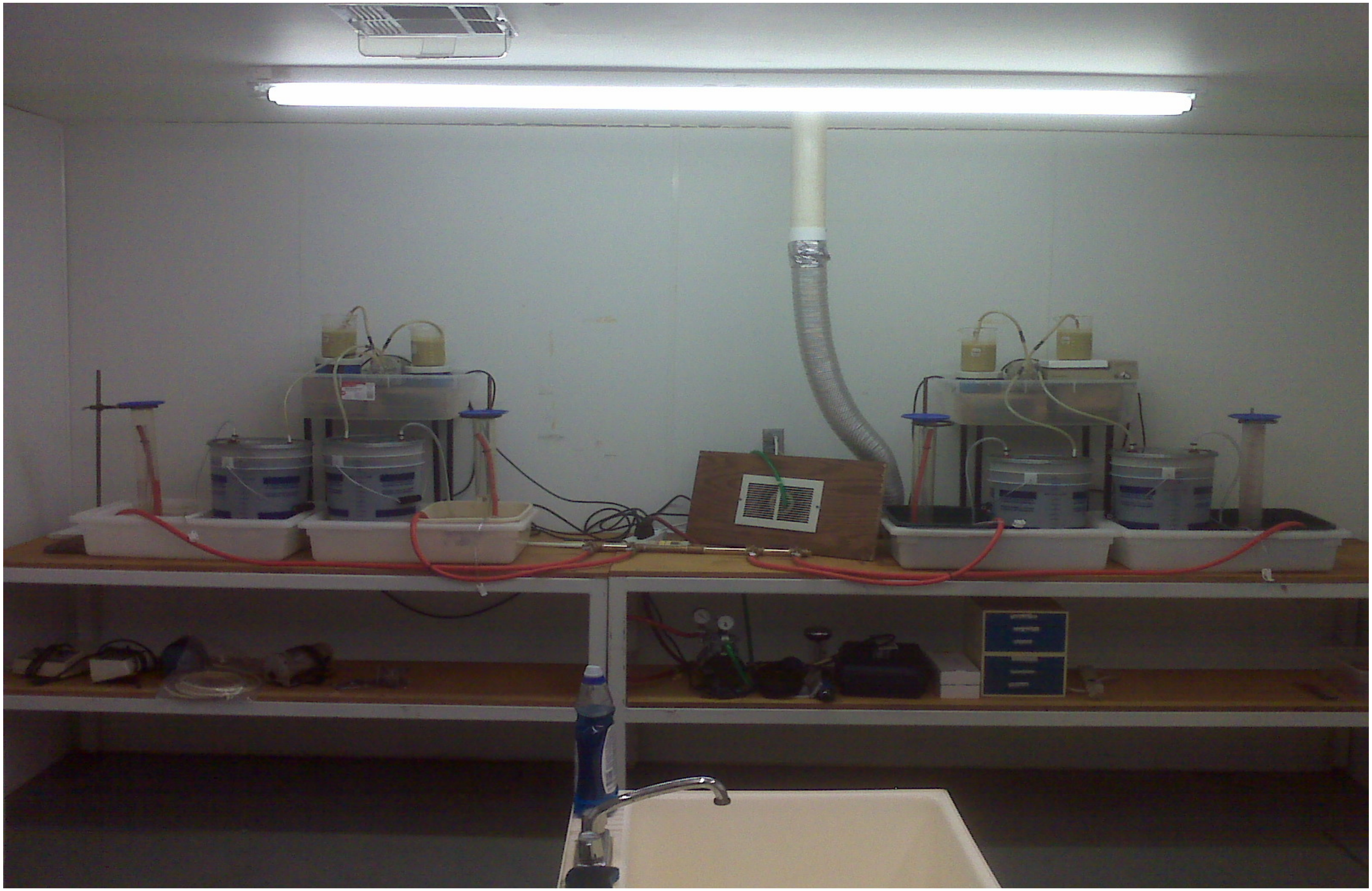
Takamura, E.S. "Anaerobic Treatment of Wastewaters Generated During Grain Fermentation." Diss. University of Texas at Austin, 1983.

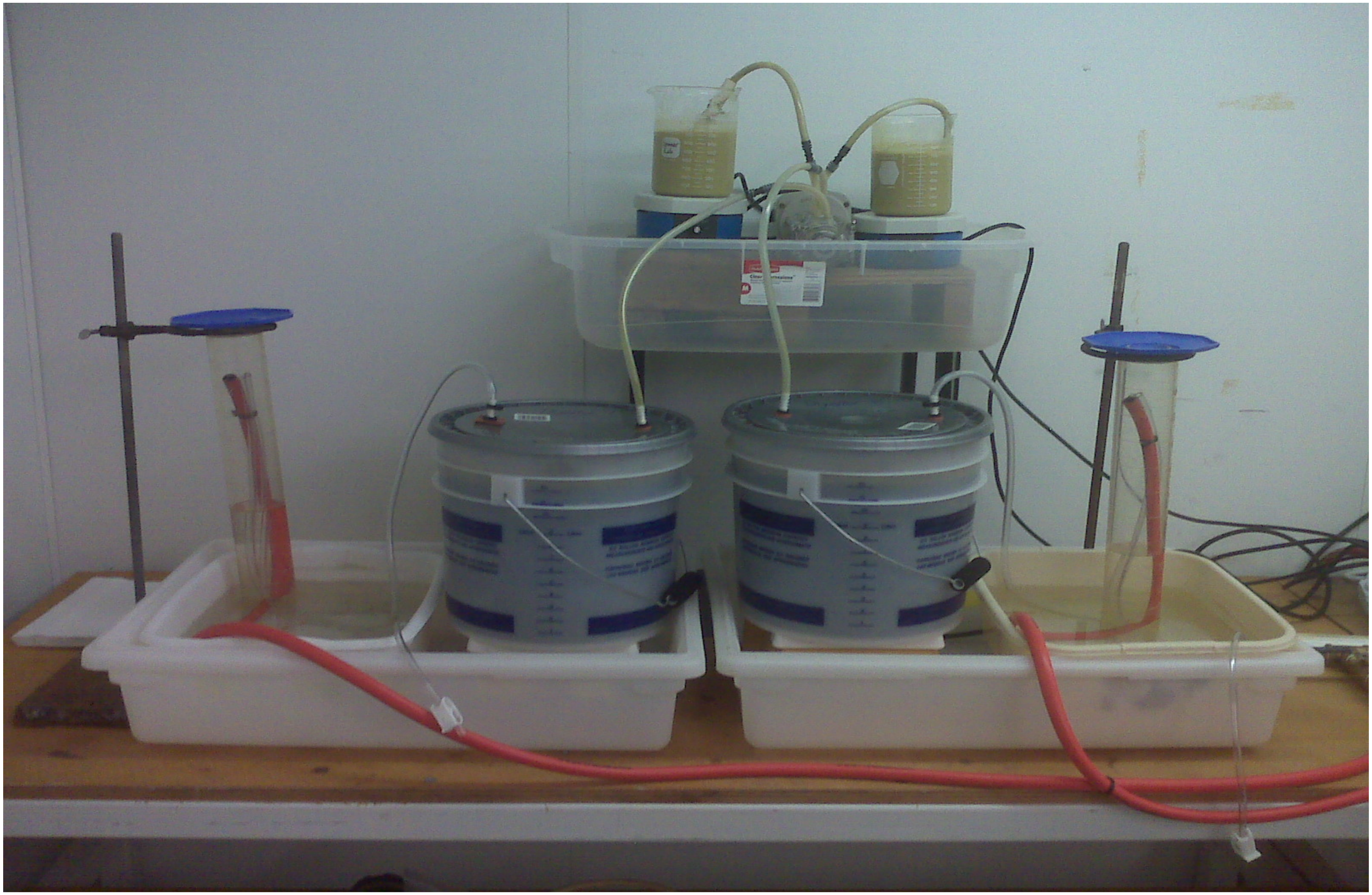
Wang, Q.H., Kuninobu, M., Ogawa, H., and Kato, Y. "Degradation of Volatile Fatty Acids in Highly Efficient Anaerobic Digestion." Biomass & Bioenergy. 16 (1999): 407-416.

Weiland, P. "Biogas Production: Current State and Perspectives." Applied Microbiology and Biotechnology. 85 (2010): 849-860.

# APPENDIX A

Bench-Scale Digester Photographs



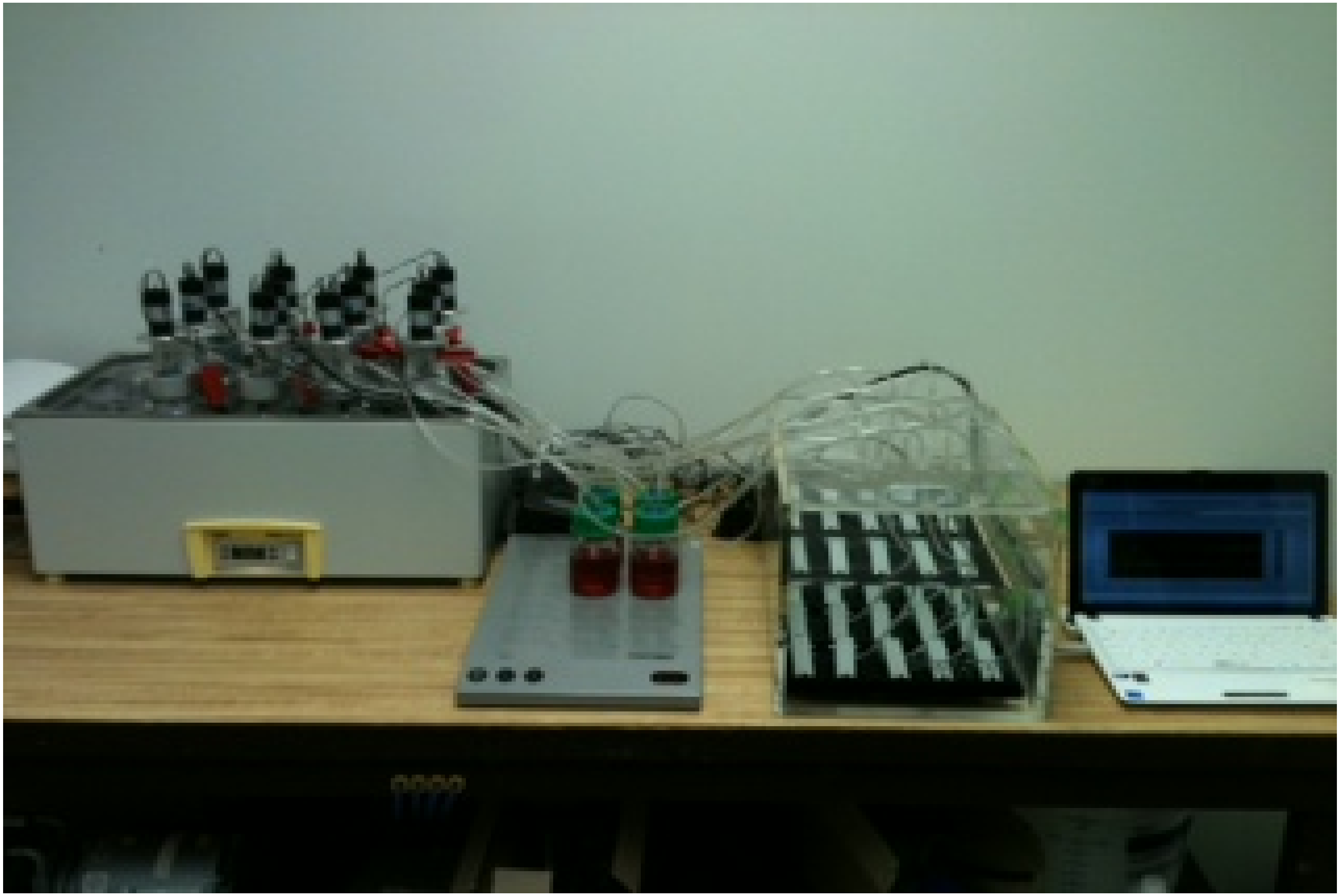



Rubbermaid


Digestor 1

APPPENDIX B

AMPTS Digester Photographs



# APPENDIX C

## Phase I Raw Data

**Phase 1-4**
**Individual Feedstock Characterization**

| Sample Description | pH (s.u.) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | tCOD (mg/L) | sCOD (mg/L) | $NH_3$-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Hen Litter | | 75.95 | 46.97 | | | | | | | |
| Swine Manure | 8.2 | 2.71 | 1.68 | 10,800 | 8,200 | 35,200 | 13,700 | 27,900 | 395 | 17 |
| Husklage | | 91.19 | 87.56 | | | | | | | |
| Silage Juice | 4.0 | 7.49 | 7.11 | 32,200 | 31,600 | 133,400 | 91,400 | 67 | 385 | 367 |
| Thin Stillage #1 | 4.6 | 5.59 | 4.91 | 27,600 | 26,600 | 93,600 | 59,300 | 89 | 1,090 | 422 |
| Thin Stillage #2 | 4.2 | 6.69 | 6.01 | 25,800 | 25,600 | 118,300 | 57,450 | 46 | 1,170 | 575 |
| Thin Stillage #3 | 4.2 | 6.22 | 5.48 | 28,600 | 28,400 | 118,400 | 63,400 | 22 | 1,315 | 600 |
| Thin Stillage #4 | 4.5 | 6.11 | 5.34 | 28,000 | 28,000 | 120,200 | 59,300 | 20 | 1,325 | 570 |
| Thin Stillage #5 | 4.5 | 5.37 | 4.56 | 20,900 | 20,500 | 104,500 | 61,600 | 14 | 1,375 | 525 |
| Thin Stillage #6 | 4.4 | 5.06 | 4.26 | 17,400 | 17,300 | 104,000 | 65,000 | 24 | 1,365 | 570 |
| Thin Stillage #7 | 3.4 | 6.24 | 5.62 | 30,800 | 30,550 | 117,300 | 61,750 | 15 | 1,165 | 730 |
| Thin Stillage #8 | 3.8 | 6.08 | 5.33 | 26,000 | 25,600 | 115,200 | 55,700 | 35 | 1,135 | 688 |

**Phase I**

Influent Feed Characterization

November 14, 2009 - January 29, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/11/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/12/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/13/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/14/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/15/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/16/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/17/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/18/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/19/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/20/09 | Blend #1 | Feed #1 | 5.0 | 107,100 | 50,100 | 7.74 | 7.01 | 27,000 | 26,000 | 1,670 | 185 | 1,058 | 545 |
| 12/21/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/22/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/23/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/24/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/25/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/26/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/27/09 | Blend #1 | Feed #2 | 5.5 | 117,200 | 60,150 | 5.77 | 5.01 | 25,400 | 25,000 | 1,550 | 222 | 1,208 | 427 |
| 12/28/09 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 12/29/09 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 12/30/09 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 12/31/09 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 1/1/10 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 1/2/10 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 1/3/10 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 1/4/10 | Blend #1 | Feed #3 | 5.5 | 107,900 | 56,100 | 5.70 | 4.94 | 28,600 | 28,600 | 1,690 | 208 | 1,380 | 447 |
| 1/5/10 | Blend #1 | Feed #4 | 5.3 | 111,400 | 57,550 | 5.60 | 4.86 | 27,400 | 27,200 | 1,210 | 269 | 1,160 | 465 |
| 1/6/10 | Blend #1 | Feed #4 | 5.3 | 111,400 | 57,550 | 5.60 | 4.86 | 27,400 | 27,200 | 1,210 | 269 | 1,160 | 465 |
| 1/7/10 | Blend #1 | Feed #4 | 5.3 | 111,400 | 57,550 | 5.60 | 4.86 | 27,400 | 27,200 | 1,210 | 269 | 1,160 | 465 |

**Phase I**

Influent Feed Characterization (Cont.)

November 14, 2009 - January 29, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/8/10 | Blend #1 | Feed #4 | 5.3 | 111,400 | 57,550 | 5.60 | 4.86 | 27,400 | 27,200 | 1,210 | 269 | 1,160 | 465 |
| 1/9/10 | Blend #1 | Feed #4 | 5.3 | 111,400 | 57,550 | 5.60 | 4.86 | 27,400 | 27,200 | 1,210 | 269 | 1,160 | 465 |
| 1/10/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/11/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/12/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/13/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/14/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/15/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/16/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/17/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/18/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/19/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/20/10 | Blend #1 | Feed #5 | 4.8 | 109,200 | 56,400 | 6.34 | 5.69 | 26,400 | 25,800 | 1,350 | 197 | 1,255 | 560 |
| 1/21/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/22/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/23/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/24/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/25/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/26/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/27/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| 1/28/10 | Blend #1 | Feed #6 | 5.2 | 91,100 | 53,650 | 6.51 | 5.78 | 30,200 | 29,600 | 2,110 | 210 | 1,345 | 555 |
| Average | | | 5.2 | 106,971 | 55,269 | 6.39 | 5.67 | 27,461 | 26,947 | 1,609 | 209 | 1,233 | 509 |
| Minimum | | | 4.8 | 91,100 | 50,100 | 5.60 | 4.86 | 25,400 | 25,000 | 1,210 | 185 | 1,058 | 427 |
| Maximum | | | 5.5 | 117,200 | 60,150 | 7.74 | 7.01 | 30,200 | 29,600 | 2,110 | 269 | 1,380 | 560 |

Phase I

Digester 1 Operations Data

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/14/09 | | | | | | | | | | | | | | | | | | | | |
| 11/15/09 | | | | | | | | | | | | | | | | | | | | |
| 11/16/09 | 7.1 | | 0.100 | | | | | | | | | | | | | | | | | |
| 11/17/09 | 7.1 | 34.0 | 0.100 | | | | | | | | | | | | | | | | | |
| 11/18/09 | 7.1 | | | | 1,790 | | | 21,000 | 19,800 | | 501 | | 69 | | | | | | | |
| 11/19/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/20/09 | 7.0 | | | | | | | | | | | | | | | | | | | |
| 11/21/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/22/09 | 7.2 | 38.5 | | | | | | | | | | | | 455 | 2,495 | 2,950 | | | | |
| 11/23/09 | 7.2 | 38.0 | 0.100 | | 2,500 | | | 32,200 | 29,800 | | 372 | | 72 | 370 | 2,650 | 3,020 | 0.250 | | | |
| 11/24/09 | 7.3 | 37.0 | 0.200 | | | | | | | | | | | 650 | 2,613 | 3,263 | 0.080 | | | |
| 11/25/09 | 7.1 | 36.0 | 0.200 | | 4,000 | 4.10 | | 34,000 | 31,400 | | 413 | | 39 | 413 | 2,725 | 3,138 | 0.130 | | | |
| 11/26/09 | 7.2 | | 0.220 | | | | | | | | | | | | | | | | | |
| 11/27/09 | 7.2 | 36.0 | 0.200 | | | | | | | | | | | | | | | | | |
| 11/28/09 | 7.2 | 36.5 | 0.200 | | | | | | | | | | | 400 | 3,375 | 3,775 | 0.080 | | | |
| 11/29/09 | 7.2 | | 0.200 | | | | | | | | | | | | | | | | | |
| 11/30/09 | 7.2 | 36.5 | 0.300 | | 2,600 | 3.87 | | 35,800 | 32,800 | | 474 | | 60 | 463 | 3,913 | 4,375 | 0.130 | | | |
| 12/1/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 413 | 3,950 | 4,363 | 0.080 | | | |
| 12/2/09 | 7.2 | 36.5 | 0.300 | | 3,825 | 3.50 | | 31,000 | 27,600 | | 753 | | 89 | 588 | 4,250 | 4,838 | 0.100 | | | |
| 12/3/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 640 | 3,960 | 4,600 | 0.050 | | | |
| 12/4/09 | 7.3 | 36.5 | 0.350 | | 2,320 | 3.48 | | 29,800 | 26,600 | | 630 | | 80 | 560 | 4,300 | 4,860 | 0.070 | | | |
| 12/5/09 | 7.3 | 37.0 | 0.300 | | | | | | | | | | | | | | | | | |
| 12/6/09 | 7.3 | 37.0 | 0.300 | | | | | | | | | | | 800 | 4,180 | 4,980 | 0.050 | | | |
| 12/7/09 | 7.3 | 36.5 | 0.100 | | 3,113 | 3.30 | | 34,600 | 30,800 | | 731 | | 121 | 960 | 4,000 | 4,960 | 0.050 | | | |
| 12/8/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 840 | 4,560 | 5,400 | 0.050 | | | |
| 12/9/09 | 7.2 | 36.0 | 0.300 | | 2,500 | 3.16 | 2.54 | 25,600 | 23,400 | | 700 | | 154 | 800 | 4,740 | 5,540 | 0.020 | | | |
| 12/10/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 680 | 4,940 | 5,620 | 0.050 | | | |
| 12/11/09 | 7.2 | 36.5 | | 21,800 | 2,025 | 3.38 | 2.73 | 26,600 | 23,000 | | 723 | | 107 | 980 | 4,600 | 5,580 | 0.050 | | | |
| 12/12/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 1,275 | 4,425 | 5,700 | 0.080 | | | |
| 12/13/09 | 7.3 | 36.0 | 0.350 | | | | | | | | | | | 1,000 | 4,975 | 5,975 | 0.080 | | | |
| 12/14/09 | 7.2 | 36.0 | 0.400 | 29,700 | 2,525 | 2.77 | 2.16 | 27,000 | 23,200 | | 725 | | 162 | 963 | 5,238 | 6,200 | 0.100 | | | |
| 12/15/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,113 | 5,113 | 6,225 | 0.080 | | | |
| 12/16/09 | 7.2 | 35.0 | 0.350 | 45,900 | 3,150 | 2.92 | 2.24 | 25,400 | 21,800 | | 653 | | 158 | 1,175 | 5,238 | 6,413 | 0.100 | | | |
| 12/17/09 | 7.2 | 35.5 | 0.375 | | | | | | | | | | | 1,075 | 5,375 | 6,540 | 0.080 | | | |
| 12/18/09 | 7.2 | 35.5 | 0.410 | 39,800 | 4,100 | 3.01 | 2.32 | 25,800 | 22,800 | | 828 | 440 | 173 | 1,163 | 5,325 | 6,488 | 0.130 | | | |
| 12/19/09 | 7.2 | 35.5 | 0.475 | | | | | | | | | | | 1,138 | 5,575 | 6,713 | 0.080 | | | |
| 12/20/09 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | 1,175 | 5,575 | 6,750 | 0.080 | | | |

Phase I

Digester 1 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/21/09 | 7.2 | 35.0 | 0.400 | 23,300 | 4,075 | 2.95 | 2.23 | 24,400 | 19,800 | | 643 | | 157 | 1,213 | 5,525 | 6,738 | 0.100 | | | |
| 12/22/09 | 7.2 | 35.5 | 0.450 | | | | | | | | | | | 1,300 | 5,588 | 6,888 | 0.080 | | | |
| 12/23/09 | 7.2 | 36.0 | 0.425 | 31,700 | 3,050 | 2.84 | 2.14 | 24,200 | 21,200 | | 783 | 625 | 200 | 1,213 | 5,425 | 6,638 | 0.480 | | | |
| 12/24/09 | 7.2 | 35.5 | 0.450 | | | | | | | | | | | 1,313 | 5,513 | 6,825 | 0.380 | | | |
| 12/25/09 | | | 0.525 | | | | | | | | | | | | | | 0.525 | | | |
| 12/26/09 | | | 0.450 | | | | | | | | | | | | | | 0.450 | | | |
| 12/27/09 | | | 0.375 | | | | | | | | | | | | | | 0.375 | | | |
| 12/28/09 | 7.3 | 35.0 | 0.400 | | | | | | | | | | | 1,150 | 5,813 | 6,963 | 0.480 | | | |
| 12/29/09 | 7.2 | 35.5 | 0.450 | 35,800 | 3,550 | 2.74 | 2.07 | 23,600 | 20,600 | 1,905 | 753 | 565 | 212 | 1,225 | 5,350 | 6,575 | 0.330 | 26.4 | | |
| 12/30/09 | 7.2 | 35.0 | 0.500 | 31,100 | 3,300 | 2.80 | 2.06 | 22,600 | 20,000 | | 878 | 640 | 200 | 1,150 | 5,650 | 6,800 | 0.360 | | 32.0% | 1,200 |
| 12/31/09 | 7.2 | 35.5 | 0.500 | 31,700 | 2,950 | 2.72 | 2.02 | 21,400 | 19,000 | | 943 | 480 | 202 | 1,475 | 5,088 | 6,563 | 0.380 | | 34.0% | 1,600 |
| 1/1/10 | 7.2 | 35.0 | 0.500 | 31,300 | 3,100 | 2.72 | 2.03 | 21,400 | 19,000 | 1,368 | 905 | 435 | 208 | | | | 0.300 | | 34.0% | 1,900 |
| 1/2/10 | 7.2 | 34.5 | 0.500 | 31,500 | 2,875 | 2.78 | 1.97 | 20,400 | 18,000 | 1,680 | 915 | 475 | 210 | 1,362 | 5,388 | 6,750 | 0.380 | | 36.0% | 1,400 |
| 1/3/10 | 7.2 | 34.5 | 0.500 | 28,400 | 2,950 | 2.65 | 1.96 | 19,400 | 17,800 | 1,756 | 960 | 675 | 208 | 1,237 | 5,463 | 6,700 | 0.360 | 18.7 | 34.0% | |
| 1/4/10 | 7.3 | 34.5 | 0.500 | 21,900 | 2,950 | 2.66 | 1.97 | 20,000 | 17,800 | 2,120 | 930 | 450 | 200 | 1,412 | 5,463 | 6,875 | 0.380 | | 32.0% | 1,200 |
| 1/5/10 | 7.2 | 35.0 | 0.500 | 31,100 | 2,302 | 2.59 | 1.90 | 21,000 | 18,000 | 1,910 | 918 | 565 | 204 | 1,162 | 5,038 | 6,200 | 0.380 | 18.7 | 34.0% | |
| 1/6/10 | 7.2 | 35.0 | 0.150 | 30,800 | 2,900 | 2.55 | 1.85 | 20,000 | 17,000 | 1,680 | 990 | 575 | 218 | 1,200 | 5,900 | 7,100 | 0.180 | | 32.0% | |
| 1/7/10 | 7.2 | 35.0 | 0.100 | 27,600 | 2,700 | 2.56 | 1.88 | 19,400 | 16,800 | | 968 | 630 | 232 | 1,213 | 5,725 | 6,938 | 0.130 | | 24.0% | |
| 1/8/10 | 7.2 | 34.0 | 0.500 | 32,300 | 3,350 | 2.66 | 1.98 | 20,400 | 17,200 | 1,940 | 943 | 535 | 214 | 1,500 | 5,475 | 6,975 | 0.280 | | | |
| 1/9/10 | 7.3 | 34.5 | 0.350 | | | | | | | | | | | 1,537 | 5,538 | 7,075 | 0.180 | | | |
| 1/10/10 | 7.2 | 34.5 | 0.050 | | | | | | | | | | | 1,463 | 5,500 | 6,963 | 0.080 | | | |
| 1/11/10 | 7.3 | 35.0 | 0.500 | 43,300 | 3,250 | 2.67 | 1.90 | 20,000 | 16,600 | | 1,000 | 595 | 232 | 1,737 | 4,988 | 6,725 | 0.380 | | | |
| 1/12/10 | 7.2 | 35.0 | 0.500 | | | | | | | | | | | | | | 0.580 | | | |
| 1/13/10 | 7.2 | 35.0 | 0.500 | 26,500 | 2,800 | 2.62 | 1.85 | 20,000 | 17,000 | | 970 | 835 | 230 | 1,562 | 5,413 | 6,975 | 0.280 | | | |
| 1/14/10 | 7.2 | 34.0 | 0.400 | | | | | | | | | | | | | | 0.200 | | 36.0% | 1,300 |
| 1/15/10 | 7.2 | 35.0 | 0.500 | 26,200 | 3,350 | 2.43 | 1.71 | 16,500 | 14,500 | | 995 | 553 | 252 | 1,550 | 5,213 | 6,763 | 0.380 | | | |
| 1/16/10 | 7.4 | 34.0 | 0.450 | | | | | | | | | | | | | | 0.350 | | | |
| 1/17/10 | 7.3 | 34.0 | 0.450 | | | | | | | | | | | | | | 0.500 | | | |
| 1/18/10 | 7.4 | 33.5 | 0.350 | 25,800 | 3,200 | 2.87 | 1.93 | 22,600 | 18,600 | 2,380 | 1,010 | 685 | 232 | 1,725 | 5,363 | 7,088 | 0.330 | | | |
| 1/19/10 | 7.3 | 35.5 | 0.500 | 23,100 | 2,700 | 3.00 | 2.02 | 21,800 | 17,200 | | 1,010 | 935 | 248 | 2,050 | 5,838 | 7,888 | 0.430 | | | |
| 1/20/10 | 7.3 | 34.0 | 0.500 | 28,200 | 3,300 | 2.87 | 1.96 | 19,600 | 16,200 | | 1,053 | 1,423 | 256 | 1,900 | 5,788 | 7,688 | 0.380 | | | |
| 1/21/10 | 7.4 | 35.5 | 0.500 | 25,800 | 2,675 | 2.74 | 1.86 | 19,200 | 16,200 | | 1,088 | 775 | 248 | 1,837 | 5,838 | 7,675 | 0.430 | | 32.0% | 1,000 |
| 1/22/10 | 7.4 | 35.5 | 0.400 | 23,000 | 2,575 | 2.70 | 1.79 | 20,200 | 16,000 | | 1,025 | 1,060 | 240 | 1,775 | 5,725 | 7,500 | 0.430 | | 34.0% | 800 |
| 1/23/10 | 7.4 | 35.5 | 0.100 | | | | | | | | | | | | | | 0.050 | | | |
| 1/24/10 | 7.4 | 35.5 | 0.200 | | | | | | | | | | | | | | 0.175 | | | |
| 1/25/10 | 7.4 | 35.5 | 0.100 | 21,500 | 2,650 | 2.51 | 1.65 | 18,800 | 15,200 | | 1,230 | 493 | 250 | 1,375 | 6,763 | 8,138 | 0.130 | | | |
| 1/26/10 | 7.5 | 34.5 | 0.500 | 24,000 | 3,375 | 2.42 | 1.67 | 17,000 | 15,000 | 1,688 | 1,235 | 735 | 252 | 2,037 | 6,138 | 8,175 | 0.330 | | 36.0% | 1,800 |
| 1/27/10 | 7.4 | 35.0 | 0.500 | 20,600 | 3,350 | 2.71 | 1.77 | 19,400 | 15,000 | | 1,240 | 550 | 256 | 2,137 | 6,063 | 8,200 | 0.380 | | 36.0% | 1,700 |

Phase I
Digester 1 Operations Data (cont.)
November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/28/10 | 7.4 | 35.5 | 0.500 | 27,600 | 3,700 | 2.60 | 1.75 | 17,200 | 14,400 | 1,870 | 1,240 | 850 | 256 | 1,950 | 6,213 | 8,163 | 0.380 | | | |
| 1/29/10 | 7.4 | 35.0 | 0.500 | | | | | | | | | | | 1,712 | 6,188 | 7,900 | 0.380 | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.2 | 35.5 | 0.357 | 29,010 | 3,011 | 2.88 | 2.00 | 23,224 | 20,192 | 1,845 | 868 | 663 | 187 | 1,192 | 5,038 | 6,231 | 0.236 | 21.27 | 33.3% | 1,390 |
| Minimum | 7.0 | 33.5 | 0.050 | 20,600 | 1,790 | 2.42 | 1.65 | 16,500 | 14,400 | 1,368 | 372 | 435 | 39 | 370 | 2,495 | 2,950 | 0.020 | 18.70 | 24.0% | 800 |
| Maximum | 7.5 | 38.5 | 0.525 | 45,900 | 4,100 | 4.10 | 2.73 | 35,800 | 32,800 | 2,380 | 1,240 | 1,423 | 256 | 2,137 | 6,763 | 8,200 | 0.580 | 26.40 | 36.0% | 1,900 |

**Phase I**

Digester 2 Operations Data

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/14/09 | | | | | | | | | | | | | | | | | | | | |
| 11/15/09 | | | | | | | | | | | | | | | | | | | | |
| 11/16/09 | 7.1 | | 0.100 | | | | | | | | | | | | | | | | | |
| 11/17/09 | 7.0 | 34.0 | 0.100 | | | | | | | | | | | | | | | | | |
| 11/18/09 | 7.1 | | | | 1,320 | | | 9,600 | 8,800 | | 472 | | 69 | | | | | | | |
| 11/19/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/20/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/21/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/22/09 | 7.2 | 38.5 | | | | | | | | | | | | 235 | 2,645 | 2,880 | | | | |
| 11/23/09 | 7.3 | 38.5 | 0.100 | | 1,920 | | | 20,800 | 19,200 | | 288 | | 56 | 475 | 2,450 | 2,925 | 0.250 | | | |
| 11/24/09 | 7.3 | 37.5 | 0.200 | | | | | | | | | | | 500 | 2,513 | 3,013 | 0.080 | | | |
| 11/25/09 | 7.2 | 36.0 | 0.200 | | 1,600 | 3.6 | | 28,000 | 25,800 | | 331 | | 35 | 475 | 2,613 | 3,088 | 0.130 | | | |
| 11/26/09 | 7.2 | | 0.220 | | | | | | | | | | | | | | | | | |
| 11/27/09 | 7.2 | 36.0 | 0.200 | | | | | | | | | | | | | | | | | |
| 11/28/09 | 7.2 | 36.5 | 0.200 | | | | | | | | | | | 400 | 3,400 | 3,800 | 0.080 | | | |
| 11/29/09 | 7.2 | | 0.200 | | | | | | | | | | | | | | | | | |
| 11/30/09 | 7.2 | 36.5 | 0.300 | | 2,000 | 3.3 | | 31,200 | 28,200 | | | | 51 | 463 | 3,625 | 4,088 | 0.130 | | | |
| 12/1/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 413 | 3,950 | 4,363 | 0.080 | | | |
| 12/2/09 | 7.2 | 36.5 | 0.300 | | 2,350 | 3.3 | | 30,800 | 27,200 | | 480 | | 63 | 600 | 4,175 | 4,775 | 0.100 | | | |
| 12/3/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 740 | 3,760 | 4,500 | 0.050 | | | |
| 12/4/09 | 7.3 | 36.5 | 0.350 | | 2,950 | 3.5 | | 28,400 | 25,600 | | 583 | | | 680 | 4,320 | 5,000 | 0.070 | | | |
| 12/5/09 | 7.3 | 36.5 | 0.300 | | | | | | | | | | | | | | | | | |
| 12/6/09 | 7.3 | 36.5 | 0.300 | | | | | | | | | | | 820 | 4,100 | 4,920 | 0.050 | | | |
| 12/7/09 | 7.3 | 36.5 | 0.100 | | 2,125 | 3.3 | | 28,600 | 26,200 | | 601 | | 106 | 1,020 | 4,220 | 5,240 | 0.070 | | | |
| 12/8/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 780 | 4,720 | 5,500 | 0.050 | | | |
| 12/9/09 | 7.2 | 36.5 | 0.300 | | 2,763 | 3.3 | 2.6 | 28,800 | 25,800 | | 798 | | 147 | 900 | 4,620 | 5,520 | 0.070 | | | |
| 12/10/09 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 780 | 4,860 | 5,640 | 0.050 | | | |
| 12/11/09 | 7.2 | 36.5 | | 25,400 | 2,100 | 3.2 | 2.6 | 25,800 | 22,800 | | 705 | | 125 | 1,060 | 4,520 | 5,580 | 0.050 | | | |
| 12/12/09 | 7.2 | 35.5 | 0.300 | | | | | | | | | | | 1,262 | 4,250 | 5,512 | 0.080 | | | |
| 12/13/09 | 7.3 | 35.5 | 0.350 | | | | | | | | | | | 1,025 | 4,838 | 5,863 | 0.080 | | | |
| 12/14/09 | 7.2 | 35.5 | 0.400 | 27,400 | 2,350 | 2.7 | 2.1 | 23,800 | 20,800 | | 658 | | 125 | 975 | 5,025 | 6,000 | 0.100 | | | |
| 12/15/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,113 | 5,050 | 6,163 | 0.080 | | | |
| 12/16/09 | 7.2 | 35.0 | 0.350 | 35,900 | 2,725 | 2.9 | 2.2 | 26,600 | 22,800 | | 595 | | 157 | 1,038 | 5,300 | 6,338 | 0.100 | | | |
| 12/17/09 | 7.2 | 35.0 | 0.375 | | | | | | | | | | | 900 | 5,350 | 6,250 | 0.080 | | | |
| 12/18/09 | 7.2 | 35.0 | 0.410 | 28,200 | 3,450 | 3.0 | 2.3 | 24,600 | 21,200 | | 665 | 290 | 168 | 1,213 | 5,138 | 6,350 | 0.130 | | | |
| 12/19/09 | 7.2 | 35.0 | 0.475 | | | | | | | | | | | 1,063 | 5,475 | 6,538 | 0.080 | | | |
| 12/20/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,063 | 5,475 | 6,538 | 0.280 | | | |

**Phase I**

Digester 2 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/22/09 | 7.2 | 35.0 | 0.450 | | | | | | | | | | | 1,150 | 5,538 | 6,625 | 0.330 | | | |
| 12/23/09 | 7.2 | 35.5 | 0.425 | 25,900 | 2,575 | 2.7 | 2.1 | 22,400 | 20,000 | | 768 | 490 | 196 | 1,050 | 5,013 | 6,063 | 0.480 | | | |
| 12/24/09 | 7.2 | 35.0 | 0.450 | | | | | | | | | | | 1,213 | 5,400 | 6,613 | 0.430 | | | |
| 12/25/09 | | | 0.525 | | | | | | | | | | | | | | 0.525 | | | |
| 12/26/09 | | | 0.450 | | | | | | | | | | | | | | 0.450 | | | |
| 12/27/09 | | | 0.375 | | | | | | | | | | | | | | 0.375 | | | |
| 12/28/09 | 7.3 | 34.5 | 0.400 | | | | | | | | | | | 1,100 | 5,563 | 6,663 | 0.480 | | | |
| 12/29/09 | 7.3 | 35.0 | 0.450 | 28,900 | 3,325 | 2.5 | 1.8 | 19,400 | 18,000 | 2,060 | 788 | 400 | 206 | 1,263 | 5,213 | 6,475 | 0.330 | | | |
| 12/30/09 | 7.3 | 35.0 | 0.500 | 26,000 | 2,950 | 2.4 | 1.8 | 18,200 | 17,000 | | 905 | 460 | 202 | 1,213 | 5,525 | 6,738 | 0.360 | | 34.0% | 2,400 |
| 12/31/09 | 7.3 | 35.0 | 0.500 | 24,400 | 2,675 | 2.2 | 1.6 | 17,200 | 15,400 | | 938 | 340 | 186 | 1,275 | 5,200 | 6,475 | 0.360 | | 36.0% | 2,100 |
| 1/1/10 | 7.3 | 34.5 | 0.500 | 23,200 | 2,875 | 2.4 | 1.7 | 18,200 | 16,200 | 1,925 | 888 | 430 | 210 | | | | 0.300 | | 34.0% | 2,000 |
| 1/2/10 | 7.3 | 34.0 | 0.500 | 16,200 | 2,925 | 2.1 | 1.5 | 14,400 | 13,000 | 2,525 | 958 | 355 | 194 | 1,250 | 5,400 | 6,650 | 0.380 | | 36.0% | 1,600 |
| 1/3/10 | 7.3 | 34.0 | 0.500 | 24,200 | 2,750 | 2.0 | 1.5 | 14,000 | 12,000 | 2,040 | 965 | 470 | 210 | 942 | 5,283 | 6,225 | 0.360 | | 34.0% | |
| 1/4/10 | 7.3 | 34.5 | 0.500 | 23,300 | 2,800 | 2.4 | 1.8 | 16,000 | 14,200 | 1,790 | 993 | 385 | 206 | 1,113 | 5,125 | 6,238 | 0.380 | | 34.0% | 1,400 |
| 1/5/10 | 7.2 | 34.5 | 0.500 | 25,200 | 2,700 | 2.4 | 1.8 | 18,600 | 16,000 | 1,910 | 965 | 585 | 162 | 1,312 | 5,363 | 6,675 | 0.380 | | 36.0% | |
| 1/6/10 | 7.3 | 34.0 | 0.450 | 27,200 | 2,650 | 2.6 | 1.9 | 18,400 | 16,200 | 1,680 | 940 | 445 | 210 | 1,000 | 5,300 | 6,300 | 0.380 | | 32.0% | |
| 1/7/10 | 7.3 | 34.0 | 0.350 | 25,000 | 2,600 | 2.5 | 1.8 | 18,200 | 15,400 | | 960 | 475 | 234 | 1,050 | 5,638 | 6,688 | 0.130 | | 32.0% | |
| 1/8/10 | 7.2 | 33.5 | 0.500 | 25,600 | 3,325 | 2.5 | 1.8 | 19,200 | 16,600 | 2,500 | 980 | 444 | 208 | 1,250 | 5,275 | 6,525 | 0.530 | 25.0 | | |
| 1/9/10 | 7.3 | 33.5 | 0.500 | | | | | | | | | | | 1,288 | 5,200 | 6,488 | 0.280 | 26.7 | | |
| 1/10/10 | 7.3 | 34.0 | 0.400 | | | | | | | | | | | 1,213 | 5,300 | 6,513 | 0.380 | | | |
| 1/11/10 | 7.3 | 34.0 | 0.250 | 39,700 | 2,500 | 2.5 | 1.8 | 19,200 | 16,800 | | 978 | 430 | 220 | 1,388 | 5,175 | 6,563 | 0.130 | | | |
| 1/12/10 | 7.2 | 34.5 | 0.550 | | | | | | | | | | | | | | 0.430 | | | |
| 1/13/10 | 7.2 | 34.0 | 0.350 | 24,500 | 2,575 | 2.6 | 1.8 | 18,750 | 16,250 | | 1,038 | 745 | 238 | 1,413 | 5,350 | 6,763 | 0.230 | | | |
| 1/14/10 | 7.2 | 35.0 | 0.100 | | | | | | | | | | | | | | | | | |
| 1/15/10 | 7.2 | 35.0 | 0.500 | 23,800 | 2,700 | 2.6 | 1.9 | 17,750 | 16,000 | | 1,033 | 425 | 236 | 1,475 | 5,388 | 6,863 | 0.380 | 22.3 | | |
| 1/16/10 | 7.5 | 35.0 | 0.400 | | | | | | | | | | | | | | 0.300 | | | |
| 1/17/10 | 7.4 | 34.5 | 0.500 | | | | | | | | | | | | | | 0.500 | | | |
| 1/18/10 | 7.4 | 34.5 | 0.500 | 22,400 | 2,500 | 2.9 | 2.0 | 21,400 | 17,600 | 2,280 | 1,023 | 423 | 236 | 1,375 | 5,338 | 6,713 | 0.380 | | | |
| 1/19/10 | 7.3 | 35.0 | 0.500 | 21,600 | 2,300 | 2.9 | 2.0 | 22,200 | 18,400 | | 1,013 | 630 | 248 | 1,475 | 5,688 | 7,163 | 0.430 | | | |
| 1/20/10 | 7.4 | 35.0 | 0.500 | 19,900 | 2,525 | 2.8 | 1.9 | 19,800 | 17,200 | | 1,060 | 413 | 260 | 1,250 | 5,800 | 7,050 | 0.380 | | | |
| 1/21/10 | 7.4 | 35.0 | 0.500 | 15,900 | 2,525 | 2.7 | 1.9 | 18,800 | 15,800 | | 1,100 | 710 | 254 | 1,475 | 5,525 | 7,000 | 0.430 | | 34.0% | 1,100 |
| 1/22/10 | 7.4 | 35.0 | 0.350 | 23,300 | 2,425 | 2.6 | 1.8 | 18,600 | 15,600 | | 1,120 | 823 | 250 | 1,338 | 5,675 | 7,013 | 0.380 | | 34.0% | 1,000 |
| 1/23/10 | 7.4 | 35.5 | 0.250 | | | | | | | | | | | | | | 0.050 | | | |
| 1/24/10 | 7.4 | 35.5 | 0.500 | | | | | | | | | | | | | | 0.400 | | | |
| 1/25/10 | 7.4 | 35.0 | 0.500 | 21,600 | 2,875 | 2.6 | 1.7 | 18,800 | 15,000 | | 1,175 | 408 | 250 | 1,400 | 6,488 | 7,888 | 0.430 | | | |
| 1/26/10 | 7.5 | 34.5 | 0.050 | 17,700 | 3,075 | 2.6 | 1.7 | 19,800 | 16,200 | 1,132 | 1,230 | 643 | 256 | 6,163 | 6,163 | 7,638 | 0.130 | | 28.0% | 1,100 |
| 1/27/10 | 7.5 | 35.0 | 0.100 | 17,500 | 2,625 | 2.5 | 1.6 | 16,800 | 13,600 | | 1,310 | 653 | 260 | 1,500 | 6,250 | 7,750 | 0.130 | | | |

**Phase I**

Digester 2 Operations Data (Cont.)
November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/28/10 | 7.4 | 35.5 | 0.500 | 23,300 | 3,400 | 2.5 | 1.7 | 16,400 | 14,200 | 1,752 | 1,290 | 540 | 256 | 1,925 | 6,200 | 8,125 | 0.180 | | | |
| 1/29/10 | 7.4 | 35.0 | 0.500 | | | | | | | | | | | 1,662 | 6,038 | 7,700 | 0.380 | 22.2 | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.3 | 35.3 | 0.364 | 24,400 | 2,606 | 2.7 | 1.9 | 20,819 | 18,251 | 1,963 | 874 | 496 | 185 | 1,158 | 4,941 | 6,011 | 0.252 | 24.05 | 33.7% | 1,588 |
| Minimum | 7.0 | 33.5 | 0.050 | 15,900 | 1,320 | 2.0 | 1.5 | 9,600 | 8,800 | 1,132 | 288 | 290 | 35 | 235 | 2,450 | 2,880 | 0.050 | 22.20 | 28.0% | 1,000 |
| Maximum | 7.5 | 38.5 | 0.550 | 39,700 | 3,450 | 3.6 | 2.6 | 31,200 | 28,200 | 2,525 | 1,310 | 823 | 260 | 6,163 | 6,488 | 8,125 | 0.530 | 26.70 | 36.0% | 2,400 |

**Phase I**

Digester 3 Operations Data

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/14/09 | | | | | | | | | | | | | | | | | | | | |
| 11/15/09 | | | | | | | | | | | | | | | | | | | | |
| 11/16/09 | 7.1 | | 0.100 | | | | | | | | | | | | | | | | | |
| 11/17/09 | 7.0 | 33.0 | 0.100 | | | | | | | | | | | | | | | | | |
| 11/18/09 | 7.1 | | | | 1,940 | | | 21,200 | 20,000 | | 480 | | 71 | | | | | | | |
| 11/19/09 | 7.0 | | | | | | | | | | | | | | | | | | | |
| 11/20/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/21/09 | 7.0 | | | | | | | | | | | | | | | | | | | |
| 11/22/09 | 7.1 | 37.5 | | | | | | | | | | | | 615 | 2,295 | 2,910 | | | | |
| 11/23/09 | 7.2 | 38.0 | 0.100 | | 2,020 | | | 30,600 | 28,400 | | 245 | | 68 | 590 | 2,365 | 2,955 | 0.250 | | | |
| 11/24/09 | 7.2 | 37.0 | 0.200 | | | | | | | | | | | 700 | 2,388 | 3,088 | 0.080 | | | |
| 11/25/09 | 7.1 | 36.0 | 0.200 | | 3,500 | 3.8 | | 35,400 | 32,600 | | 368 | | 35 | 463 | 2,675 | 3,138 | 0.130 | | | |
| 11/26/09 | 7.2 | | 0.220 | | | | | | | | | | | | | | | | | |
| 11/27/09 | 7.2 | 35.0 | 0.200 | | | | | | | | | | | | | | | | | |
| 11/28/09 | 7.2 | 35.0 | 0.200 | | | | | | | | | | | 400 | 3,313 | 3,713 | 0.080 | | | |
| 11/29/09 | 7.2 | | 0.200 | | | | | | | | | | | | | | | | | |
| 11/30/09 | 7.2 | 36.0 | 0.300 | | 3,100 | 3.5 | | 31,600 | 29,000 | | 356 | | 49 | 450 | 3,725 | 4,175 | 0.130 | | | |
| 12/1/09 | 7.2 | 35.5 | 0.300 | | | | | | | | | | | 463 | 3,763 | 4,225 | 0.080 | | | |
| 12/2/09 | 7.2 | 34.0 | 0.300 | | 2,325 | 3.4 | | 32,800 | 29,600 | | 488 | | 64 | 600 | 3,463 | 4,963 | 0.100 | | | |
| 12/3/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 720 | 3,840 | 4,560 | 0.050 | | | |
| 12/4/09 | 7.3 | 36.0 | 0.350 | | 2,750 | 3.5 | | 31,600 | 28,400 | | 685 | | 88 | 580 | 4,360 | 4,940 | 0.070 | | | |
| 12/5/09 | 7.3 | 35.5 | 0.300 | | | | | | | | | | | | | | | | | |
| 12/6/09 | 7.3 | 35.5 | 0.300 | | | | | | | | | | | 840 | 4,220 | 5,060 | 0.050 | | | |
| 12/7/09 | 7.3 | 35.5 | 0.100 | | 2,500 | 3.5 | | 31,000 | 28,400 | | 566 | | 97 | 960 | 4,160 | 5,120 | 0.070 | | | |
| 12/8/09 | 7.2 | 35.0 | 0.300 | | | | | | | | | | | 840 | 4,660 | 5,500 | 0.050 | | | |
| 12/9/09 | 7.2 | 35.0 | 0.300 | | 3,163 | 3.3 | 2.6 | 29,000 | 26,000 | | 730 | | 155 | 820 | 4,700 | 5,520 | 0.070 | | | |
| 12/10/09 | 7.2 | 35.0 | 0.300 | | | | | | | | | | | 780 | 5,120 | 5,900 | 0.050 | | | |
| 12/11/09 | 7.2 | 35.0 | | 30,000 | 2,175 | 3.4 | 2.7 | 27,400 | 23,800 | | 783 | | 108 | 700 | 5,140 | 5,840 | 0.050 | | | |
| 12/12/09 | 7.2 | 35.0 | 0.350 | | | | | | | | | | | 1,275 | 4,288 | 5,563 | 0.080 | | | |
| 12/13/09 | 7.3 | 35.0 | 0.250 | | | | | | | | | | | 1,000 | 4,963 | 5,963 | 0.080 | | | |
| 12/14/09 | 7.2 | 35.0 | 0.400 | 43,500 | 1,975 | 2.9 | 2.3 | 26,400 | 23,000 | | 708 | | 137 | 975 | 5,100 | 6,075 | 0.100 | | | |
| 12/15/09 | 7.2 | 34.5 | 0.400 | | | | | | | | | | | 1,013 | 5,125 | 6,138 | 0.080 | | | |
| 12/16/09 | 7.2 | 34.5 | 0.375 | 44,900 | 3,025 | 3.0 | 2.3 | 25,800 | 22,200 | | 523 | | 155 | 1,000 | 5,163 | 6,163 | 0.100 | | | |
| 12/17/09 | 7.2 | 34.5 | 0.375 | | | | | | | | | | | 1,013 | 5,175 | 6,188 | 0.080 | | | |
| 12/18/09 | 7.2 | 35.0 | 0.410 | 31,800 | 3,600 | 3.0 | 2.3 | 27,200 | 23,800 | | 778 | 470 | 164 | 1,200 | 5,150 | 6,350 | 0.130 | | | |
| 12/19/09 | 7.2 | 35.0 | 0.350 | | | | | | | | | | | 1,150 | 5,413 | 6,563 | 0.080 | | | |
| 12/20/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,100 | 5,600 | 6,700 | 0.080 | | | |

**Phase I**

Digester 3 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/21/09 | 7.2 | 34.5 | 0.400 | 36800 | 3975 | 2.9 | 2.2 | 24,800 | 21,200 | | 665 | | 150 | 1,175 | 5,325 | 6,500 | 0.100 | | | |
| 12/22/09 | 7.2 | 35.0 | 0.250 | | | | | | | | | | | 1,450 | 5,138 | 6,588 | 0.130 | | | |
| 12/23/09 | 7.2 | 35.0 | 0.425 | 32,000 | 2,800 | 2.7 | 2.1 | 23,200 | 20,800 | | 738 | 545 | 192 | 1,088 | 5,150 | 6,238 | 0.430 | | | |
| 12/24/09 | 7.2 | 35.0 | 0.450 | | | | | | | | | | | 1,163 | 5,288 | 6,450 | 0.330 | | | |
| 12/25/09 | | | 0.500 | | | | | | | | | | | | | | 0.500 | | | |
| 12/26/09 | | | 0.450 | | | | | | | | | | | | | | 0.450 | | | |
| 12/27/09 | | | 0.375 | | | | | | | | | | | | | | 0.375 | | | |
| 12/28/09 | 7.3 | 34.0 | 0.400 | | | | | | | | | | | 1,163 | 5,550 | 6,713 | 0.480 | | | |
| 12/29/09 | 7.3 | 35.0 | 0.400 | 35,500 | 3,300 | 2.6 | 2.0 | 20,400 | 18,600 | 2,200 | 720 | 570 | 196 | 1,275 | 5,050 | 6,325 | 0.230 | | | |
| 12/30/09 | 7.2 | 34.5 | 0.400 | 34,000 | 2,925 | 2.7 | 2.0 | 20,800 | 18,400 | | 898 | 560 | 194 | 1,375 | 5,363 | 6,738 | 0.280 | | 34.0% | 2,200 |
| 12/31/09 | 7.3 | 34.5 | 0.400 | 28,700 | 2,675 | 2.6 | 1.9 | 19,800 | 18,000 | | 920 | 440 | 180 | 1,137 | 5,113 | 6,250 | 0.330 | | 36.0% | 1,800 |
| 1/1/10 | 7.3 | 34.0 | 0.400 | 28,400 | 2,875 | 2.6 | 2.0 | 20,000 | 18,400 | 1,940 | 870 | 400 | 196 | | | | 0.250 | | 34.0% | 2,000 |
| 1/2/10 | 7.3 | 34.0 | 0.400 | 28,300 | 2,850 | 2.6 | 1.9 | 20,200 | 17,800 | 2,750 | 953 | 435 | 202 | 1,275 | 5,125 | 6,400 | 0.330 | | 34.0% | 1,800 |
| 1/3/10 | 7.3 | 34.0 | 0.400 | 28,400 | 2,725 | 2.6 | 1.9 | 18,800 | 16,800 | 2,060 | 973 | 610 | 188 | 1,088 | 5,275 | 6,363 | 0.330 | | 34.0% | |
| 1/4/10 | 7.3 | 34.0 | 0.400 | 29,000 | 2,975 | 2.5 | 1.9 | 18,800 | 16,600 | 1,902 | 988 | 615 | 192 | 1,237 | 5,438 | 6,675 | 0.330 | | 32.0% | 1,200 |
| 1/5/10 | 7.3 | 34.0 | 0.400 | 28,100 | 2,875 | 2.5 | 1.9 | 19,200 | 16,400 | 1,876 | 948 | 630 | 190 | 1,262 | 5,213 | 6,475 | 0.330 | | 34.0% | |
| 1/6/10 | 7.3 | 34.0 | 0.400 | 33,100 | 2,950 | 2.5 | 1.9 | 18,600 | 16,800 | 1,772 | 923 | 630 | 204 | 1,175 | 5,325 | 6,500 | 0.330 | | 34.0% | |
| 1/7/10 | 7.3 | 34.0 | 0.100 | 27,700 | 2,575 | 2.5 | 1.9 | 19,400 | 16,600 | | 943 | 540 | 220 | 1,012 | 5,238 | 6,250 | 0.130 | | 26.0% | |
| 1/8/10 | 7.2 | 34.0 | 0.400 | 29,900 | 3,375 | 2.5 | 1.9 | 18,800 | 17,000 | 2,320 | 975 | 745 | 202 | 1,400 | 5,325 | 6,725 | 0.130 | 24.9 | | |
| 1/9/10 | 7.3 | 34.0 | 0.150 | | | | | | | | | | | 1,500 | 5,550 | 7,050 | 0.130 | | | |
| 1/10/10 | 7.3 | 34.0 | 0.150 | | | | | | | | | | | 1,412 | 5,363 | 6,775 | 0.080 | | | |
| 1/11/10 | 7.4 | 34.5 | 0.200 | 44,400 | 2,950 | 2.5 | 1.8 | 19,800 | 16,600 | | 1,020 | 725 | 220 | 1,450 | 5,475 | 6,925 | 0.130 | | | |
| 1/12/10 | 7.2 | 34.0 | 0.350 | | | | | | | | | | | 913 | 6,838 | 7,750 | 0.380 | | | |
| 1/13/10 | 7.2 | 34.5 | 0.350 | 26,600 | 2,900 | 2.5 | 1.8 | 19,250 | 16,000 | | 1,015 | 490 | 222 | 1,537 | 5,363 | 6,900 | 0.230 | | | |
| 1/14/10 | 7.2 | 34.5 | 0.350 | | | | | | | | | | | | | | 0.150 | | 36.0% | 1,100 |
| 1/15/10 | 7.2 | 35.0 | 0.400 | 28,700 | 3,125 | 2.5 | 1.9 | 18,750 | 16,500 | | 1,028 | 463 | 244 | 1,238 | 5,575 | 6,813 | 0.330 | | | |
| 1/16/10 | 7.4 | 34.5 | 0.350 | | | | | | | | | | | | | | 0.250 | | | |
| 1/17/10 | 7.4 | 35.0 | 0.350 | | | | | | | | | | | | | | 0.450 | | | |
| 1/18/10 | 7.4 | 34.5 | 0.100 | 17,700 | 2,625 | 2.7 | 1.9 | 21,200 | 18,000 | 2,460 | 1,065 | 658 | 240 | 1,438 | 6,000 | 7,438 | 0.130 | | | |
| 1/19/10 | 7.3 | 35.0 | 0.350 | 25,800 | 2,625 | 2.9 | 2.1 | 21,200 | 18,200 | | 1,033 | 823 | 234 | 1,638 | 6,150 | 7,788 | 0.130 | | | |
| 1/20/10 | 7.4 | 35.0 | 0.400 | 27,300 | 2,950 | 2.8 | 1.9 | 20,600 | 17,800 | | 1,040 | 1,050 | 254 | 1,425 | 6,450 | 7,875 | 0.330 | | | |
| 1/21/10 | 7.4 | 35.0 | 0.400 | 26,800 | 2,725 | 2.8 | 2.0 | 20,200 | 17,000 | | 1,115 | 670 | 246 | 1,638 | 5,725 | 7,363 | 0.280 | | 34.0% | 1,000 |
| 1/22/10 | 7.4 | 34.5 | 0.075 | 28,800 | 2,625 | 2.8 | 2.0 | 21,000 | 17,200 | | 1,080 | 980 | 246 | 1,600 | 5,713 | 7,313 | 0.130 | | 26.0% | 600 |
| 1/23/10 | 7.3 | 35.0 | 0.450 | | | | | | | | | | | | | | | | | |
| 1/24/10 | 7.3 | 35.0 | 0.400 | | | | | | | | | | | | | | | | | |
| 1/25/10 | 7.3 | 34.5 | 0.450 | 25,900 | 2,875 | 2.7 | 1.9 | 20,200 | 16,400 | | 945 | 498 | 254 | 1,788 | 5,775 | 7,563 | 0.380 | | | |
| 1/26/10 | 7.4 | 34.5 | 0.450 | 25,400 | 2,850 | 2.8 | 1.9 | 19,800 | 17,000 | 1,762 | 1,135 | 478 | 252 | 1,662 | 5,813 | 7,475 | 0.330 | | 34.0% | 1,400 |
| 1/27/10 | 7.4 | 34.5 | 0.450 | 24,900 | 2,700 | 2.7 | 1.9 | 19,800 | 15,800 | | 1,175 | 853 | 252 | 1,775 | 6,138 | 7,913 | 0.330 | | 34.0% | 1,300 |

**Phase I**

Digester 3 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/28/10 | 7.3 | 35.0 | 0.450 | 27,800 | 3,225 | 2.8 | 1.9 | 19,200 | 16,200 | 1,660 | 1,385 | 918 | 222 | 1,975 | 6,200 | 8,175 | 0.380 | 17.8 | | |
| 1/29/10 | 7.3 | 34.5 | 0.450 | | | | | | | | | | | 1,825 | 6,088 | 7,913 | 0.380 | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.2 | 34.9 | 0.325 | 30,352 | 2,841 | 2.8 | 2.0 | 23,076 | 20,305 | 2,064 | 845 | 632 | 178 | 1,131 | 4,987 | 6,134 | 0.207 | 21.4 | 33.0% | 1,440 |
| Minimum | 7.0 | 33.0 | 0.075 | 17,700 | 1,940 | 2.5 | 1.8 | 18,600 | 15,800 | 1,660 | 245 | 400 | 35 | 400 | 2,295 | 2,910 | 0.050 | 17.8 | 26.0% | 600 |
| Maximum | 7.4 | 38.0 | 0.500 | 44,900 | 3,975 | 3.8 | 2.7 | 35,400 | 32,600 | 2,750 | 1,385 | 1,050 | 254 | 1,975 | 6,838 | 8,175 | 0.500 | 24.9 | 36.0% | 2,200 |

**Phase I**

Digester 4 Operations Data

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/14/09 | | | | | | | | | | | | | | | | | | | | |
| 11/15/09 | | | | | | | | | | | | | | | | | | | | |
| 11/16/09 | 7.1 | | 0.100 | | | | | | | | | | | | | | | | | |
| 11/17/09 | 7.0 | 35.0 | 0.100 | | | | | | | | | | | | | | | | | |
| 11/18/09 | 7.0 | | | | 1,830 | | | 15,200 | 14,800 | | 428 | | 64 | | | | | | | |
| 11/19/09 | 7.0 | | | | | | | | | | | | | | | | | | | |
| 11/20/09 | 7.1 | | | | | | | | | | | | | | | | | | | |
| 11/21/09 | 7.0 | | | | | | | | | | | | | | | | | | | |
| 11/22/09 | 7.1 | 39.5 | | | | | | | | | | | | 625 | 2,610 | 3,235 | | | | |
| 11/23/09 | 7.1 | 40.0 | 0.100 | | 3,300 | | | 14,600 | 14,000 | | 328 | | 83 | 530 | 2,670 | 3,200 | 0.250 | | | |
| 11/24/09 | 7.2 | 39.0 | 0.200 | | | | | | | | | | | 538 | 2,813 | 3,350 | 0.080 | | | |
| 11/25/09 | 7.1 | 36.0 | 0.200 | | 8,100 | 4.1 | | 39,800 | 35,800 | | 525 | | 46 | 475 | 2,950 | 3,425 | 0.130 | | | |
| 11/26/09 | 7.2 | | 0.220 | | | | | | | | | | | | | | | | | |
| 11/27/09 | 7.2 | 36.0 | 0.200 | | | | | | | | | | | | | | | | | |
| 11/28/09 | 7.2 | 36.5 | 0.200 | | | | | | | | | | | 550 | 3,625 | 4,175 | 0.080 | | | |
| 11/29/09 | 7.2 | | 0.200 | | | | | | | | | | | | | | | | | |
| 11/30/09 | 7.2 | 36.0 | 0.300 | | 4,700 | 3.8 | | 39,000 | 35,600 | | 515 | | 78 | 650 | 3,938 | 4,588 | 0.130 | | | |
| 12/1/09 | 7.2 | 35.5 | 0.300 | | | | | | | | | | | 600 | 4,188 | 4,788 | 0.080 | | | |
| 12/2/09 | 7.2 | 36.0 | 0.300 | | 2,775 | 3.5 | | 30,200 | 26,400 | | 585 | | 70 | 513 | 4,338 | 4,850 | 0.100 | | | |
| 12/3/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 800 | 3,860 | 4,660 | 0.050 | | | |
| 12/4/09 | 7.3 | 36.0 | 0.350 | | 2,860 | 3.4 | | 31,200 | 28,400 | | 723 | | | 540 | 4,520 | 5,060 | 0.070 | | | |
| 12/5/09 | 7.3 | 36.0 | 0.300 | | | | | | | | | | | | | | | | | |
| 12/6/09 | 7.3 | 36.0 | 0.300 | | | | | | | | | | | 600 | 3,980 | 4,580 | 0.050 | | | |
| 12/7/09 | 7.3 | 36.0 | 0.100 | | 2,313 | 3.4 | | 30,000 | 27,600 | | 574 | | 108 | 980 | 4,100 | 5,080 | 0.070 | | | |
| 12/8/09 | 7.2 | 36.0 | 0.300 | | | | | | | | | | | 820 | 4,600 | 5,420 | 0.050 | | | |
| 12/9/09 | 7.2 | 35.5 | 0.300 | | 2,975 | 3.3 | 2.7 | 28,600 | 25,600 | | 848 | | 159 | 960 | 4,540 | 5,500 | 0.700 | | | |
| 12/10/09 | 7.2 | 35.0 | 0.300 | | | | | | | | | | | 680 | 4,900 | 5,850 | 0.050 | | | |
| 12/11/09 | 7.2 | 35.5 | | 54,400 | 2,450 | 3.4 | 2.7 | 27,200 | 23,600 | | 608 | | 120 | 600 | 5,240 | 5,840 | 0.050 | | | |
| 12/12/09 | 7.2 | 35.5 | 0.350 | | | | | | | | | | | 1,162 | 4,488 | 5,650 | 0.080 | | | |
| 12/13/09 | 7.3 | 35.5 | 0.250 | | | | | | | | | | | 975 | 4,975 | 5,950 | 0.080 | | | |
| 12/14/09 | 7.2 | 35.5 | 0.400 | 39,600 | 2,450 | 2.9 | 2.3 | 26,200 | 22,800 | | 803 | | 163 | 1,038 | 5,025 | 6,063 | 0.100 | | | |
| 12/15/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,063 | 5,025 | 6,063 | 0.080 | | | |
| 12/16/09 | 7.2 | 35.0 | 0.375 | 45,300 | 3,375 | 3.5 | 2.3 | 25,600 | 21,800 | | 590 | | 159 | 1,038 | 5,200 | 6,238 | 0.100 | | | |
| 12/17/09 | 7.2 | 35.0 | 0.375 | | | | | | | | | | | 1,050 | 5,275 | 6,325 | 0.080 | | | |

**Phase I**

Digester 4 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/18/09 | 7.2 | 35.5 | 0.410 | 33,000 | 4,150 | 3.1 | 2.4 | 26,400 | 23,600 | | 723 | 655 | 169 | 1,075 | 5,400 | 6,475 | 0.130 | | | |
| 12/19/09 | 7.2 | 35.0 | 0.350 | | | | | | | | | | | 1,038 | 5,613 | 6,650 | 0.080 | | | |
| 12/20/09 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 988 | 5,913 | 6,900 | 0.080 | | | |
| 12/21/09 | 7.2 | 35.0 | 0.400 | 39,000 | 4,325 | 2.9 | 2.2 | 25,200 | 21,400 | | 625 | | 159 | 1,075 | 5,538 | 6,613 | 0.100 | | | |
| 12/22/09 | 7.2 | 35.0 | 0.250 | | | | | | | | | | | 1,125 | 5,900 | 7,025 | 0.280 | | | |
| 12/23/09 | 7.2 | 35.5 | 0.425 | 36,000 | 3,175 | 2.9 | 2.2 | 23,600 | 20,600 | | 638 | 685 | 196 | 1,250 | 5,663 | 6,913 | 0.380 | | | |
| 12/24/09 | 7.2 | 35.0 | 0.450 | | | | | | | | | | | 1,150 | 5,638 | 6,788 | 0.430 | | | |
| 12/25/09 | | | 0.500 | | | | | | | | | | | | | | 0.500 | | | |
| 12/26/09 | | | 0.450 | | | | | | | | | | | | | | 0.450 | | | |
| 12/27/09 | | | 0.375 | | | | | | | | | | | | | | 0.375 | | | |
| 12/28/09 | 7.2 | 34.5 | 0.400 | | | | | | | | | | | 1,138 | 5,925 | 7,063 | 0.480 | | | |
| 12/29/09 | 7.2 | 35.0 | 0.400 | 37,000 | 3,550 | 2.7 | 2.1 | 21,800 | 20,800 | 2,460 | 708 | 575 | 208 | 1,250 | 5,100 | 6,350 | 0.280 | | | |
| 12/30/09 | 7.3 | 35.0 | 0.400 | 28,000 | 3,150 | 2.7 | 2.1 | 22,800 | 20,800 | | 860 | 610 | 210 | 1,275 | 5,225 | 6,500 | 0.330 | 16.6 | 34.0% | 2,200 |
| 12/31/09 | 7.3 | 35.0 | 0.400 | 31,800 | 2,900 | 2.7 | 2.0 | 21,200 | 19,800 | | 885 | 445 | 200 | 1,350 | 5,288 | 6,638 | 0.330 | | 36.0% | 1,800 |
| 1/1/10 | 7.2 | 34.5 | 0.400 | 33,400 | 3,175 | 2.7 | 2.1 | 21,600 | 19,600 | 2,525 | 845 | 465 | 142 | | | | 0.250 | | 34.0% | 1,800 |
| 1/2/10 | 7.3 | 34.5 | 0.400 | 34,900 | 3,225 | 2.6 | 2.0 | 21,000 | 18,600 | 1,865 | 878 | 615 | 206 | 1,087 | 5,213 | 6,300 | 0.330 | | 34.0% | 1,400 |
| 1/3/10 | 7.3 | 34.5 | 0.400 | 27,600 | 3,100 | 2.7 | 2.0 | 20,600 | 18,400 | 2,220 | 908 | 625 | 204 | 1,012 | 5,313 | 6,325 | 0.330 | 17.3 | 32.0% | |
| 1/4/10 | 7.3 | 34.5 | 0.400 | 33,200 | 3,100 | 2.6 | 1.9 | 20,400 | 18,200 | 1,902 | 940 | 645 | 200 | 1,138 | 5,375 | 6,513 | 0.330 | 17.3 | 34.0% | |
| 1/5/10 | 7.2 | 34.5 | 0.400 | 21,600 | 3,075 | 2.6 | 1.9 | 20,000 | 17,600 | 2,220 | 908 | 670 | 198 | 1,162 | 5,063 | 6,225 | 0.330 | | 28.0% | |
| 1/6/10 | 7.2 | 34.5 | 0.400 | 35,200 | 3,175 | 2.6 | 1.9 | 19,800 | 17,600 | 1,832 | 915 | 640 | 210 | 1,287 | 5,288 | 6,575 | 0.330 | 17.3 | 36.0% | |
| 1/7/10 | 7.2 | 34.5 | 0.300 | 28,400 | 2,900 | 2.7 | 2.0 | 21,000 | 18,400 | | 908 | 570 | 238 | 1,213 | 5,475 | 6,688 | 0.130 | | 34.0% | |
| 1/8/10 | 7.2 | 34.0 | 0.400 | 33,700 | 3,950 | 2.7 | 2.0 | 21,000 | 17,800 | 2,260 | 903 | 790 | 208 | 1,400 | 5,325 | 6,725 | 0.430 | | | |
| 1/9/10 | 7.3 | 34.5 | 0.400 | | | | | | | | | | | 1,225 | 5,000 | 6,225 | 0.230 | | | |
| 1/10/10 | 7.3 | 34.5 | 0.350 | | | | | | | | | | | 1,500 | 5,388 | 6,888 | 0.280 | | | |
| 1/11/10 | 7.3 | 35.0 | 0.350 | 54,000 | 2,950 | 2.7 | 1.9 | 20,400 | 17,800 | | 933 | 620 | 232 | 1,563 | 5,250 | 6,813 | 0.330 | | | |
| 1/12/10 | 7.2 | 34.5 | 0.350 | | | | | | | | | | | 825 | 7,100 | 7,925 | 0.280 | | | |
| 1/13/10 | 7.2 | 34.5 | 0.400 | 30,300 | 3,225 | 2.6 | 1.9 | 20,000 | 17,250 | | 870 | 745 | 234 | 1,488 | 5,275 | 6,763 | 0.280 | | | |
| 1/14/10 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | | | | 0.150 | | 36.0% | 900 |
| 1/15/10 | 7.2 | 35.5 | 0.200 | 27,200 | 3,650 | 2.8 | 2.0 | 20,500 | 18,000 | | 930 | 605 | 240 | 1,487 | 5,688 | 7,175 | 0.230 | | | |
| 1/16/10 | 7.4 | 35.0 | 0.300 | | | | | | | | | | | | | | 0.200 | | | |
| 1/17/10 | 7.3 | 35.0 | 0.350 | | | | | | | | | | | | | | 0.450 | | | |
| 1/18/10 | 7.3 | 35.0 | 0.400 | 28,900 | 3,150 | 3.1 | 2.0 | 22,800 | 18,400 | 2,680 | 948 | 655 | 234 | 1,713 | 5,875 | 7,588 | 0.230 | | | |
| 1/19/10 | 7.3 | 35.5 | 0.400 | 27,400 | 2,625 | 3.0 | 2.1 | 23,000 | 18,400 | | 940 | 1,038 | 242 | 1,838 | 6,075 | 7,913 | 0.330 | | | |
| 1/20/10 | 7.4 | 35.5 | 0.150 | 26,500 | 2,875 | 2.9 | 2.0 | 20,600 | 17,200 | | 985 | 895 | 248 | 1,588 | 6,125 | 7,713 | 0.130 | | | |
| 1/21/10 | 7.4 | 35.5 | 0.350 | 23,900 | 2,875 | 2.9 | 2.0 | 20,400 | 17,400 | | 1,000 | 1,040 | 252 | 1,938 | 5,775 | 7,713 | 0.180 | | 32.0% | 700 |
| 1/22/10 | 7.3 | 35.5 | 0.450 | 27,800 | 3,025 | 3.0 | 2.0 | 23,200 | 18,200 | | 980 | 1,350 | 232 | 1,875 | 6,025 | 7,900 | 0.330 | | 34.0% | 1,000 |
| 1/23/10 | 7.3 | 35.5 | 0.300 | | | | | | | | | | | | | | 0.150 | | | |
| 1/24/10 | 7.3 | 35.5 | 0.300 | | | | | | | | | | | | | | 0.300 | | | |
| 1/25/10 | 7.3 | 35.0 | 0.450 | 17,200 | 2,850 | 2.6 | 1.9 | 20,600 | 16,800 | | 1,040 | 545 | 252 | 1,825 | 5,925 | 7,750 | 0.380 | | | |

**Phase I**

Digester 4 Operations Data (Cont.)

November 14, 2009 - January 29, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/26/10 | 7.4 | 35.0 | 0.450 | 27,600 | 3,100 | 2.9 | 2.0 | 22,200 | 18,000 | 2,320 | 1,005 | 1,148 | 242 | 1,950 | 5,663 | 7,613 | 0.330 | | 34.0% | 1,100 |
| 1/27/10 | 7.3 | 35.5 | 0.450 | 26,400 | 2,725 | 2.9 | 2.0 | 21,400 | 17,000 | | 1,050 | 933 | 254 | 1,938 | 5,750 | 7,688 | 0.330 | | 36.0% | 1,100 |
| 1/28/10 | 7.3 | 35.5 | 0.450 | 25,100 | 3,225 | 2.9 | 1.9 | 20,600 | 17,600 | 1,726 | 1,020 | 850 | 242 | 1,875 | 5,675 | 7,550 | 0.380 | | | |
| 1/29/10 | 7.3 | 35.0 | 0.500 | | | | | | | | | | | 1,925 | 5,713 | 7,638 | 0.380 | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.2 | 35.4 | 0.337 | 32,221 | 3,253 | 3.0 | 2.1 | 23,505 | 20,585 | 2,183 | 807 | 737 | 186 | 1,149 | 5,061 | 6,214 | 0.235 | 17.13 | 33.9% | 1,333 |
| Minimum | 7.0 | 34.0 | 0.100 | 17,200 | 1,830 | 2.6 | 1.9 | 14,600 | 14,000 | 1,726 | 328 | 445 | 46 | 475 | 2,610 | 3,200 | 0.050 | 16.60 | 28.0% | 700 |
| Maximum | 7.4 | 40.0 | 0.500 | 54,400 | 8,100 | 4.1 | 2.7 | 39,800 | 35,800 | 2,680 | 1,050 | 1,350 | 254 | 1,950 | 7,100 | 7,925 | 0.700 | 17.30 | 36.0% | 2,200 |

# APPENDIX D

Phase II Raw Data

**Phase II**

Influent Feed Characterization

February 28, 2010 - April 16, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/28/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/1/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/2/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/3/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/4/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/5/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/6/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/7/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/8/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/9/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/10/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/11/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/12/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/13/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/14/10 | Blend #1 | Feed #8 | 5.5 | 119,700 | 55,900 | 6.23 | 5.40 | 31,000 | 30,400 | 2,280 | 193 | 1,270 | 580 |
| 3/15/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/16/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/17/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/18/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/19/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/20/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/21/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/22/10 | Blend #1 | Feed #9 | 5.6 | 110,300 | 52,800 | 6.50 | 5.67 | 28,800 | 27,700 | 2,360 | 202 | 1,600 | 570 |
| 3/23/10 | | | | | | | | | | | | | |
| 3/24/10 | | | | | | | | | | | | | |
| 3/25/10 | | | | | | | | | | | | | |
| 3/26/10 | Blend #1 | Feed #10 | 5.5 | 100,400 | 58,200 | 5.29 | 4.41 | 22,400 | 21,600 | 1,390 | 200 | 1,335 | 570 |
| 3/27/10 | Blend #1 | Feed #10 | 5.5 | 100,400 | 58,200 | 5.29 | 4.41 | 22,400 | 21,600 | 1,390 | 200 | 1,335 | 570 |
| 3/28/10 | Blend #1 | Feed #10 | 5.5 | 100,400 | 58,200 | 5.29 | 4.41 | 22,400 | 21,600 | 1,390 | 200 | 1,335 | 570 |
| 3/29/10 | Blend #1 | Feed #10 | 5.5 | 100,400 | 58,200 | 5.29 | 4.41 | 22,400 | 21,600 | 1,390 | 200 | 1,335 | 570 |
| 3/30/10 | Blend #1 | Feed #10 | 5.5 | 100,400 | 58,200 | 5.29 | 4.41 | 22,400 | 21,600 | 1,390 | 200 | 1,335 | 570 |
| 3/31/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/1/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/2/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/3/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/4/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/5/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/6/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/7/10 | Blend #1 | Feed #11 | 4.7 | 96,100 | 56,200 | 5.60 | 4.67 | 21,300 | 20,300 | 1,532 | 252 | 1,355 | 525 |
| 4/8/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/9/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/10/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/11/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/12/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/13/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/14/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/15/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/16/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| Average | | | 5.5 | 115,763 | 54,963 | 6 | 5 | 29,908 | 29,133 | 2,270 | 196 | 1,383 | 576 |
| Minimum | | | 5.5 | 100,400 | 52,800 | 5 | 4 | 22,400 | 21,600 | 1,390 | 193 | 1,270 | 570 |
| Maximum | | | 5.6 | 119,700 | 58,200 | 7 | 6 | 31,000 | 30,400 | 2,360 | 202 | 1,600 | 580 |

**Phase II**

Digester 1 Operations Data

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/28/10 | 7.6 | | 0.250 | | | | | | | | | | | 1,788 | 6,825 | 8,613 | 0.080 | | | |
| 3/1/10 | 7.5 | 35.0 | 0.250 | 30,500 | 4,520 | 2.40 | 1.52 | 16,000 | 12,800 | | 1,340 | 1,058 | 282 | 1,887 | 6,663 | 8,550 | 0.080 | | | |
| 3/2/10 | 7.3 | 35.0 | 0.350 | | | | | | | | | | | 2,150 | 6,200 | 8,350 | 0.080 | | | |
| 3/3/10 | 7.6 | 35.0 | 0.350 | 25,200 | 4,890 | 2.48 | 1.54 | 16,200 | 12,000 | | 1,480 | 660 | 278 | 1,862 | 7,013 | 8,875 | 0.080 | | | |
| 3/4/10 | 7.7 | 35.0 | 0.250 | | | | | | | | | | | 1,888 | 6,825 | 8,713 | 0.080 | | | |
| 3/5/10 | 7.6 | 35.5 | 0.300 | 24,800 | 5,220 | 2.54 | 1.58 | 15,800 | 12,000 | | 1,420 | 798 | 250 | 1,775 | 7,163 | 8,938 | 0.130 | | | |
| 3/6/10 | 7.5 | | 0.400 | | | | | | | | | | | 1,962 | 7,088 | 9,050 | 0.080 | | | |
| 3/7/10 | 7.7 | | 0.200 | | | | | | | | | | | 1,638 | 7,650 | 9,288 | 0.080 | | | |
| 3/8/10 | 7.6 | 35.5 | 0.400 | 23,700 | 5,780 | 2.59 | 1.57 | 18,200 | 13,500 | | 1,550 | 1,223 | 300 | 1,750 | 7,375 | 9,125 | 0.130 | | | |
| 3/9/10 | 7.4 | 35.5 | 0.300 | | | | | | | | | | | 1,938 | 7,225 | 9,163 | 0.080 | | | |
| 3/10/10 | 7.6 | 35.5 | 0.400 | 24,700 | 5,950 | 2.57 | 1.58 | 17,500 | 13,400 | | 1,225 | 920 | 298 | 1,800 | 7,425 | 9,225 | 0.380 | | | |
| 3/11/10 | 7.5 | 35.0 | 0.400 | | | | | | | | | | | 1,775 | 7,350 | 9,125 | 0.330 | | | 1,400 |
| 3/12/10 | 7.4 | 35.0 | 0.400 | 25,150 | 5,700 | 2.56 | 1.57 | 17,300 | 12,900 | | 1,520 | 913 | 302 | 1,787 | 7,138 | 8,925 | 0.130 | | 36.0% | 2,000 |
| 3/13/10 | 7.6 | 35.0 | 0.400 | 23,750 | 6,010 | 2.57 | 1.55 | 16,200 | 12,300 | | 1,305 | 995 | 296 | 1,713 | 7,325 | 9,038 | 0.430 | 16.2 | 36.0% | 2,000 |
| 3/14/10 | 7.6 | 35.0 | 0.400 | 26,550 | 5,780 | 2.59 | 1.57 | 15,600 | 12,300 | | 1,315 | 755 | 298 | 1,612 | 7,238 | 8,850 | 0.430 | 29.5 | 30.0% | 1,800 |
| 3/15/10 | 7.5 | 35.0 | 0.400 | 24,350 | 5,760 | 2.59 | 1.57 | 17,000 | 12,600 | | 1,490 | 883 | 294 | 1,775 | 7,488 | 8,263 | 0.330 | 18.6 | | |
| 3/16/10 | 7.5 | 34.5 | 0.400 | 26,700 | 5,930 | 2.53 | 1.55 | 16,300 | 11,500 | | 1,435 | 820 | 266 | 1,675 | 7,175 | 8,850 | 0.280 | 16.8 | 28.0% | 1,300 |
| 3/17/10 | 7.4 | 35.0 | 0.400 | 25,400 | 6,050 | 2.48 | 1.46 | 16,800 | 12,200 | 2,800 | 1,585 | 1,163 | 290 | 1,838 | 7,150 | 8,988 | 0.380 | 20.4 | 28.0% | |
| 3/18/10 | 7.3 | 35.0 | 0.400 | 25,100 | 6,090 | 2.69 | 1.61 | 19,200 | 13,900 | | 1,015 | 778 | 284 | 1,837 | 7,288 | 9,125 | 0.330 | 15.4 | 28.0% | 1,000 |
| 3/19/10 | 7.5 | 35.0 | 0.300 | 25,100 | 6,290 | 2.54 | 1.50 | 17,800 | 12,400 | 3,280 | 1,600 | 925 | 222 | 2,037 | 6,863 | 8,900 | 0.130 | | 30.0% | 1,100 |
| 3/20/10 | 7.4 | 35.0 | 0.400 | 24,750 | 6,290 | 2.60 | 1.54 | 17,500 | 12,400 | | 1,645 | 1,078 | 296 | 2,313 | 7,025 | 9,338 | 0.430 | 17.4 | 30.0% | 1,000 |
| 3/21/10 | 7.4 | 34.5 | 0.400 | 25,050 | 5,900 | 2.56 | 1.49 | 18,400 | 13,700 | | 1,600 | 975 | 296 | 1,875 | 7,344 | 9,219 | 0.380 | 16.9 | 28.0% | 800 |
| 3/22/10 | 7.3 | 35.0 | 0.400 | 24,350 | 6,140 | 2.61 | 1.54 | 18,300 | 13,400 | | 1,570 | 735 | 306 | 1,907 | 7,156 | 9,063 | 0.380 | 18.6 | | |
| 3/23/10 | 7.4 | 35.5 | | 23,900 | 5,840 | 2.72 | 1.60 | 16,500 | 11,900 | | 1,655 | 940 | 258 | 2,094 | 7,250 | 9,344 | 0.130 | | | |
| 3/24/10 | 7.6 | | 0.100 | | | | | | | | | | | | | | | | | |
| 3/25/10 | 7.6 | | 0.100 | 25,250 | 6,200 | 2.67 | 1.55 | 17,400 | 12,400 | | 1,650 | 840 | 228 | | | | | | | |
| 3/26/10 | 7.5 | 35.5 | 0.200 | 23,600 | 6,180 | 2.66 | 1.58 | 19,200 | 13,500 | 2,525 | 1,570 | 788 | 303 | 1,875 | 7,781 | 9,656 | 0.230 | | 30.0% | |
| 3/27/10 | 7.4 | 35.5 | 0.400 | 23,750 | 6,510 | 2.65 | 1.55 | 17,900 | 12,200 | | 1,640 | 905 | 302 | 1,750 | 7,469 | 9,219 | 0.330 | 16.7 | | |
| 3/28/10 | 7.4 | 35.0 | 0.400 | 23,750 | 6,130 | 2.54 | 1.45 | 17,400 | 12,400 | | 1,585 | 728 | 260 | 1,718 | 7,344 | 9,062 | 0.280 | 13.3 | | |
| 3/29/10 | 7.2 | 35.5 | 0.400 | 24,200 | 6,230 | 2.59 | 1.51 | 17,500 | 12,400 | | 1,555 | 818 | 294 | 2,000 | 7,219 | 9,219 | 0.330 | 21.1 | 28.0% | 2,000 |
| 3/30/10 | 7.5 | 35.5 | 0.400 | 24,550 | 5,950 | 2.63 | 1.53 | 18,000 | 13,000 | | 1,535 | 1,003 | 304 | 1,750 | 7,469 | 9,219 | 0.230 | 18.5 | 30.0% | 2,000 |
| 3/31/10 | 7.5 | 35.5 | 0.400 | 22,850 | 5,980 | 2.53 | 1.45 | 17,400 | 12,500 | | 1,550 | 735 | 294 | 1,594 | 7,250 | 8,844 | 0.280 | 17.5 | 28.0% | 2,000 |
| 4/1/10 | 7.5 | 35.5 | 0.400 | 24,000 | 6,310 | 2.63 | 1.53 | 17,400 | 12,900 | | 1,545 | 845 | 290 | 1,813 | 6,656 | 8,469 | 0.330 | 16.0 | 30.0% | 2,000 |
| 4/2/10 | 7.4 | 35.5 | 0.400 | 22,400 | 7,120 | 2.67 | 1.51 | 17,600 | 12,200 | 2,675 | 1,515 | 845 | 304 | 1,750 | 7,188 | 8,938 | 0.330 | 18.6 | 28.0% | 2,000 |
| 4/3/10 | 7.6 | 35.5 | 0.200 | 22,550 | 5,960 | 2.31 | 1.37 | 13,500 | 11,300 | | 1,515 | 698 | 298 | 1,407 | 7,406 | 8,813 | 0.280 | | 26.0% | 1,600 |
| 4/4/10 | 7.5 | 35.5 | 0.400 | | | | | | | | | | | 1,719 | 7,250 | 8,969 | 0.280 | 19.6 | | |
| 4/5/10 | 7.5 | 35.0 | 0.400 | 22,800 | 6,000 | 2.63 | 1.44 | 16,800 | 11,900 | | 1,520 | 688 | 274 | 1,906 | 7,219 | 9,125 | 0.130 | 10.5 | 30.0% | 2,000 |
| 4/6/10 | 7.4 | 35.5 | 0.400 | 23,450 | 6,340 | 2.64 | 1.53 | 17,200 | 12,300 | | 1,460 | 1,043 | 302 | 1,719 | 6,875 | 8,594 | 0.330 | 16.3 | 30.0% | 2,000 |
| 4/7/10 | 7.4 | 35.5 | 0.400 | 21,750 | 6,090 | 2.50 | 1.41 | 15,900 | 11,700 | | 1,430 | 838 | 312 | 1,625 | 6,594 | 8,219 | 0.330 | 16.0 | 30.0% | 2,000 |

**Phase II**

Digester 1 Operations Data (Cont.)

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/8/10 | 7.4 | 35.0 | 0.400 | 23,350 | 6,170 | 2.61 | 1.49 | 17,000 | 12,000 | | 1,425 | 668 | 270 | 1,906 | 6,688 | 8,594 | 0.330 | 16.6 | 30.0% | 2,000 |
| 4/9/10 | 7.6 | 35.5 | 0.400 | 22,600 | 6,260 | 2.61 | 1.48 | 16,500 | 11,100 | | 1,235 | 1,180 | 318 | 1,000 | 7,438 | 8,438 | 0.330 | 17.6 | 28.0% | 2,000 |
| 4/10/10 | 7.8 | 35.5 | 0.400 | 22,150 | 6,130 | 2.58 | 1.43 | 16,800 | 11,800 | | 1,370 | 713 | 334 | 1,000 | 7,563 | 8,563 | 0.330 | 15.1 | 25.0% | 2,000 |
| 4/11/10 | 8.0 | 35.5 | 0.400 | 22,150 | 5,810 | 2.26 | 1.28 | 12,900 | 10,700 | | 1,400 | 635 | 342 | 1,094 | 7,969 | 9,063 | 0.330 | 16.2 | 28.0% | 2,000 |
| 4/12/10 | 8.0 | 35.0 | 0.400 | 21,300 | 5,770 | 2.66 | 1.46 | 17,100 | 11,700 | | 1,370 | 753 | 314 | 938 | 7,406 | 8,344 | 0.330 | 15.3 | 28.0% | 2,000 |
| 4/13/10 | 7.9 | 35.5 | 0.400 | 22,100 | 5,960 | 2.48 | 1.36 | 15,400 | 10,800 | | 1,315 | 720 | 344 | 1,156 | 7,688 | 8,844 | 0.330 | 14.0 | 30.0% | 2,000 |
| 4/14/10 | 7.7 | 35.5 | 0.400 | 21,750 | 5,840 | 2.33 | 1.29 | 14,700 | 10,800 | | 1,310 | 660 | 329 | 1,219 | 7,594 | 8,813 | 0.230 | 16.2 | 28.0% | 2,000 |
| 4/15/10 | 7.7 | 35.5 | 0.400 | 21,600 | 5,860 | 2.51 | 1.41 | 15,500 | 10,600 | | 1,315 | 888 | 217 | 1,156 | 6,969 | 8,125 | 0.230 | 16.3 | 28.0% | 2,000 |
| 4/16/10 | 8.0 | 35.5 | 0.400 | | | | | | | | | | | 875 | 7,688 | 8,563 | 0.330 | 16.2 | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.5 | 35.2 | 0.356 | 23,972 | 5,972 | 2.56 | 1.50 | 16,834 | 12,247 | 2,820 | 1,462 | 858 | 291 | 1,688 | 7,217 | 8,883 | 0.257 | 17.15 | 29.2% | 1,769 |
| Minimum | 7.2 | 34.5 | 0.100 | 21,300 | 4,520 | 2.26 | 1.28 | 12,900 | 10,600 | 2,525 | 1,015 | 635 | 217 | 875 | 6,200 | 8,125 | 0.080 | 10.50 | 25.0% | 800 |
| Maximum | 8.0 | 35.5 | 0.400 | 30,500 | 7,120 | 2.72 | 1.61 | 19,200 | 13,900 | 3,280 | 1,655 | 1,223 | 344 | 2,313 | 7,969 | 9,656 | 0.430 | 29.50 | 36.0% | 2,000 |

**Phase II**

Digester 2 Operations Data

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/28/10 | 7.6 | | 0.300 | | | | | | | | | | | 1,838 | 6,625 | 8,463 | 0.080 | | | |
| 3/1/10 | 7.5 | 35.0 | 0.200 | 28,200 | 4,860 | 2.32 | 1.52 | 14,800 | 12,000 | | 1,390 | 593 | 288 | 1,725 | 6,575 | 8,300 | 0.080 | | | |
| 3/2/10 | 7.3 | 35.0 | 0.350 | | | | | | | | | | | 2,100 | 6,200 | 8,300 | 0.080 | | | |
| 3/3/10 | 7.6 | 35.0 | 0.350 | 24,950 | 5,050 | 2.43 | 1.52 | 15,600 | 11,600 | | 1,470 | 448 | 286 | 1,625 | 6,925 | 8,550 | 0.130 | | | |
| 3/4/10 | 7.6 | 34.5 | 0.300 | | | | | | | | | | | 1,775 | 6,775 | 8,550 | 0.080 | | | |
| 3/5/10 | 7.6 | 35.5 | 0.300 | 24,200 | 5,220 | 2.53 | 1.57 | 16,000 | 12,200 | | 1,405 | 603 | 296 | 1,487 | 6,638 | 8,125 | 0.130 | | | |
| 3/6/10 | 7.6 | | 0.400 | | | | | | | | | | | 1,650 | 7,050 | 8,700 | 0.080 | | | |
| 3/7/10 | 7.5 | | 0.400 | | | | | | | | | | | 1,513 | 7,100 | 8,613 | 0.080 | | | |
| 3/8/10 | 7.5 | 35.5 | 0.400 | 24,300 | 5,440 | 2.59 | 1.56 | 17,700 | 13,600 | | 1,445 | 1,153 | 302 | 1,450 | 6,825 | 8,275 | 0.130 | | | |
| 3/9/10 | 7.3 | 35.5 | 0.300 | | | | | | | | | | | 1,600 | 6,838 | 8,438 | 0.080 | | | |
| 3/10/10 | 7.6 | 35.5 | 0.400 | 24,000 | 5,510 | 2.57 | 1.58 | 17,200 | 13,300 | | 1,305 | 908 | 288 | 1,375 | 6,975 | 8,350 | 0.330 | | | |
| 3/11/10 | 7.5 | 35.0 | 0.400 | | | | | | | | | | | 1,600 | 6,950 | 8,550 | 0.330 | | 32.0% | 2,000 |
| 3/12/10 | 7.3 | 35.0 | 0.400 | 24,750 | 5,760 | 2.64 | 1.62 | 17,500 | 12,900 | | 1,415 | 1,033 | 322 | 1,625 | 7,025 | 8,650 | 0.330 | 18.6 | 26.0% | 1,800 |
| 3/13/10 | 7.6 | 35.0 | 0.400 | 24,300 | 5,610 | 2.61 | 1.53 | 16,900 | 12,900 | | 1,270 | 673 | 242 | 1,575 | 7,113 | 8,688 | 0.230 | 13.8 | 34.0% | 2,000 |
| 3/14/10 | 7.6 | 35.0 | 0.400 | 25,100 | 5,980 | 2.70 | 1.64 | 18,100 | 13,100 | | 1,305 | 545 | 298 | 1,562 | 7,113 | 8,675 | 0.380 | 27.8 | 32.0% | 2,000 |
| 3/15/10 | 7.5 | 35.5 | 0.400 | 24,650 | 6,000 | 2.55 | 1.54 | 16,700 | 12,000 | | 1,440 | 553 | 298 | 1,550 | 7,063 | 8,613 | 0.380 | 21.5 | 28.0% | 1,500 |
| 3/16/10 | 7.5 | 35.0 | 0.400 | 24,250 | 5,880 | 2.40 | 1.48 | 15,700 | 12,300 | | 1,385 | 668 | 256 | 1,500 | 6,875 | 8,375 | 0.330 | 20.5 | 26.0% | 1,000 |
| 3/17/10 | 7.3 | 35.0 | 0.400 | 24,200 | 5,730 | 2.41 | 1.42 | 16,000 | 12,200 | 2,480 | 1,470 | 540 | 282 | 1,512 | 6,738 | 8,250 | 0.580 | 20.4 | 28.0% | 1,000 |
| 3/18/10 | 7.3 | 35.0 | 0.400 | 24,650 | 5,750 | 2.61 | 1.58 | 18,200 | 13,300 | | 1,485 | 570 | 240 | 1,588 | 6,725 | 8,313 | 0.580 | 17.7 | 28.0% | 700 |
| 3/19/10 | 7.5 | 35.0 | 0.200 | 22,850 | 5,910 | 2.46 | 1.45 | 16,500 | 11,800 | 3,320 | 1,410 | 570 | 204 | 1,900 | 6,525 | 8,425 | 0.130 | | 30.0% | 700 |
| 3/20/10 | 7.4 | 35.0 | 0.400 | 23,800 | 5,900 | 2.50 | 1.48 | 16,600 | 11,800 | | 1,515 | 1,008 | 282 | 1,850 | 6,513 | 8,363 | 0.480 | 17.7 | 28.0% | 300 |
| 3/21/10 | 7.3 | 34.5 | 0.400 | 25,150 | 6,730 | 2.57 | 1.53 | 17,600 | 12,800 | | 1,485 | 940 | 286 | 1,594 | 6,594 | 8,188 | 0.480 | 18.4 | 28.0% | 200 |
| 3/22/10 | 7.3 | 35.0 | 0.300 | 25,100 | 5,880 | 2.49 | 1.48 | 16,000 | 11,900 | | 1,485 | 708 | 290 | 1,500 | 6,781 | 8,281 | 0.380 | 15.9 | 30.0% | 800 |
| 3/23/10 | 7.4 | 35.0 | | 23,350 | 5,460 | 2.47 | 1.45 | 16,700 | 12,200 | | 1,490 | 773 | 182 | 1,844 | 6,500 | 8,344 | 0.130 | | 26.0% | |
| 3/24/10 | 7.6 | | 0.100 | | | | | | | | | | | | | | | | | |
| 3/25/10 | 7.5 | | 0.100 | 21,900 | 5,800 | 2.44 | 1.42 | 16,500 | 11,700 | | 1,520 | 935 | 248 | | | | | | | |
| 3/26/10 | 7.4 | 35.5 | 0.200 | 22,150 | 5,760 | 2.56 | 1.51 | 17,200 | 12,500 | 2,550 | 1,490 | 893 | 272 | 1,750 | 6,781 | 8,531 | 0.330 | | 30.0% | 700 |
| 3/27/10 | 7.4 | 35.5 | 0.500 | 23,000 | 6,010 | 2.44 | 1.45 | 17,000 | 12,000 | | 1,510 | 568 | 278 | 1,531 | 6,469 | 8,000 | 0.430 | 17.5 | 28.0% | 1,700 |
| 3/28/10 | 7.3 | 35.0 | 0.400 | 23,300 | 5,870 | 2.39 | 1.39 | 15,900 | 11,700 | | 1,450 | 600 | 272 | 1,719 | 6,406 | 8,125 | 0.430 | 17.3 | 30.0% | 2,000 |
| 3/29/10 | 7.2 | 35.0 | 0.400 | 22,400 | 6,230 | 2.37 | 1.37 | 15,100 | 11,300 | | 1,460 | 673 | 284 | 1,688 | 6,000 | 7,688 | 0.430 | 19.1 | 30.0% | 2,000 |
| 3/30/10 | 7.4 | 35.5 | 0.400 | 23,100 | 5,590 | 2.43 | 1.39 | 15,700 | 11,900 | | 1,340 | 550 | 280 | 1,469 | 6,594 | 8,063 | 0.430 | 18.4 | 34.0% | 2,000 |
| 3/31/10 | 7.4 | 35.5 | 0.400 | 22,000 | 5,510 | 2.33 | 1.32 | 15,300 | 11,100 | | 1,365 | 615 | 284 | 1,531 | 6,063 | 7,594 | 0.430 | 18.9 | 30.0% | 2,000 |
| 4/1/10 | 7.4 | 35.5 | 0.400 | 23,400 | 5,660 | 2.32 | 1.35 | 14,900 | 11,000 | | 1,325 | 605 | 280 | 1,375 | 5,656 | 7,031 | 0.430 | 19.0 | 30.0% | 2,000 |
| 4/2/10 | 7.4 | 35.5 | 0.400 | 21,850 | 5,520 | 2.36 | 1.35 | 15,600 | 11,100 | 2,525 | 1,185 | 623 | 274 | 1,688 | 6,156 | 7,844 | 0.430 | 17.3 | 28.0% | 2,000 |
| 4/3/10 | 7.5 | 35.5 | 0.400 | 21,650 | 5,290 | 2.01 | 1.15 | 12,100 | 10,700 | | 1,305 | 550 | 278 | 1,344 | 6,156 | 7,500 | 0.430 | 18.0 | 30.0% | 2,000 |
| 4/4/10 | 7.4 | 35.5 | 0.400 | | | | | | | | | | | 1,875 | 5,938 | 7,813 | 0.280 | 18.0 | | |
| 4/5/10 | 7.4 | 35.5 | 0.400 | 22,050 | 5,250 | 2.43 | 1.27 | 14,700 | 10,800 | | 1,315 | 905 | 272 | 1,657 | 6,406 | 8,063 | 0.380 | 20.3 | 30.0% | 2,000 |
| 4/6/10 | 7.4 | 35.5 | 0.400 | 22,050 | 5,630 | 2.43 | 1.34 | 16,100 | 11,200 | | 1,115 | 595 | 260 | 1,532 | 6,031 | 7,563 | 0.380 | 18.0 | 30.0% | 2,000 |
| 4/7/10 | 7.3 | 35.5 | 0.400 | 23,300 | 5,430 | 2.37 | 1.31 | 16,000 | 11,100 | | 1,325 | 553 | 330 | 1,531 | 6,250 | 7,781 | 0.330 | 17.8 | 30.0% | 2,000 |

**Phase II**

Digester 2 Operations Data (Cont.)

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/8/10 | 7.3 | 35.0 | 0.400 | 22,600 | 5,490 | 2.44 | 1.39 | 15,700 | 11,200 | | 1,310 | 593 | 288 | 1,875 | 5,938 | 7,813 | 0.330 | 17.5 | 30.0% | 2,000 |
| 4/9/10 | 7.5 | 35.5 | 0.400 | 22,200 | 5,720 | 2.34 | 1.32 | 15,900 | 11,100 | | 1,145 | 748 | 286 | 1,031 | 6,625 | 7,656 | 0.330 | 18.8 | 30.0% | 2,000 |
| 4/10/10 | 7.8 | 35.5 | 0.400 | 21,050 | 5,560 | 2.40 | 1.30 | 15,300 | 11,200 | | 1,290 | 493 | 306 | 812 | 7,063 | 7,875 | 0.230 | 17.7 | 32.0% | 2,000 |
| 4/11/10 | 7.9 | 35.5 | 0.400 | 20,250 | 5,190 | 2.51 | 1.35 | 16,300 | 11,100 | | | 543 | 292 | 938 | 6,906 | 7,844 | 0.330 | 16.1 | 28.0% | 2,000 |
| 4/12/10 | 7.9 | 35.5 | 0.400 | 20,900 | 5,220 | 2.30 | 1.28 | 14,300 | 10,600 | | 1,215 | 1,198 | 318 | 938 | 6,906 | 7,844 | 0.330 | 18.3 | 32.0% | 2,000 |
| 4/13/10 | 7.8 | 35.0 | 0.400 | 20,750 | 5,580 | 2.45 | 1.33 | 15,800 | 10,800 | | 1,240 | 545 | 319 | 1,187 | 7,344 | 8,531 | 0.330 | 17.5 | 30.0% | 2,000 |
| 4/14/10 | 7.6 | 35.5 | 0.400 | 20,850 | 5,560 | 2.26 | 1.28 | 13,600 | 10,300 | | 1,225 | 630 | 312 | 937 | 7,219 | 8,156 | 0.130 | 17.3 | 28.0% | 2,000 |
| 4/15/10 | 7.7 | 35.5 | 0.400 | 21,200 | 5,610 | 2.48 | 1.38 | 14,500 | 10,000 | | 1,265 | 1,090 | 307 | 1,125 | 7,063 | 8,188 | 0.230 | 17.0 | 28.0% | 2,000 |
| 4/16/10 | 7.9 | 35.5 | 0.400 | | | | | | | | | | | 906 | 7,313 | 8,219 | 0.280 | 19.6 | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.5 | 35.2 | 0.364 | 23,151 | 5,636 | 2.45 | 1.43 | 15,982 | 11,745 | 2,719 | 1,367 | 705 | 281 | 1,517 | 6,659 | 8,176 | 0.297 | 18.44 | 29.5% | 1,638 |
| Minimum | 7.2 | 34.5 | 0.100 | 20,250 | 4,860 | 2.01 | 1.15 | 12,100 | 10,000 | 2,480 | 1,115 | 448 | 182 | 812 | 5,656 | 7,031 | 0.080 | 13.80 | 26.0% | 200 |
| Maximum | 7.9 | 35.5 | 0.500 | 28,200 | 6,730 | 2.70 | 1.64 | 18,200 | 13,600 | 3,320 | 1,520 | 1,198 | 330 | 2,100 | 7,344 | 8,700 | 0.580 | 27.80 | 34.0% | 2,000 |

**Phase II**

Digester 3 Operations Data

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/28/10 | 7.7 | | 0.200 | | | | | | | | | | | 1,950 | 7,113 | 9,063 | 0.080 | | | |
| 3/1/10 | 7.6 | 35.0 | 0.200 | 25,800 | 4,990 | 2.36 | 1.50 | 15,400 | 12,600 | | 1,490 | 830 | 288 | 1,975 | 7,050 | 9,025 | 0.080 | | | |
| 3/2/10 | 7.6 | 35.0 | 0.100 | | | | | | | | | | | 1,925 | 7,313 | 9,238 | 0.080 | | | |
| 3/3/10 | 7.9 | 35.0 | 0.200 | 25,850 | 5,510 | 2.43 | 1.50 | 15,600 | 11,800 | | 1,640 | 770 | 290 | 1,875 | 7,350 | 9,225 | 0.130 | | | |
| 3/4/10 | 7.8 | 35.0 | 0.200 | | | | | | | | | | | 2,100 | 6,713 | 8,813 | 0.080 | | | |
| 3/5/10 | 7.9 | 35.5 | 0.100 | 25,950 | 5,240 | 2.44 | 1.50 | 16,200 | 12,400 | | 1,520 | 633 | 252 | 1,862 | 7,188 | 9,050 | 0.130 | | | |
| 3/6/10 | 8.0 | | 0.200 | | | | | | | | | | | 1,900 | 7,113 | 9,013 | 0.080 | | | |
| 3/7/10 | 7.9 | | 0.200 | | | | | | | | | | | 2,200 | 6,888 | 9,088 | 0.080 | | | |
| 3/8/10 | 7.6 | 35.5 | 0.400 | 27,550 | 5,440 | 2.63 | 1.68 | 18,800 | 14,200 | | 1,495 | 745 | 294 | 2,013 | 7,000 | 9,013 | 0.130 | | | |
| 3/9/10 | 7.5 | 36.0 | 0.200 | | | | | | | | | | | 2,050 | 6,650 | 8,700 | 0.080 | | | |
| 3/10/10 | 7.7 | 35.5 | 0.300 | 26,450 | 5,750 | 2.61 | 1.68 | 18,300 | 14,300 | | 1,400 | 870 | 270 | 2,063 | 7,150 | 9,213 | 0.080 | | | |
| 3/11/10 | 7.5 | 35.5 | 0.400 | | | | | | | | | | | 2,412 | 6,788 | 9,200 | 0.080 | | 32.0% | 2,000 |
| 3/12/10 | 7.5 | 35.0 | 0.200 | 25,650 | 5,360 | 2.26 | 1.67 | 18,400 | 13,700 | | 1,415 | 1,165 | 344 | 1,825 | 7,413 | 9,238 | 0.130 | 10.0 | 36.0% | 1,600 |
| 3/13/10 | 7.6 | 35.0 | 0.400 | 29,150 | 6,130 | 2.66 | 1.68 | 18,200 | 14,100 | | 1,250 | 715 | 302 | 2,050 | 7,225 | 9,275 | 0.280 | 17.6 | 32.0% | 1,200 |
| 3/14/10 | 7.6 | 35.0 | 0.400 | 30,050 | 6,010 | 2.65 | 1.69 | 18,300 | 14,200 | | 1,400 | 755 | 258 | 1,912 | 7,013 | 8,925 | 0.330 | 22.3 | 32.0% | 1,700 |
| 3/15/10 | 7.5 | 35.0 | 0.400 | 28,250 | 5,480 | 2.68 | 1.67 | 20,300 | 15,700 | | 1,385 | 603 | 294 | 1,775 | 7,500 | 9,275 | 0.330 | | 26.0% | 1,200 |
| 3/16/10 | 7.5 | 34.5 | 0.400 | 29,800 | 5,470 | 2.68 | 1.71 | 18,400 | 14,400 | | 1,440 | 668 | 304 | 1,837 | 7,038 | 8,875 | 0.330 | 16.6 | 34.0% | 1,400 |
| 3/17/10 | 7.4 | 34.5 | 0.400 | 28,850 | 5,680 | 2.46 | 1.58 | 16,400 | 14,200 | 3,300 | 1,525 | 955 | 266 | 1,663 | 7,175 | 8,838 | 0.380 | 15.0 | 28.0% | |
| 3/18/10 | 7.3 | 34.5 | 0.400 | 28,150 | 5,420 | 2.51 | 1.65 | 18,000 | 15,000 | | 1,445 | 755 | 288 | 1,737 | 7,363 | 9,100 | 0.330 | 18.7 | 30.0% | 600 |
| 3/19/10 | 7.4 | 35.0 | 0.400 | 27,900 | 5,560 | 2.75 | 1.72 | 19,500 | 14,300 | 3,860 | 1,540 | 965 | 288 | 2,125 | 7,125 | 9,250 | 0.380 | 11.5 | 32.0% | 400 |
| 3/20/10 | 7.4 | 35.5 | 0.400 | 28,000 | 5,530 | 2.85 | 1.75 | 20,100 | 14,900 | | 1,700 | 968 | 290 | 2,100 | 6,900 | 9,000 | 0.330 | 10.0 | 30.0% | 200 |
| 3/21/10 | 7.3 | 34.5 | 0.400 | 28,550 | 5,570 | 2.80 | 1.71 | 20,500 | 15,300 | | 1,540 | 1,113 | 284 | 1,969 | 7,031 | 9,000 | 0.330 | 9.1 | 28.0% | |
| 3/22/10 | 7.3 | 35.0 | 0.400 | 28,900 | 5,880 | 2.77 | 1.71 | 19,900 | 15,400 | | 1,535 | 920 | 316 | 1,969 | 7,406 | 9,375 | 0.330 | 15.4 | | |
| 3/23/10 | 7.4 | 34.5 | | 30,250 | 5,690 | 2.75 | 1.75 | 18,000 | 14,500 | | 1,565 | 1,113 | 188 | 2,000 | 7,156 | 9,156 | 0.130 | | | |
| 3/24/10 | 7.6 | | 0.100 | | | | | | | | | | | | | | | | | |
| 3/25/10 | 7.5 | | 0.100 | 27,000 | 5,550 | 2.76 | 1.69 | 19,700 | 14,700 | | 1,590 | 1,175 | 250 | | | | | | | |
| 3/26/10 | 7.5 | 35.0 | 0.200 | 27,000 | 5,810 | 2.80 | 1.74 | 19,600 | 14,600 | 3,400 | 1,555 | 1,030 | 306 | 1,906 | 7,438 | 9,344 | 0.230 | | 32.0% | 2,000 |
| 3/27/10 | 7.5 | 35.5 | 0.500 | 26,700 | 5,990 | 2.71 | 1.64 | 19,200 | 14,200 | | 1,585 | 885 | 304 | 2,062 | 7,188 | 9,250 | 0.330 | 11.6 | 28.0% | 1,200 |
| 3/28/10 | 7.4 | 35.0 | 0.450 | 29,450 | 6,030 | 2.66 | 1.66 | 17,600 | 13,700 | | 1,525 | 853 | 304 | 1,937 | 7,094 | 9,031 | 0.330 | 11.7 | 32.0% | 2,000 |
| 3/29/10 | 7.2 | 35.0 | 0.400 | 26,250 | 5,860 | 2.73 | 1.63 | 18,600 | 13,700 | | 1,535 | 798 | 306 | 1,932 | 7,188 | 9,125 | 0.330 | | 32.0% | 2,000 |
| 3/30/10 | 7.4 | 35.0 | 0.400 | 27,200 | 5,630 | 2.60 | 1.55 | 18,600 | 13,900 | | 1,505 | 865 | 304 | 1,907 | 7,281 | 9,188 | 0.330 | 15.9 | 34.0% | 2,000 |
| 3/31/10 | 7.4 | 35.0 | 0.400 | 26,000 | 5,700 | 2.62 | 1.61 | 17,600 | 13,400 | | 1,500 | 703 | 302 | 1,750 | 7,000 | 8,750 | 0.380 | 14.1 | 32.0% | 2,000 |
| 4/1/10 | 7.5 | 35.0 | 0.300 | 26,600 | 5,730 | 2.72 | 1.64 | 17,900 | 13,300 | | 1,490 | 1,025 | 304 | 1,844 | 6,750 | 8,594 | 0.330 | 14.7 | 30.0% | 2,000 |
| 4/2/10 | 7.4 | 35.0 | 0.400 | 25,800 | 5,920 | 2.64 | 1.56 | 18,400 | 13,400 | 3,200 | 1,495 | 915 | 302 | 1,657 | 7,031 | 8,688 | 0.330 | 14.1 | 30.0% | 2,000 |
| 4/3/10 | 7.5 | 35.0 | 0.450 | 24,100 | 5,830 | 2.31 | 1.35 | 14,700 | 12,500 | | 1,440 | 563 | 304 | 1,438 | 7,375 | 8,813 | 0.330 | 14.3 | 30.0% | 2,000 |
| 4/4/10 | 7.5 | 35.0 | 0.200 | | | | | | | | | | | 1,688 | 7,531 | 9,219 | 0.330 | | | |
| 4/5/10 | 7.5 | 35.0 | 0.400 | 24,050 | 5,730 | 2.69 | 1.52 | 17,100 | 12,300 | | 1,365 | 1,033 | 238 | 1,937 | 7,094 | 9,031 | 0.380 | 20.2 | 30.0% | 2,000 |
| 4/6/10 | 7.4 | 35.5 | 0.400 | 23,850 | 6,360 | 2.67 | 1.52 | 17,700 | 12,500 | | 1,435 | 1,095 | 378 | 1,625 | 7,188 | 8,813 | 0.380 | 12.8 | 30.0% | 2,000 |
| 4/7/10 | 7.4 | 35.5 | 0.400 | 24,050 | 5,670 | 2.60 | 1.46 | 18,000 | 12,600 | | 1,455 | 833 | 340 | 1,625 | 6,906 | 8,531 | 0.380 | 18.3 | 34.0% | 2,000 |

**Phase II**

Digester 3 Operations Data (Cont.)

February 28, 2010 - April 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/8/10 | 7.4 | 35.0 | 0.400 | 24,500 | 5,810 | 2.63 | 1.51 | 17,300 | 12,100 | | 1,340 | 783 | 338 | 1,782 | 6,406 | 8,188 | 0.330 | 18.4 | 34.0% | 1,200 |
| 4/9/10 | 7.5 | 34.5 | 0.400 | 24,100 | 5,550 | 2.57 | 1.47 | 17,100 | 12,300 | | 1,375 | 1,010 | 334 | 1,156 | 7,469 | 8,625 | 0.330 | 15.0 | 32.0% | 1,400 |
| 4/10/10 | 7.8 | 35.5 | 0.400 | 23,000 | 5,460 | 2.67 | 1.50 | 17,800 | 12,400 | | 1,335 | 838 | 312 | 906 | 7,750 | 8,656 | 0.330 | 15.3 | 32.0% | 1,900 |
| 4/11/10 | 7.9 | 35.5 | 0.400 | 23,450 | 5,130 | 2.75 | 1.55 | 18,600 | 12,700 | | 1,360 | 728 | 324 | 1,000 | 7,563 | 8,563 | 0.330 | 12.4 | 32.0% | 2,000 |
| 4/12/10 | 7.9 | 34.0 | 0.400 | 22,250 | 4,970 | 2.48 | 1.39 | 16,700 | 12,300 | | | 885 | 336 | 1,156 | 7,438 | 8,594 | 0.330 | 10.3 | 32.0% | 1,000 |
| 4/13/10 | 7.8 | 33.5 | 0.400 | 21,250 | 5,330 | 2.13 | 1.19 | 12,200 | 9,500 | | 1,280 | 658 | 348 | 1,063 | 7,031 | 8,094 | 0.330 | 11.3 | | |
| 4/14/10 | 7.6 | 33.0 | 0.400 | 20,800 | 5,510 | 2.14 | 1.21 | 12,600 | 9,500 | | 1,300 | 695 | 279 | 1,250 | 7,531 | 8,781 | 0.330 | 11.8 | 30.0% | 1,200 |
| 4/15/10 | 7.6 | 33.5 | 0.400 | 22,550 | 5,670 | 2.51 | 1.37 | 15,400 | 10,700 | | 1,360 | 763 | 251 | 1,563 | 7,281 | 8,844 | 0.330 | 17.1 | 30.0% | 2,000 |
| 4/16/10 | 8.0 | 35.5 | 0.400 | | | | | | | | | | | 969 | 7,781 | 8,750 | 0.330 | 16.7 | | |
| Average | 7.6 | 34.9 | 0.332 | 26,186 | 5,630 | 2.60 | 1.58 | 17,703 | 13,350 | 3,440 | 1,462 | 860 | 297 | 1,770 | 7,173 | 8,944 | 0.263 | 14.6 | 31.2% | 1,579 |
| Minimum | 7.2 | 33.0 | 0.100 | 20,800 | 4,970 | 2.13 | 1.19 | 12,200 | 9,500 | 3,200 | 1,250 | 563 | 188 | 906 | 6,406 | 8,094 | 0.080 | 9.1 | 26.0% | 200 |
| Maximum | 8.0 | 36.0 | 0.500 | 30,250 | 6,360 | 2.85 | 1.75 | 20,500 | 15,700 | 3,860 | 1,700 | 1,175 | 378 | 2,412 | 7,781 | 9,375 | 0.380 | 22.3 | 36.0% | 2,000 |

APPENDIX E

Phase III Raw Data

**Phase IV**

Influent Feed Characterization

April 22, 2010 – June 16, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/22/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/23/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/24/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/25/10 | Blend #1 | Feed #12 | 5.5 | 104,800 | 63,300 | 5.63 | 4.72 | 21,900 | 20,900 | 1,408 | 231 | 1,350 | 554 |
| 4/26/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 4/27/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 4/28/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 4/29/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 4/30/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/1/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/2/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/3/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/4/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/5/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/6/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/7/10 | Blend #1 | Feed #13 | 4.6 | 102,600 | 58,600 | 4.54 | 3.65 | 19,300 | 18,900 | 1,416 | 251 | 1,330 | 628 |
| 5/8/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/9/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/10/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/11/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/12/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/13/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/14/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/15/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/16/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/17/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/18/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/19/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/20/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/21/10 | Blend #1 | Feed #14 | 4.9 | 100,300 | 57,150 | 4.60 | 3.72 | 21,600 | 21,200 | 1,408 | 233 | 1,305 | 615 |
| 5/22/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/23/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/24/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/25/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/26/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/27/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/28/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/29/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/30/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 5/31/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 6/1/10 | Blend #1 | Feed #15 | 4.2 | 105,400 | 58,100 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,335 | 618 |
| 6/2/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/3/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/4/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/5/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/6/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/7/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/8/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/9/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/10/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/11/10 | Blend #1 | Feed #16 | 4.2 | 105,300 | 61,500 | 4.77 | 3.91 | 22,400 | 21,700 | 1,432 | 214 | 1,310 | 600 |
| 6/12/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/13/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/14/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |

**Phase III**

Influent Feed Characterization (Cont.)

April 22, 2010 – June 16, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/15/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/16/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| | | | | | | | | | | | | | |
| Average | | | 4.6 | 102,830 | 59,694 | 4.64 | 3.76 | 20,804 | 20,354 | 1,418 | 230 | 1,314 | 625 |
| Minimum | | | 4.2 | 98,300 | 57,150 | 4.38 | 3.52 | 18,900 | 18,600 | 1,402 | 209 | 1,230 | 554 |
| Maximum | | | 5.5 | 105,400 | 66,450 | 5.63 | 4.72 | 22,400 | 22,200 | 1,470 | 251 | 1,350 | 770 |

**Phase III**

Digester 1 Operations Data

April 22, 2010 - June 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/22/10 | 7.6 | 35.5 | 0.400 | | | | | | | | | | | 1,031 | 6,719 | 7,750 | 0.330 | | | |
| 4/23/10 | 7.6 | | 0.400 | | | | | | | | | | | | | | | | | |
| 4/24/10 | 7.9 | 35.5 | 0.400 | | | | | | | | | | | 906 | 6,938 | 7,844 | 0.480 | | | |
| 4/25/10 | 7.9 | 35.5 | 0.400 | | | | | | | | | | | | | | | | | |
| 4/26/10 | 7.3 | 35.5 | 0.400 | 22,050 | 5,820 | 2.28 | 1.20 | 13,800 | 10,400 | | 1,150 | 693 | 362 | 1,594 | 6,875 | 8,469 | 0.730 | | | |
| 4/27/10 | 7.1 | 35.5 | 0.400 | | | | | | | | | | | 2,438 | 5,656 | 8,094 | 0.280 | | | |
| 4/28/10 | 7.3 | 35.0 | 0.400 | 21,550 | 5,640 | 2.40 | 1.29 | 12,000 | 10,200 | | 1,135 | 703 | 368 | 1,781 | 6,313 | 8,094 | 0.280 | | | |
| 4/29/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,781 | 6,156 | 7,938 | 0.280 | | | |
| 4/30/10 | 7.4 | 35.5 | 0.000 | 19,850 | 5,340 | 2.54 | 1.26 | 16,800 | 10,500 | | 1,135 | 680 | 366 | 1,750 | 6,594 | 8,344 | 0.130 | | | |
| 5/1/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,562 | 5,594 | 7,156 | 0.080 | | | |
| 5/2/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,562 | 5,438 | 7,000 | 0.230 | | | |
| 5/3/10 | 7.3 | 35.5 | 0.400 | 22,450 | 5,710 | 2.53 | 1.29 | 15,800 | 10,900 | | 1,110 | 658 | 363 | 1,687 | 5,813 | 7,500 | 0.380 | | | |
| 5/4/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,500 | 6,000 | 7,500 | 0.430 | | | |
| 5/5/10 | 7.3 | 35.5 | 0.430 | 21,600 | 5,660 | 2.60 | 1.36 | 17,300 | 11,700 | | 1,030 | 718 | 368 | 1,594 | 5,844 | 7,438 | 0.380 | | | |
| 5/6/10 | 7.3 | 35.5 | 0.450 | | | | | | | | | | | 1,406 | 5,875 | 7,281 | 0.380 | | | |
| 5/7/10 | 7.4 | 35.5 | 0.100 | 20,250 | 4,950 | 2.60 | 1.34 | 17,200 | 11,100 | | 1,075 | 765 | 349 | 1,563 | 6,313 | 7,875 | 0.130 | | | |
| 5/8/10 | 7.1 | 35.5 | 0.500 | | | | | | | | | | | 2,375 | 5,469 | 7,844 | 0.180 | | | |
| 5/9/10 | | | 0.500 | | | | | | | | | | | | | | | | | |
| 5/10/10 | 7.0 | 35.5 | 0.500 | 20,300 | 4,770 | 2.29 | 1.21 | 12,800 | 10,300 | | 955 | 595 | 339 | 1,907 | 4,906 | 6,813 | 0.630 | | | |
| 5/11/10 | 7.4 | 35.5 | 0.500 | | | | | | | | | | | 968 | 5,563 | 6,531 | 0.380 | | | |
| 5/12/10 | 7.5 | 35.5 | 0.500 | 21,150 | 4,910 | 2.88 | 1.45 | 18,300 | 11,600 | | 970 | 760 | 357 | 1,594 | 5,500 | 7,094 | 0.780 | | | |
| 5/13/10 | 7.5 | 35.5 | 0.550 | | | | | | | | | | | 1,125 | 5,469 | 6,594 | 0.480 | | | |
| 5/14/10 | 7.4 | 35.5 | 0.600 | 22,450 | 4,730 | 2.86 | 1.42 | 18,000 | 11,300 | | 975 | 638 | 354 | 1,688 | 5,531 | 7,219 | 0.480 | | | |
| 5/15/10 | 7.5 | 35.5 | 0.600 | | | | | | | | | | | 1,062 | 5,438 | 6,500 | 0.480 | | | |
| 5/16/10 | 7.5 | 35.5 | 0.600 | | | | | | | | | | | 1,094 | 5,531 | 6,625 | 0.480 | | | |
| 5/17/10 | 7.5 | 35.5 | 0.600 | 22,500 | 4,460 | 2.80 | 1.50 | 19,500 | 12,500 | | 870 | 650 | 359 | 1,219 | 5,625 | 6,844 | 0.480 | | 34.0% | 2,000 |
| 5/18/10 | 7.4 | 35.5 | 0.600 | 22,450 | 4,410 | 2.57 | 1.43 | 16,300 | 11,700 | | 860 | 628 | | 1,281 | 5,031 | 6,313 | 0.530 | 24.8 | 32.0% | 2,000 |
| 5/19/10 | 7.3 | 35.5 | 0.600 | 21,700 | 4,220 | 2.78 | 1.39 | 19,200 | 12,500 | 3,100 | 845 | 708 | 357 | 1,750 | 4,781 | 6,531 | 0.580 | 26.5 | 34.0% | 2,000 |
| 5/20/10 | 7.5 | 36.0 | 0.600 | 22,850 | 4,240 | 2.76 | 1.64 | 16,500 | 11,500 | | 865 | 768 | | 1,218 | 5,313 | 6,531 | 0.430 | 23.1 | 34.0% | 2,000 |
| 5/21/10 | 7.4 | 35.5 | 0.600 | 23,050 | 4,430 | 2.78 | 1.44 | 18,500 | 11,800 | | 840 | 720 | 364 | 1,500 | 5,063 | 6,563 | 0.555 | | 34.0% | 2,000 |
| 5/22/10 | 7.5 | 35.5 | 0.600 | 21,600 | 4,320 | 2.44 | 1.31 | 14,600 | 10,300 | | 795 | 670 | | 1,125 | 5,125 | 6,250 | 0.530 | 22.0 | 34.0% | 2,000 |
| 5/23/10 | 7.4 | 35.5 | 0.600 | 21,250 | 4,280 | 2.70 | 1.35 | 17,500 | 10,800 | | 705 | 598 | 362 | 1,219 | 5,031 | 6,250 | 0.530 | 21.8 | 34.0% | 2,000 |
| 5/24/10 | 7.4 | 35.5 | 0.600 | 20,950 | 4,020 | 2.58 | 1.28 | 16,600 | 11,000 | | 800 | | | 1,062 | 4,969 | 6,031 | 0.530 | 19.5 | 32.0% | 2,000 |
| 5/25/10 | 7.4 | 35.5 | 0.600 | 21,100 | 3,990 | 2.79 | 1.42 | 18,700 | 12,000 | | 780 | 680 | 366 | 1,094 | 5,031 | 6,125 | 0.580 | 20.7 | 34.0% | 2,000 |
| 5/26/10 | 7.4 | 35.5 | 0.600 | 21,750 | 4,090 | 2.50 | 1.27 | 15,300 | 10,900 | | 795 | | | 1,031 | 4,938 | 5,969 | 0.530 | 25.9 | 34.0% | 2,000 |
| 5/27/10 | 7.3 | 35.5 | 0.600 | | | 2.72 | 1.33 | 17,600 | 11,800 | 3,975 | 710 | 735 | 366 | 1,094 | 4,781 | 5,875 | 0.430 | 25.9 | 34.0% | 2,000 |
| 5/28/10 | 7.4 | 35.5 | 0.600 | 22,850 | 4,170 | 2.71 | 1.30 | 17,000 | 11,000 | | 800 | | | 1,063 | 5,031 | 6,094 | 0.480 | 22.9 | | |
| 5/29/10 | 7.5 | 35.5 | 0.600 | 20,650 | 4,220 | 2.42 | 1.20 | 16,400 | 10,800 | | 800 | 693 | 379 | 1,250 | 4,875 | 6,125 | 0.580 | 23.6 | | |
| 5/30/10 | 7.4 | 35.5 | 0.600 | 21,450 | 4,360 | 2.61 | 1.29 | 15,500 | 9,800 | | | | | 1,313 | 4,906 | 6,219 | 0.530 | 29.7 | | |

**Phase III**

Digester 1 Operations Data

April 22, 2010 - June 16, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/31/10 | 7.4 | 35.5 | 0.600 | 18,350 | 4,110 | 2.49 | 1.23 | 14,900 | 9,800 | | 800 | 665 | 386 | 1,188 | 4,906 | 6,094 | 0.480 | 29.2 | | |
| 6/1/10 | 7.4 | 35.5 | 0.600 | 18,750 | 4,220 | 2.45 | 1.23 | 14,600 | 10,100 | | | | | 1,125 | 4,625 | 5,750 | 0.630 | 28.4 | | |
| 6/2/10 | 7.4 | 35.5 | 0.600 | 18,500 | 4,110 | 2.32 | 1.17 | 14,100 | 8,900 | | 785 | 718 | 379 | 1,062 | 4,688 | 5,750 | 0.480 | 29.4 | | |
| 6/3/10 | 7.3 | 35.5 | 0.600 | 18,650 | 4,480 | 2.18 | 1.16 | 13,200 | 9,400 | | | | | 1,093 | 4,688 | 5,781 | 0.530 | 29.5 | | |
| 6/4/10 | 7.4 | 35.5 | 0.600 | 18,150 | 4,070 | 2.46 | 1.24 | 15,800 | 10,000 | | 705 | 705 | 392 | 906 | 4,500 | 5,406 | 0.530 | | | |
| 6/5/10 | 7.4 | 35.5 | 0.600 | | | | | | | | | | | 1,156 | 4,688 | 5,844 | 0.580 | | | |
| 6/6/10 | 7.3 | 35.5 | 0.600 | | | | | | | | | | | 1,250 | 4,625 | 5,875 | 0.580 | | | |
| 6/7/10 | 7.4 | 35.5 | 0.600 | 18,850 | 4,180 | 2.25 | 1.16 | 14,500 | 9,300 | | 745 | 750 | 389 | 1,219 | 4,625 | 5,844 | 0.530 | | | |
| 6/8/10 | 7.4 | 35.5 | 0.650 | | | | | | | | | | | 1,063 | 4,625 | 5,688 | 0.580 | | | |
| 6/9/10 | 7.4 | 36.0 | 0.650 | 18,650 | 4,030 | 2.26 | 1.13 | 13,300 | 9,100 | | 715 | 715 | 387 | 1,093 | 4,563 | 5,656 | 0.580 | | | |
| 6/10/10 | 7.3 | 35.5 | 0.650 | | | | | | | | | | | 1,125 | 4,469 | 5,594 | 0.630 | | | |
| 6/11/10 | 7.3 | 35.5 | 0.625 | 18,700 | 3,870 | 2.22 | 1.12 | 12,600 | 9,100 | | 740 | 635 | 399 | 1,094 | 4,406 | 5,500 | 0.580 | | | |
| 6/12/10 | 7.4 | 36.0 | 0.660 | | | | | | | | | | | 1,125 | 4,375 | 5,500 | 0.630 | | | |
| 6/13/10 | 7.4 | 36.0 | 0.400 | | | | | | | | | | | 969 | 4,344 | 5,313 | 0.430 | | | |
| 6/14/10 | 7.5 | 36.0 | 0.100 | 16,950 | 3,700 | 2.39 | 1.16 | 14,200 | 9,100 | | 725 | 760 | 402 | 938 | 4,750 | 5,688 | 0.130 | | | |
| 6/15/10 | 7.5 | 35.5 | 0.300 | | | | | | | | | | | 844 | 4,656 | 5,500 | 0.180 | | | |
| 6/16/10 | 7.3 | 35.5 | 0.700 | 18,350 | 3,980 | 2.19 | 1.11 | 12,000 | 9,300 | | 665 | 575 | 383 | 1,313 | 4,250 | 5,563 | 0.680 | | | |
| Average | 7.4 | 35.5 | 0.510 | 20,616 | 4,484 | 2.53 | 1.29 | 15,770 | 10,621 | 3,538 | 863 | 688 | 371 | 1,316 | 5,242 | 6,558 | 0.462 | 25.18 | 33.6% | 2,000 |
| Minimum | 7.0 | 35.0 | 0.000 | 16,950 | 3,700 | 2.18 | 1.11 | 12,000 | 8,900 | 3,100 | 665 | 575 | 339 | 844 | 4,250 | 5,313 | 0.080 | 19.50 | 32.0% | 2,000 |
| Maximum | 7.9 | 36.0 | 0.700 | 23,050 | 5,820 | 2.88 | 1.64 | 19,500 | 12,500 | 3,975 | 1,150 | 768 | 402 | 2,438 | 6,938 | 8,469 | 0.780 | 29.70 | 34.0% | 2,000 |

**Phase III**

Digester 5 Operations Data

April 22, 2010 - June 16 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/22/10 | 7.9 | 33.5 | 0.400 | | | | | | | | | | | 718 | 7,063 | 7,781 | | | | |
| 4/23/10 | 7.5 | | 0.400 | | | | | | | | | | | | | | | | | |
| 4/24/10 | 7.9 | 33.5 | 0.400 | | | | | | | | | | | 1,281 | 7,375 | 8,656 | | | | |
| 4/25/10 | 7.9 | 35.5 | 0.400 | | | | | | | | | | | | | | | | | |
| 4/26/10 | 7.3 | 35.0 | 0.400 | 24,450 | 6,300 | 2.67 | 1.50 | 18,500 | 12,700 | | 1,305 | 920 | 357 | 2,063 | 5,094 | 7,156 | 0.050 | | | |
| 4/27/10 | 7.1 | 35.0 | 0.400 | | | | | | | | | | | 1,625 | 5,438 | 7,063 | | | | |
| 4/28/10 | 7.3 | 35.5 | 0.500 | 27,050 | 6,240 | 3.06 | 1.66 | 22,300 | 14,500 | | 1,195 | 1,185 | 355 | 1,375 | 5,594 | 7,063 | 0.050 | | | |
| 4/29/10 | 7.3 | 35.5 | 0.500 | | | | | | | | | | | 1,531 | 5,625 | 7,156 | | | | |
| 4/30/10 | 7.4 | 35.5 | 0.500 | 27,050 | 6,070 | 3.03 | 1.60 | 22,500 | 15,000 | | 1,240 | 1,450 | 359 | 1,219 | 5,875 | 7,094 | 0.050 | | | |
| 5/1/10 | 7.4 | 35.5 | 0.500 | | | | | | | | | | | 1,344 | 6,531 | 7,875 | | | | |
| 5/2/10 | 7.3 | 35.5 | 0.500 | | | | | | | | | | | 1,218 | 5,813 | 7,031 | | | | |
| 5/3/10 | 7.3 | 35.5 | 0.500 | 31,200 | 6,380 | 3.07 | 1.85 | 21,600 | 16,200 | | 1,180 | 1,220 | 349 | 1,625 | 5,406 | 7,031 | 0.040 | | | |
| 5/4/10 | 7.3 | 35.5 | 0.520 | | | | | | | | | | | 1,344 | 5,844 | 7,188 | | | | |
| 5/5/10 | 7.3 | 35.5 | 0.530 | 31,050 | 6,580 | 3.28 | 1.90 | 24,500 | 16,800 | | 1,170 | 1,040 | 367 | 1,344 | 5,375 | 6,719 | 0.050 | | | |
| 5/6/10 | 7.3 | 35.5 | 0.530 | | | | | | | | | | | 1,281 | 5,813 | 7,094 | | | | |
| 5/7/10 | 7.2 | 34.5 | 0.600 | 28,400 | 5,880 | 3.11 | 1.77 | 21,800 | 15,300 | | 1,115 | 1,245 | 357 | 1,500 | 5,594 | 7,094 | 0.050 | | | |
| 5/8/10 | 7.2 | 34.5 | 0.600 | | | | | | | | | | | 1,250 | 5,406 | 6,656 | | | | |
| 5/9/10 | | | 0.600 | | | | | | | | | | | | | | | | | |
| 5/10/10 | 7.1 | 34.5 | 0.600 | 29,900 | 4,910 | 3.61 | 2.10 | 26,600 | 17,800 | | 1,055 | 1,250 | 315 | 1,687 | 4,938 | 6,625 | 0.040 | | | |
| 5/11/10 | 7.4 | 35.0 | 0.400 | | | | | | | | | | | 593 | 6,188 | 6,781 | | | | |
| 5/12/10 | 7.5 | 34.5 | 0.400 | 29,550 | 5,180 | 2.96 | 1.75 | 19,200 | 14,800 | | 1,000 | 1,090 | 359 | 1,188 | 5,500 | 6,688 | 0.040 | | | |
| 5/13/10 | 7.4 | 35.0 | 0.500 | | | | | | | | | | | 938 | 5,781 | 6,719 | | | | |
| 5/14/10 | 7.4 | 35.0 | 0.600 | 31,500 | 5,280 | 3.53 | 2.01 | 23,900 | 15,800 | | 1,030 | 1,185 | 364 | 1,000 | 5,438 | 6,438 | 0.040 | | | |
| 5/15/10 | 7.5 | 34.0 | 0.600 | | | | | | | | | | | 1,000 | 5,375 | 6,375 | | | | |
| 5/16/10 | 7.5 | 34.0 | 0.600 | | | | | | | | | | | 1,219 | 5,469 | 6,688 | | | | |
| 5/17/10 | 7.5 | 33.5 | 0.600 | 32,150 | 4,900 | 3.67 | 2.14 | 26,500 | 18,100 | | 970 | 1,520 | 378 | 1,125 | 5,250 | 6,375 | 0.050 | | 34.0% | 2,000 |
| 5/18/10 | 7.4 | 34.5 | 0.600 | 30,500 | 4,890 | 3.46 | 2.08 | 24,700 | 17,000 | | 990 | 1,360 | | 1,375 | 5,063 | 6,438 | 0.050 | 26.8 | 34.0% | 2,000 |
| 5/19/10 | 7.3 | 35.0 | 0.600 | 31,300 | 4,750 | 3.18 | 1.95 | 22,700 | 16,900 | 4,225 | 1,020 | 1,300 | 376 | 1,375 | 4,844 | 6,219 | 0.050 | 28.0 | 36.0% | 2,000 |
| 5/20/10 | 7.5 | 34.5 | 0.600 | 31,350 | 4,790 | 3.46 | 1.89 | 24,200 | 17,200 | | 1,025 | 1,480 | | 1,188 | 5,375 | 6,563 | 0.050 | 21.2 | 34.0% | 2,000 |
| 5/21/10 | 7.5 | 34.5 | 0.600 | 31,900 | 5,170 | 3.28 | 2.01 | 22,300 | 15,900 | | 1,050 | 1,340 | 385 | 1,188 | 5,406 | 6,594 | 0.050 | 25.0 | 34.0% | 2,000 |
| 5/22/10 | 7.5 | 34.5 | 0.600 | 33,000 | 5,650 | 3.19 | 1.89 | 22,000 | 15,300 | | 1,060 | 1,305 | | 1,156 | 5,438 | 6,594 | 0.050 | 22.4 | 34.0% | 2,000 |
| 5/23/10 | 7.4 | 34.0 | 0.600 | 35,300 | 5,470 | 3.56 | 2.10 | 26,000 | 17,700 | | 1,065 | 1,540 | 386 | 1,406 | 4,844 | 6,250 | 0.050 | 27.3 | 34.0% | 2,000 |
| 5/24/10 | 7.5 | 34.0 | 0.600 | 32,750 | 5,220 | 3.60 | 2.06 | 27,800 | 18,400 | | 1,060 | | | 1,281 | 5,219 | 6,500 | 0.050 | 21.0 | 32.0% | 2,000 |
| 5/25/10 | 7.5 | 34.0 | 0.600 | 32,750 | 5,360 | 3.62 | 2.13 | 26,000 | 17,700 | | 1,040 | 1,190 | 394 | 1,187 | 5,438 | 6,625 | 0.050 | 25.0 | 34.0% | 2,000 |
| 5/26/10 | 7.5 | 34.5 | 0.600 | 35,250 | 5,650 | 3.72 | 2.23 | 26,100 | 17,700 | | 1,055 | | | 1,219 | 5,344 | 6,563 | 0.050 | 28.4 | 34.0% | 2,000 |
| 5/27/10 | 7.4 | 34.5 | 0.600 | 36,450 | 7,050 | 3.32 | 2.01 | 23,800 | 17,300 | 3,750 | 1,035 | 1,535 | 396 | 1,375 | 5,031 | 6,406 | 0.050 | 26.9 | 34.0% | 2,000 |
| 5/28/10 | 7.5 | 34.5 | 0.600 | 33,200 | 5,120 | 3.33 | 1.96 | 24,500 | 17,200 | | | | | 1,031 | 5,344 | 6,375 | 0.050 | 28.2 | | |
| 5/29/10 | 7.5 | 34.0 | 0.600 | 33,550 | 5,640 | 3.07 | 1.89 | 22,300 | 1,700 | | 960 | 1,535 | 410 | 1,063 | 5,281 | 6,344 | 0.050 | 31.7 | | |
| 5/30/10 | 7.4 | 34.5 | 0.600 | 35,750 | 5,300 | 3.53 | 2.16 | 24,600 | 16,900 | | | | | 1,250 | 5,094 | 6,344 | 0.050 | 29.4 | | |

**Phase III**

Digester 5 Operations Data

April 22, 2010 - June 16 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5/31/10 | 7.5 | 34.5 | 0.600 | 29,250 | 5,270 | 3.36 | 1.93 | 24,900 | 16,600 | | 945 | 1,425 | 407 | 1,093 | 5,063 | 6,156 | 0.050 | 29.8 | | |
| 6/1/10 | 7.5 | 34.5 | 0.600 | 32,250 | 5,020 | 3.52 | 2.10 | 24,600 | 1,700 | | | | | 1,188 | 5,000 | 6,188 | 0.050 | 28.9 | | |
| 6/2/10 | 7.4 | 34.5 | 0.600 | 31,800 | 4,750 | 3.44 | 2.05 | 21,800 | 15,300 | | 945 | 1,745 | 401 | 1,093 | 5,063 | 6,156 | 0.050 | 32.8 | | |
| 6/3/10 | 7.4 | 34.5 | 0.600 | 36,150 | 4,910 | 3.81 | 2.23 | 28,200 | 18,500 | | | | | 1,156 | 5,063 | 6,219 | 0.050 | 30.5 | | |
| 6/4/10 | 7.5 | 34.5 | 0.600 | 33,600 | 4,950 | 3.66 | 2.20 | 27,300 | 19,100 | | 925 | 1,775 | 414 | 1,000 | 5,125 | 6,125 | 0.050 | | | |
| 6/5/10 | 7.5 | 35.0 | 0.600 | | | | | | | | | | | 1,125 | 5,031 | 6,156 | | | | |
| 6/6/10 | 7.4 | 35.0 | 0.620 | | | | | | | | | | | 1,094 | 4,500 | 5,594 | | | | |
| 6/7/10 | 7.4 | 34.5 | 0.630 | 37,850 | 4,970 | 4.39 | 2.48 | 34,400 | 21,300 | | 910 | 2,215 | 403 | 1,344 | 4,719 | 6,063 | 0.050 | | | |
| 6/8/10 | 7.4 | 34.0 | 0.700 | | | | | | | | | | | 1,125 | 4,969 | 6,094 | | | | |
| 6/9/10 | 7.4 | 34.5 | 0.700 | 34,350 | 4,650 | 3.78 | 2.23 | 27,000 | 18,100 | | 860 | 1,540 | 409 | 1,156 | 4,594 | 5,750 | 0.050 | | | |
| 6/10/10 | 7.4 | 34.5 | 0.700 | | | | | | | | | | | 1,219 | 4,781 | 6,000 | | | | |
| 6/11/10 | 7.4 | 34.5 | 0.730 | 35,650 | 4,440 | 4.25 | 2.47 | 33,400 | 21,300 | | 900 | 1,610 | 417 | 1,188 | 4,750 | 5,938 | 0.050 | | | |
| 6/12/10 | 7.5 | 35.0 | 0.740 | | | | | | | | | | | 1,031 | 4,844 | 5,875 | | | | |
| 6/13/10 | 7.3 | 35.0 | 0.800 | | | | | | | | | | | 1,125 | 4,813 | 5,938 | | | | |
| 6/14/10 | 7.4 | 35.0 | 0.800 | 35,700 | 4,380 | 4.54 | 2.62 | 35,700 | 22,300 | | 820 | 1,955 | 404 | 1,188 | 4,531 | 5,719 | 0.050 | | | |
| 6/15/10 | 7.4 | 34.5 | 0.800 | | | | | | | | | | | 1,281 | 4,438 | 5,719 | | | | |
| 6/16/10 | 7.4 | 35.0 | 0.800 | 35,400 | 4,330 | 4.06 | 2.38 | 31,000 | 20,700 | | 805 | 1,130 | 400 | 1,125 | 4,594 | 5,719 | 0.050 | | | |
| | | | | | | | | | | | | | | | | | | | | |
| Average | 7.4 | 34.7 | 0.580 | 32,344 | 5,317 | 3.49 | 2.04 | 25,233 | 16,327 | 3,988 | 1,025 | 1,411 | 382 | 1,228 | 5,309 | 6,539 | 0.049 | 27.25 | 34.0% | 2,000 |
| Minimum | 7.1 | 33.5 | 0.400 | 24,450 | 4,330 | 2.67 | 1.50 | 18,500 | 1,700 | 3,750 | 805 | 920 | 315 | 593 | 4,438 | 5,594 | 0.040 | 21.00 | 32.0% | 2,000 |
| Maximum | 7.9 | 35.5 | 0.800 | 37,850 | 7,050 | 4.54 | 2.62 | 35,700 | 22,300 | 4,225 | 1,305 | 2,215 | 417 | 2,063 | 7,375 | 8,656 | 0.050 | 32.80 | 36.0% | 2,000 |

# APPENDIX F

## Phase IV Raw Data

**Phase IV**

Influent Feed Characterization

June 17, 2010 - December 10, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/17/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/18/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/19/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/20/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/21/10 | Blend #1 | Feed #17 | 4.3 | 98,300 | 66,450 | 4.51 | 3.62 | 22,300 | 22,200 | 1,470 | 250 | 1,230 | 770 |
| 6/22/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/23/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/24/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/25/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/26/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/27/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/28/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/29/10 | Blend #1 | Feed #18 | 4.2 | 98,400 | 56,450 | 4.12 | 3.22 | 20,400 | 20,100 | 1,360 | 207 | 1,290 | 650 |
| 6/30/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/1/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/2/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/3/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/4/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/5/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/6/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/7/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/8/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/9/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/10/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/11/10 | Blend #1 | Feed #19 | 4.2 | 101,100 | 59,350 | 4.12 | 3.22 | 19,800 | 19,200 | 1,770 | 204 | 1,380 | 650 |
| 7/12/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/13/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/14/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/15/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/16/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/17/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/18/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/19/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/20/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/21/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/22/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/23/10 | Blend #1 | Feed #20 | 4.2 | 98,600 | 44,350 | 4.24 | 3.37 | 23,000 | 22,700 | 1,410 | 193 | 1,700 | 733 |
| 7/24/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/25/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/26/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/27/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/28/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/29/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/30/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 7/31/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/1/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/2/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/3/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/4/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/5/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/6/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/7/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/8/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/9/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/10/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/11/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |

**Phase IV**

Influent Feed Characterization (Cont.)

June 17, 2010 - December 10, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/12/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/13/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/14/10 | Blend #1 | Feed #21 | 4.3 | 97,100 | 50,150 | 4.42 | 3.54 | 22,900 | 22,200 | 1,650 | 215 | 1,465 | 723 |
| 8/15/10 | Blend #1 | | | | | | | | | | | | |
| 8/16/10 | Blend #1 | | | | | | | | | | | | |
| 8/17/10 | Blend #1 | | | | | | | | | | | | |
| 8/18/10 | Blend #1 | | | | | | | | | | | | |
| 8/19/10 | Blend #1 | | | | | | | | | | | | |
| 8/20/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/21/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/22/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/23/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/24/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/25/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/26/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/27/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/28/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/29/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/30/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 8/31/10 | Blend #1 | Feed #22 | 4.2 | 114,500 | 48,250 | 5.49 | 4.78 | 28,300 | 27,900 | 1,430 | 184 | 1,375 | 700 |
| 9/1/10 | Blend #1 | | | | | | | | | | | | |
| 9/2/10 | Blend #1 | | | | | | | | | | | | |
| 9/3/10 | Blend #1 | | | | | | | | | | | | |
| 9/4/10 | Blend #1 | | | | | | | | | | | | |
| 9/5/10 | Blend #1 | | | | | | | | | | | | |
| 9/6/10 | Blend #1 | | | | | | | | | | | | |
| 9/7/10 | Blend #1 | | | | | | | | | | | | |
| 9/8/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/9/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/10/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/11/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/12/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/13/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/14/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/15/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/16/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/17/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/18/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/19/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/20/10 | Blend #1 | Feed #23 | 4.4 | 93,100 | 48,850 | 4.51 | 3.72 | 22,300 | 21,800 | 1,620 | 225 | 1,395 | 773 |
| 9/21/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/22/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/23/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/24/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/25/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/26/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/27/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/28/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/29/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 9/30/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 10/1/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 10/2/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 10/3/10 | Blend #1 | Feed #24 | 4.4 | 94,800 | 46,550 | 4.39 | 3.59 | 21,800 | 21,400 | 1,700 | 249 | 1,415 | 733 |
| 10/4/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/5/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/6/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |

**Phase IV**

Influent Feed Characterization(Cont.)

June 17, 2010 - December 10, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/7/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/8/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/9/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/10/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/11/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/12/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/13/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/14/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/15/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/16/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/17/10 | Blend #1 | Feed #25 | 4.3 | 86,400 | 46,600 | 3.92 | 3.13 | 15,900 | 15,900 | 1,650 | 230 | 1,335 | 743 |
| 10/18/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/19/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/20/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/21/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/22/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/23/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/24/10 | Blend #1 | Feed #26 | 4.4 | 105,400 | 44,850 | 3.92 | 3.12 | 19,900 | 19,400 | 1,680 | 258 | 1,405 | 753 |
| 10/25/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/26/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/27/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/28/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/29/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/30/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 10/31/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 11/1/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 11/2/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 11/3/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 11/4/10 | Blend #1 | Feed #27 | 4.4 | 93,500 | 45,550 | 3.93 | 3.14 | 20,200 | 20,200 | 1,620 | 248 | 1,415 | 743 |
| 11/5/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/6/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/7/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/8/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/9/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/10/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/11/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/12/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/13/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/14/10 | Blend #1 | Feed #28 | 4.5 | 88,700 | 42,450 | 3.74 | 2.95 | 18,500 | 18,500 | 1,630 | 241 | 1,460 | 675 |
| 11/15/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/16/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/17/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/18/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/19/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/20/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/21/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/22/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/23/10 | Blend #1 | Feed #29 | 4.5 | 90,900 | 45,050 | 3.78 | 2.96 | 18,100 | 18,000 | 1,710 | 267 | 1,520 | 750 |
| 11/24/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/25/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/26/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/27/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/28/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/29/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 11/30/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 12/1/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |

**Phase IV**

Influent Feed Characterization (Cont.)

June 17, 2010 - December 10, 2010

| Date | Feed Description | Feed Number | pH (s.u.) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | $PO_4$-P (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/2/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 12/3/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 12/4/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 12/5/10 | Blend #1 | Feed #30 | 4.5 | 89,100 | 41,350 | 3.76 | 2.86 | 18,800 | 18,800 | 1,710 | 253 | 1,530 | 753 |
| 12/6/10 | Blend #1 | Feed #31 | 4.4 | 105,100 | 52,300 | 5.13 | 4.30 | 24,200 | 23,900 | 1,740 | 290 | 1,670 | 605 |
| 12/7/10 | Blend #1 | Feed #31 | 4.4 | 105,100 | 52,300 | 5.13 | 4.30 | 24,200 | 23,900 | 1,740 | 290 | 1,670 | 605 |
| 12/8/10 | Blend #1 | Feed #31 | 4.4 | 105,100 | 52,300 | 5.13 | 4.30 | 24,200 | 23,900 | 1,740 | 290 | 1,670 | 605 |
| 12/9/10 | Blend #1 | Feed #31 | 4.4 | 105,100 | 52,300 | 5.13 | 4.30 | 24,200 | 23,900 | 1,740 | 290 | 1,670 | 605 |
| 12/10/10 | Blend #1 | Feed #31 | 4.4 | 105,100 | 52,300 | 5.13 | 4.30 | 24,200 | 23,900 | 1,740 | 290 | 1,670 | 605 |
| | | | | | | | | | | | | | |
| Average | | | 4.3 | 96,386 | 48,520 | 4.26 | 3.43 | 21,113 | 20,801 | 1,616 | 229 | 1,441 | 721 |
| Minimum | | | 4.2 | 86,400 | 41,350 | 3.74 | 2.86 | 15,900 | 15,900 | 1,360 | 184 | 1,230 | 605 |
| Maximum | | | 4.5 | 114,500 | 66,450 | 5.49 | 4.78 | 28,300 | 27,900 | 1,770 | 290 | 1,700 | 773 |

**Phase IV**

Digester 1 Operations Data

June 17, 2010 - December 10, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/17/10 | 7.4 | 36.0 | 0.200 | | | | | | | | | | | 1,063 | 4,625 | 5,688 | 0.280 | | | |
| 6/18/10 | 7.3 | 36.0 | 0.700 | 18,250 | 4,040 | 2.16 | 1.12 | 10,800 | 9,000 | | 675 | 725 | 393 | 1,437 | 4,219 | 5,656 | 0.630 | | | |
| 6/19/10 | 7.2 | 36.0 | 0.700 | | | | | | | | | | | 1,218 | 4,188 | 5,406 | 0.680 | | | |
| 6/20/10 | 7.1 | 36.5 | 0.800 | | | | | | | | | | | 1,313 | 4,000 | 5,313 | 0.780 | | | |
| 6/21/10 | 7.3 | 37.0 | 0.750 | 17,350 | 3,720 | 2.40 | 1.23 | 14,700 | 9,900 | | 565 | 678 | 382 | 1,094 | 4,156 | 5,250 | 0.680 | | | |
| 6/22/10 | 7.3 | 36.5 | 0.320 | | | | | | | | | | | 1,000 | 4,313 | 5,313 | 0.330 | | | |
| 6/23/10 | 7.3 | 36.5 | 0.200 | 18,250 | 3,900 | 2.08 | 1.01 | 11,900 | 9,000 | | 590 | 608 | 382 | 1,032 | 4,281 | 5,313 | 0.180 | | | |
| 6/24/10 | 7.3 | 37.0 | 0.750 | | | | | | | | | | | 1,219 | 4,125 | 5,344 | 0.580 | | | |
| 6/25/10 | 7.3 | 37.0 | 0.700 | 20,100 | 3,740 | 2.23 | 1.11 | 12,600 | 9,200 | | 548 | 590 | 382 | 1,125 | 3,969 | 5,094 | 0.580 | | | |
| 6/26/10 | 7.3 | 37.0 | 0.750 | 17,750 | 3,620 | 2.12 | 1.11 | 11,400 | 8,600 | | 520 | 610 | 382 | 1,187 | 4,188 | 5,375 | 0.630 | | | |
| 6/27/10 | 7.3 | 37.5 | 0.700 | | | | | | | | | | | 1,031 | 4,094 | 5,125 | 0.680 | | | |
| 6/28/10 | 7.4 | 37.0 | 0.600 | 19,050 | 3,600 | 2.12 | 1.12 | 11,700 | 8,800 | | 505 | 615 | 388 | 1,188 | 4,406 | 5,594 | 0.630 | | | |
| 6/29/10 | 7.3 | 36.5 | 0.600 | | | | | | | | | | | 1,188 | 4,281 | 5,469 | 0.280 | | | |
| 6/30/10 | 7.3 | 36.5 | 0.750 | 19,800 | 3,700 | 1.98 | 1.01 | 9,900 | 8,400 | | 500 | 595 | 378 | 1,313 | 4,563 | 5,875 | 0.680 | | | |
| 7/1/10 | 7.4 | 36.5 | 0.750 | | | | | | | | | | | 1,250 | 4,094 | 5,344 | 0.430 | | | |
| 7/2/10 | 7.3 | 36.0 | 0.700 | 18,900 | 3,700 | 2.33 | 1.20 | 13,300 | 9,300 | | 495 | 520 | 388 | 1,094 | 4,344 | 5,438 | 0.630 | | | |
| 7/3/10 | 7.3 | 36.0 | 0.700 | | | | | | | | | | | 1,031 | 4,531 | 5,563 | 0.580 | | | |
| 7/4/10 | 7.4 | 36.0 | 0.700 | 18,800 | 3,740 | 2.33 | 1.20 | 13,700 | 9,600 | | 498 | 733 | 400 | 1,000 | 4,375 | 5,375 | 0.580 | | | |
| 7/5/10 | 7.4 | 36.0 | 0.700 | | | | | | | | | | | 1,094 | 4,344 | 5,438 | 0.580 | | | |
| 7/6/10 | 7.4 | 36.0 | 0.700 | 18,050 | 3,700 | 2.27 | 1.15 | 12,300 | 9,100 | | 458 | 710 | 366 | 938 | 4,375 | 5,313 | 0.530 | | | |
| 7/7/10 | 7.4 | 35.5 | 0.700 | | | | | | | | | | | 1,094 | 4,344 | 5,438 | 0.580 | | | |
| 7/8/10 | 7.4 | 35.5 | 0.700 | 18,500 | 3,940 | 2.31 | 1.08 | 12,900 | 9,000 | | 455 | 635 | 368 | 1,125 | 4,281 | 5,406 | 0.430 | | | |
| 7/9/10 | 7.3 | 35.5 | 0.700 | | | | | | | | | | | 1,125 | 4,313 | 5,438 | 0.580 | | | |
| 7/10/10 | 7.3 | 36.0 | 0.700 | | | | | | | | | | | 1,156 | 4,250 | 5,406 | 0.580 | | | |
| 7/11/10 | 7.4 | 36.0 | 0.700 | | | | | | | | | | | 1,156 | 3,938 | 5,094 | 0.530 | | | |
| 7/12/10 | 7.1 | 36.0 | 0.700 | | | | | | | | | | | 1,469 | 3,594 | 5,063 | 0.580 | | | |
| 7/13/10 | 7.1 | 36.5 | 0.700 | 14,250 | 3,260 | | | 9,200 | 7,100 | | 227 | | 193 | 1,125 | 3,781 | 4,906 | 0.680 | | | |
| 7/14/10 | 7.1 | 36.5 | 0.700 | 21,150 | 3,160 | | | 12,800 | 9,000 | | 213 | | 182 | 1,406 | 3,813 | 5,219 | 0.580 | | | |
| 7/15/10 | 7.1 | 36.5 | 0.700 | | | | | | | | | | | 1,500 | 3,719 | 5,219 | 0.580 | | | |
| 7/16/10 | 7.1 | 36.5 | 0.700 | 18,750 | 3,060 | | | 12,200 | 8,200 | | 185 | | 202 | 1,406 | 4,063 | 5,469 | 0.680 | | | |
| 7/17/10 | 7.1 | 36.5 | 0.700 | | | | | | | | | | | 1,343 | 3,938 | 5,281 | 0.580 | | | |
| 7/18/10 | 7.0 | 36.5 | 0.700 | | | | | | | | | | | 1,375 | 3,969 | 5,344 | 0.580 | | | |
| 7/19/10 | 7.1 | 37.0 | 0.700 | 20,100 | 3,415 | | | 11,400 | 7,900 | | 203 | | 140 | 1,375 | 3,813 | 5,188 | 0.680 | | | |
| 7/20/10 | 7.2 | 36.5 | 0.700 | | | | | | | | | | | 1,062 | 3,844 | 4,906 | 0.580 | | | |
| 7/21/10 | 7.2 | 37.0 | 0.700 | 18,900 | 7,290 | | | 11,100 | 7,400 | | 241 | | 232 | 1,375 | 4,000 | 5,375 | 0.680 | | | |
| 7/22/10 | 7.0 | 37.0 | 0.700 | | | | | | | | | | | 1,406 | 3,969 | 5,375 | 0.580 | | | |
| 7/23/10 | 7.2 | 37.0 | 0.700 | | | | | | | | | | | 1,000 | 3,938 | 4,938 | 0.680 | | | |
| 7/24/10 | 7.1 | 37.0 | 0.700 | | | | | | | | | | | 1,094 | 3,375 | 4,469 | 0.580 | | | |
| 7/25/10 | 7.2 | 37.0 | 0.400 | | | | | | | | | | | 1,032 | 4,156 | 5,188 | 0.330 | | | |

**Phase IV**

Digester 1 Operations Data (Cont.)

June 17, 2010 - December 10, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/26/10 | 7.3 | 36.5 | 0.100 | | | | | | | | | | | 906 | 3,813 | 4,719 | 0.080 | | | |
| 7/27/10 | 7.2 | 36.5 | 0.300 | | | | | | | | | | | 937 | 3,938 | 4,875 | 0.230 | | | |
| 7/28/10 | 7.2 | 36.5 | 0.600 | | | | | | | | | | | 1,312 | 3,719 | 5,031 | 0.580 | 31.2 | 34.0% | 2,000 |
| 7/29/10 | 7.1 | 37.0 | 0.700 | | | | | | | | | | | 1,437 | 3,594 | 5,031 | 0.580 | 32.2 | 34.0% | 2,000 |
| 7/30/10 | 7.2 | 37.0 | 0.700 | | | | | | | | | | | 1,313 | 4,000 | 5,313 | 0.730 | 32.1 | 34.0% | 2,000 |
| 7/31/10 | 7.3 | 37.5 | 0.700 | | | | | | | | | | | 1,125 | 4,031 | 5,156 | 0.530 | | 32.0% | 2,000 |
| 8/1/10 | 7.2 | 38.0 | 0.600 | | | | | | | | | | | 1,125 | 4,344 | 5,469 | 0.630 | 16.1 | | |
| 8/2/10 | 7.2 | 38.0 | 0.700 | | | | | | | | | | | 1,125 | 4,406 | 5,531 | 0.530 | 19.4 | | |
| 8/3/10 | 7.2 | 38.0 | 0.700 | | | | | | | | | | | 1,000 | 4,250 | 5,250 | 0.630 | | | |
| 8/4/10 | 7.2 | 38.0 | 0.700 | | | | | | | | | | | 937 | 4,344 | 5,281 | 0.580 | 13.1 | | |
| 8/5/10 | 7.2 | 37.5 | 0.700 | | | | | | | | | | | 1,000 | 4,281 | 5,281 | 0.530 | 19.8 | | |
| 8/6/10 | 7.2 | 37.0 | 0.750 | | | | | | | | | | | 1,156 | 4,250 | 5,406 | 0.630 | 17.7 | | |
| 8/7/10 | 7.2 | 37.0 | 0.750 | | | | | | | | | | | 1,094 | 4,219 | 5,313 | 0.630 | 22.0 | | |
| 8/8/10 | 7.3 | 37.0 | 0.700 | | | | | | | | | | | 1,000 | 3,844 | 4,844 | 0.580 | 26.1 | | |
| 8/9/10 | 7.2 | 37.5 | 0.700 | | | | | | | | | | | 1,219 | 3,906 | 5,125 | 0.680 | 27.7 | | |
| 8/10/10 | 7.1 | 37.0 | 0.700 | | | | | | | | | | | 1,313 | 3,781 | 5,094 | 0.580 | 20.4 | | |
| 8/11/10 | 7.1 | 37.0 | 0.700 | | | | | | | | | | | 1,188 | 3,781 | 4,969 | 0.680 | | 34.0% | 6,000 |
| 8/12/10 | 7.1 | 37.5 | 0.700 | | | | | | | | | | | 1,156 | 3,500 | 4,656 | 0.730 | 36.1 | 34.0% | 5,000 |
| 8/13/10 | 7.1 | 37.5 | 0.700 | | | | | | | | | | | 1,187 | 3,594 | 4,781 | 0.580 | 33.4 | | |
| 8/14/10 | | | | | | | | | | | | | | | | | | | | |
| 8/15/10 | | | | | | | | | | | | | | | | | | | | |
| 8/16/10 | | | | | | | | | | | | | | | | | | | | |
| 8/17/10 | | | | | | | | | | | | | | | | | | | | |
| 8/18/10 | | | | | | | | | | | | | | | | | | | | |
| 8/19/10 | | | | | | | | | | | | | | | | | | | | |
| 8/20/10 | 7.1 | 36.5 | | | | | | | | | | | | 1,094 | 4,156 | 5,250 | 0.080 | | | |
| 8/21/10 | 7.0 | 37.0 | 0.700 | | | | | | | | | | | 1,000 | 4,281 | 5,281 | 0.580 | | | |
| 8/22/10 | 7.1 | 36.5 | 0.600 | | | | | | | | | | | 1,282 | 4,156 | 5,438 | 0.580 | | | |
| 8/23/10 | 7.2 | 36.5 | 0.450 | | | | | | | | | | | 1,000 | 3,906 | 4,906 | 0.530 | | | |
| 8/24/10 | 7.1 | 37.0 | 0.550 | | | | | | | | | | | 1,125 | 4,156 | 5,281 | 0.580 | | | |
| 8/25/10 | 7.1 | 36.0 | 0.700 | | | | | | | | | | | 1,094 | 3,625 | 4,719 | 0.580 | | | |
| 8/26/10 | 7.1 | 35.0 | 0.700 | | | | | | | | | | | 1,563 | 3,500 | 5,063 | 0.730 | | | |
| 8/27/10 | 7.0 | 34.5 | 0.700 | | | | | | | | | | | 1,875 | 3,063 | 4,938 | 0.530 | | | |
| 8/28/10 | 6.9 | 35.0 | 0.700 | | | | | | | | | | | 2,219 | 2,969 | 5,188 | 0.580 | | | |
| 8/29/10 | 6.9 | 35.0 | 0.700 | | | | | | | | | | | 2,156 | 2,844 | 5,000 | 0.630 | | | |
| 8/30/10 | 7.0 | 36.0 | 0.700 | | | | | | | | | | | 2,344 | 2,844 | 5,188 | 0.580 | | | |
| 8/31/10 | | | | | | | | | | | | | | | | | | | | |
| 9/1/10 | | | | | | | | | | | | | | | | | | | | |
| 9/2/10 | | | | | | | | | | | | | | | | | | | | |

**Phase IV**

Digester 1 Operations Data (Cont.)

June 17, 2010 - December 10, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/3/10 | | | | | | | | | | | | | | | | | | | | |
| 9/4/10 | | | | | | | | | | | | | | | | | | | | |
| 9/5/10 | | | | | | | | | | | | | | | | | | | | |
| 9/6/10 | | | | | | | | | | | | | | | | | | | | |
| 9/7/10 | | | | | | | | | | | | | | | | | | | | |
| 9/8/10 | 7.2 | 35.0 | | | | | | | | | | | | 1,031 | 4,313 | 5,344 | 0.080 | | | |
| 9/9/10 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,062 | 4,563 | 5,625 | 0.430 | | | |
| 9/10/10 | 7.2 | 35.5 | 0.500 | | | | | | | | | | | 1,344 | 4,625 | 5,969 | 0.480 | | | |
| 9/11/10 | 7.2 | 35.5 | 0.650 | | | | | | | | | | | 1,312 | 4,344 | 5,656 | 0.580 | | | |
| 9/12/10 | 7.2 | 35.0 | 0.550 | | | | | | | | | | | 1,406 | 4,313 | 5,719 | 0.580 | | | |
| 9/13/10 | 7.2 | 35.0 | 0.600 | | | | | | | | | | | 1,344 | 4,000 | 5,344 | 0.380 | | | |
| 9/14/10 | 7.2 | 35.5 | 0.600 | | | | | | | | | | | 1,281 | 4,219 | 5,500 | 0.530 | | | |
| 9/15/10 | 7.1 | 35.5 | 0.650 | | | | | | | | | | | 1,656 | 4,000 | 5,656 | 0.550 | | | |
| 9/16/10 | 7.2 | 35.5 | 0.650 | | | | | | | | | | | 1,344 | 4,250 | 5,594 | 0.580 | | | |
| 9/17/10 | 7.2 | 35.0 | 0.700 | | | | | | | | | | | 1,531 | 4,219 | 5,750 | 0.580 | | | |
| 9/18/10 | 7.2 | 35.5 | 0.700 | | | | | | | | | | | 1,250 | 3,969 | 5,219 | 0.680 | | | |
| 9/19/10 | 7.3 | 35.5 | 0.700 | | | | | | | | | | | 1,375 | 4,063 | 5,438 | 0.630 | | | |
| 9/20/10 | 7.2 | 35.5 | 0.750 | | | | | | | | | | | 1,312 | 3,969 | 5,281 | 0.780 | | | |
| 9/21/10 | 7.2 | 35.5 | 0.750 | | | | | | | | | | | 1,344 | 3,969 | 5,313 | 0.680 | | | |
| 9/22/10 | 7.3 | 35.5 | 0.100 | | | | | | | | | | | 969 | 4,500 | 5,469 | 0.080 | | | |
| 9/23/10 | 7.2 | 35.5 | 0.750 | | | | | | | | | | | 1,281 | 4,094 | 5,375 | 0.630 | | | |
| 9/24/10 | 7.2 | 35.5 | 0.750 | | | | | | | | | | | 1,531 | 4,094 | 5,625 | 0.680 | | | |
| 9/25/10 | 7.2 | 35.5 | 0.700 | | | | | | | | | | | 1,281 | 4,125 | 5,406 | 0.630 | | | |
| 9/26/10 | 7.2 | 35.0 | 0.750 | | | | | | | | | | | 1,312 | 4,094 | 5,406 | 0.680 | | | |
| 9/27/10 | 7.1 | 35.0 | 0.750 | | | | | | | | | | | 1,500 | 3,969 | 5,469 | 0.830 | | | |
| 9/28/10 | 7.1 | 35.5 | 0.750 | | | | | | | | | | | 2,219 | 3,594 | 5,813 | 0.580 | | | |
| 9/29/10 | 7.1 | 35.5 | 0.750 | | | | | | | | | | | 1,625 | 3,469 | 5,094 | 0.580 | | | |
| 9/30/10 | 7.1 | 35.5 | 0.750 | | | | | | | | | | | 2,281 | 3,469 | 5,750 | 0.730 | | | |
| 10/1/10 | 7.1 | 35.5 | 0.750 | | | | | | | | | | | 1,969 | 3,406 | 5,375 | 0.680 | | | |
| 10/2/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,875 | 3,656 | 5,531 | 0.680 | | | |
| 10/3/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | | | | | | | |
| 10/4/10 | 7.3 | 35.5 | 0.800 | | | | | | | | | | | 1,531 | 4,563 | 6,094 | 0.680 | | | |
| 10/5/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,813 | 4,500 | 6,313 | 0.730 | | | |
| 10/6/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,531 | 4,563 | 6,094 | 0.730 | | | |
| 10/7/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,688 | 4,406 | 6,094 | 0.830 | 25.4 | | |
| 10/8/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,938 | 4,406 | 6,344 | 0.705 | 27.6 | | |
| 10/9/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,563 | 4,000 | 5,563 | 0.780 | | | |
| 10/10/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | | | | 0.650 | | | |
| 10/11/10 | 7.2 | 35.5 | 0.800 | 23,900 | 4,090 | 2.34 | 1.32 | 13,800 | 10,200 | | 625 | | 423 | 1,594 | 4,219 | 5,813 | 0.705 | | | |

**Phase IV**

Digester 1 Operations Data (Cont.)

June 17, 2010 - December 10, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/12/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,657 | 4,281 | 5,938 | 0.880 | | | |
| 10/13/10 | 7.1 | 35.5 | 0.800 | 21,900 | 3,930 | 2.23 | 1.26 | 13,600 | 9,700 | | 640 | 1,725 | 438 | 1,375 | 3,844 | 5,219 | 0.605 | | | |
| 10/14/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,563 | 4,156 | 5,719 | 0.830 | | | |
| 10/15/10 | 7.2 | 35.5 | 0.800 | 21,850 | 4,280 | 2.28 | 1.27 | 16,500 | 11,200 | | 463 | | 468 | 1,469 | 4,250 | 5,719 | 0.705 | | | |
| 10/16/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,657 | 4,281 | 5,938 | 0.830 | | | |
| 10/17/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | | | | 0.700 | | | |
| 10/18/10 | 7.2 | 35.5 | 0.800 | 20,600 | 3,620 | 2.23 | 1.24 | 14,800 | 10,100 | | 445 | | 447 | 1,469 | 4,406 | 5,875 | 0.705 | | | |
| 10/19/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,937 | 4,188 | 6,125 | 0.730 | | | |
| 10/20/10 | 7.1 | 35.5 | 0.800 | 22,450 | 4,230 | 2.41 | 1.31 | 15,200 | 10,200 | | 605 | 1,620 | 442 | 1,593 | 4,063 | 5,656 | 0.705 | | | |
| 10/21/10 | 7.2 | 35.5 | 0.800 | | | | | | | | | | | 1,531 | 4,000 | 5,531 | 0.780 | | | |
| 10/22/10 | 7.1 | 35.5 | 0.800 | 19,500 | 4,310 | 1.79 | 0.95 | 10,000 | 7,800 | | 605 | | 423 | 1,281 | 4,063 | 5,344 | 0.705 | | | |
| 10/23/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 1,437 | 3,719 | 5,156 | 0.880 | | | |
| 10/24/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | | | | 0.750 | | | |
| 10/25/10 | 7.1 | 35.5 | 0.800 | 20,850 | 4,850 | 1.88 | 1.05 | 10,900 | 8,400 | | 620 | 1,580 | 424 | 1,625 | 3,906 | 5,531 | 0.755 | | | |
| 10/26/10 | 7.1 | 35.0 | 0.800 | | | | | | | | | | | 2,063 | 3,781 | 5,844 | 0.780 | | | |
| 10/27/10 | 7.1 | 35.5 | 0.800 | 22,250 | 5,210 | 1.84 | 1.00 | 9,900 | 7,900 | | 700 | | 381 | 2,063 | 3,625 | 5,688 | 0.605 | | | |
| 10/28/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 2,000 | 3,594 | 5,594 | 0.780 | | | |
| 10/29/10 | 7.1 | 35.5 | 0.800 | 20,750 | 5,850 | 1.88 | 0.99 | 9,900 | 7,900 | | 635 | | 396 | 3,812 | 3,563 | 7,375 | 0.705 | | | |
| 10/30/10 | 7.3 | 36.0 | | | | | | | | | | | | 1,813 | 4,031 | 5,844 | | | | |
| 10/31/10 | 7.1 | 35.5 | 0.800 | | | | | | | | | | | 6,063 | 4,875 | 10,938 | 0.730 | | | |
| 11/1/10 | 7.3 | 35.5 | | 17,700 | 5,430 | 1.71 | 0.84 | 8,600 | 7,100 | | 755 | | 407 | 1,625 | 4,281 | 5,906 | 0.205 | | | |
| 11/2/10 | 7.4 | 35.5 | | | | | | | | | | | | 1,250 | 4,438 | 5,688 | 0.080 | | | |
| 11/3/10 | 7.2 | 35.5 | 0.600 | 20,300 | 4,550 | 1.99 | 1.03 | 12,500 | 8,900 | | 825 | 1,200 | 431 | 1,438 | 4,625 | 6,063 | 0.205 | | | |
| 11/4/10 | 7.2 | 35.0 | 0.600 | | | | | | | | | | | 2,000 | 4,531 | 6,531 | 0.580 | | | |
| 11/5/10 | 7.2 | 35.0 | 0.600 | 21,750 | 4,660 | 2.25 | 1.17 | 15,300 | 10,100 | | 705 | | 403 | 1,875 | 4,563 | 6,438 | 0.605 | | | |
| 11/6/10 | 7.2 | 35.0 | 0.600 | | | | | | | | | | | 1,750 | 4,531 | 6,281 | 0.580 | | | |
| 11/7/10 | 7.2 | 35.5 | 0.600 | | | | | | | | | | | | | | 0.550 | | | |
| 11/8/10 | 7.2 | 35.5 | 0.600 | | | | | | | | | | | 1,625 | 4,688 | 6,313 | 0.605 | | | |
| 11/9/10 | 7.1 | 35.5 | 0.700 | | | | | | | | | | | 1,687 | 4,688 | 6,375 | 0.630 | | | |
| 11/10/10 | 7.2 | 36.0 | 0.500 | | | | | | | | | | | 1,687 | 4,688 | 6,375 | 0.430 | | | |
| 11/11/10 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | 1,437 | 4,594 | 6,031 | 0.380 | | | |
| 11/12/10 | 7.2 | 35.5 | 0.450 | | | | | | | | | | | 1,531 | 4,750 | 6,281 | 0.330 | | | |
| 11/13/10 | | | | | | | | | | | | | | | | | | | | |
| 11/14/10 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | | | | 0.350 | | | |
| 11/15/10 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | 1,375 | 4,563 | 5,938 | 0.280 | | | |
| 11/16/10 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,281 | 4,656 | 5,938 | 0.330 | | | |
| 11/17/10 | 7.3 | 35.0 | 0.400 | | | | | | | | | | | 1,625 | 4,813 | 6,438 | 0.330 | | | |
| 11/18/10 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,656 | 4,875 | 6,531 | 0.230 | | | |
| 11/19/10 | 7.2 | 35.0 | 0.400 | | | | | | | | | | | 1,969 | 4,844 | 6,813 | 0.280 | | | |

**Phase IV**

Digester 1 Operations Data (Cont.)

June 17, 2010 - December 10, 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/20/10 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | 1,531 | 4,688 | 6,219 | 0.330 | | | |
| 11/21/10 | 7.2 | 35.5 | 0.400 | | | | | | | | | | | 1,594 | 4,781 | 6,375 | 0.280 | | 34.0% | |
| 11/22/10 | 7.3 | 36.0 | 0.400 | | | | | | | | | | | 1,406 | 5,094 | 3,500 | 0.330 | | 28.0% | |
| 11/23/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,344 | 5,094 | 6,438 | 0.230 | 13.7 | 28.0% | |
| 11/24/10 | 7.3 | 35.5 | 0.400 | | | | | | | | | | | 1,532 | 5,156 | 6,688 | 0.280 | | 18.0% | |
| 11/25/10 | 7.3 | 35.5 | 0.400 | 19,600 | 4,190 | 2.12 | 1.06 | 11,400 | 8,400 | | | | | 1,125 | 5,219 | 6,344 | 0.405 | | | |
| 11/26/10 | | | | | | | | | | | | | | | | | | | | |
| 11/27/10 | 7.2 | 35.0 | 0.400 | 19,900 | 4,300 | 2.15 | 1.13 | 13,500 | 9,600 | | 785 | | 470 | 1,312 | 5,063 | 6,375 | 0.380 | 9.6 | | |
| 11/28/10 | 7.2 | 35.0 | 0.400 | 18,200 | 4,130 | 2.24 | 1.17 | 13,200 | 8,800 | | | | | 1,531 | 5,313 | 6,844 | 0.305 | 5.0 | 24.0% | |
| 11/29/10 | 7.2 | 35.5 | 0.400 | 17,400 | 4,490 | 2.05 | 1.04 | 13,700 | 8,900 | 2,725 | 790 | 1,555 | 510 | 1,438 | 5,031 | 6,469 | 0.205 | 12.0 | 22.0% | |
| 11/30/10 | 7.3 | 35.0 | 0.400 | 17,500 | 4,140 | 2.06 | 1.04 | 12,600 | 8,700 | | | | | 1,187 | 5,313 | 6,500 | 0.355 | 9.6 | 24.0% | |
| 12/1/10 | 7.3 | 35.0 | 0.400 | 17,500 | 4,220 | 2.12 | 1.06 | 12,900 | 8,300 | | 805 | | 492 | 1,187 | 5,313 | 6,500 | 0.305 | 11.5 | 26.0% | |
| 12/2/10 | 7.4 | 35.0 | 0.400 | 18,350 | 4,340 | 2.11 | 1.11 | 12,200 | 8,400 | | | | | 1,125 | 5,000 | 3,125 | 0.355 | 12.1 | | |
| 12/3/10 | 7.4 | 35.0 | 0.400 | 18,400 | 4,320 | 2.11 | 1.11 | 12,600 | 8,600 | | | | | 1,250 | 5,156 | 6,406 | 0.205 | | | |
| 12/4/10 | 7.1 | 35.0 | 1.150 | 22,750 | 5,720 | 2.40 | 1.34 | 14,800 | 10,400 | | 935 | | 480 | 3,063 | 4,656 | 7,719 | 1.105 | 13.3 | 40.0% | |
| 12/5/10 | 6.9 | 35.0 | 1.150 | 25,000 | 7,640 | 2.56 | 1.40 | 16,100 | 10,200 | | | | | 4,375 | 3,469 | 7,844 | 1.005 | 13.6 | | |
| 12/6/10 | 6.8 | 35.0 | 1.150 | 30,100 | 9,910 | 2.39 | 1.37 | 14,700 | 10,400 | 2,525 | 825 | 1,440 | 532 | 4,531 | 2,500 | 7,031 | 0.955 | 10.7 | 42.0% | |
| 12/7/10 | 6.6 | 35.0 | 1.150 | 30,900 | 11,830 | 2.37 | 1.41 | 13,700 | 10,800 | | | | | 4,312 | 1,938 | 6,250 | 1.055 | 8.1 | 40.0% | 3,000 |
| 12/8/10 | 6.6 | 35.5 | 1.150 | 34,400 | 13,430 | 2.49 | 1.48 | 14,700 | 10,500 | | 760 | | 596 | 5,438 | 1,875 | 7,313 | 0.855 | | 42.0% | 3,000 |
| 12/9/10 | 7.0 | 35.0 | | 29,950 | 12,090 | 2.57 | 1.43 | 16,500 | 10,600 | | | | | 4,656 | 3,000 | 7,656 | 0.205 | | 30.0% | 2,000 |
| 12/10/10 | 7.0 | 35.0 | | 27,450 | 12,230 | 2.15 | 1.26 | 11,300 | 8,600 | | 845 | | 524 | 3,563 | 2,625 | 6,188 | 0.205 | | 24.0% | 1,500 |
| Average | 7.2 | 35.9 | 0.660 | 20,910 | 5,199 | 2.19 | 1.16 | 12,716 | 9,074 | 2,625 | 578 | 949 | 396 | 1,565 | 4,133 | 5,659 | 0.562 | 19.24 | 31.2% | 2,850 |
| Minimum | 6.6 | 34.5 | 0.100 | 14,250 | 3,060 | 1.71 | 0.84 | 8,600 | 7,100 | 2,525 | 185 | 520 | 140 | 906 | 1,875 | 3,125 | 0.080 | 5.00 | 18.0% | 1,500 |
| Maximum | 7.4 | 38.0 | 1.150 | 34,400 | 13,430 | 2.57 | 1.48 | 16,500 | 11,200 | 2,725 | 935 | 1,725 | 596 | 6,063 | 5,313 | 10,938 | 1.105 | 36.10 | 42.0% | 6,000 |

**Phase IV**

Digester 5 Operations Data

June 17, 2010 - December 10 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/17/10 | 7.4 | 35.0 | 0.900 | | | | | | | | | | | 1,156 | 4,625 | 5,781 | | | | |
| 6/18/10 | 7.4 | 35.5 | 0.500 | 36,550 | 4,410 | 4.55 | 2.62 | 34,900 | 22,300 | | 835 | 1,525 | 390 | 1,062 | 4,563 | 5,625 | 0.050 | | | |
| 6/19/10 | 7.4 | 36.0 | 1.000 | | | | | | | | | | | 1,063 | 4,500 | 5,563 | | | | |
| 6/20/10 | 7.3 | 35.0 | 1.100 | | | | | | | | | | | 969 | 4,844 | 5,813 | | | | |
| 6/21/10 | 7.5 | 35.5 | 0.700 | 34,800 | 3,860 | 4.33 | 2.37 | 32,300 | 19,700 | | 735 | 1,925 | 385 | 938 | 4,656 | 5,594 | 0.050 | | | |
| 6/22/10 | 7.4 | 35.5 | 0.800 | | | | | | | | | | | 844 | 4,656 | 5,500 | | | | |
| 6/23/10 | 7.3 | 36.0 | 0.900 | 37,350 | 3,770 | 3.86 | 2.29 | 31,200 | 20,500 | | 640 | 1,870 | 376 | 938 | 4,406 | 5,344 | 0.050 | | | |
| 6/24/10 | 7.3 | 34.5 | 1.000 | | | | | | | | | | | 1,000 | 4,219 | 5,219 | | | | |
| 6/25/10 | 7.4 | 36.0 | 1.000 | 38,200 | 3,850 | 4.11 | 2.45 | 31,600 | 20,600 | | 652 | 1,810 | 372 | 937 | 4,313 | 5,250 | 0.050 | | | |
| 6/26/10 | 7.4 | 36.0 | 1.000 | 35,750 | 3,620 | 3.86 | 2.24 | 29,900 | 20,100 | | 568 | 1,360 | 360 | 813 | 4,375 | 5,188 | 0.050 | | | |
| 6/27/10 | 7.3 | 35.5 | 1.000 | | | | | | | | | | | 875 | 4,344 | 5,219 | | | | |
| 6/28/10 | 7.4 | 36.0 | 0.800 | 39,200 | 3,970 | 4.33 | 2.54 | 33,400 | 22,000 | | 593 | 2,235 | 382 | 781 | 4,594 | 5,375 | 0.050 | | | |
| 6/29/10 | 7.3 | 35.0 | 0.800 | | | | | | | | | | | 813 | 4,250 | 5,063 | | | | |
| 6/30/10 | 7.4 | 35.5 | 1.000 | 40,150 | 3,970 | 4.32 | 2.57 | 34,400 | 22,700 | | 648 | 2,065 | 370 | 688 | 4,281 | 4,969 | 0.050 | | | |
| 7/1/10 | 7.4 | 35.5 | 1.000 | | | | | | | | | | | 625 | 4,625 | 5,250 | | | | |
| 7/2/10 | 7.4 | 35.5 | 1.100 | 42,400 | 3,760 | 4.94 | 2.84 | 39,800 | 24,700 | | 680 | 1,545 | 384 | 688 | 4,406 | 5,094 | 0.100 | | | |
| 7/3/10 | 7.4 | 34.0 | 1.000 | | | | | | | | | | | 781 | 4,375 | 5,156 | | | | |
| 7/4/10 | 7.4 | 34.0 | 1.000 | 45,500 | 4,020 | 5.50 | 3.11 | 46,400 | 27,300 | | 668 | 1,785 | 376 | 844 | 4,344 | 5,188 | 0.050 | | | |
| 7/5/10 | 7.4 | 34.5 | 1.000 | | | | | | | | | | | 688 | 4,469 | 5,156 | | | | |
| 7/6/10 | 7.4 | 34.5 | 1.000 | 45,850 | 3,750 | 5.22 | 2.96 | 42,600 | 26,000 | | 640 | 2,350 | 358 | 688 | 4,469 | 5,156 | 0.050 | | | |
| 7/7/10 | 7.4 | 34.5 | 1.000 | | | | | | | | | | | 750 | 4,500 | 5,250 | | | | |
| 7/8/10 | 7.4 | 35.5 | 1.000 | 44,600 | 4,380 | 4.80 | 2.84 | 39,200 | 25,500 | | 635 | 2,200 | 380 | 688 | 4,563 | 5,250 | 0.050 | | | |
| 7/9/10 | 7.4 | 34.0 | 1.000 | | | | | | | | | | | 938 | 4,344 | 5,281 | | | | |
| 7/10/10 | 7.4 | 34.0 | 1.000 | | | | | | | | | | | 1,031 | 4,031 | 5,063 | | | | |
| 7/11/10 | 7.4 | 34.5 | 1.000 | | | | | | | | | | | 1,093 | 4,063 | 5,156 | | | | |
| 7/12/10 | 7.2 | 35.5 | 1.000 | | | | | | | | | | | 1,375 | 4,125 | 5,500 | 0.100 | | | |
| 7/13/10 | 7.2 | 36.5 | 1.000 | 47,000 | 3,820 | | | 39,300 | 24,800 | | 320 | | 187 | 1,094 | 4,125 | 5,219 | 0.100 | | | |
| 7/14/10 | 7.2 | 37.0 | 1.000 | 51,000 | 3,630 | | | 38,600 | 23,200 | | 249 | | 154 | 1,219 | 4,219 | 5,438 | 0.100 | | | |
| 7/15/10 | 7.1 | 35.0 | 1.000 | | | | | | | | | | | 1,469 | 3,906 | 5,375 | | | | |
| 7/16/10 | 7.0 | 34.5 | 1.000 | 46,800 | 3,950 | | | 44,100 | 24,800 | | 249 | | 170 | 1,657 | 3,406 | 5,063 | 0.100 | | | |
| 7/17/10 | 7.0 | 34.5 | 1.000 | | | | | | | | | | | 1,750 | 3,250 | 5,000 | | | | |
| 7/18/10 | 7.0 | 35.5 | 1.000 | | | | | | | | | | | 1,531 | 3,594 | 5,125 | | | | |
| 7/19/10 | 7.1 | 36.0 | 1.000 | 44,850 | 3,745 | | | 32,300 | 20,500 | | 267 | | 182 | 1,375 | 3,688 | 5,063 | 0.100 | | | |
| 7/20/10 | 7.2 | 36.0 | 1.000 | | | | | | | | | | | 1,250 | 4,063 | 5,313 | | | | |
| 7/21/10 | 7.2 | 36.0 | 1.000 | 43,300 | 9,320 | | | 34,000 | 20,100 | | 333 | | 113 | 1,687 | 3,219 | 4,906 | 0.100 | | | |
| 7/22/10 | 7.0 | 35.0 | 1.000 | | | | | | | | | | | 1,688 | 3,250 | 4,938 | | | | |
| 7/23/10 | 7.0 | 35.0 | 1.000 | | | | | | | | | | | 1,594 | 2,875 | 4,469 | 0.100 | | | |
| 7/24/10 | 7.1 | 34.5 | 1.000 | | | | | | | | | | | 1,563 | 3,125 | 4,688 | | | | |
| 7/25/10 | 7.3 | 37.0 | 0.100 | | | | | | | | | | | 843 | 4,313 | 5,156 | | | | |

**Phase IV**

Digester 5 Operations Data (Cont.)

June 17, 2010 - December 10 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/26/10 | 7.4 | 36.5 | 0.200 | | | | | | | | | | | 844 | 4,250 | 5,094 | 0.100 | | | |
| 7/27/10 | 7.4 | 36.5 | 0.300 | | | | | | | | | | | 875 | 4,625 | 5,500 | | | | |
| 7/28/10 | 7.2 | 36.0 | 1.000 | | | | | | | | | | | 1,562 | 3,313 | 4,875 | 0.100 | 46.6 | 38.0% | 2,000 |
| 7/29/10 | 7.1 | 37.0 | 1.000 | | | | | | | | | | | 1,093 | 3,688 | 4,781 | | 41.2 | 36.0% | 2,000 |
| 7/30/10 | 7.1 | 37.0 | 1.000 | | | | | | | | | | | 1,250 | 3,719 | 4,969 | | 45.8 | 36.0% | 2,000 |
| 7/31/10 | 7.3 | 37.0 | 1.000 | | | | | | | | | | | 1,125 | 3,969 | 5,094 | | 47.1 | 34.0% | 2,000 |
| 8/1/10 | 7.2 | 37.5 | 1.000 | | | | | | | | | | | 1,344 | 4,250 | 5,594 | | | | |
| 8/2/10 | 7.2 | 37.0 | 1.200 | | | | | | | | | | | 1,250 | 3,906 | 5,156 | | 45.7 | | |
| 8/3/10 | 7.2 | 37.5 | 1.300 | | | | | | | | | | | 1,219 | 4,031 | 5,250 | | 39.3 | | |
| 8/4/10 | 7.3 | 37.5 | 1.200 | | | | | | | | | | | 938 | 4,250 | 5,188 | | 48.9 | | |
| 8/5/10 | 7.2 | 37.0 | 1.200 | | | | | | | | | | | 1,000 | 4,313 | 5,313 | | 48.4 | | |
| 8/6/10 | 7.2 | 37.0 | 1.100 | | | | | | | | | | | 844 | 4,375 | 5,219 | | 43.2 | | |
| 8/7/10 | 7.2 | 37.5 | 1.200 | | | | | | | | | | | 1,031 | 4,094 | 5,215 | | 36.8 | | |
| 8/8/10 | 7.3 | 37.0 | 1.000 | | | | | | | | | | | 969 | 4,406 | 5,375 | | 31.8 | | |
| 8/9/10 | 7.3 | 37.5 | 1.000 | | | | | | | | | | | 875 | 3,969 | 4,844 | 0.100 | 43.2 | | |
| 8/10/10 | 7.2 | 37.0 | 1.000 | | | | | | | | | | | 937 | 3,813 | 4,750 | | 40.6 | | |
| 8/11/10 | 7.2 | 37.5 | 1.000 | | | | | | | | | | | 844 | 3,531 | 4,375 | 0.100 | | 32.0% | 6,000 |
| 8/12/10 | 7.2 | 37.5 | 1.000 | | | | | | | | | | | 938 | 3,750 | 4,688 | | 46.6 | 36.0% | 7,500 |
| 8/13/10 | 7.2 | 38.0 | 1.000 | | | | | | | | | | | 812 | 3,219 | 4,031 | | 46.3 | | |
| 8/14/10 | | | | | | | | | | | | | | | | | | | | |
| 8/15/10 | | | | | | | | | | | | | | | | | | | | |
| 8/16/10 | | | | | | | | | | | | | | | | | | | | |
| 8/17/10 | | | | | | | | | | | | | | | | | | | | |
| 8/18/10 | | | | | | | | | | | | | | | | | | | | |
| 8/19/10 | | | | | | | | | | | | | | | | | | | | |
| 8/20/10 | 7.1 | 35.5 | | | | | | | | | | | | 2,812 | 5,969 | 8,781 | | | | |
| 8/21/10 | 7.0 | 36.0 | 1.000 | | | | | | | | | | | 1,312 | 3,969 | 5,281 | | | | |
| 8/22/10 | 7.1 | 36.0 | 0.900 | | | | | | | | | | | 1,343 | 3,563 | 4,906 | | | | |
| 8/23/10 | 7.2 | 36.0 | 0.600 | | | | | | | | | | | 1,250 | 3,719 | 4,969 | | | | |
| 8/24/10 | 7.2 | 36.5 | 0.700 | | | | | | | | | | | 1,000 | 3,750 | 4,750 | | | | |
| 8/25/10 | 7.2 | 35.5 | 1.000 | | | | | | | | | | | 1,156 | 3,719 | 4,875 | | | | |
| 8/26/10 | 7.1 | 34.5 | 1.000 | | | | | | | | | | | 1,375 | 3,563 | 4,938 | | | | |
| 8/27/10 | 7.1 | 34.0 | 1.000 | | | | | | | | | | | 1,375 | 3,344 | 4,719 | | | | |
| 8/28/10 | 7.1 | 34.0 | 1.000 | | | | | | | | | | | 1,282 | 3,156 | 4,438 | | | | |
| 8/29/10 | 7.1 | 35.0 | 1.000 | | | | | | | | | | | 1,281 | 3,375 | 4,656 | | | | |
| 8/30/10 | 7.1 | 35.5 | 1.000 | | | | | | | | | | | 1,156 | 3,688 | 4,844 | | | | |
| 8/31/10 | | | | | | | | | | | | | | | | | | | | |
| 9/1/10 | | | | | | | | | | | | | | | | | | | | |
| 9/2/10 | | | | | | | | | | | | | | | | | | | | |

**Phase IV**

Digester 5 Operations Data (Cont.)

June 17, 2010 - December 10 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/3/10 | | | | | | | | | | | | | | | | | | | | |
| 9/4/10 | | | | | | | | | | | | | | | | | | | | |
| 9/5/10 | | | | | | | | | | | | | | | | | | | | |
| 9/6/10 | | | | | | | | | | | | | | | | | | | | |
| 9/7/10 | | | | | | | | | | | | | | | | | | | | |
| 9/8/10 | 7.3 | 34.0 | | | | | | | | | | | | 1,000 | 5,219 | 6,219 | | | | |
| 9/9/10 | 7.2 | 34.0 | 0.700 | | | | | | | | | | | 1,156 | 4,750 | 5,906 | | | | |
| 9/10/10 | 7.2 | 34.0 | 0.800 | | | | | | | | | | | 1,282 | 4,656 | 5,938 | | | | |
| 9/11/10 | 7.2 | 34.5 | 0.900 | | | | | | | | | | | 1,625 | 4,406 | 6,031 | | | | |
| 9/12/10 | 7.3 | 34.5 | 0.850 | | | | | | | | | | | 1,250 | 4,844 | 6,094 | | | | |
| 9/13/10 | 7.2 | 34.0 | 0.850 | | | | | | | | | | | 1,093 | 4,438 | 5,531 | | | | |
| 9/14/10 | 7.2 | 34.0 | 0.850 | | | | | | | | | | | 1,281 | 4,188 | 5,469 | | | | |
| 9/15/10 | 7.1 | 34.0 | 0.900 | | | | | | | | | | | 1,406 | 3,875 | 5,281 | | | | |
| 9/16/10 | 7.2 | 34.5 | 0.900 | | | | | | | | | | | 1,281 | 4,031 | 5,313 | | | | |
| 9/17/10 | 7.2 | 34.0 | 1.000 | | | | | | | | | | | 1,438 | 4,125 | 5,563 | | | | |
| 9/18/10 | 7.3 | 34.0 | 1.000 | | | | | | | | | | | 1,281 | 4,094 | 5,375 | | | | |
| 9/19/10 | 7.3 | 33.5 | 1.000 | | | | | | | | | | | 1,219 | 3,969 | 5,188 | | | | |
| 9/20/10 | 7.3 | 34.5 | 1.100 | | | | | | | | | | | 1,156 | 4,563 | 5,719 | | | | |
| 9/21/10 | 7.3 | 35.0 | 1.100 | | | | | | | | | | | 843 | 4,438 | 5,281 | | | | |
| 9/22/10 | 7.3 | 34.5 | 1.100 | | | | | | | | | | | 813 | 4,531 | 5,344 | | | | |
| 9/23/10 | 7.3 | 34.5 | 1.100 | | | | | | | | | | | 875 | 4,781 | 5,656 | | | | |
| 9/24/10 | 7.3 | 34.5 | 1.100 | | | | | | | | | | | 937 | 4,563 | 5,500 | | | | |
| 9/25/10 | 7.3 | 34.5 | 1.150 | | | | | | | | | | | 813 | 4,656 | 5,469 | | | | |
| 9/26/10 | 7.3 | 34.5 | 1.200 | | | | | | | | | | | 843 | 4,688 | 5,531 | | | | |
| 9/27/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 875 | 4,469 | 5,344 | | | | |
| 9/28/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 1,031 | 4,188 | 5,219 | | | | |
| 9/29/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 1,000 | 4,313 | 5,313 | | | | |
| 9/30/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 1,031 | 4,250 | 5,281 | | | | |
| 10/1/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 969 | 4,375 | 5,344 | | | | |
| 10/2/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 969 | 4,250 | 5,219 | | | | |
| 10/3/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | | | | | | | |
| 10/4/10 | 7.2 | 34.5 | 1.200 | | | | | | | | | | | 625 | 4,438 | 5,063 | | | | |
| 10/5/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 1,093 | 4,438 | 5,531 | | | | |
| 10/6/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 1,000 | 4,594 | 5,594 | 0.125 | | | |
| 10/7/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 938 | 4,375 | 5,313 | | | | |
| 10/8/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 1,157 | 4,281 | 5,438 | 0.125 | | | |
| 10/9/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 1,062 | 4,063 | 5,125 | | | | |
| 10/10/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | | | | | | | |
| 10/11/10 | 7.2 | 35.0 | 1.200 | 47,400 | 4,550 | 5.07 | 3.04 | 41,100 | 26,300 | | 735 | | 389 | 875 | 4,219 | 5,094 | 0.125 | | | |

**Phase IV**

Digester 5 Operations Data (Cont.)

June 17, 2010 - December 10 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/12/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 875 | 4,188 | 5,063 | | | | |
| 10/13/10 | 7.2 | 35.0 | 1.200 | 46,850 | 4,220 | 4.89 | 2.95 | 39,100 | 25,900 | 3,804 | 705 | 2,810 | 413 | 875 | 4,188 | 5,063 | 0.125 | | | |
| 10/14/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 875 | 4,156 | 5,031 | | | | |
| 10/15/10 | 7.2 | 35.0 | 1.200 | 45,450 | 4,240 | 4.95 | 3.01 | 42,800 | 28,500 | | 575 | | 456 | 906 | 4,125 | 5,031 | 0.125 | | | |
| 10/16/10 | 7.1 | 35.0 | 1.200 | | | | | | | | | | | 938 | 4,000 | 4,938 | | | | |
| 10/17/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | | | | | | | |
| 10/18/10 | 7.2 | 35.0 | 1.200 | 48,250 | 4,330 | 4.99 | 3.04 | 47,900 | 31,700 | | 565 | | 447 | 906 | 4,219 | 5,125 | 0.125 | | | |
| 10/19/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 1,000 | 4,281 | 5,281 | | | | |
| 10/20/10 | 7.2 | 35.0 | 1.200 | 49,950 | 4,340 | 5.24 | 3.16 | 48,900 | 31,700 | 4,640 | 725 | 2,810 | 412 | 907 | 4,156 | 5,063 | 0.125 | | | |
| 10/21/10 | 7.2 | 35.0 | 1.200 | | | | | | | | | | | 906 | 4,219 | 5,125 | | | | |
| 10/22/10 | 7.2 | 34.5 | 1.150 | 57,350 | 5,010 | 5.31 | 3.17 | 46,600 | 30,800 | | 720 | | 404 | 1,343 | 3,563 | 4,906 | 0.125 | | | |
| 10/23/10 | 7.1 | 34.5 | 1.100 | | | | | | | | | | | 1,219 | 3,875 | 5,094 | | | | |
| 10/24/10 | 7.2 | 35.0 | 1.100 | | | | | | | | | | | | | | | | | |
| 10/25/10 | 7.2 | 35.0 | 1.100 | 54,350 | 4,160 | 5.62 | 3.32 | 55,500 | 35,800 | 6,000 | 715 | 5,200 | 418 | 875 | 4,250 | 5,125 | 0.125 | | | |
| 10/26/10 | 7.1 | 34.5 | 1.100 | | | | | | | | | | | 1,219 | 4,031 | 5,250 | | | | |
| 10/27/10 | 7.2 | 34.5 | 1.100 | 51,850 | 4,490 | 5.36 | 3.18 | 49,500 | 31,900 | | 705 | | 394 | 1,344 | 3,625 | 4,969 | 0.125 | | | |
| 10/28/10 | 7.2 | 34.5 | 1.100 | | | | | | | | | | | 1,344 | 3,594 | 4,938 | | | | |
| 10/29/10 | 7.2 | 33.5 | 1.100 | 51,600 | 4,320 | 5.61 | 3.17 | 50,800 | 31,300 | | 680 | | 383 | 1,125 | 4,188 | 5,313 | 0.125 | | | |
| 10/30/10 | 7.2 | 33.5 | | | | | | | | | | | | | | | | | | |
| 10/31/10 | 7.2 | 33.5 | 1.100 | | | | | | | | | | | 1,343 | 3,813 | 5,156 | | | | |
| 11/1/10 | 7.3 | 33.5 | | 52,100 | 4,200 | 5.28 | 3.01 | 50,800 | 31,400 | | 780 | | 380 | 875 | 4,688 | 5,563 | 0.125 | | | |
| 11/2/10 | 7.3 | 33.5 | | | | | | | | | | | | 688 | 4,250 | 4,938 | | | | |
| 11/3/10 | 7.3 | 35.0 | 0.900 | 49,950 | 4,170 | 4.92 | 2.95 | 46,600 | 31,300 | 5,360 | 910 | 3,320 | 407 | 813 | 4,906 | 5,719 | 0.125 | | | |
| 11/4/10 | 7.3 | 36.0 | 1.000 | | | | | | | | | | | 938 | 4,656 | 5,594 | | | | |
| 11/5/10 | 7.2 | 34.0 | 1.000 | 49,900 | 4,260 | 5.24 | 2.99 | 55,100 | 34,900 | | 800 | | 390 | 1,032 | 4,531 | 5,563 | 0.125 | | | |
| 11/6/10 | 7.3 | 35.5 | 1.000 | | | | | | | | | | | 937 | 4,719 | 5,656 | | | | |
| 11/7/10 | 7.3 | 35.5 | 1.000 | | | | | | | | | | | | | | | | | |
| 11/8/10 | 7.3 | 36.0 | 1.000 | 57,450 | 4,470 | 5.36 | 3.31 | 49,700 | 33,600 | | 795 | | 388 | 937 | 4,813 | 5,750 | 0.125 | | | |
| 11/9/10 | 7.2 | 36.0 | 1.100 | | | | | | | | | | | 781 | 4,531 | 5,313 | | | | |
| 11/10/10 | 7.2 | 36.0 | 1.100 | 48,050 | 4,250 | 4.81 | 2.97 | 46,200 | 31,300 | 5,320 | 795 | 3,040 | 400 | 875 | 4,656 | 5,531 | 0.125 | | | |
| 11/11/10 | 7.2 | 35.5 | 1.100 | | | | | | | | | | | 1,062 | 4,438 | 5,500 | | | | |
| 11/12/10 | 7.2 | 36.0 | 1.100 | 47,600 | 3,700 | 4.71 | 2.93 | 38,200 | 26,600 | | 880 | | 710 | 938 | 4,656 | 5,594 | 0.125 | | | |
| 11/13/10 | | | | | | | | | | | | | | | | | | | | |
| 11/14/10 | 7.3 | 35.5 | 1.100 | | | | | | | | | | | | | | | | | |
| 11/15/10 | 7.3 | 35.0 | | 52,600 | 4,250 | 5.41 | 3.38 | 47,100 | 32,400 | 6,040 | 860 | 3,460 | 730 | 844 | 4,500 | 5,344 | 0.125 | | | |
| 11/16/10 | 7.3 | 36.0 | 1.100 | | | | | | | | | | | 1,063 | 4,531 | 5,594 | | | | |
| 11/17/10 | 7.2 | 36.0 | 1.100 | 48,700 | 4,480 | 5.05 | 3.12 | 43,000 | 29,000 | | 720 | | 403 | 1,000 | 4,281 | 5,281 | 0.125 | | | |
| 11/18/10 | 7.2 | 36.0 | 1.100 | | | | | | | | | | | 938 | 4,500 | 5,438 | | | | |
| 11/19/10 | 7.1 | 35.0 | 1.100 | 46,950 | 4,110 | 5.13 | 3.15 | 43,300 | 28,700 | | 730 | | 410 | 1,032 | 4,406 | 5,438 | 0.125 | | | |

**Phase IV**

Digester 5 Operations Data (Cont.)

June 17, 2010 - December 10 , 2010

| Date | pH (s.u.) | Temp. (oC) | Feed (L/day) | tCOD (mg/L) | sCOD (mg/L) | TS (%) | VS (%) | TSS (mg/L) | VSS (mg/L) | TKN (mg/L) | NH3-N (mg/L) | T-P (mg/L) | PO4-P (mg/L) | VFA (mg/L) | P-Alk (mg/L) | T-Alk (mg/L) | Waste (L/day) | Biogas (L/day) | Biogas CO2 (%) | Biogas H2S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/20/10 | 7.0 | 34.5 | 1.100 | | | | | | | | | | | 1,375 | 3,906 | 5,281 | | | | |
| 11/21/10 | 7.1 | 35.0 | 1.100 | | | | | | | | | | | 969 | 4,344 | 5,313 | | | 32.0% | |
| 11/22/10 | 7.2 | 34.5 | 1.100 | 46,450 | 4,420 | 4.85 | 2.95 | 42,000 | 28,000 | 6,240 | 710 | 3,400 | 413 | 1,063 | 4,156 | 5,219 | 0.125 | | 32.0% | |
| 11/23/10 | 7.2 | 34.5 | 1.100 | | | | | | | | | | | 1,375 | 3,750 | 5,125 | | 35.7 | 32.0% | 500 |
| 11/24/10 | 7.2 | 35.5 | 1.100 | 49,700 | 4,510 | 5.03 | 2.99 | 44,300 | 29,900 | | 715 | | 421 | 875 | 4,469 | 5,344 | 0.125 | | 32.0% | 1,000 |
| 11/25/10 | 7.2 | 34.5 | 1.100 | 48,150 | 4,700 | 5.14 | 3.06 | 42,400 | 28,100 | | | | | 969 | 4,250 | 5,219 | 0.125 | 37.7 | 32.0% | 1,000 |
| 11/26/10 | | | | | | | | | | | | | | | | | | 27.2 | | |
| 11/27/10 | 7.2 | 34.0 | 1.100 | 50,000 | 5,390 | 5.28 | 3.20 | 47,400 | 30,800 | | 670 | | 413 | 1,156 | 3,563 | 4,719 | 0.125 | 27.2 | | |
| 11/28/10 | 7.1 | 34.0 | 1.100 | 49,700 | 4,390 | 5.39 | 3.27 | 46,500 | 30,400 | | | | | 1,125 | 3,938 | 5,063 | 0.125 | | 34.0% | 1,250 |
| 11/29/10 | 7.1 | 34.0 | 1.100 | 48,650 | 4,470 | 5.07 | 3.09 | 42,700 | 28,300 | 5,625 | 725 | 3,120 | 468 | 1,469 | 3,531 | 5,000 | 0.125 | | 32.0% | 1,200 |
| 11/30/10 | 7.3 | 34.5 | 1.100 | 50,350 | 4,210 | 4.72 | 3.04 | 40,000 | 28,500 | | | | | 719 | 4,406 | 5,125 | 0.125 | 16.3 | 34.0% | 1,200 |
| 12/1/10 | 7.3 | 35.0 | 1.100 | 47,050 | 4,460 | 4.77 | 3.06 | 42,100 | 29,700 | | 735 | | 484 | 750 | 4,531 | 5,281 | 0.125 | 22.6 | 34.0% | 1,200 |
| 12/2/10 | 7.3 | 34.5 | 1.100 | 49,700 | 4,360 | 4.84 | 3.03 | 42,100 | 28,800 | | | | | 813 | 4,500 | 5,313 | 0.125 | 29.2 | | |
| 12/3/10 | 7.2 | 35.0 | 1.100 | 48,650 | 4,250 | 5.07 | 3.13 | 42,900 | 29,200 | | 745 | | 460 | 750 | 4,250 | 5,000 | 0.125 | 20.0 | 32.0% | 1,300 |
| 12/4/10 | 7.3 | 35.5 | 1.100 | 46,100 | 4,020 | 4.53 | 3.06 | 38,100 | 28,900 | | | | | 782 | 4,281 | 5,063 | 0.125 | 33.6 | 32.0% | 1,000 |
| 12/5/10 | 7.2 | 35.0 | 1.100 | 48,750 | 4,460 | 4.66 | 3.08 | 40,400 | 29,200 | | | | | 656 | 3,750 | 4,406 | 0.125 | | | |
| 12/6/10 | 7.2 | 35.0 | 1.100 | 52,400 | 4,260 | 4.79 | 3.07 | 39,000 | 27,700 | 5,275 | 680 | 3,090 | 434 | 750 | 4,000 | 4,750 | 0.125 | 30.7 | 32.0% | 1,500 |
| 12/7/10 | 7.1 | 35.0 | 1.100 | 50,350 | 4,300 | 4.59 | 3.09 | 36,200 | 27,000 | | | | | 906 | 4,125 | 5,031 | 0.125 | | 36.0% | 1,800 |
| 12/8/10 | 7.3 | 35.0 | 1.100 | 51,400 | 4,390 | 4.29 | 2.97 | 36,300 | 28,100 | | 770 | | 446 | 687 | 4,063 | 4,750 | 0.125 | 19.3 | 34.0% | 2,000 |
| 12/9/10 | 7.3 | 35.0 | 1.100 | 49,500 | 4,480 | 4.70 | 3.05 | 39,600 | 27,500 | | | | | 812 | 4,594 | 5,406 | 0.125 | 26.6 | 34.0% | 2,000 |
| 12/10/10 | 7.3 | 35.0 | 1.100 | 48,950 | 4,530 | 4.36 | 3.00 | 34,600 | 26,200 | | 850 | | 524 | 1,000 | 4,656 | 5,656 | 0.125 | | 36.0% | 2,100 |
| Average | 7.2 | 35.2 | 1.032 | 47,363 | 4,333 | 4.89 | 2.97 | 41,624 | 27,533 | 5,367 | 668 | 2,546 | 394 | 1,057 | 4,188 | 5,246 | 0.107 | 36.21 | 33.7% | 2,028 |
| Minimum | 7.0 | 33.5 | 0.100 | 34,800 | 3,620 | 3.86 | 2.24 | 29,900 | 19,700 | 3,804 | 249 | 1,360 | 113 | 625 | 2,875 | 4,031 | 0.050 | 16.30 | 32.0% | 500 |
| Maximum | 7.5 | 38.0 | 1.300 | 57,450 | 9,320 | 5.62 | 3.38 | 55,500 | 35,800 | 6,240 | 910 | 5,200 | 730 | 2,812 | 5,969 | 8,781 | 0.125 | 48.90 | 38.0% | 7,500 |

APPENDIX G

AMPTS Study Raw Data

AMPTS Study Data

Influent Characterization Data

| Digester | Sludge (L) | Feed (L) | tCOD (mg/L) | tCOD (g) | sCOD (mg/L) | sCOD (g) |
|---|---|---|---|---|---|---|
| 1 | 0.300 | 0.000 | 0 | 0.000 | 0 | 0.000 |
| 2 | 0.300 | 0.000 | 0 | 0.000 | 0 | 0.000 |
| 3 | 0.300 | 0.012 | 103,150 | 1.238 | 56,450 | 0.677 |
| 4 | 0.300 | 0.012 | 103,150 | 1.238 | 56,450 | 0.677 |
| 5 | 0.300 | 0.015 | 103,150 | 1.547 | 56,450 | 0.847 |
| 6 | 0.300 | 0.015 | 103,150 | 1.547 | 56,450 | 0.847 |
| 7 | 0.300 | 0.024 | 103,150 | 2.476 | 56,450 | 1.355 |
| 8 | 0.300 | 0.024 | 103,150 | 2.476 | 56,450 | 1.355 |
| 9 | 0.300 | 0.030 | 103,150 | 3.095 | 56,450 | 1.694 |
| 10 | 0.300 | 0.030 | 103,150 | 3.095 | 56,450 | 1.694 |
| 11 | 0.300 | 0.036 | 103,150 | 3.713 | 56,450 | 2.032 |
| 12 | 0.300 | 0.036 | 103,150 | 3.713 | 56,450 | 2.032 |
| 13 | 0.300 | 0.048 | 103,150 | 4.951 | 56,450 | 2.710 |
| 14 | 0.300 | 0.048 | 103,150 | 4.951 | 56,450 | 2.710 |
| 15 | 0.300 | 0.060 | 103,150 | 6.189 | 56,450 | 3.387 |
| 16 | 0.300 | 0.060 | 103,150 | 6.189 | 56,450 | 3.387 |
| 17 | 0.300 | 0.060 | 103,150 | 6.189 | 56,450 | 3.387 |
| 18 | 0.300 | 0.060 | 103,150 | 6.189 | 56,450 | 3.387 |
| 19 | 0.300 | 0.090 | 103,150 | 9.284 | 56,450 | 5.081 |
| 20 | 0.300 | 0.090 | 103,150 | 9.284 | 56,450 | 5.081 |
| 21 | 0.300 | 0.120 | 103,150 | 12.378 | 56,450 | 6.774 |
| 22 | 0.300 | 0.120 | 103,150 | 12.378 | 56,450 | 6.774 |
| Average | 0.300 | 0.045 | 93,773 | 4.642 | 51,318 | 2.540 |
| Minimum | 0.300 | 0.012 | 103,150 | 1.238 | 56,450 | 0.000 |
| Maximum | 0.300 | 0.120 | 103,150 | 12.378 | 56,450 | 6.774 |

AMPTS Study Data

Seed Sludge Characteristics

| Digester | tCOD (mg/L) | tCOD (g) | sCOD (mg/L) | sCOD (g) | TSS (mg/L) | TSS (g) | VSS (mg/L) | VSS (g) | TKN (mg/L) | TKN (g) | $NH_3$-N (mg/L) | $NH_3$-N (g) | T-P (mg/L) | T-P (g) | $PO_4$-P (mg/L) | $PO_4$-P (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 2 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 3 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 4 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 5 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 6 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 7 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 8 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 9 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 10 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 11 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 12 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 13 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 14 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 15 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 16 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 17 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 18 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 19 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 20 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 21 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| 22 | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| Average | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| Minimum | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |
| Maximum | 40,150 | 12.045 | 11,310 | 3.393 | 32,800 | 9.840 | 19,900 | 5.970 | 6,550 | 1.965 | 1,790 | 0.537 | 4,160 | 1.248 | 740 | 0.222 |

AMPTS Study Data

Biogas Data

| Digester | Biogas (L) | Methane (L) | Biogas (L/g COD R) | Methane (L/g COD R) | VA (mg/L) | P-Alk (mg/L) | VA/P-Alk |
|---|---|---|---|---|---|---|---|
| 1 | 0.220 | | 0.157 | | 3,900 | 10,450 | 0.373 |
| 2 | 0.320 | | 0.243 | | 3,400 | 8,800 | 0.386 |
| 3 | 0.560 | | 0.286 | | 3,700 | 8,625 | 0.429 |
| 4 | | 0.400 | | 0.161 | 3,875 | 8,900 | 0.435 |
| 5 | 0.710 | | 0.335 | | 3,875 | 7,200 | 0.538 |
| 6 | | 0.500 | | 0.207 | 3,325 | 7,275 | 0.457 |
| 7 | 0.700 | | 0.313 | | 4,325 | 7,150 | 0.605 |
| 8 | | 0.590 | | 0.199 | 4,175 | 7,100 | 0.588 |
| 9 | 0.800 | | 0.302 | | 4,750 | 5,925 | 0.802 |
| 10 | | 0.640 | | 0.255 | 5,175 | 5,775 | 0.896 |
| 11 | 0.760 | | 0.263 | | 5,625 | 5,900 | 0.953 |
| 12 | | 0.590 | | 0.170 | 4,975 | 5,425 | 0.917 |
| 13 | 0.620 | | 0.205 | | 5,750 | 5,075 | 1.133 |
| 14 | | 0.480 | | 0.137 | 6,600 | 5,250 | 1.257 |
| 15 | 0.600 | | 0.162 | | 6,675 | 4,475 | 1.492 |
| 16 | | 0.410 | | 0.083 | 6,025 | 4,425 | 1.362 |
| 17 | 0.600 | | 0.170 | | 7,000 | 4,075 | 1.718 |
| 18 | | 0.410 | | 0.111 | 7,125 | 4,125 | 1.727 |
| 19 | 0.850 | | 0.176 | | 6,475 | 3,175 | 2.039 |
| 20 | | 0.560 | | 0.121 | 6,525 | 2,950 | 2.212 |
| 21 | 0.980 | | 0.146 | | 7,400 | 2,625 | 2.819 |
| 22 | | 0.540 | | 0.082 | 7,025 | 2,000 | 3.513 |
| Average | 0.643 | 0.512 | 0.230 | 0.153 | 5,350 | 5,759 | 1.211 |
| Minimum | 0.220 | 0.400 | 0.146 | 0.082 | 3,325 | 2,000 | 0.373 |
| Maximum | 0.980 | 0.640 | 0.335 | 0.255 | 7,400 | 10,450 | 3.513 |

AMPTS Study Data

Effluent Characterization Data

| Digester | sCOD (mg/L) | sCOD (g) | TSS (mg/L) | TSS (g) | VSS (mg/L) | VSS (g) |
|---|---|---|---|---|---|---|
| 1 | 6,650 | 1.995 | 29,600 | 8.880 | 19,700 | 5.910 |
| 2 | 6,920 | 2.076 | 28,900 | 8.670 | 19,400 | 5.820 |
| 3 | 8,560 | 2.671 | 26,000 | 8.112 | 18,200 | 5.678 |
| 4 | 6,900 | 2.153 | 26,000 | 8.112 | 18,600 | 5.803 |
| 5 | 8,960 | 2.822 | 25,900 | 8.159 | 18,400 | 5.796 |
| 6 | 8,000 | 2.520 | 27,100 | 8.537 | 19,000 | 5.985 |
| 7 | 11,220 | 3.635 | 25,000 | 8.100 | 17,800 | 5.767 |
| 8 | 8,940 | 2.897 | 24,300 | 7.873 | 18,000 | 5.832 |
| 9 | 11,620 | 3.835 | 25,700 | 8.481 | 18,100 | 5.973 |
| 10 | 12,060 | 3.980 | 26,900 | 8.877 | 18,800 | 6.204 |
| 11 | 12,540 | 4.213 | 23,800 | 7.997 | 17,000 | 5.712 |
| 12 | 10,840 | 3.642 | 23,300 | 7.829 | 17,200 | 5.779 |
| 13 | 15,280 | 5.317 | 24,000 | 8.352 | 17,700 | 6.160 |
| 14 | 13,900 | 4.837 | 25,100 | 8.735 | 18,200 | 6.334 |
| 15 | 16,320 | 5.875 | 24,000 | 8.640 | 17,600 | 6.336 |
| 16 | 12,960 | 4.666 | 25,000 | 9.000 | 19,100 | 6.876 |
| 17 | 16,840 | 6.062 | 27,100 | 9.756 | 18,900 | 6.804 |
| 18 | 16,360 | 5.890 | 25,400 | 9.144 | 17,900 | 6.444 |
| 19 | 20,100 | 7.839 | 23,800 | 9.282 | 17,900 | 6.981 |
| 20 | 20,680 | 8.065 | 23,400 | 9.126 | 17,400 | 6.786 |
| 21 | 21,540 | 9.047 | 26,800 | 11.256 | 19,300 | 8.106 |
| 22 | 21,960 | 9.223 | 24,800 | 10.416 | 18,300 | 7.686 |
| Average | 13,143 | 4.694 | 25,541 | 8.788 | 18,295 | 6.308 |
| Minimum | 6,650 | 1.995 | 23,300 | 7.829 | 17,000 | 5.678 |
| Maximum | 21,960 | 9.223 | 29,600 | 11.256 | 19,700 | 8.106 |

VITA

Ted Ross Stover

Candidate for the Degree of

Doctor of Philosophy

Thesis: ANAEROBIC DIGESTION OPTIMIZATION FOR ENHANCED RENEWABLE BIOMETHANE PRODUCTION

Major Field: Civil Engineering

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Civil Engineering at Oklahoma State University, Stillwater, Oklahoma in July, 2011.

Completed the requirements for the Master of Science in Environmental Engineering at Oklahoma State University, Stillwater, Oklahoma in 2009.

Completed the requirements for the Bachelor of Science in Zoology at Oklahoma State University, Stillwater, Oklahoma in 2008.

Experience:

Treatability and Process Development Manager, THE STOVER GROUP
Stillwater, Oklahoma, 2008-present

Project Scientist, THE STOVER GROUP
Stillwater, Oklahoma, 2004-2008

Laboratory Technician, THE STOVER GROUP
Stillwater, Oklahoma, 2000-2004

Professional Memberships:

American Academy of Environmental Engineers, AAEE

Honorary Societies:

Chi Epsilon
Magna Cum Laude National Scholars Honor Society
Golden Key International Honour Society

Name: Ted Ross Stover Date of Degree: July, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ANAEROBIC DIGESTION OPTIMIZATION FOR ENHANCED RENEWABLE BIOMETHANE PRODUCTION

Pages in Study: 168 Candidate for the Degree of Doctor of Philosophy

Major Field: Civil Engineering

Scope and Method of Study: The scope of this research project was to operate suspended growth, continuous stirred tank reactor (CSTR) anaerobic digesters at the bench-scale level to evaluate improved operation techniques/methods and develop biokinetic relationships. Multiple digester reactors were operated simultaneously for approximately fourteen months to obtain data that was used to develop improved operational processes and biokinetic relationships, along with evaluation of treatment performance under various operating conditions. The goal for developing improved operational processes and biokinetic relationships at the bench-scale level, is to apply the improved techniques and relationships to full-scale biogas/bioenergy production facilities for improved digester operations and enhanced biogas production by producing the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume.

Findings and Conclusions: Individual feedstocks chosen for this study when combined to form a co-digestion substrate proved to be highly biodegradable and can be successfully converted to biogas with consistent average methane content between 65% - 70% using anaerobic digestion processes. Specific substrate utilization rate, specific biogas production rate, and specific methane production rate act as a function of mass specific substrate loading rate. Substrate selection, substrate monitoring, and digester monitoring for key analytical testing and on-line monitoring parameters are critical for maintaining anaerobic digester health, stability, and reliability. Minimizing substrate loading rate peaks and valleys is critical to stable digester operations and maximizing biogas production per unit of reactor volume. Biomass recycle is an excellent option for increased substrate utilization and enhanced biogas production. Operating anaerobic digestion systems for the primary purpose of biogas/bioenergy production, rather than for waste treatment, places greater emphasis on obtaining the maximum specific biogas/methane production rate possible from a given anaerobic digester reactor volume.

ADVISER'S APPROVAL: Dr. Enos L. Stover