ACID-PHASE ANAEROBIC DIGESTION OF PRIMARY SLUDGE: THE ROLE OF HYDRAULIC RETENTION TIME (HRT), TEMPERATURE AND A STARCH-RICH INDUSTRIAL WASTEWATER

BY

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INDIRA J. MAHARAJ

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of MASTER OF SCIENCE

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ABSTRACT

The following study presents the results of research related to acid-phase anaerobic digestion. The effects of hydraulic retention time (HRT) and low temperatures were explored on volatile fatty acid (VFA) production. A starch-rich industrial wastewater was also used in combination with primary sludge in order to determine their combined effects on acidogenesis.

Throughout the course of the study two identical 3L completely mixed reactors with clarifiers and solids recycling capabilities were used. Each reactor was operated under ambient temperatures (@ 25°C) while HRTs of 30, 48 and 60hrs were investigated. The HRT was then maintained at its optimal value of 30hrs while the effects of temperature were explored at 16 and 8°C. One reactor was fed with primary sludge while the other was run on a 50:50 volumetric mixture of starch-rich industrial wastewater and primary sludge. In each case an acidogenic state was achieved and maintained throughout the entire study.

The optimal net VFA and soluble chemical oxygen demand (SCOD) concentrations were attained at the 30hr HRT at 25°C. In the industrial-municipal reactor, the maximum net VFA and SCOD concentrations were 769mg/L and 1333mg/L respectively, and in the municipal-only reactor were 530mg/L and 978mg/L, respectively. The optimal specific VFA and SCOD production rates were also achieved at the 30hr HRT and appeared to decrease at the 48 and 60hr HRTs in accordance with the net concentrations. The VFA and SCOD production rates for the industrial-municipal reactor were 0.0453mg VFA/mg

VSS*d and 0.0789mg SCOD/mg VSS*d respectively, and 0.0306mg VFA/mg VSS*d and 0.0537mg SCOD/mg VSS*d, respectively for the municipal-only reactor.

The net VFA and SCOD concentrations as well as the specific VFA and SCOD production rates all decreased with a decrease in temperature. Maximum concentrations and production rates (as stated above) were attained at 25°C at an HRT of 30hrs and reached a minimum at 8°C. The net VFA and SCOD concentrations at 8°C in the industrial-municipal reactor were 278mg/L and 475mg/L respectively, and in the municipal-only reactor were 85mg/L and 125mg/L, respectively.

The reactor using the 50:50 combination of starch-rich industrial wastewater and primary sludge always achieved significantly higher net VFA and SCOD concentrations as well as higher specific VFA and SCOD production rates, than the reactor using only primary sludge.

In both reactors, acetic acid was the dominant VFA produced with average values per run ranging from 56 to 74%. Propionic acid followed composing 10 to 18% of the VFAs formed in the combined industrial-municipal reactor and 24 to 35% of those formed in the municipal-only reactor. N-butyric acid was produced in nearly the same quantities as propionic acid in the combined industrial-municipal reactor, but it was much lower in the municipal-only reactor. The starch-rich wastewater therefore caused an increase in n-butyric acid levels while decreasing the amount of propionic acid produced. HRT had no effect on VFA speciation in either reactor. The decrease in temperature did however result in a decreased production of acetic acid and an increase in the amount of propionic and n-butyric acid produced in the combined industrial-municipal reactor. In the

municipal-only reactor, propionic acid concentrations increased with the decrease in temperature.

Volatile suspended solids (VSS) reduction appears to be independent of HRT with an average reduction of 73% in the industrial-municipal system and 46% in the municipal-only system. A decrease in VSS reduction was however experienced with a decrease in temperature to a level of 50% in the combined industrial-municipal reactor, while no significant variation was observed in the municipal-only reactor.

VFA:SCOD ratios were high at the 30 and 48hr HRTs (@ 25°C) with values near 0.8 or higher in both reactors. At 60hrs and at the low temperatures of 16 and 8°C the ratio was approximately 100% indicating complete conversion of soluble organics to VFAs. The high VFA:SCOD ratios reflect an extremely successful acidogenic state.

In the combined industrial-municipal reactor, there was basically no net ammonia production at the 30 and 48hr HRTs (@ 25°C), or during the runs conducted at 16 and 8°C. The net ammonia production did however become apparent at the 60hr HRT. In the municipal-only reactor, net ammonia production increased with HRT but decreased with temperature.

A first-order kinetic relationship was found between HRT and VFA production in both the combined industrial-municipal system and the municipal-only system.

The fact that there was significant VFA production throughout the course of this study, regardless of operating and environmental conditions or feed composition, could enhance biological nitrogen and phosphorus removal processes.

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GLOSSARY OF TERMS

AAIV - autoanalyzer IV
ADP - adenosine diphosphate
ATP - adenosine 5'-triphosphate
BNR - biological nutrient removal
BOD - biochemical oxygen demand
BPR - biological phosphorus removal
CoA - coenzyme A
COD - chemical oxygen demand
CoV - coefficient of variation
FID - flame ionization detector
GC - gas chromatograph
HRT - hydraulic retention time
MPN - most probable number
NAD - nicotinamide adenine dinucleotide
NADH - nicotinamide adenine dinucleotide (reduced)
ORP - oxidation reduction potential
PFRP - process to further reduce pathogens
PSRP - process to significantly reduce pathogens
SCOD - soluble chemical oxygen demand
SRT - solids retention time
SS - suspended solids
TCOD - total chemical oxygen demand
TKN - total Kjeldahl nitrogen
TS - total solids
TSS - total suspended solids
UASB - upflow anaerobic sludge blanket
VFA - volatile fatty acid
VS - volatile solids
VSS - volatile suspended solids

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CHAPTER 1

INTRODUCTION

When one thinks of all the things that could ruin the earth as an inhabitable planet, many depressing scenarios come to mind. Global warming causing the melting of the polar ice-caps and the flooding of virtually all the earth's land; the greenhouse effect causing all of the toxins produced by humans everyday to be locked into our atmosphere until every living creature is suffocated; the depletion of the ozone layer to the point that incoming ultra-violet rays cause the mutation and death of the majority of the earth's inhabitants; the threat of a nuclear blast blocking out all sunlight causing the breakdown of food-chains and the eventual demise of almost every living creature, not to mention the horrific conditions that would have to be endured until that time. These are some of the most popular theories as to the depletion of life on earth. There are however more subtle dangers that if left unchecked could result in similar tragedies. One possibility is that people will eventually poison all of the earth's waters. It is for this reason alone that the treatment of various wastewaters is of enormous importance.

The world population is continually expanding resulting in the growing production of a variety of wastes. As such, there is a large quantity of wastewater produced from both industrial and municipal sources. If all of these wastewaters were discharged without any form of treatment, the degree of pollution in the receiving waters would be incredible. Pollutants would include various toxic compounds released by a number of industries, as well as the biological hazards caused by the release of municipal wastewaters.

Luckily, current technology allows for the treatment of industrial and municipal wastewaters through various liquid waste management schemes. One such scheme which has been used for at least one hundred years is anaerobic digestion. Traditionally, one of the main goals of anaerobic digestion has been the production of methane to be used as an energy source. However, anaerobic digestion also aids in the stabilization of wastes and in doing so produces volatile fatty acids (VFA) as intermediates. The production of VFAs is not however some insignificant step in the overall anaerobic process as they may be used in the removal of nutrients (nitrogen and phosphorus) from wastewaters.

The removal of nitrogen and phosphorus is essential to the survival of surface water bodies. Nitrogen and particularly phosphorus are responsible for the eutrophication and the eventual demise of surface waters. VFAs may serve as the carbon source needed in the nutrient removal process. If anaerobic digestion is carried out on-site in conjunction with nutrient removal, the costs of using VFAs as a carbon source would be minimal. A decrease in the levels of nitrogen and phosphorus discharged to surface waters would go a long way to preventing the eutrophication of water bodies, and aid in preserving one of the essential components to life on this planet. An investigation of the production of VFAs during acid-phase anaerobic digestion is therefore imperative. As such, the purpose of this study was to optimize VFA production by experimenting with various operational and environmental conditions. Thus, the effects of hydraulic retention time (HRT), temperature and a starch-rich industrial wastewater on acidogenesis were studied.

CHAPTER 2

LITERATURE REVIEW

2.1 THE BACKGROUND OF ANAEROBIC DIGESTION

Anaerobic digestion has been used in the treatment of wastewater sludges for over one hundred years. It was first used by Louis H. Mouras in about 1860 when he invented the 'Mouras automatic scavenger' to treat settled wastewater solids (Buswell, 1957 cited in Wang, 1994). This development was considered to be "a complete solution of the problem which for centuries had been an insolent menace hurled in the face of all humanity " (M. Allain Targe in Wang, 1994). The history of anaerobic digestion can be traced much farther back though, to the use of septic tanks for town sewage (Hobson, 1980). The biology behind the system has also been studied and in 1906, Omelinanski was able to attribute the degradation of cellulose with methane formation to microbial activity (Novaes, 1986). Presently, the main objectives of the anaerobic digestion of wastewater sludges are "the stabilization of organic matter with a concurrent reduction in odors, pathogen concentration, and the mass of solid organic material that requires further processing" (Parkin and Owen, 1986).

During anaerobic digestion, the organic and inorganic matter in the sludge is decomposed in the absence of molecular oxygen. Microorganisms like bacteria, fungi, protozoa, rotifers, and algae are primarily responsible for this transformation (Metcalf and Eddy, 1991). However, anaerobic digestion is not a process isolated to the digestion of sewage sludge. It has also been found to occur in bovine rumen, the intestinal tracts of animals, underwater sediments and mud (Marty, 1986).

There are several advantages associated with the anaerobic digestion of sludge. These include the production of methane as an energy source, reduction in sludge quantity, production of a soil conditioner, and pathogen destruction (Malina, 1992), as well as the ability to process large volumes of sludge at a relatively low cost (Ghosh et al., 1975). In fact, anaerobic digestion is classified as a 'process to significantly reduce pathogens' (PSRP) which means that treated sludge may be applied to crops with some restrictions to human access. If the sludge was digested under thermophilic conditions it is considered to be a 'process to further reduce pathogens' (PFRP) which implies no restrictions (Malina, 1992). Furthermore, anaerobic digestion has the ability to remove toxic compounds (pesticides, polyaromatic hydrocarbons, heterocyclic nitrogenous compounds, phthalates, phenolics) from sludges that may be used in land application, thereby reducing the risk of soil contamination and uptake by crops (Parker et al., 1994). The disadvantages of anaerobic digestion include a high capitol cost, long hydraulic detention times, and a poor quality supernatant (Malina, 1992).

Anaerobic digestion is currently being used, not only as a means of stabilizing domestic sludges, but in the treatment of industrial wastewaters as well. In the last two years, 400 systems have been implemented to treat industrial wastewaters and organic residuals. As of late 1997, there were more than 1000 systems operating or under construction worldwide (International Energy Agency, 1997 cited in Riggle, 1998). In Europe the anaerobic treatment option has grown due to the high cost of energy, land limitations, and strict discharge limits. North America is not far behind due to the costs associated with the treatment of aerobic effluents compounded with more rigid discharge limitations (Schneider and Jordan, 1989).

The applications of anaerobic digestion seem to be expanding. It has not only been used in the stabilization of domestic and industrial wastes, but also on chemically treated primary sludge, biological sludges, and sludge mixtures which include industrial wastes (Parkin and Owen, 1986). On the cutting edge of this age-old technology is the quest to maximize volatile fatty acid production through the fermentation of primary sludge (GonCalves et al., 1994) in order to remove nutrients (nitrogen and phosphorus) responsible for the cultural eutrophication of many of the earth's surface waters.

2.2 MUNICIPAL WASTEWATER

Municipal wastewaters consist of both organic and inorganic components. The organic matter is generally used in anaerobic digestion. This organic matter is mainly composed of carbon, hydrogen, oxygen and nitrogen, although sulfur, phosphorus and iron may also be present. Carbohydrates, fats, proteins, amino acids, and volatile acids make up about three-quarters of the organic carbon. The remaining quarter is a mixture of hormones, vitamins, surfactants, antibiotics, hormonal contraceptives, purines, pesticides, hydrocarbons and pigments (Gray, 1989).

Other research has indicated that carbohydrates make up about 25 to 50 percent of the organic matter found in wastewater, while lipids are responsible for approximately 10 percent, and proteins for 40 to 60 percent (Metcalf and Eddy, 1991). But, only half of these organics are actually available for digestion, as some of the carbohydrates and nitrogenous compounds cannot be degraded because of their structure or because they are protected by vegetable lignin, silica, waxes and other polymeric materials (Hobson,

1980). The non-biodegradable fraction of municipal sludge can range from 35 to 40 percent of the volatile matter to as high as 70 to 80 percent (Parkin and Owen, 1986).

Present day municipal sewage is basically 'a very large volume of dilute aqueous solution with a low suspended solids content.' The resulting sludge contains toilet and other papers, residues of food preparation, detergent residues, debris from street drains, and even waste from factories. It could also contain mineral oils, plastic materials, grit, soil and stones (Hobson, 1980). Wastewater also has a microbiological component consisting of viruses, bacteria, fungi, protozoans, and other microbes (Gray, 1989).

2.2.1 CARBOHYDRATES

The carbohydrates found in municipal wastewater are basically composed of sugars, starches, cellulose, pectin, lignin and wood fiber (Banerjee, 1997). These compounds contain carbon, hydrogen, and oxygen. The more common carbohydrates consist of six or multiples of six carbon atoms per molecule (Metcalf and Eddy, 1991). The major carbohydrates are glucose, sucrose and lactose with galactose, fructose, xylose and arabinose in smaller amounts (Gray, 1989).

Starch is not generally found in large amounts in municipal wastewaters. This is because it is rapidly used up by both humans and animals (Hobson, 1980). Any starch that is present is converted to a sugar by the existing microbial population and dilute mineral acids (Metcalf and Eddy, 1991).

2.2.2 LIPIDS

Lipids can be found in the form of triglycerides or triacylglycerols, phospholipids, steroids, carotenoids, and other compounds. Most of them contain fatty acids which have an average length of 16 or 18 carbon atoms (Prescott et al., 1996). Lipids are not considered to be easily biodegradable. They originate in wastewater from sources like butter, lard, margarine, vegetable fats, oils, meats, cereals, nuts, certain fruit and human excreta (Gray, 1989).

2.2.3 PROTEINS

All animal and plant tissue contains a significant amount of protein. Proteins are made up of a large number of amino acids linked together by peptide bonds. These molecules contain carbon, hydrogen, oxygen, and nitrogen. They may also contain sulfur, phosphorus and iron. The molecular weight of these molecules varies from 20000 to 20 million (Gray, 1989; Metcalf and Eddy, 1991).

Urea is another major source of nitrogen in wastewater. It is however usually only found in fresh wastewater as it decomposes quickly to ammonia. The sources of protein in wastewater include casein from milk, and albumen and gelatin from animal tissue and bone (Gray, 1989; Metcalf and Eddy, 1991).

2.3 INDUSTRIAL WASTEWATER

It is common in many areas for certain industries to discharge their wastewaters into the municipal sewage system. Research on the effects of mixing various types of wastewater for treatment within the plant is therefore warranted. Malpei et al. (1998) investigated the effects of anaerobic treatment on a combination of print pastes and primary sludge. It was found that total volatile acid and chemical oxygen demand (COD) concentrations increased two to three times when print pastes were added to the influent. Anaerobic digestion was considered to be a viable treatment option if only small amounts of print pastes were used. Carrieri et al. (1993) carried out an experiment where olive mill effluent, cheese whey, and landfill leachate were each mixed with sewage sludge and anaerobically digested. The results indicate that with the addition of such soluble substrates, the volumetric loading rate could be more than doubled in conventional digesters. The microbial activity of the combined treatment biomass also appears to be higher than that of sewage sludge alone, resulting in equal or better conversion rates than would be found in high-rate digesters. In fact, the treatment of olive mill effluent can be difficult. In places like Italy where such effluents are abundantly produced, anaerobic digestion is becoming the treatment of choice (Beccari et al., 1996).

The potato industry is responsible for the production of one of North America's most favorite snack time foods – POTATO CHIPS!!! But during the processing of this delicious delicacy the potatoes are washed and sliced, resulting in a wastewater which is extremely high in starch content. This effluent is also high in BOD_5 (biochemical oxygen demand), COD, and SS (suspended solids) concentrations (Abeling and Seyfried, 1993; Banerjee, 1997). It has been shown that waste potatoes when added to a pig waste

digester are easily fermented without the need for any acclimation period (Summers and Bousfield, 1976 cited in Hobson, 1980). Banerjee et al. (1998) combined a starch-rich potato wastewater and primary sludge in a 1:1 ratio to observe the effects on the acid-phase anaerobic digestion process at various hydraulic retention times (HRT) and temperatures. The addition of the potato wastewater proved beneficial in that a significant increase was found in the net VFA production and COD solubilization over the use of primary sludge alone regardless of HRT or temperature. Leighton and Forster (1997 cited in Riffat et al., 1998) conducted an experiment using starch as the primary substrate in a two-phase thermophilic anaerobic process in order to determine the toxicity effects of copper, nickel, zinc and lead. The results showed that nickel and zinc actually stimulated the production of propionate and butyrate, while copper and lead suppressed VFA production.

2.4 THE ANAEROBIC DIGESTION PROCESS

The anaerobic treatment process is complex in that there are many types of bacteria which carry out the microbiological processes in 'an assembly line fashion.' Ultimately, the performance of the system depends on the balance between the major types of bacteria (Parkin and Owen, 1986). Higher rates of conversion are possible in processes which have been designed to have various species of bacteria living in proximity to one another (McCarty and Smith, 1986). Nutrients, once metabolized, provide the energy and carbon needed for the growth of new cells.

The anaerobic digestion process operates optimally under mesophilic (~35°C) and thermophilic (55-60°C) conditions. When operated at lower temperatures, a sufficient residence time for the production of methane must be ensured (Malina, 1992; Pohland, 1992). The process can be broken down into three basic steps: hydrolysis, acid formation and methane formation (Figure 2.1).

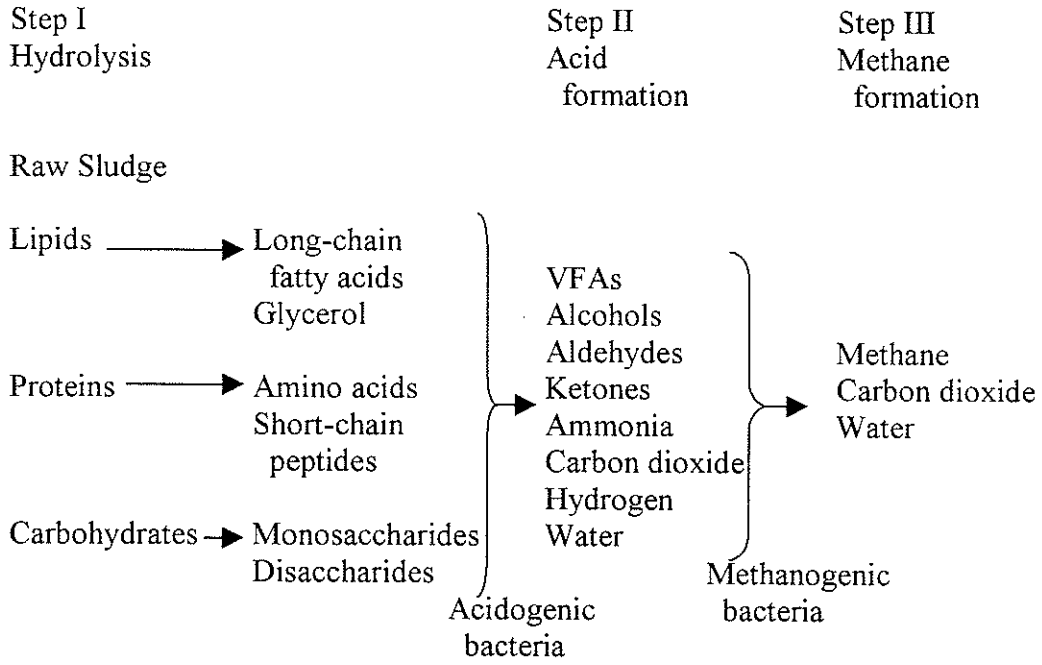

Figure 2.1: The three steps of sludge digestion. (Adapted from Gray, 1989)

During *hydrolysis*, compounds of high molecular mass (carbohydrates, lipids and proteins) are transformed into compounds which can be used as a source of energy and cell carbon by extracellular enzymatic reactions (Wang, 1994). This is an important step in the digestion process as most of the constituents of wastewater cannot be readily assimilated by bacteria due to their complex structure and/or insolubility. As it is, not all

organic compounds are hydrolyzable because of their structure, inaccessibility or the presence of complex nonhydrolyzable linkages. It should be noted that no organic waste stabilization occurs during hydrolysis. But, the rate of stabilization may be limited by the rate of hydrolysis, and may even cease to occur if hydrolysis is not functioning properly (Parkin and Owen, 1986).

The second step in anaerobic digestion is *acidogenesis* which involves the bacterial conversion of the hydrolysis products from the first step into lower molecular intermediate compounds (Wang, 1994). The acidogens responsible for this transformation are mainly obligate anaerobes (Marty, 1986). The intermediate compounds produced include VFAs, such as acetic, propionic, iso-butyric, n-butyric, iso-valeric, n-valeric and caproic acids, as well as small amounts of formic acid, lactic acid, and C_2 to C_4 alcohols (Andrews and Pearson, 1965). Some aldehydes, ketones, ammonia, carbon dioxide, hydrogen, and water are also produced by acid-forming bacteria (Gray, 1989).

The final step of the anaerobic digestion process is *acetogenesis* and *methanogenesis*. Here the intermediate products of the acidogenic phase are converted to carbon dioxide and methane by several species of obligate anaerobic bacteria (Gray, 1989; Wang, 1994). The methane is mainly produced from acetic acid and hydrogen or carbon dioxide. Methane is insoluble in water and therefore escapes in a gaseous form. Carbon dioxide can either leave as a gas or be converted to bicarbonate alkalinity. Methanogenesis like hydrolysis can be the rate limiting step of the anaerobic digestion process (Parkin and Owen, 1986; Wang, 1994).

A more detailed explanation of the process of anaerobic degradation may be seen in Figure 2.2. This model breaks the process down into six steps (Gujer and Zehnder, 1983):

1. Hydrolysis of carbohydrates, lipids, and proteins.
2. Fermentation of amino acids and sugars.
3. Anaerobic oxidation of long chain fatty acids and alcohols.
4. Anaerobic oxidation of intermediary products (except acetate).
5. Conversion of acetate to methane.
6. Conversion of hydrogen to methane.

Reactions 1 to 3 make up the hydrolysis and acidogenesis steps, while reactions 4 to 6 are responsible for methanogenesis (Elefsiniotis, 1993). These reactions are autocatalytic resulting in microbial populations proportional to the amount of substrate available for each group of the microorganisms (Gujer and Zehnder, 1983).

In order to improve the efficiency of anaerobic digestion, a two-phase process has been developed. Physically separating the hydrolysis step from the acidogenesis step is extremely difficult as acidogenic bacteria immediately consume the substrate once it has been liquefied. It is also hard to separate acetogenesis from methanogenesis as acetogens cannot survive at the hydrogen concentrations typically produced in the company of acidogens. Therefore the two-phase concept involves a physical separation of the acidogenic and methanogenic phases (Wang, 1994). There are many advantages to using such a system. For example, in a conventional single-stage digester a short HRT may

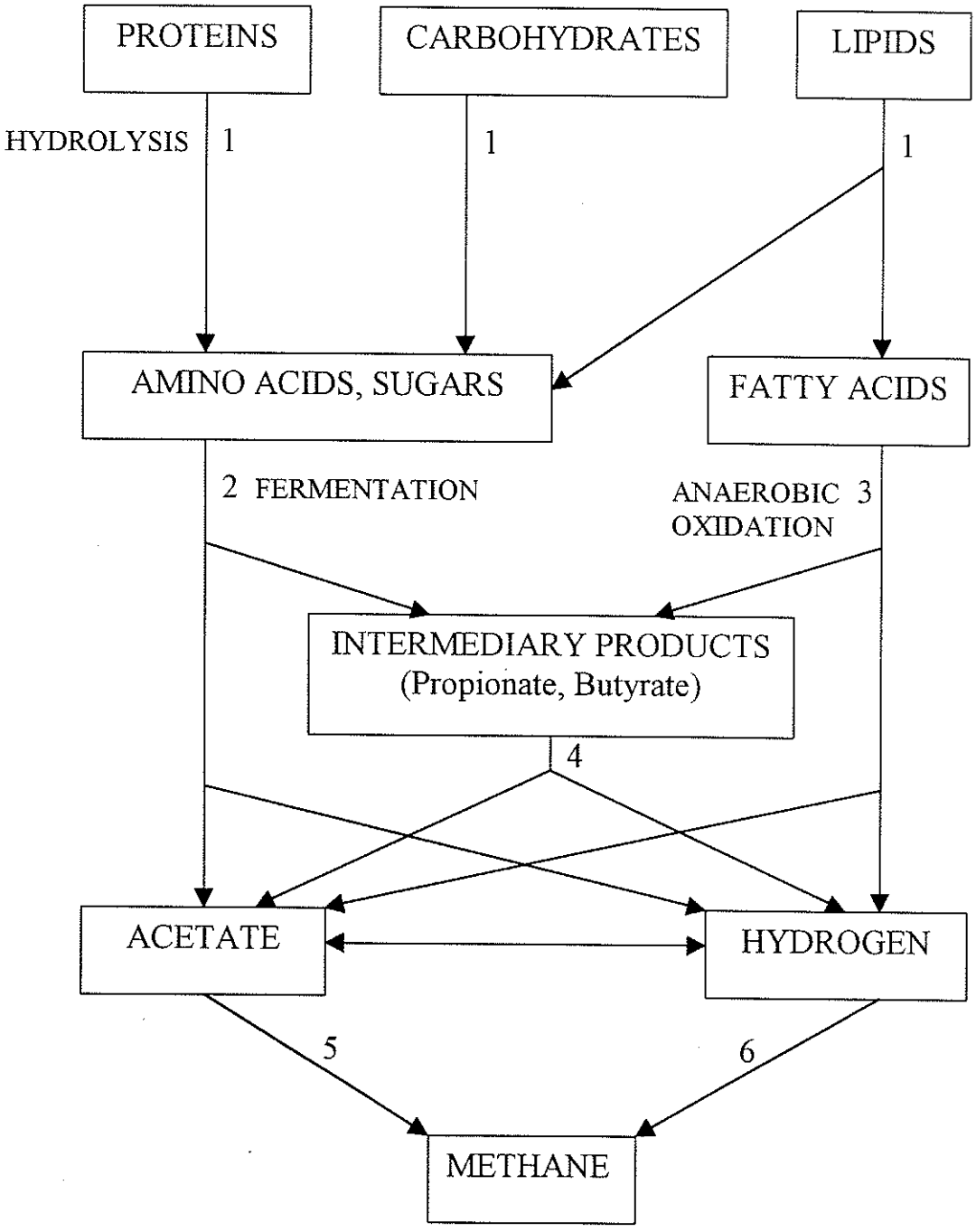

Figure 2.2: A six-step process for the anaerobic digestion of domestic sludge. (Adapted from Gujer and Zehnder, 1983)

result in the excessive production of VFAs causing digester failure (Ghosh, 1991). These separate phases allow hydrolysis and VFA production to be maximized in the first reactor while methane production is optimized in the second (Ghosh, 1987). This is done by simply providing the right environmental and operational conditions for each group of microorganisms, thereby achieving greater process control and stability (Parkin and Owen, 1986). Recent studies done by Jeyaseelan and Matsuo (1995) and Ghosh (1987) show that the two-phase anaerobic digestion system achieves a higher degree of efficiency than conventional single-stage systems. In fact, Bhattacharya et al. (1996) produced a 1.9% to 6.0 % increase in VS reduction with the use of a two-phase system over conventional digestion.

The separation of acidogens and methanogens does not infer the existence of a pure culture of either group. The acidogens are made up a various species of bacteria as are the methanogens. "It is probably the case that in all natural circumstances (and a digester is in many respects natural), the anaerobes must grow in association with other anaerobes or facultative anaerobes: it is through these relationships that they have survived over the millennia in a biosphere primarily dependant on oxygen and sunlight" (Hobson, 1980).

2.5 ACIDOGENESIS

The acid-phase of anaerobic digestion units usually encompasses both the hydrolysis and acidogenesis steps of the degradation process. The acid-phase is responsible for the conversion of complex carbohydrates to simple sugars, proteins to amino acids, and lipids

to long-chain fatty acids. The sugars and amino acids then undergo fermentation to VFAs and other such products, while the long-chain VFAs are oxidized to form simple VFAs (Antia et al., 1997). The bacteria responsible for the fermentation of the organic wastes consist of obligate and some facultative anaerobes, like *Clostridium spp.*, *Peptococcus anaerobus*, *Bifidobacterium spp.*, *Desulphovibrio spp.*, *Corynebacterium spp.*, *Lactobacillus*, *Actinomyces*, *Staphylococcus*, and *Escherichia coli* (Metcalf and Eddy, 1991).

During acid-phase anaerobic digestion there is virtually no change in the amount of organic matter present in the system. There is only the redistribution of organics into simpler forms as well as the release of gases like carbon dioxide, hydrogen and hydrogen sulfide (Malina, 1992). Acetic, propionic, and butyric acids seem to be the most common products of acid fermentation (Gray, 1989). The fact that VFA yields of 0.95g/g of total sludge solids can be attained makes acid-phase anaerobic digestion an 'attractive' process (Antia et al., 1997).

2.5.1 CARBOHYDRATE METABOLISM

The hydrolysis of polysaccharides is the first step to metabolizing carbohydrates. Cellulose tends to degrade very slowly with enzymes. This may be due to the fact that cellulolytic bacteria are usually fewer than other acidogens. It may also be due to an association with lignin which makes degradation more difficult. Cellulase, the enzyme that hydrolyzes cellulose, is more common in fungi than bacteria (Marty, 1986). *Clostridia*, *Ruminococcus*, *Butyrivibrio*, *Bacteroids* and *Cellobacterium* are all

responsible for the hydrolysis of cellulose (Hungate, 1966 & Maki, 1954 cited in Marty, 1986). Other polysaccharides include hemicellulose, chitin, pectin, and mucopolysaccharide which can be hydrolyzed to hexoses, pentoses, aminosugars, and uronic acids (Marty, 1986).

Starch tends to be more easily hydrolyzed than cellulose (Marty, 1986). There are four types of enzymes capable of breaking-down starch: amylases (alpha- and beta-), pullulanase or isoamylase, and glucoamylase. The resulting products are glucose, maltose and dextrins (Gottschalk, 1986).

Once the polysaccharides have been hydrolyzed to simpler forms, they may be assimilated by cells for use as a source of carbon and energy. The most common product of carbohydrate catabolism is glucose, and the most common route of degradation for glucose is the Embden-Meyerhof pathway (Figure 2.3). This pathway can be broken down into two stages. The first is the six-carbon stage where glucose is phosphorylated twice resulting in fructose 1,6-biphosphate. During this stage other sugars may join the pathway if converted to glucose 6-phosphate or fructose 6-phosphate. In the three-carbon stage the enzyme aldolase assists in the production of pyruvate. Once pyruvate is produced, it may be degraded to various volatile acids and alcohols (Prescott et al., 1996) as shown in Figure 2.4.

Acetic acid is one of the products of glucose, and therefore pyruvate degradation. The reaction representing this degradation is as follows (Gottschalk, 1986):

$$C_6H_{12}O_6 \rightarrow 3CH_3COOH$$

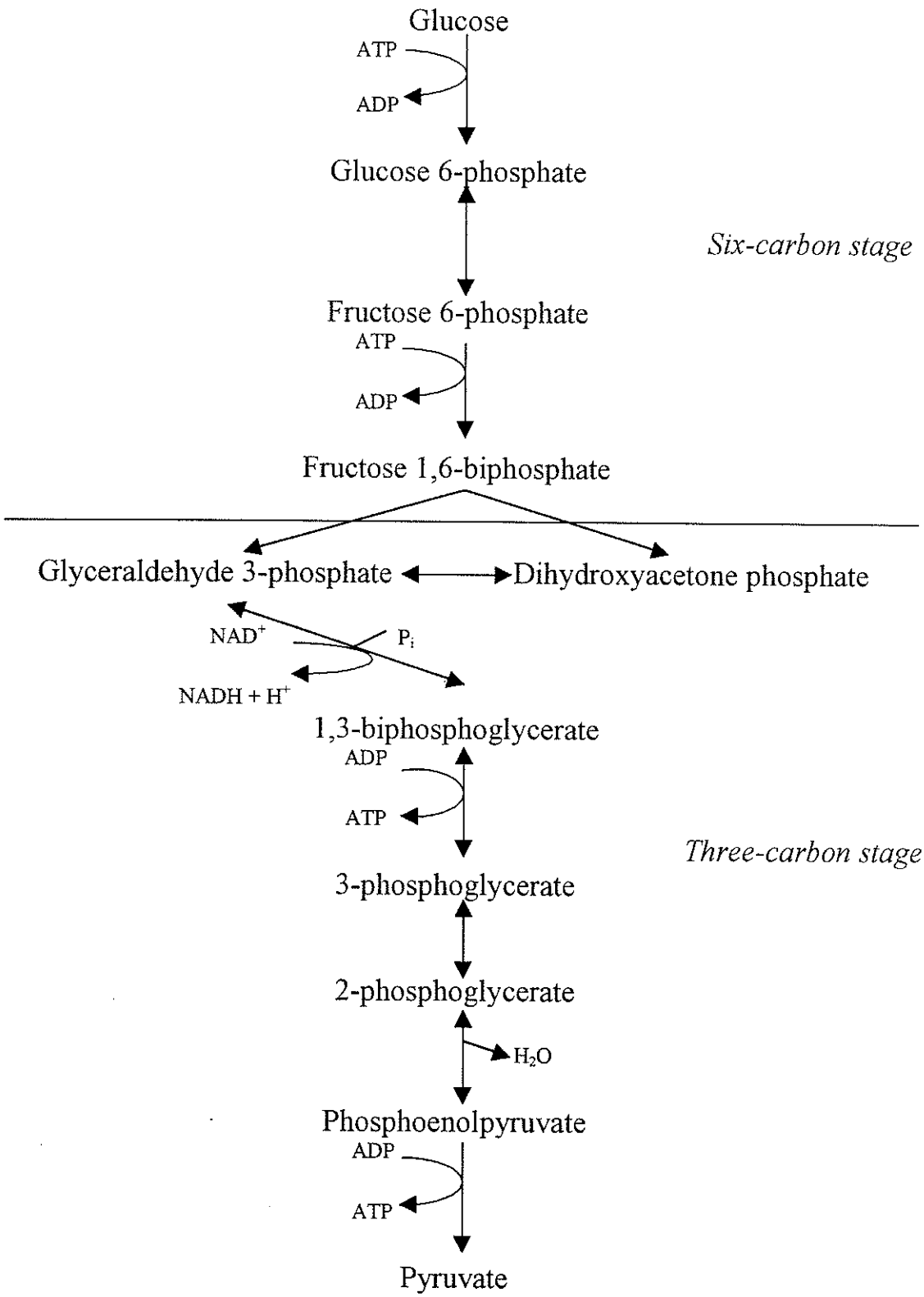

Figure 2.3: The Embden-Meyerhof pathway.
(Adapted from Prescott et al., 1996)

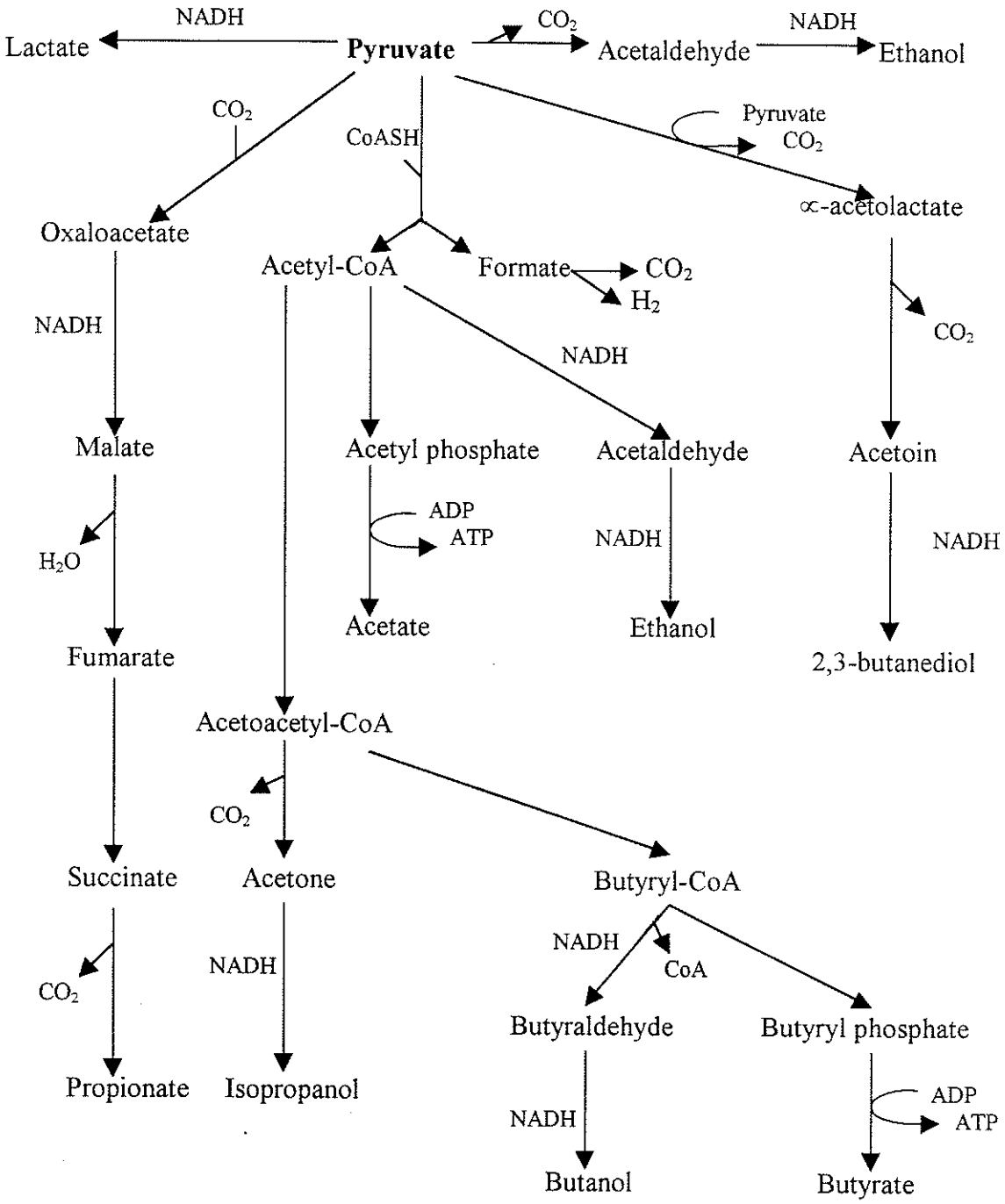

Figure 2.4: Pyruvate degradation pathway.
(Adapted from Prescott et al., 1996)

Acetic acid may also be formed from hydrogen and carbon dioxide according to (Gottschalk, 1986):

$$4H_2 + 2CO_2 \rightarrow CH_3COOH + 2H_2O$$

Propionic acid may be formed via the succinate-propionate pathway or the acrylate pathway. In the succinate-propionate pathway, lactate by way of pyruvate and succinate is converted to propionate. In the acrylate pathway, lactate is reduced to propionate. It is obvious then that lactate is a preferred substrate for propionate-forming bacteria. The succinate-propionate pathway is however more commonly used than the acrylate pathway (Gottschalk,1986).

Butyrate is produced by obligate anaerobes from the pyruvate formed in the Embden-Meyerhof pathway. Pyruvate is converted to butyryl-CoA, followed by butyryl phosphate and finally butyrate (Gottschalk, 1986).

2.5.2 LIPID METABOLISM

Triglycerides or triacylglycerols, esters of glycerol and fatty acids are the more common forms of lipids used by microorganisms as an energy source. These lipids are hydrolyzed to glycerol and fatty acids by lipases (Prescott et al.,1996). Lipases are secreted by the *Bacillus*, *Chromobacterium* and *Serratia* species (Finnerty, 1988 cited in Elefsiniotis, 1993). Phospholipids are another form of lipids which can be found in the plasma membrane of bacteria. Phospholipases are used to hydrolyze phospholipids after the cell has died (Prescott et al., 1996; Elefsiniotis, 1993).

Once the lipids have been hydrolyzed to glycerol, they may be absorbed by bacterial cells to join the Embden-Meyerhof pathway and undergo glycolysis with the carbohydrates (Prescott et al., 1996). The fatty acids however are fermented via anaerobic oxidation as represented by the following reaction (Gujer and Zehnder, 1983):

$$(-CH_2\text{-}CH_2\text{-}) + 2H_2O \rightarrow CH_3COOH + 2H_2$$

2.5.3 PROTEIN METABOLISM

Bacteria may also use protein as a source of carbon and energy. Proteins are hydrolyzed by proteases to polypeptides, oligopeptides, and amino acids. Bacteria are capable of catabolizing the smaller peptides and amino acids as they can be transported through their cell walls (Gray, 1989; Prescott et al., 1996). This behavior may be carried out by bacilli, pseudomonads, *Proteus vulgaris* and the *Clostridium* species (Gottschalk, 1986). The most active of these proteolytic bacteria is by far the *Clostridium* species (Gray, 1989).

After the proteins have been hydrolyzed to amino acids and assimilated by the bacteria, they go through the process of deamination. Here the amino group is removed from the amino acid. The amino group may be transferred to an alpha-keto acid acceptor – a process known as transamination. The remaining organic acid may be converted to pyruvate or may be used as a carbon source for the synthesis of cell constituents (Prescott et al., 1996).

Some clostridia ferment mixtures of amino acids through coupled oxidation-reduction reactions known as the Stickland reactions. For example, in the following reactions alanine is oxidized while glycine is reduced to produce acetic acid (Gottschalk, 1986):

$$CH_3\text{-}CH(NH_2)\text{-}COOH + 2H_2O \rightarrow CH_3\text{-}COOH + CO_2 + NH_3 + 4H$$

$$2NH_2\text{–}CH_2\text{-}COOH + 4H \rightarrow 2CH_3\text{-}COOH + 2NH_3$$

2.6 FACTORS AFFECTING VFA PRODUCTION

The study of acidogenesis has not traditionally been the main topic of concern in the field of anaerobic digestion. The production of methane was considered to be much more important due to its implications regarding cost and energy benefits. During the last decade many studies have been done in an attempt to optimize VFA production. These studies investigate operational parameters like HRT and SRT (solids retention time), as well as environmental parameters like temperature and pH. The effects of using various wastewaters and the composition of the wastewater have also been studied with regards to VFA production.

2.6.1 OPERATIONAL PARAMETERS

Elefsiniotis and Oldham (1994a) investigated the effects of HRT on the acidogenic digestion of primary sludge in a series of continuous-flow experiments at ambient temperatures (18°C to 22°C). Their results indicated that VFA concentration would increase with HRT but only to a maximum of 12 hours. The next HRT tested was at 15 hours and was accompanied by an increased production of gaseous end products. This

along with a decrease in VFA production provides evidence of the beginning of methanogenesis. Gupta et al. (1985) conducted batch experiments at temperatures ranging from 10°C to 30°C as opposed to ambient temperatures. They found that VFA concentrations increased at 10°C and 20°C with HRTs from 3 to 9 days and at 30°C with HRTs of 3 to 6 days, but decreased at 30°C and 9 days possibly due to the onset of methanogenesis.

Banerjee at al. (1998) also investigated the effects of HRT and temperature on acidogenesis, and incorporated the use of a starch-rich wastewater which caused an increase in VFA production. When HRT was raised from 18 to 30 hours, VFA production increased by 37% with a 1:1 mixture of starch-rich wastewater and primary sludge, in comparison to a 14% increase with primary sludge alone. As well, when temperature was increased from 22°C to 30°C, the mixed wastewater produced a 15% increase in net VFA production, while the net production decreased with the primary sludge alone due to poor clarifier performance.

In an experiment carried out by Skalsky and Daigger (1995) volatile acid yields were found to increase with SRT. However, even at very low SRTs volatile acid production was near the maximum attained. It was also found that dilute reactors favored the production of volatile acids. These results are somewhat contradictory in that a low SRT would require a smaller reactor volume, while a low solids concentration would require a higher reactor volume, yet both scenarios would yield a high degree of volatile acid production. Elefsiniotis and Oldham (1994b) also experimented with SRT and found that VFA production slightly increased with an increase in SRT from 10 to 20 days, but drastically decreased at an SRT of 5 days.

2.6.2 ENVIRONMENTAL PARAMETERS

Cha and Noike (1997) explored the effects of rapid temperature change on anaerobic acidogenesis. The significance of this study lies in the increasing trend of using low temperature anaerobic digestion in order to save energy. They discovered that substrate degradation would be significantly affected by a rapid drop in temperature from 30 to 15°C, especially at low HRTs. The stability of the reactor was however slowly recovered. They also found that acidogens were not significantly affected by the changes in temperature with there numbers ranging from 107 to 109 MPN/mL (most probable number per milliliter).

Perot et al. (1988) conducted an experiment where the effects of pH, temperature and agitation speed were investigated with respect to VFA production. The pH ranged between 5 and 7, the temperature between 35°C and 55°C, and the agitation speed between 350rpm and 650rpm. Optimal hydrolysis conditions appeared to be a pH of 6.8 at a temperature of 50°C and an agitation speed of 545rpm.

Elefsiniotis and Oldham (1994c) during their experiments on the acid-phase anaerobic digestion of primary sludge found that a decrease in pH from 5.1 to 4.5 has no effect on VFA generation rate. Increasing the pH to 6.1 did however result in lowering acid production rates by 25% to 30%. Ghosh (1987) produced results that indicate that hydrolysis and acidification were more efficient at a pH of 6 with an HRT of 2 days under thermophilic conditions in contrast to a pH of 5 or 7 at an HRT equaling 1.3 days under mesophilic conditions.

2.6.3 WASTEWATER COMPOSITION

In addition to the previously mentioned studies, Chyi and Dague (1994) have found that substrates with a smaller particle sizes (20μm) operating at a longer HRT produce more soluble COD than larger particle sizes (50μm) operating at a shorter HRT. Jeyaseelan and Matsuo (1995) in their work on phase separation found that skimmed milk (53% carbohydrates, 34% proteins, 1% lipids) always produced higher amounts of volatile acids COD in comparison to baby milk (40% carbohydrates, 6% proteins, 54% lipids). They then concluded that lipids while being hydrolyzed and acidified themselves, hinder such conversions with proteins and carbohydrates. Elefsiniotis (1993) discovered that using a different source of influent sludge may affect VFA production rates because of variations in lipid and carbohydrate utilization patterns. Finally, Banister and Pretorius (1998) showed that increasing the number of acidogens by adding partially fermented sludge to fresh primary sludge would significantly improve VFA yields.

2.7 THE IMPORTANCE OF VFA PRODUCTION

The production of volatile fatty acids is rapidly becoming an essential component of the wastewater treatment process. These short-chain soluble organic compounds serve an important role in biological nutrient removal processes. By limiting the release of nitrogen and phosphorus the eutrophication of receiving waters may be prevented.

VFAs have an enormous potential to aid in the removal of nutrients from wastewaters. They can be produced on-site with low operational costs and no storage and handling problems (Elefsiniotis and Oldham, 1993). Pitman et al. (1983) have

already shown that the use of VFAs allows for high rates of denitrification as well as low phosphorus residuals (<1.0mg P/L). The following sections will reveal the importance of VFAs to biological nutrient removal.

2.7.1 BIOLOGICAL NITROGEN REMOVAL

In biological nutrient removal, nitrogen is removed via nitrification and denitrification processes. But nitrogen may also be removed through cell growth and wastage as bacteria use the nitrogen in amino acids and other compounds as building blocks for various cell constituents. Autotrophic microorganisms are mainly responsible for nitrification. The process is represented by the following equations:

$$55NH_4^+ + 76O_2 + 109HCO_3^- \rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$$

$$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^-$$

The conversion of ammonium to nitrite is carried out by *Nitrosomonas* and *Nitrosococcus* while *Nitrobacter* and *Nitrosocystis* are responsible for the production of nitrate from nitrite (Oleszkiewicz, 1995a).

The process of denitrification is carried out by facultative heterotrophs like Pseudomonas under anoxic conditions. It is here that nitrate is converted into reduced forms such as N_2, N_2O, or NO. A typical reaction for denitrification is (Oleszkiewicz, 1995a):

$$NO_3^- + 5/6CH_3OH + 1/6H_2CO_3 \rightarrow 1/2N_2 + 4/3H_2O + HCO_3^-$$

The heterotrophic denitrification process does require a source of carbon which acetate, propionate, butyrate, and valerate are all capable of providing. As well,

acidogenic fermentation and denitrification both occur at relatively the same oxidation reduction potential (ORP) levels. These factors make VFAs a logical and convenient choice of substrate for denitrification (Fass et al., 1994; Oleszkiewicz, 1995b). In fact, Hatziconstantinou et al. (1996) achieved a plant denitrification rate 30% higher with the use of hydrolysate than without; and Brinch et al. (1994) found a 44% increase in denitrification rate when hydrolysate was used at the Tuelso wastewater treatment plant in Denmark.

2.7.2 BIOLOGICAL PHOSPHORUS REMOVAL

In biological phosphorus removal (BPR) microorganisms like *Acinetobacter* are subjected to both anaerobic and aerobic conditions. VFAs may be used as a carbon source in the anaerobic zone where they would be taken up by the biomass while phosphorus is released. Then, if the anaerobic zone is followed by an aerobic zone the cells will be able to assimilate phosphorus at levels higher than would normally be possible. The phosphorus is then removed with the sludge containing these cells (Metcalf and Eddy, 1991).

There is a distinctive relationship between the amount of phosphorus taken up by the biomass and the amount of VFAs available to them. The availability of the VFAs in the anaerobic zone will dictate the amount of phosphorus released, while the amount released is directly related to the amount assimilated in the aerobic zone (Wentzel et al., 1985). Considering that untreated sewage usually contains less than 5mg/L of VFAs, the addition of anaerobically fermented primary sludge supernatant to the anaerobic zone of

the BPR process would maximize VFA availability (Elefsiniotis and Oldham, 1993; Nicholls et al., 1985).

The amount of phosphorus removed not only depends on the amount of VFAs available but also on the specific type of VFA. Recent studies have found that acetic acid is the most beneficial to BPR, while propionic is the least beneficial if not detrimental. Branched VFAs were also found to stimulate greater phosphorus release and uptake than linear forms of the same molecule (Abu-ghararah and Randall, 1991; Randall et al., 1994; Randall et al., 1997).

The removal of phosphorus is extremely important because unlike nitrogen it cannot escape in a gaseous form. When phosphorus enters the aquatic cycle it is hydrolyzed and assimilated by algal and bacterial cells under aerobic conditions. The cells will eventually die and fall to the bottom of the water body where anaerobic hydrolysis will take place. The phosphorus from the cells will then be released back into the water, and will continue to accumulate in such a manner (Oleszkiewicz, 1995b). Pitman et al. (1992) managed to significantly improve the phosphorus removal at the Johannesburg Northern Works plant with the use of VFAs. Similarly, at biological nutrient removal (BNR) plants in Kelowna and Penticton, British Columbia, VFAs were found to enhance biological nutrient removal resulting in very low effluent phosphorus levels of 0.2 to 0.3mg/L (Oldham et al., 1994). However, continual research into the removal of nutrients and especially phosphorus is imperative to the well-being of aquatic environments around the world.

2.8 PROCESS CONFIGURATION

Presently, there are a number of different anaerobic treatment options to choose from (Figure 2.5). Choices include the completely mixed reactor, the anaerobic contact process, upflow and downflow packed bed reactors, fluidized and expanded bed reactors, the upflow anaerobic sludge blanket (UASB) and baffled reactors. This study used the anaerobic contact process, which has also been used in the meat-packing industry as well as other industries that produce high strength soluble wastes (Metcalf and Eddy, 1991). It basically consists of a completely mixed reactor with a clarifier and solids recycling capabilities.

In the anaerobic contact process as with the completely mixed reactor, particles enter the tank and are immediately and evenly dispersed throughout. At the same time particles leave the tank in proportion to their statistical population. The effluent should therefore theoretically be identical to the reactor contents (McCarty and Smith, 1986; Metcalf and Eddy, 1991). Sometimes a completely mixed reactor can contain groups of flocculated particles which can act as a biofilm. A biofilm is usually considered to be 'a dense layer of microorganisms attached to an inert surface.' It can however be 'a dense aggregation of microorganisms held together by electrostatic forces or synthetic or natural polymers.' In completely mixed reactors biofilms are held in suspension along with other dispersed microorganisms and provide a diverse environment in close proximity to one another, which in turn allows for the efficient conversion of organic wastes (McCarty and Smith, 1986).

In conventional digesters the HRT is usually the same as the SRT as there is no recycling of the settled biomass (Parkin and Owen, 1986). With recycling, the SRT can

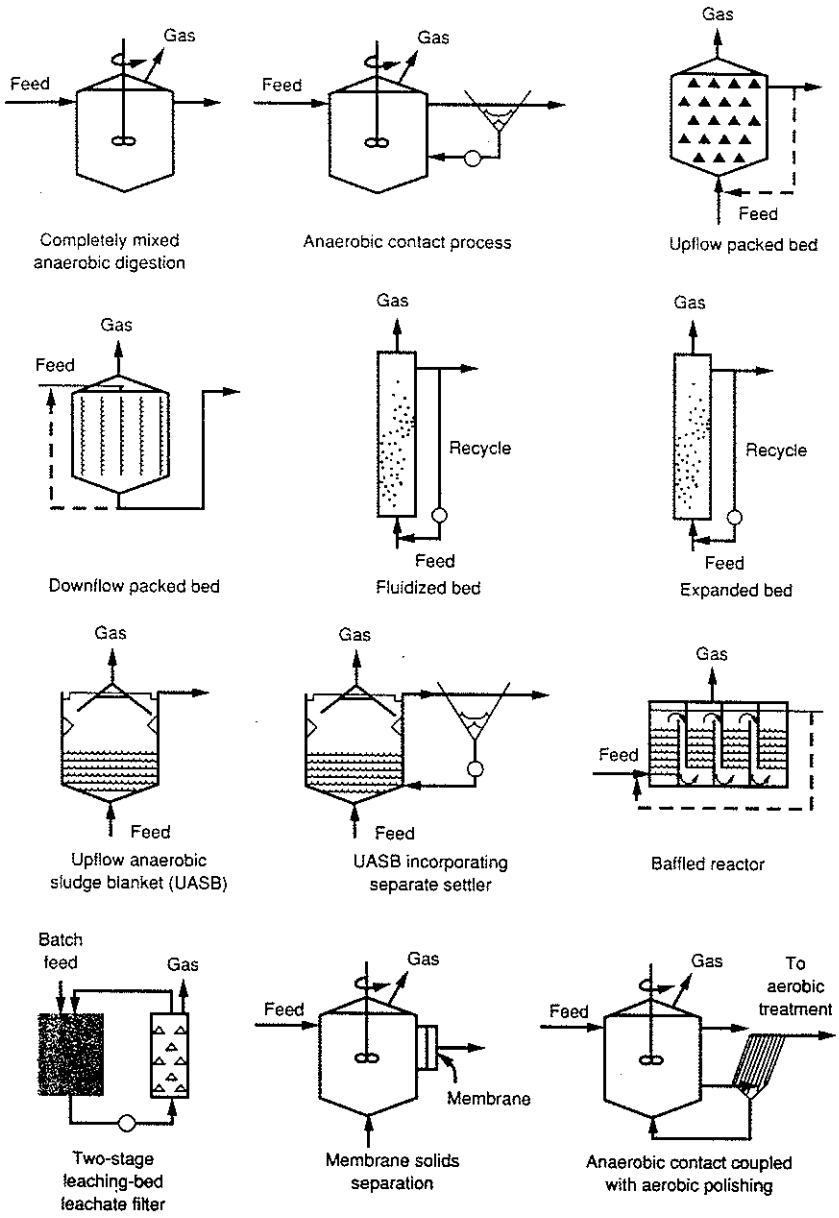

Figure 2.5: Anaerobic treatment configurations.
(Adapted from Speece, 1983 and Metcalf and Eddy, 1991)

be maintained at the required level while the HRT may be reduced. Recycling will also allow the active microorganisms and the undigested influent to mix thus promoting the biodegradation capabilities of the reactor on the wastewater. Also, with the reduced HRT a larger volume of wastewater may be treated with a smaller reactor volume (Hall, 1992). Advantages and disadvantages of the anaerobic contact process are provided in Table 2.1.

ADVANTAGES
■ Suitable for wastes with high soluble organic concentrations ■ Process can provide uniform substrate, temperature, and pH conditions throughout the reactor ■ Easy sampling of reactor for process monitoring ■ Good internal mixing can minimize dead volume accumulation and flow channeling ■ Can achieve a relatively high quality of effluent ■ Completely mixed reactor volumes can be reduced considerably in comparison to conventional anaerobic digestion ■ Aerobic post-treatment sludge can be wasted for stabilization to the anaerobic reactor
DISADVANTAGES
■ Successful operation depends on biomass settleability ■ Most suitable for wastes with low to intermediate levels of suspended solids ■ To produce a settleable floc pre-treatment of biosludge may be necessary (i.e. temperature shock, vacuum degasing, etc.) ■ Relatively short anaerobic reactor HRT results in reduced equalization capacity for shock inputs

Table 2.1: The advantages and disadvantages of the anaerobic contact process. (Adapted from Hall, 1992)

CHAPTER 3

RESEARCH OBJECTIVES

The main purpose of this study is to explore various aspects of the acidogenic phase of anaerobic digestion. As mentioned previously, research in this area has traditionally focused on methanogenesis while the benefits of acid-phase anaerobic degradation are just beginning to be realized. Studies have been performed which investigate the effects of operational parameters like HRT and SRT, and environmental parameters including temperature and pH on VFA production (Section 2.6). One topic of particular interest to those living in colder climates is the effect of low temperatures on acid production.

Anaerobic digestion has usually been used on sewage sludge alone. However the industrial discharge of high strength wastewaters to treatment plants has led to an interest in treating various combinations of wastes. As such, experiments have been carried out using combinations of olive mill effluents, cheese whey, landfill leachate, and print pastes with primary and/or secondary sludges (Carrieri et al., 1993; Malpei at al., 1998). In Manitoba, the potato industry produces a wastewater high in starch and discharges their effluents to the sewage system, which would therefore eventually require treatment along with municipal wastes.

The objective of this study is not only to broaden the present knowledge in the field of acid-phase anaerobic digestion, but to optimize the conditions under which VFAs are produced. The significance of this optimization lies in the area of biological nutrient

removal (Section 2.7), and basically the survival of the earth's surface waters. This study therefore investigated the following areas:

1) The effect of HRT on acidogenesis;
2) The effect of temperature on acidogenesis; and
3) The effect of combining a starch-rich wastewater with primary sludge on acidogenesis.

In order to determine the effects of HRT, temperature and the starch-rich industrial wastewater, two continuous-flow reactors were assembled. While maintaining the required HRT and temperature, one reactor was fed with primary sludge alone and the other with a 50:50 combination of starch-rich wastewater and primary sludge. VFA production was measured regularly to monitor the acidogenic state within each reactor.

CHAPTER 4

EXPERIMENTAL METHODS

4.1 WASTEWATER SOURCES

The primary sludge used for this study was collected approximately every fourteen days from the South End Water Pollution Control Center in Winnipeg, Manitoba. It was stored in 20L opaque plastic containers at 6°C. The total solids (TS) content of the sludge was found to be between 27000 to 82000mg/L. Before feeding, it was diluted with tap water to a solids level of 5000mg/L (influent characteristics are presented in Section 5.1).

The starch-rich industrial wastewater was obtained from the Old Dutch Food Company which is also located in Winnipeg. The company manufactures potato chips and in doing so releases a great deal of the starch held by the potatoes. The resulting wastewater must proceed through a series of settling tanks in order to remove much of this starch. The wastewater used in this study was collected just prior to its entrance through the series of settling tanks. The effluent as previously mentioned is discharged to the sewer system. Fresh industrial wastewater was obtained each month and the solids content ranged from 56000 to 127000mg/L. Before feeding, it too was diluted to 5000mg/L in order to minimize mechanical problems (ie. clogged hoses), and to provide a relatively consistent feed throughout the course of the study. This TS concentration was also chosen to allow for direct comparison with previous studies (Banerjee, 1997; Banerjee et al., 1998), and because of the evidence which indicates that low sludge TS concentrations favor VFA production (Skalsky and Daigger, 1995), and improve the anaerobic contact process performance (Hall, 1992).

4.2 EXPERIMENTAL SET-UP, OPERATION AND SAMPLING

4.2.1 SYSTEM LAYOUT

This study used two identical anaerobic contact process configurations (Figures 4.1 and 4.2). Each system consisted of a reactor with an internal diameter of 11.4cm, a total volume of 4.0L and a liquid volume of 3.0L. The reactors were made out of Plexiglas, and were continuously stirred at a rate which virtually ensured complete mixing. Mixing was achieved with the use of a steel rod and a Cole-Parmer pump adapted for use with a stirring rod. The stirring rod had two paddles, such that one was situated in the upper third of the liquid volume and the other in the lower third. The rate of mixing was controlled with MasterFlex speed controllers. Sampling and wasting from the reactors was achieved through a port located 17cm from its base.

Each reactor was fed with their respective wastewaters at 30 minute intervals for a period of 1 minute. The feed was pumped from the 6°C cold storage chamber where it was contained in 20L plastic buckets. Each of the feed buckets were mechanically stirred at a rate which would ensure proper mixing, using stirring rods with one paddle located at the end of each rod.

The clarifier for each system had an internal diameter of 10.8cm and a liquid volume of 2.0L. They may be considered to be modified Imhoff cones as the bottom of each clarifier was made in an inverted cone shape to aid in the settling of biomass. Recycling of the biomass was done every 30 minutes for a period of 1 minute along with the feeding. MasterFlex speed controllers were once again used to control the amount of biomass recycled and the rate of feeding. The supernatant from the clarifiers was collected in 10.0L plastic containers and discarded after sampling.

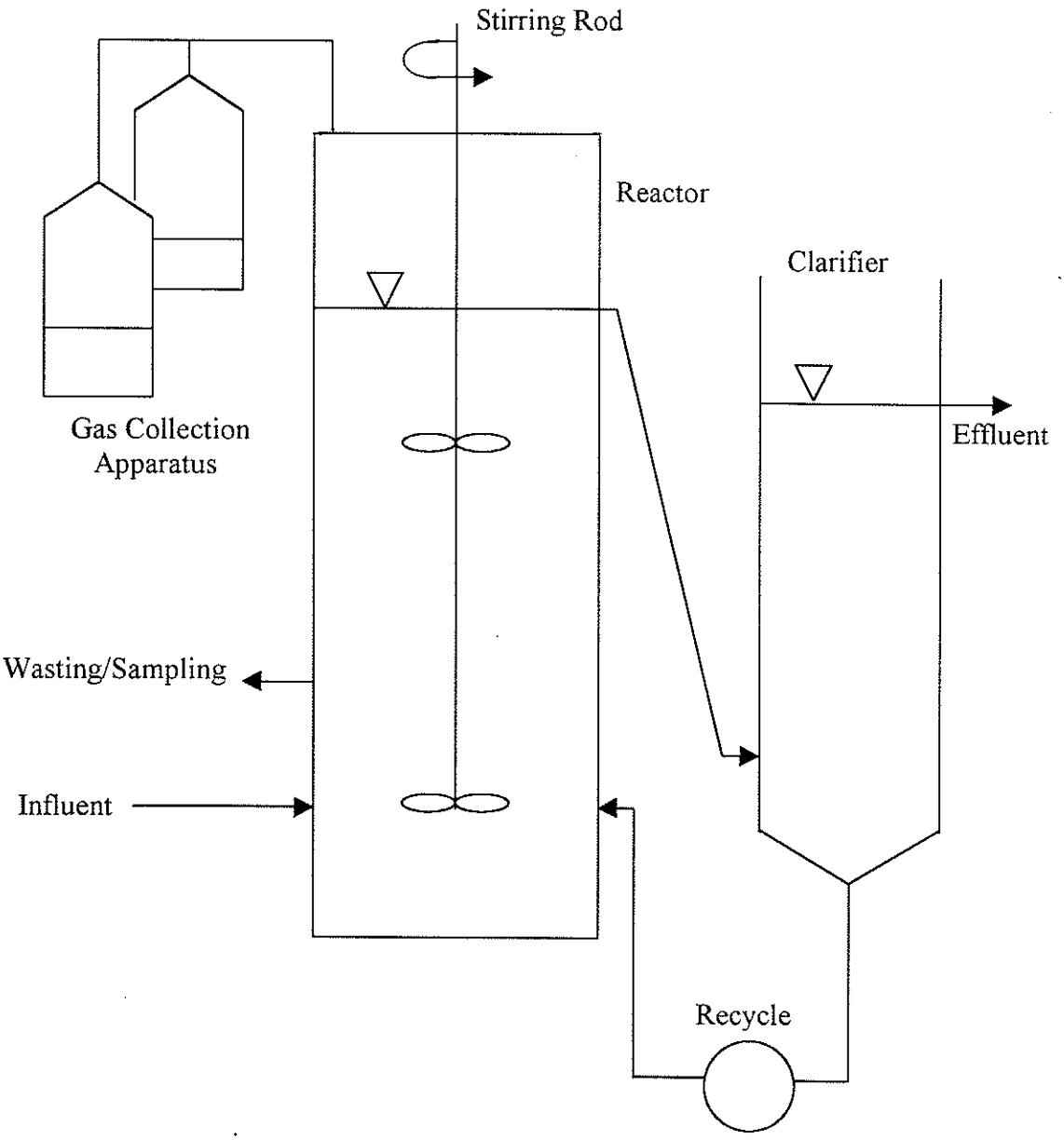

Figure 4.1: Reactor configuration.

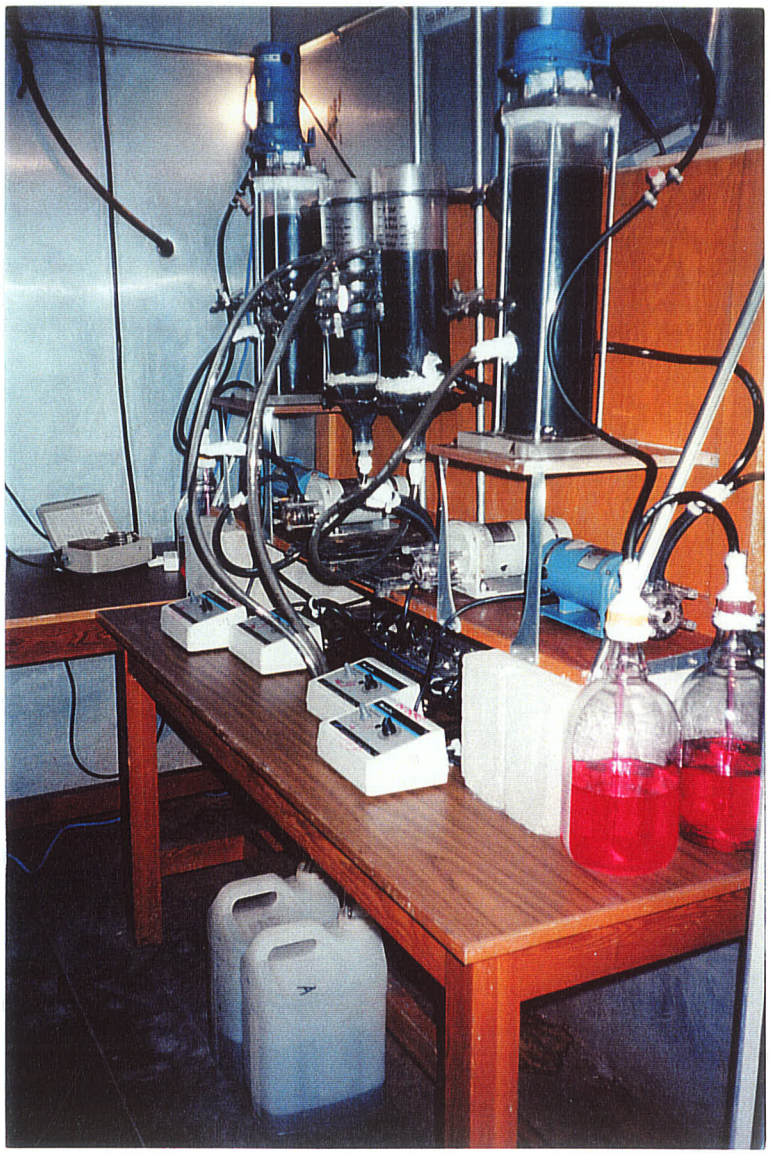

Figure 4.2: Reactors A and B within a temperature controlled chamber.

Each of the two anaerobic reactors were also connected to a set of gas collection apparatus which consisted of two glass bottles with a volume of 2.25L. Each bottle contained a gas retaining fluid as did the tubing which connected them. Once gas was produced in the reactor the level of fluid in the first bottle directly connected to the reactor would drop, and the level of fluid in the second bottle would increase. The first bottle is calibrated such that the amount of gas produced could be measured with the drop in fluid level. The composition of gases in the headspace of the reactor may be identified via a sampling port located in the middle of the tubing connecting the reactor to the gas collection apparatus.

4.2.2 SYSTEM OPERATION AND SAMPLING

At the beginning of this study both reactors were seeded with 1.0L of digested sludge from the North End Water Pollution Control Center in Winnipeg, Manitoba. The seed had a total solids concentration of 25000mg/L. Primary sludge feed was used for both reactors during the first run of the study. It was diluted to 5000mg/L and a small amount was immediately pumped into the system, and was then pumped in overnight until the entire system was filled. Once this had occurred, each of the reactors were purged with nitrogen gas in order to eliminate the presence of oxygen.

During the course of this study a total of 6 runs were conducted under varying conditions. The first run used primary sludge as the feed for both systems with an HRT of 30hrs at an ambient temperature. The second run incorporated the use of the industrial wastewater with the primary sludge feed at a 1:1 ratio in system A. A set of fifteen data

points was collected for each run which took approximately 7-8 weeks, including an acclimation period of 1-1.5 weeks. Run P however, consisted of only seven data points collected over a 6 week period (including acclimation). Steady-state as defined in Section 5.2 was achieved for each run. The conditions under which each of the runs were operated are summarized in Table 4.1.

Runs	Wastewater		HRT	Temperature
	System A	System B	(hrs)	(°C)
P	PS	PS	30	25
1	PS & IND	PS	30	25
2	PS & IND	PS	48	25
3	PS & IND	PS	60	25
4	PS & IND	PS	30	16
5	PS & IND	PS	30	8

Table 4.1: Experimental conditions at an SRT ~ 10 days.
(PS = primary sludge; IND = industrial wastewater;
P = preliminary run)

The HRT of the system was checked daily in order to ensure proper operation. A yard stick was calibrated with each of the feed buckets such that the volume of liquid in each bucket could be taken at any given time without interrupting system operation. This was done by recording the level of a given volume of liquid in each bucket on the yard stick. For example, 10.0L of feed may correspond to 7 inches in a specific bucket. The change in liquid volume over a certain period of time could then be easily calculated and converted to an HRT.

The SRT of the system was controlled by wasting a specific amount of the reactor contents each day. An attempt was made to maintain the SRT at 10 days, but at times it had dropped below this level. In these cases there was no wasting of the reactor contents except when sampling was necessary. The gas production of each reactor and temperature were also monitored on a daily bases.

On analysis days, samples were taken from the influent buckets, the reactors, the clarifiers, and the effluents buckets. They were gathered in small plastic cups and capped immediately. The influent samples were taken directly from each of the influent buckets while they were being mixed. The reactor samples were taken via the sampling port. The amount wasted each day to maintain SRT would be used as the reactor samples on analysis days. Two different samples were taken from each clarifier. For one of these, a 10mL pipette was used to withdraw the supernatant with minimal disturbance. For the other, the clarifier was first well mixed before the 10mL sample was withdrawn from its middle area. And lastly, the samples from the effluent buckets were taken once they had been shaken and completely mixed. It should be noted that no sampling or analysis was done within the first 2 to 6 HRTs after a new run was started. This was done in order to let the system adapt to the new operating and/or environmental conditions.

The samples taken from the influent buckets and the reactors were analyzed for pH and alkalinity, total solids (TS), total suspended solids (TSS), volatile solids (VS), volatile suspended solids (VSS), VFA content and soluble COD content. The samples removed from the clarifiers with minimal disturbance were used to assess effluent VFA and soluble COD content. Those taken after mixing the clarifier were used to find VSS and thus the system SRT. The samples from the effluent buckets were used to determine

the effluent pH and alkalinity, TS, TSS, VS and VSS. Most of these tests were conducted on the day the samples were taken so as to avoid long preservation times.

It should also be mentioned that the total COD content was measured during every third analysis on the influent, reactor and effluent bucket samples. Ammonia and total Kjeldahl nitrogen (TKN) content were also measured on these samples five times per run, and gas composition was measured occasionally. Also, nearing the end of this experimental study a few ORP and nitrate measurements were done. Phosphorus (ie. total phosphorus, PO_4^{-3}) is a conservative component in anaerobic digestion and was therefore not measured (Elefsiniotis, 1993). Furthermore, each analysis including pH, alkalinity, TS, TSS, VS, VSS, VFA, soluble and total COD, ammonia, TKN and nitrates were carried out in duplicate to ensure the reliability of the results.

4.3 METHODS OF ANALYSIS

4.3.1 pH AND ALKALINITY

The pH and alkalinity of the samples were measured using a Fisher Accumet pH/ion meter (model 230) with a combination pH probe. Before reading the samples, the instrument was always calibrated with standard buffer solutions with a pH of 4.0 and 7.0. The buffer with a pH of 10.0 was occasionally used. The samples were well stirred before 10mL was withdrawn and measured. To measure alkalinity the same 10mL was then placed on a magnetic stirrer where deionized water was added in order to increase its level in the sample dish. It was then titrated with a 0.02N H_2SO_4 solution to a pH of 4.5.

4.3.2 SOLIDS CONTENT

The various solids measured in this study were done using Methods 2540 B, D and E of Standard Methods (A.P.H.A. et al., 1992) with some variations. All weight measurements were carried out on a Mettler AJ100 scale.

4.3.2a TOTAL AND VOLATILE SOLIDS

Evaporating dishes for total and volatile solids were prepared by igniting them at 550°C for 1hr. They were allowed to cool briefly before being placed in a desiccator for storage until needed. Prepared dishes were weighed and a known amount of sample was placed in them. The pipette used to withdraw the sample was rinsed with deionized water into the prepared dish, such that none of the solids were lost. Samples were then dried at 105°C for a minimum of 5hrs. Afterwards, they were placed in a desiccator and allowed to cool. Once the samples dried at 105°C were weighed to find TS, they were placed in a 550°C oven for 1hr. Again they were allowed to cool briefly before being removed to a desiccator. Once the samples had completely cooled in the desiccator they were weighed to find VS.

4.3.2b TOTAL SUSPENDED AND VOLATILE SUSPENDED SOLIDS

Basically the same procedure was used to measure suspended solids as is used for total solids. The evaporating dishes were however prepared differently. Whatman 934-AH glass microfibre filters were pressed into filtration crucibles. These crucibles were then placed on the vacuum filtration apparatus and deionized water was used to wash the filters. Once this had occurred the procedure described in the previous section was

applied to find the TSS and VSS portions of the TS and VS respectively. The only difference is that the samples here have to be placed in the crucibles while on the vacuum filtration apparatus.

4.3.3 VOLATILE FATTY ACIDS

The volatile fatty acids measured were acetic, propionic, iso-butyric, n-butyric, iso-valeric and n-valeric. One of two instruments was used in the determination of these acids. The first is the Antek 3000 gas chromatograph (GC), manufactured in Houston, Texas, and equipped with an FID (flame ionization detector) and an HP-FFAP cross-linked column (10m X 0.53mm X 1.0μm) using helium as a carrier gas. The second was a Hewlett-Packard 5890 GC using the same column and hydrogen as a carrier gas. The integrators used were a Waters 740 data module or a Shimadzu CR501.

Samples for VFA analysis first had to be micro-centrifuged in a IECCentra-M centrifuge for 5 minutes. Once that was done the samples were diluted with deionized water such that they would fall into the range of 0 to 100mg/L. If the samples needed to be preserved phosphoric acid would first be added to the dilution water. The diluted samples would then be filtered through a 25mm 0.45 micron nylon syringe filter into a small glass vial. The caps used are designed to allow only minimal air seepage into and out of the vials. Samples were then stored in a 5°C fridge until injections were to be made. Injections were made with a 1μL Hamilton syringe with or without a spacer depending on the GC used. Samples were always injected in duplicate and adjusted if necessary according to the results of the standards used.

4.3.4 CHEMICAL OXYGEN DEMAND

The CODs of this study were measured by a Closed Reflux Colorimetric Method in accordance with Section 5220 D of Standard Methods (A.P.H.A. et al., 1992). Samples for COD analysis were prepared as stated in the previous section. If fact, the same samples used for the determination of VFAs were used for soluble CODs as well. A 2.5mL portion of the sample was added to a glass culture tube, along with 1.5mL of digestion solution and 3.5mL of catalyst (sulfuric acid). Both the digestion solution and catalyst were added slowly down the sides of the tube. The tubes were then capped tightly with Teflon lined caps. They were usually left to sit overnight. Samples were then inverted and placed in a block digester for 4hrs at 150°C. There were duplicates of each sample. They were then left to cool and sit until they were measured in a Bausch & Lomb Spectronic 21 spectrophotometer at a wavelength of 600nm. The transmittance readings were then compared to those of the standards ranging from 50 to 800mg/L. A blank sample was also prepared using deionized water. A transmittance vs. concentration curve for the standards and blank was developed such that the transmittance readings of the samples could be directly correlated to a specific COD concentration.

Total CODs were prepared and measured in the same manner as the soluble CODs. The samples used were not however centrifuged or filtered, but just diluted such that they would fall into the range of 50 to 800mg/L. They were also digested for approximately 7 to 9hrs.

4.3.5 NITROGEN

Throughout the course of this study two different methods were used in the determination of total ammonia and TKN. The first method required distillation for the samples, while the second used an automated system with a colorimeter. Nitrates were also measured occasionally nearing the end of the study to investigate the denitrification potential.

4.3.5a TOTAL AMMONIA AND TKN DETERMINATION BY DISTILLATION

To find the total ammonia content of the sample, 5mL of sample was added to a digestion tube along with 50mL of deionized water, 25mL of borate buffer, and enough 6N NaOH to raise the pH to approximately 11.0. The digestion tube was then placed in a Kjeltec Auto 1030 Analyzer for distillation. The value given could then be converted to mg/L of ammonia nitrogen (Section 4500-NH_3 B of Standard Methods, A.P.H.A. et al., 1992).

To find the total Kjeldahl nitrogen 5mL of sample was again added to a digestion tube with 50mL of deionized water, but with 2 kjeltabs and 10mL of concentrated sulfuric acid. These samples were then placed into a Tecator DS 20-1015 block digester, and digested at temperatures as high as 365°C. The digestion also required the use of a Tecator model 1012 autostep controller and an Exhaust System 1013 scrubber. Once the tubes were sufficiently cooled 50mL of deionized water was added to each one in order to prevent the formation of potassium sulfate crystals. The samples were then ready for distillation (Section 4500-N_{org} C of Standard Methods, A.P.H.A. et al., 1992). The values

given here could also be converted to mg/L of TKN. Distillation of blanks and standards were also carried out for both the total ammonia and the TKN analyses.

4.3.5b TOTAL AMMONIA AND TKN DETERMINATION BY THE AUTOMATED PHENATE METHOD

In order to find ammonia concentration using the Automated Phenate Method (Section 4500-NH_3 H of Standard Methods, A.P.H.A. et al., 1992) samples first had to filtered using a #1 Filter paper to remove any turbid matter which may affect the photometric readings and results. Once the samples were filtered they were diluted (if necessary) to fall between the range of standards used. Each sample was analyzed in duplicate using a Technicon automated system with an AAIV (autoanalyzer IV) sampler, a pump 111, a colorimeter with a 15mm flow cell and 630nm filters, and a dual pen recorder. The results were compared with those of the standards and blanks to find the corresponding concentration of each sample.

To find TKN concentrations, samples were first digested in duplicate as described in the previous section. Once digested, the samples were allowed to cool slightly and 25 to 30mL of deionized water was added to each digestion tube. The contents of the digestion tubes were then poured into 50mL culture tubes and deionized water was added until the tubes were filled to 50mL. The samples were then ready for analysis on the autoanalyzer. When analyzed for TKN, an NaOH line had to be connected to provide neutralization of the samples. Once again a series of standards and blanks were run so as to find the concentrations of the samples.

4.3.5c NITRATES

The nitrates measured in this study were done according to the Automated Cadmium Reduction Method (Section 4500-NO_3 F of Standard Methods, A.P.H.A. et al., 1992). Samples were first filtered through #1 filter paper. Nitrates were measured by a Technicon autoanalyzer with a NO_3/NO_2 manifold which included an on-line cadmium reduction column. The recorder used was a GOW-MAC model 70-700. Samples were once again run in duplicate and compared to standards and blanks to determine concentration.

4.3.6 OXIDATION REDUCTION POTENTIAL

The oxidation reduction potential (ORP) was measured with a Fisher Scientific Accumet pH meter (model 50) and an ORP probe. Before use the system was always tested with a freshly prepared quinhydrone solution to ensure the reliability of the results. ORPs were tested immediately after sampling to reduce any errors which may occur from the change of environment.

4.3.7 GAS ANALYSIS

A Thermal Conductivity GOW-MAC Series 550 gas chromatograph with a Porapak Q column (80/100) and a Molecular Sieve 5A column (60/80) was used to measure the composition of the gases present in the head-space of each reactor. Helium was used as the carrier gas for this GC. Samples of the head-space gases were collected from the gas

sampling port with a 1.0mL syringe just prior to injection. Gases were identified by comparison of retention times to those of known standards. The concentrations of each gas was calculated by the comparison of the sample peaks to those of the same known standards.

4.3.8 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

Throughout the course of this study, each analysis was carried out in duplicate such that the reliability of the results were ensured. The analytical error (ie. the variation observed on a sample between duplicate measurements) was usually 1% or less when measuring pH. The error was usually no greater than 10% with respect to alkalinity, and 20% when measuring solids and VFA concentrations. Errors no greater than 2% and 4% were typically found when conducting soluble and total COD analyses, respectively, while the analytical error found when measuring ammonia and TKN concentrations was usually no more than 20%. Nitrate measurements typically resulted in an error no greater than 5%.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 INFLUENT COMPOSITION

In order to evaluate the productivity of the anaerobic systems used in this study, it was necessary to conduct analyses on the influent as well as on the reactor contents. The general composition for both the primary sludge and the mixed (starch-rich industrial and primary sludge) influents are shown in Tables 5.1 and 5.2, respectively. Detailed results corresponding to each of the tests carried out in this study are presented in Appendix B.

All of the measurements shown in Table 5.1 were taken on the influent, which was simply the primary sludge diluted to 5000mg/L. The variation in solids content is small as indicated by the relatively low standard deviations and coefficients of variation (CoV) which do not exceed 10%. This level of statistical accuracy is expected as the total solids content was adjusted to aforementioned concentration.

The VFA, COD and nitrogen measurements do not however compare with those of the solids concentrations. Extenuating conditions such as rainfall and infiltration or the clean up or failure of plant equipment would cause large variations in these constituents (Banerjee, 1997). The continuous stirring of the influent bucket would have also caused the volatilization of some VFA and NH_3 compounds. The aging of the sludge would have contributed to some of the changes in concentration of the carbonaceous compounds as well. Since neither the VFA, COD or nitrogen were adjusted before feeding, the variations in concentration of these constituents was certainly evident.

The results of the statistical evaluation of the mixed industrial and municipal influent in Table 5.2 indicate a greater degree of variation for most parameters. The CoV for the various solids concentration do not fall below 10% as with the primary sludge influent. The extremely high solids concentration of the starch-rich industrial wastewater, combined with the almost immediate onset of settling made it very difficult to measure and mix a specific amount with tap water for dilution. Therefore the standard deviations and CoV for the solids concentrations are higher, which in turn affect the results of the VFA, COD and nitrogen concentrations.

Parameter	Average	Standard Deviation	Coefficient of Variation (%)
pH	6.89	0.07	1.0
Alkalinity (mg/L as $CaCO_3$)	281	43	15.2
TS (mg/L)	5293	124	2.4
VS (mg/L)	3943	192	4.9
TSS (mg/L)	4814	145	3.0
VSS (mg/L)	3598	290	8.1
VFA (mg/L)	92	52	55.9
SCOD (mg/L)	343	128	37.4
TCOD (mg/L)	5412	1166	21.5
NH_3-N (mg/L)	32	11	35.3
TKN (mg/L)	208	34	16.4

Table 5.1: Primary sludge influent characteristics.
Note: Statistical evaluation is based on influent data from runs 1 to 5 (number of samples = 75).

Parameter	Average	Standard Deviation	Coefficient of Variation (%)
pH	6.23	0.37	6.0
Alkalinity (mg/L as $CaCO_3$)	167	20	12.1
TS (mg/L)	5604	565	10.1
VS (mg/L)	4755	570	12.0
TSS (mg/L)	5186	784	15.1
VSS (mg/L)	4493	783	17.4
VFA (mg/L)	154	98	63.9
SCOD (mg/L)	392	208	52.9
TCOD (mg/L)	5995	1092	18.2
NH_3-N (mg/L)	8.5	4.4	52.3
TKN (mg/L)	133	29	22.2

Table 5.2: 50:50 starch-rich industrial wastewater and primary sludge influent characteristics.
Note: Statistical evaluation is based on influent data from runs 1 to 5 (number of samples = 75).

5.2 ACCLIMATION PERIOD

In order to guarantee the reliability of the results produced in this investigation, the stability of the systems used first had to be ensured. This was accomplished by allowing an acclimation period of 2-6 HRTs at the beginning of each run before any usable results were attained. The acclimation period provided the time needed for the selection and enhancement of the species most suited to the available carbon source. The length of the

acclimation period is dependant on the type of seed used, the characteristics of the feed, as well as operational and environmental conditions (Elefsiniotis, 1993).

Acclimation was considered to be complete when the VFA production of the reactor reached steady-state (ie. a variation less than approximately 20% with no apparent trend). The net VFA produced was used as the indicator as the total VFA would incorporate the amount entering the reactor with the influent. Considering that the influent VFA concentration varied greatly with a CoV of 55.9% and 63.9% for the primary sludge and the mixed influents respectively, it would have been inappropriate to use the total VFA of the reactors as an indication of stability.

The reactor pH was also used as a sign of stability. Once the pH values reached a biologically stable level (ie. a variation less than approximately 5%), which was significantly lower than that of the influent, acclimation was considered to be achieved under acidogenic conditions.

5.3 VFA PRODUCTION, SCOD PRODUCTION AND SS REDUCTION

5.3.1 THE EFFECTS OF HRT

The hydraulic retention time simply refers to the amount of time a specific particle spends in the reactor before it is discharged to the clarifier. It is possible to control HRT by controlling the rate of feeding to a reactor with a known liquid volume. A specific amount of influent is pumped into the reactor while at the same time an equal amount of the reactor contents is discharged to the clarifier. HRT may therefore be determined by dividing the liquid volume of the reactor with the influent flow rate.

HRT is not simply the period of time a particle resides in a reactor, but it is also the amount of time it spends in the presence of the microorganisms contained in the reactor. By controlling HRT, the amount of time which the bacteria have to work on the feed particles and convert them to VFAs is also controlled. The selected HRT would then determine the amount and type of substrate assimilated by bacteria. The HRT would also be responsible for the maintenance of the acidogenic phase by allowing the growth and enhancement of acidogenic bacteria while suppressing that of the methanogens (Elefsiniotis, 1993). Cha and Noike (1997) found evidence of species selection related to HRT. At an HRT of 6hrs (@15°C) they found that the majority of the bacteria in their acidogenic anaerobic reactors were short and thick while at an HRT of 48hrs (@15°C) the bacteria were long and slender (Figure 5.1).

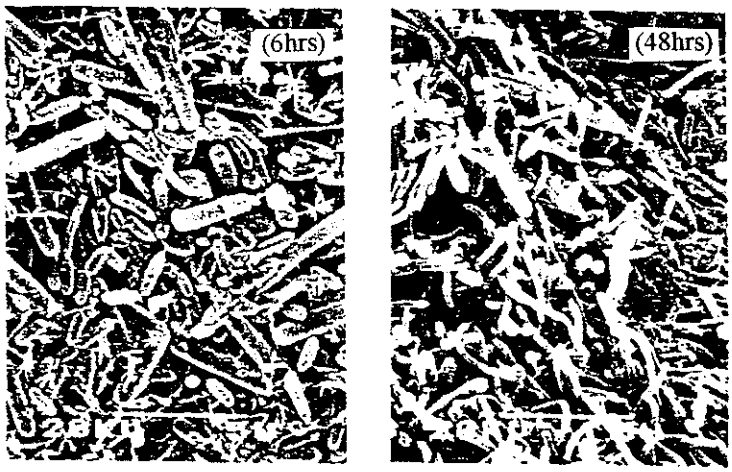

Figure 5.1: Bacteria at HRTs of 6 and 48 hrs.
(Adapted from Cha and Noike, 1997)

The HRTs explored in this investigation were at 30, 48 and 60hrs. Each of these HRTs were studied at ambient temperatures with averages ranging from 24.8 to 25.3°C.

Both reactors, that is the one consisting of 100% primary sludge and the one made up of 50% starch-rich industrial wastewater and 50% primary sludge were tested under these conditions.

5.3.1a VFA PRODUCTION

During the acidogenic phase of anaerobic digestion acids are produced by the existing biomass. Examination of Figure 5.2 shows that VFAs were produced in both the municipal and industrial (reactor A) system and the municipal (reactor B) system alone. The VFAs produced in each case were significantly higher than those entering the reactor with the feed. Even when the standard deviations are taken into account the influent acid concentrations don't even come close to those of the reactors (as shown with the error bars). This not only proves the existence of acid-producing bacteria within the reactors, but also that the prevailing conditions favor the growth and well being of acidogenic microorganisms.

It is also apparent from Figure 5.2 that the amount of VFAs produced by reactor A was considerably greater than that produced by reactor B. On average, the amount of total VFAs produced in reactor A was 255mg/L (as acetic acid) greater than that produced in reactor B for run 1. The use of the starch-rich industrial wastewater therefore appears to be favorable by enhancing the microbial conversion of this feed to VFAs.

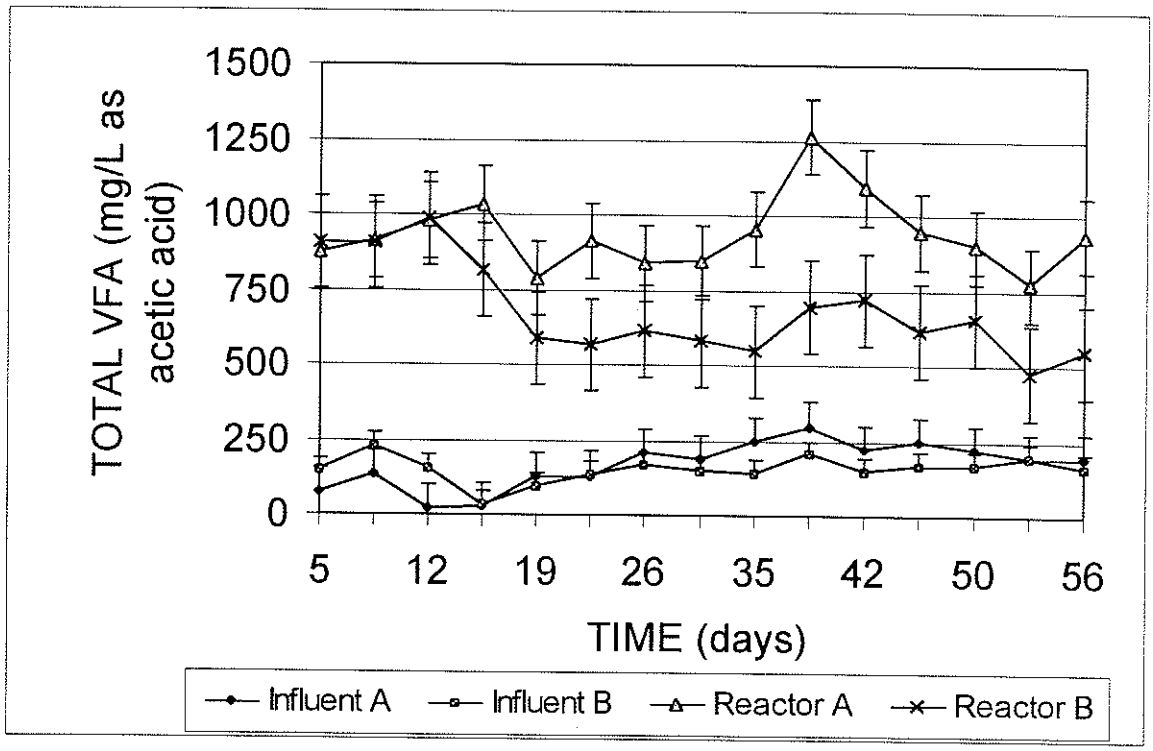

Figure 5.2: Total VFA concentrations for run 1 (30hrs @ 25°C).
A = industrial and municipal.
B = municipal only.

Figure 5.3 represents the net VFA production (as acetic acid) in both reactors A and B. It is clear that the HRT of 30hrs yields the maximum amount of VFA production in both cases. Reactor A produced a net amount of 769 ± 131mg/L at 30hrs and only 371 ± 116mg/L and 391 ± 76mg/L at 48 and 60hrs respectively. Reactor B produced 530 ± 162mg/L at 30hrs, and at 48 and 60hrs yielded 306 ± 101mg/L and 219 ± 95mg/L respectively. The decrease in net VFA production after 30hrs may be attributed to a decrease in VSS within the reactors (Table 5.3). This decrease of VSS was due at least in part to a decline in clarifier performance, especially with clarifier B (Section 5.9).

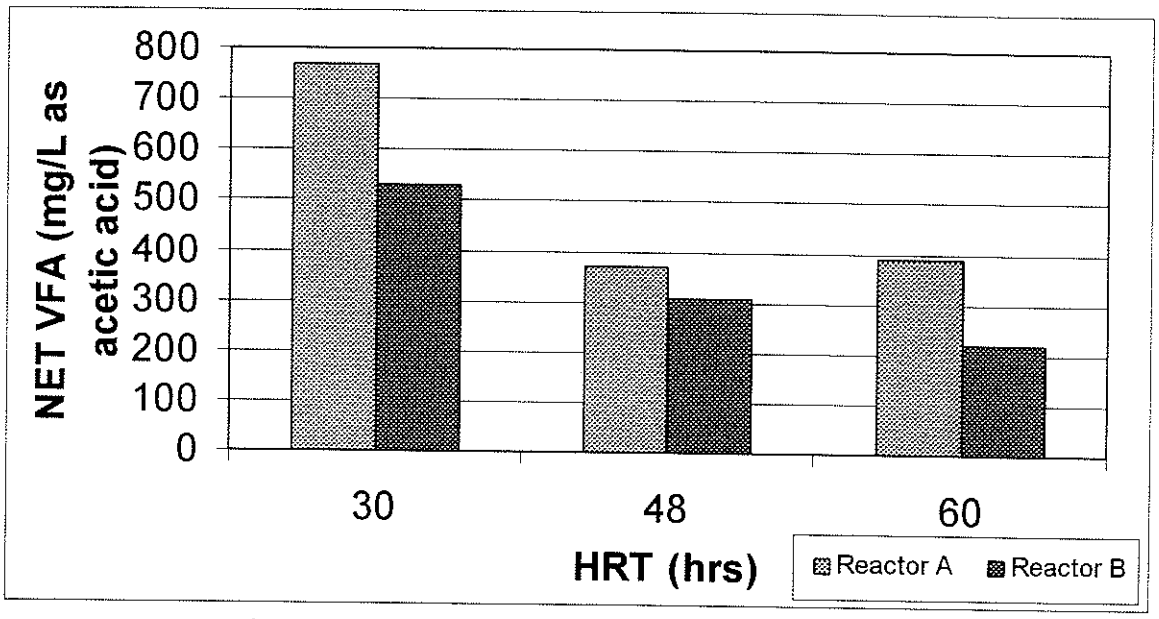

Figure 5.3: Net VFA concentrations at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

It is also apparent from this illustration that the industrial and municipal reactor always produced more VFAs than the municipal-only reactor, and leveled off at 48 and 60hrs while production in the municipal reactor continued to decrease. The net VFA production is a more valid means of evaluating the amount of acids produced within the reactor than the total VFA production, as the net does not include the VFAs fed into the reactor with the feed. This proves that the starch-rich industrial wastewater has a positive effect on the conversion of the feed into VFAs at HRTs of 30, 48 and 60hrs.

Banerjee et al. (1998) carried out a study at a temperature of 22°C and HRTs of 18 and 30hrs using the same starch-rich industrial wastewater and primary sludge for feeding. They also found that the 30hr HRT yielded a greater net VFA production, and that the use of the industrial wastewater enhanced this production even further. Considering that the work done by Banerjee et al. (1998) was conducted at an ambient

temperature and that the reactor configurations and feed characteristics were similar to those used in this study, it would be possible to conclude that an HRT of 30hrs produces the maximum net VFA production over HRTs of 18, 48, and 60hrs (Figure 5.4). However, it is interesting to note that there is a difference in the maximum VFA productions at 30hrs which seem to be caused by the difference in temperatures between 22 and 25°C (as used in this study). It is apparent that at the aforementioned HRTs the use of the starch-rich wastewater has the ability to increase this production even further.

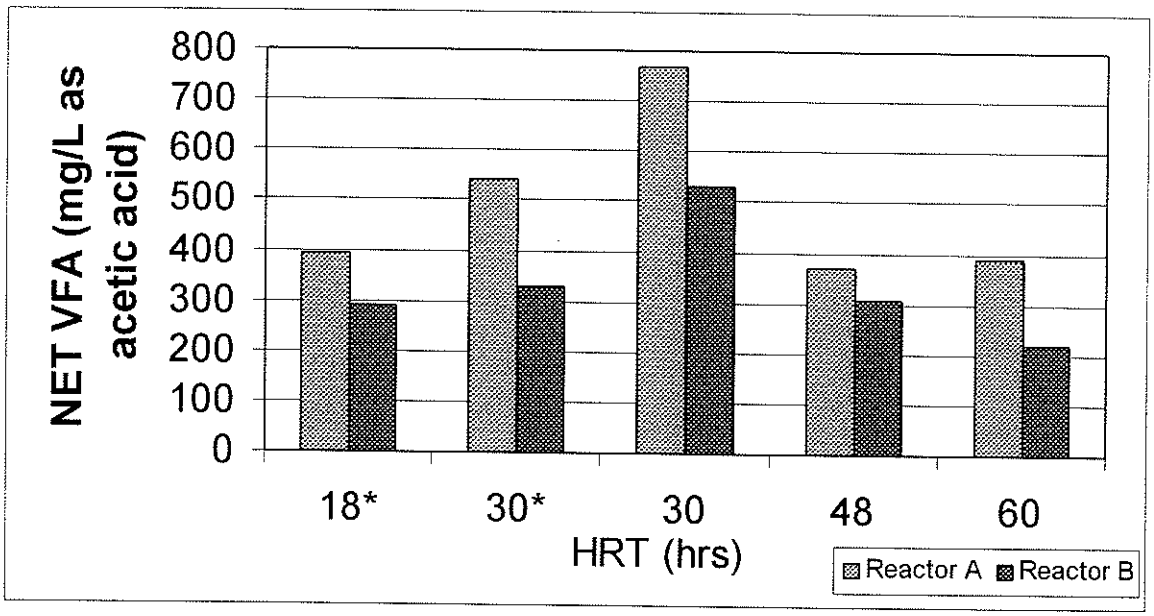

Figure 5.4: Net VFA concentration at 18, 30, 48 and 60hrs.
*data at 22°C from Banerjee et al., 1998.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Other studies which attempted to find an optimal HRT include one conducted by Elefsiniotis and Oldham (1994a) at ambient temperatures using primary sludge. They found that VFA production was at a maximum at an HRT of 12hrs, but decreased at an HRT of 15hrs due to the onset of methanogenesis in both the completely mixed reactor

and the UASB reactor. The difference between the 12hr optimal HRT and the 30hr optimal HRT found in this study could potentially be due to variations in influent characteristics.

The specific VFA production rate (Table 5.3) displays the same trend observed with the net VFA production. Both reactors obtained their maximum rate at the 30hr HRT, and production rate then decreased at 48 and 60hr. Furthermore, reactor A always maintained a significantly higher VFA production rate than reactor B. In the reactor fed with industrial waste the production rate leveled off just as the net production had done. In the reactor fed with the primary sludge alone however, the rate did not decrease as it occurred with the net production, but it too leveled off. The production rates for both reactors after 30hrs decreased because of a drop in VSS concentration within each reactor as well as a drop in net VFA production at increasingly higher HRTs. The rates at the 48 and 60hr HRTs appear to have reached a plateau in both reactors, despite the further loss of solids at the longest HRT. The plateau indicates that the specific production rate may be independent of HRT beyond a certain value, and possibly independent of the VSS level as well. It should be mentioned that in general, the VFA production rates found in this study are similar to those observed by Banerjee et al. (1998), but are significantly lower than those found by Elefsiniotis and Oldham (1994a) who achieved a rate of 0.092mg VFA/mg VSS*d at an HRT of 15hrs and ambient temperatures.

Table 5.4 represents the relationship between the VFA content of the reactors and the clarifiers. According to the t-test (Moore, 1995) there is no significant differences in VFA concentration between the two. In cases where the effluent concentration is less than that of the reactor, the difference would be due to a small amount of VFA

volatilization. On the other hand, effluent concentrations greater than reactor concentrations can be attributed to a small degree of acidogenesis within the clarifier. After all, the biomass within the clarifier is composed mainly of acidogens. This combined with the fact that the clarifiers are not one hundred percent efficient, that is that some particles may be left in the clarifier for longer periods of time than others before recycling, could contribute to a small amount of acidogenesis.

HRT (hrs)	VSS (mg/L)		VFA Production Rate (mg VFA/mg VSS*d)	
	Reactor A	Reactor B	Reactor A	Reactor B
30	14817	14467	0.0453	0.0306
48	6303	11478	0.0323	0.0137
60	4600	7888	0.0343	0.0119

Table 5.3: VFA production rates at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

It is interesting to note that all the runs using the starch-rich industrial waste (runs 1, 2 and 3 in reactor A) only exhibit signs of volatilization, while only the runs using the municipal waste alone (run P in reactor A and runs 1 and 2 in reactor B) show signs of acidogenesis. This trend is due to the excellent settling characteristics of the combined industrial-municipal waste, and therefore efficient clarifier performance which leads to a shorter retention time for the solids in the clarifier, in comparison to what can only be described as the adequate settling abilities of the municipal waste resulting in a decreased clarifier efficiency (Section 5.9).

Reactor	Run	Total VFA (mg/L as acetic acid)		Significant Difference ?
		Reactor	Effluent	
A	P	524 (153)	607 (105)	NO
	1	937 (124)	880 (84)	NO
	2	583 (113)	540 (116)	NO
	3	663 (83)	623 (81)	NO
B	P	658 (114)	658 (203)	NO
	1	681 (155)	731 (171)	NO
	2	447 (120)	485 (154)	NO
	3	290 (57)	247 (44)	YES

Table 5.4: Statistical significance between reactor and effluent concentrations for runs P to 3 (using a 95% confidence level).
Note: Corresponding standard deviations are in parentheses.
Reactor A = industrial and municipal.
Reactor B = municipal only.

5.3.1b VFA SPECIATION

Knowledge on the type of volatile fatty acids formed and on the quantities produced provide useful information as to the dominating species of acidogens within a reactor, as well as the favored biochemical pathways of VFA formation. Figure 5.5 represents the distribution of the various acids measured in this study within reactor A. Acetic acid is by far the dominating species of VFA at the 30, 48 and 60hr HRT ranging from 61 to 74% of the total VFA production. Propionic and n-butyric acids follow providing approximately 10 to 14% and 9 to 15 % of the total amount of VFAs, respectively. I-

butyric, i-valeric and n-valeric acid then produce about 1 to 4% each of the remaining total. Considering the relative stability of the proportion of each acid from run to run, it can be concluded that HRT does not seem to play a role in the selection of the dominating VFA formation pathways or acidogens.

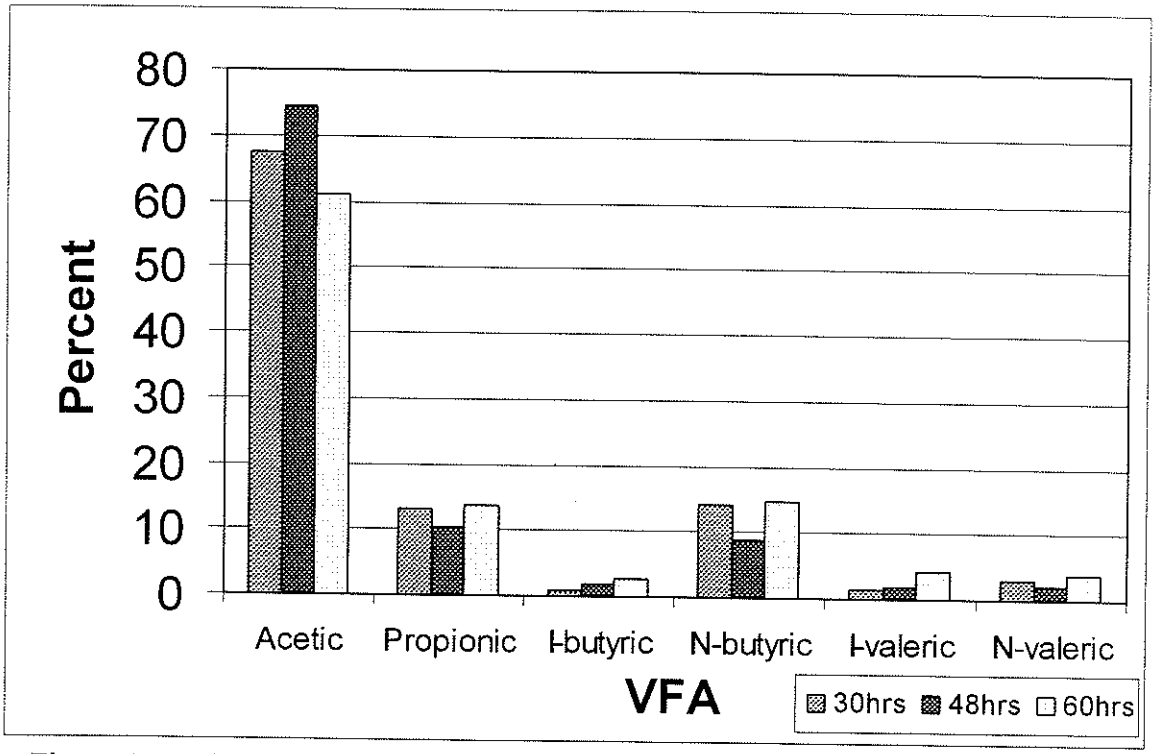

Figure 5.5: Distribution of VFAs in reactor A (industrial and municipal) with HRT.

Figure 5.6 illustrates the distribution of the VFAs produced in reactor B. Once again acetic acid dominates making up 62 to 66% of total amount of VFAs within the reactor. Propionic acid follows at a relatively constant level of 24%. The rest of the acids consist of approximately 1 to 6% of the total VFA content of reactor B. Once again there is no relation between the distribution of the individual acids and HRT.

It is interesting to note that reactor B using municipal sludge alone produces even less of a variation in the proportions of these VFAs than reactor A with the industrial waste. With regards to acetic acid, there is a 13% variation in reactor A and only a 4% variation in reactor B. Propionic acid varies by 4% in reactor A but is extremely stable in reactor B, and is also at least 10% greater. N-butyric acid is as common as propionic acid in reactor A but only makes up a very small proportion of the VFAs in reactor B. It can therefore be said that the addition of the starch-rich industrial wastewater to reactor A produced a less stable distribution of VFAs in comparison to using municipal sludge alone at the HRT range investigated.

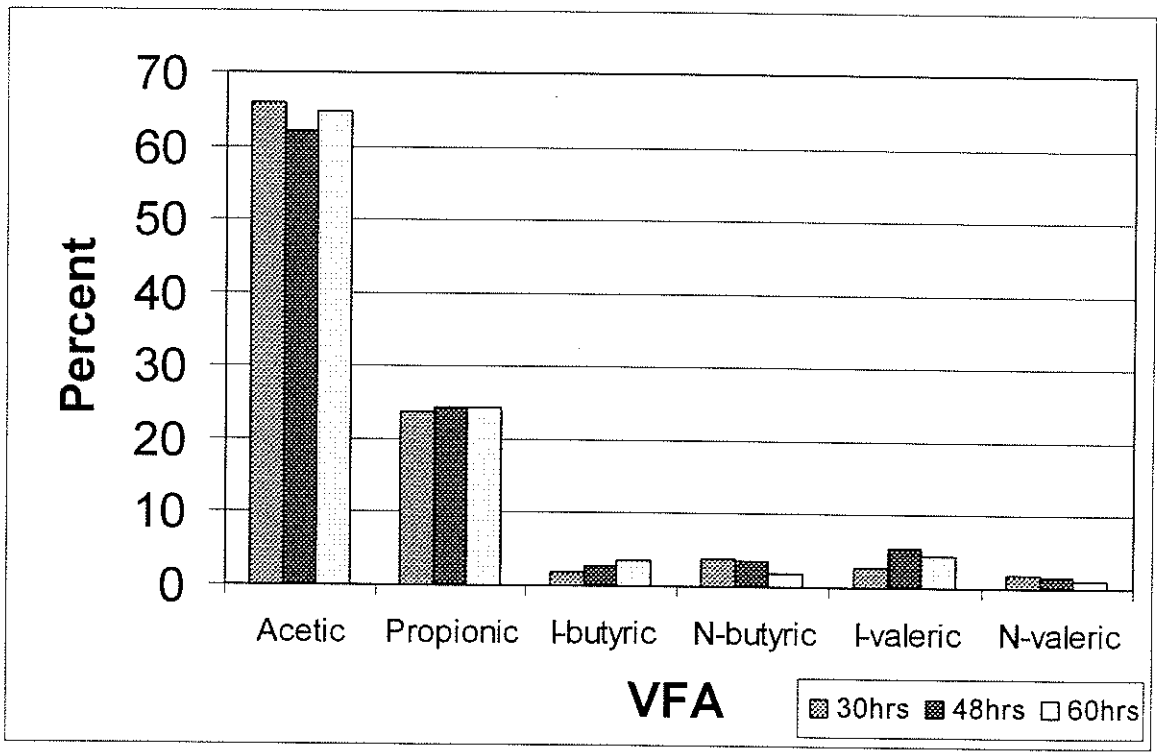

Figure 5.6: Distribution of VFAs in reactor B (municipal only) with HRT.

Other researchers have found similar results with regards to VFA speciation. Elefsiniotis and Oldham (1994a) during their experiments using a completely mixed system fed with primary sludge at ambient temperatures and various HRTs found that acetic and propionic acid were the dominating VFAs. They also found that VFA distribution was not affected by HRT. Banerjee (1997) who conducted similar experiments also found acetic and propionic acid to be dominant. However, when starch-rich industrial wastewater was added to the feed, the concentration of n-butyric acid increased to an amount approximately equal the propionic acid as in this experiment. The increase of n-butyric acid experienced by Banerjee (1997) and in this study may be attributed to the high carbohydrate content of the starch-rich influent (Section 2.5.1). Variations in HRT did not seem to play a role in the selection of the dominating VFA formation pathways as experienced in this study as well.

5.3.1c SCOD PRODUCTION AND SS REDUCTION

Soluble chemical oxygen demand (SCOD) is an expression of the degree of the hydrolysis and solubilization which have occurred. Figure 5.7 shows that there is a definite increase in SCOD concentration from influent to reactor. It also shows reactor A producing an average of 284mg/L more of SCODs than reactor B, despite the fact that reactor B did not stabilize in terms of total SCOD production until the third week of run 1. The same patterns were observed with total VFA production in Figure 5.2.

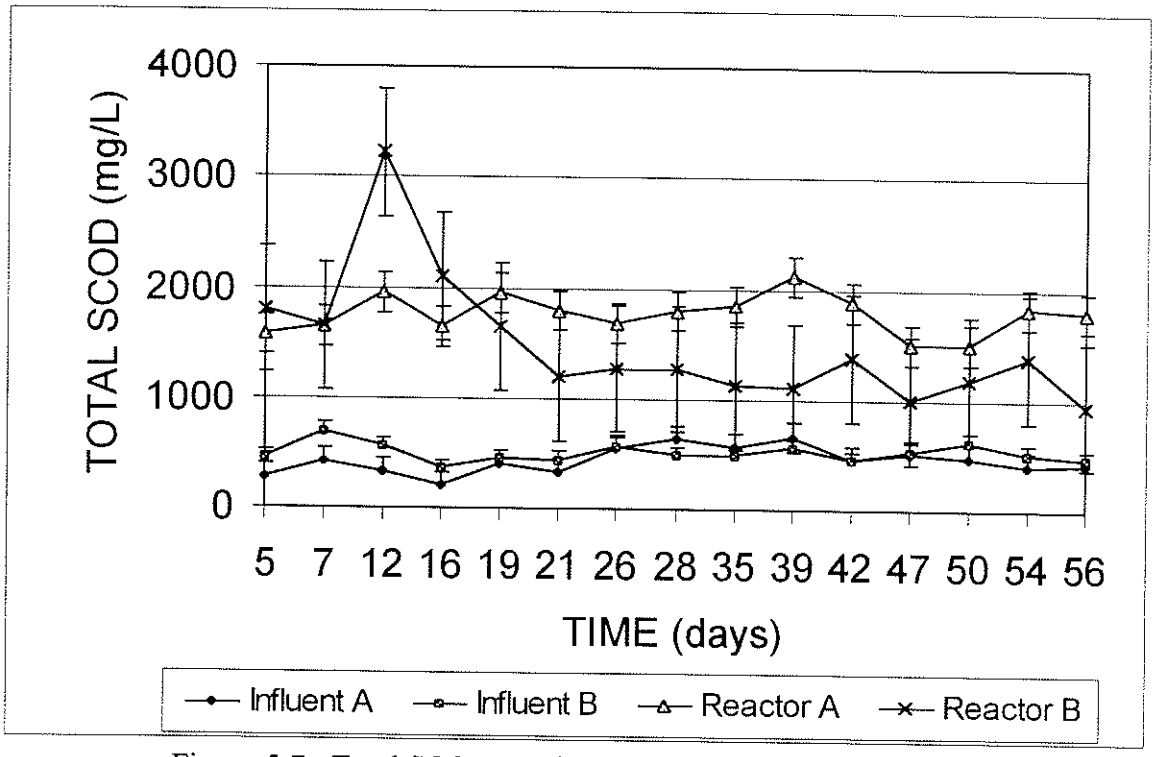

Figure 5.7: Total SCOD concentrations for run 1 (30hrs @ 25°C).
A = industrial and municipal.
B = municipal only.

Figure 5.8 represents the effect of HRT on net SCOD production. Once again as shown with the net VFA production in Figure 5.3, the 30hr HRT yielded the maximum net SCOD production at 1333mg/L in reactor A and 978mg/L in reactor B. Reactor A using the mixture of industrial and municipal waste again produced more SCODs than reactor B at all the HRTs tested, and leveled of at 48 and 60hrs. The net SCOD production for reactor B continued to decrease at 48 and 60hrs as expected, based on the trends experienced with the net VFA production (Figure 5.3).

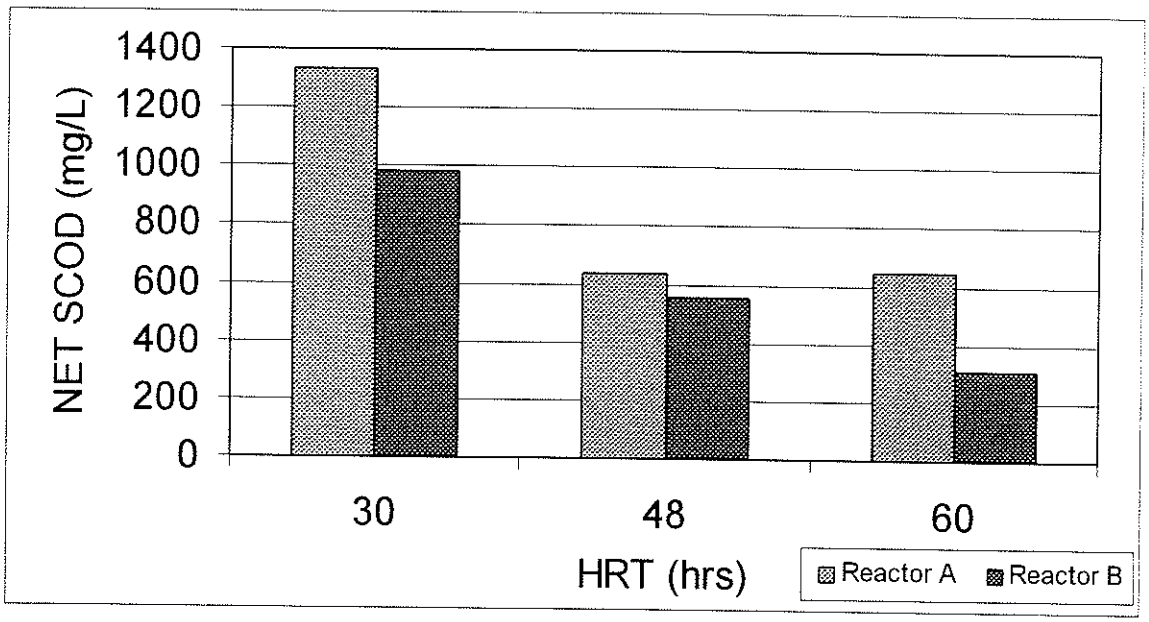

Figure 5.8: Net SCOD concentrations at 30,48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

The specific SCOD production rates for both reactors A and B are shown in Table 5.5. The production rate reached its maximum at the 30hr HRT and decreased at 48 and 60hrs, following the same trend as the net SCOD production and the VFA production rate (Table 5.3). The production rates for reactor A were again always higher than those of reactor B. The rates for reactor A leveled off at 48 and 60hrs. However the rates for reactor B at 48 and 60hrs did not level off as they did for the VFA production rates, but continued to decrease. The decrease at the 60hr HRT is indicative of a limitation in the ability of bacteria to hydrolyze and solubilize the substrate, which implies that hydrolysis has become the rate limiting step. The ability of the biomass to produce VFAs does not however seem to be affected at the 60hr HRT.

HRT (hrs)	VSS (mg/L)		SCOD Production Rate (mg SCOD/mg VSS*d)	
	Reactor A	Reactor B	Reactor A	Reactor B
30	14817	14467	0.0789	0.0537
48	6303	11478	0.0561	0.0245
60	4600	7888	0.0560	0.0154

Table 5.5: SCOD production rates at 30,48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Particulate matter must first be hydrolyzed or liquefied before being assimilated by bacteria. As such there is a reduction in VSS concentration from the influent to the effluent of any properly functioning anaerobic digestion system. A mass balance was used to determine the amount of reduction in VSS occurring within the reactors (Table B28 – Appendix B) as shown in Table 5.6. The differences in VSS reduction as HRT increased from 30 to 60hrs in reactor A were not statistically significant according to the t-test (Moore, 1995). There is also no statistical significance between the VSS reduction values presented for reactor B. It is therefore possible that VSS reduction is independent of HRT. It may also be concluded that the use of the industrial wastewater enhances the VSS destruction capabilities of the bacteria, as reactor A consistently produced a higher degree of destruction than reactor B. A higher degree of destruction is expected in reactor A as it also produced a consistently higher amount of VFAs than reactor B. The TSS reduction results are in full agreement with these conclusions.

When Banerjee (1997) conducted his experiments using industrial and municipal wastes he also found the same (76 to 77%) degree of VSS destruction at HRTs of 18 and

30hrs. In his municipal-only reactor, he found that VSS destruction increased with an increase in HRT from 18 to 30hrs. Considering that the VSS destruction in the municipal-only reactor of this study remains relatively the same between HRTs of 30 and 60hrs, it can be concluded that an HRT of 30hrs produces the maximum VSS destruction which levels off at this point when HRT is further increased.

HRT (hrs)	TSS Reduction (%)		VSS Reduction (%)	
	Reactor A	Reactor B	Reactor A	Reactor B
30	71.9	40.9	74.6	45.8
48	70.8	42.2	72.9	45.0
60	68.8	41.5	71.8	46.5

Table 5.6: SS reduction at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

In conclusion, HRT plays a significant role in the production of VFAs. The maximum net VFA and SCOD productions were found at an HRT of 30hrs in both the industrial-municipal and municipal-only reactors. The specific VFA and SCOD production rates were also a maximum at 30hrs, and the VFA production rate was found to be independent of HRT beyond 30hrs. The SCOD production rate was also independent of HRT after 30hrs in reactor A, but the biomass in reactor B was affected by the increase in HRT from 48 to 60hrs. HRT did not however have any effect on VFA speciation or on VSS reduction in this study. Furthermore, the net VFA and SCOD productions, the VFA and SCOD production rates and the VSS reductions were always higher in the combined industrial-municipal reactor.

5.3.2 THE EFFECTS OF TEMPERATURE

Temperature is an environmental parameter which tends to have profound effects on the acidogenic phase of anaerobic digestion. There even exists a 'rule of thumb' which states that biological reaction rates double with every increase of 10°C to a certain point. Knowledge of the effects of temperature can therefore be essential to the efficient operation and optimization of the various treatment processes within a wastewater treatment plant, especially if the region in question is subject to extreme temperatures.

There have been studies which research the effects of temperature on acidogenesis (Banerjee et al., 1998; Skalsky and Daigger, 1995). Cha and Noike (1997) found that the bacteria which existed in their acidogenic anaerobic reactors at an HRT of 6hrs were morphologically different at a temperature of 30°C than those at 15°C. Figure 5.9 shows that the bacteria at 30°C were long and slender while the bacteria at 15°C were short and thick.

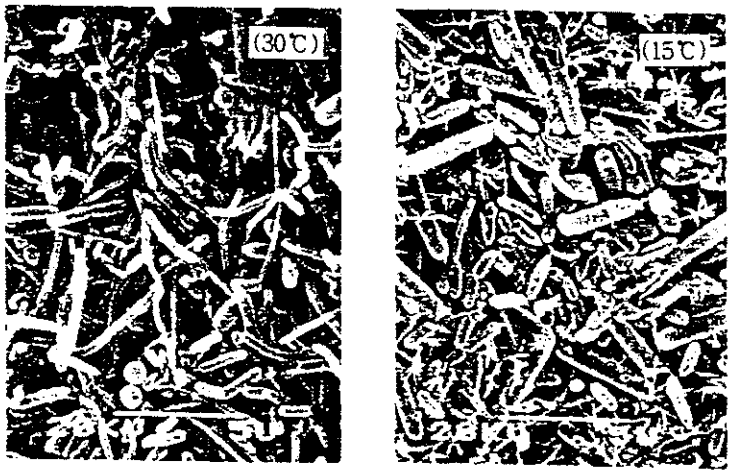

Figure 5.9: Bacteria at temperatures of 15 and 30°C.
(Cha and Noike, 1997)

This investigation explored temperatures of 25, 16 and 8°C. The effects of these temperatures on acidogenesis were explored at an HRT of 30hrs. Both continuous flow systems, that is the one using the industrial and municipal waste and the one using the municipal waste alone were studied under these conditions.

5.3.2a VFA PRODUCTION

Under anaerobic conditions, volatile fatty acids are produced by acidogenic microorganisms. There is an increase of total VFAs within each reactor at 25, 16 an 8°C (Appendix B) over influent concentrations, and once again the combination industrial-municipal reactor is always superior to the municipal-only reactor.

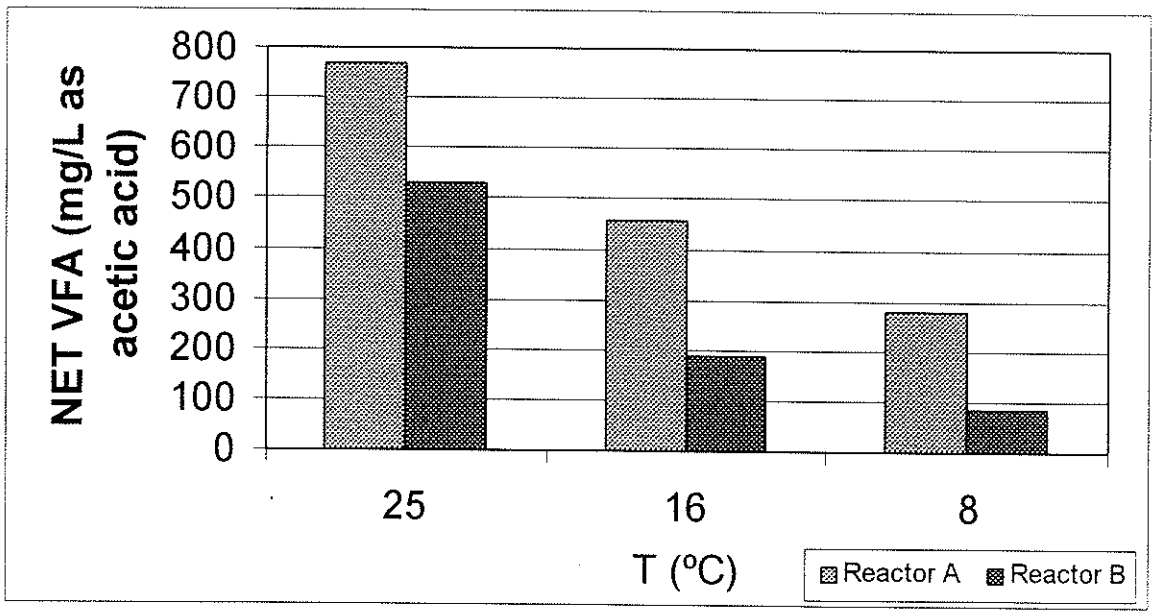

Figure 5.10: Net VFA concentration at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Figure 5.10 shows the net VFA production (as acetic acid) for reactors A and B. It is evident that the 25°C temperature yields the highest net VFA production for both systems. Reactor A produced a net of 769 ± 131mg/L of VFAs at 25°C and 457 ±102mg/L and 278 ± 87mg/L at 16 and 8°C respectively. Reactor B produced 530 ±162mg/L at 25°C while at 16 and 8°C yielded 185 ± 50mg/L and 85 ± 37mg/L, respectively. The drop in net VFA production does not seem to be due to a drop in VSS as it did with HRT. In fact, the VSS levels remain relatively stable at all temperatures tested (Table 5.7). The decrease in temperature has a debilitating effect on the acidogenic bacteria, such that their ability to convert carbohydrates, lipids and proteins to VFAs diminishes with decreasing temperature.

Figure 5.10 also shows that the industrial and municipal reactor always produced more VFAs than the municipal reactor. The difference in net production between the two is statistically significant at 25, 16 and 8°C and ranges from 193 to 272mg/L. This once again proves that the starch-rich industrial wastewater has a positive influence on the production of VFAs at the aforementioned temperatures.

Banerjee et at., (1998) also conducted an experiment with varying temperatures at a 30hr HRT using the same starch-rich industrial wastewater and primary sludge and similar reactor configurations. It was found in the system using a 50:50 combination of industrial and municipal waste that increasing temperature from 22 to 30°C caused an increase in net VFA production, but produced a decrease when temperature was increased further to 35°C. In the reactor using only municipal waste there was a continual decrease in net VFA production with increasing temperature attributed to a decline in clarifier performance with increasing temperature. Figure 5.11 compares the

results of this study with those of Banerjee et al. (1998). It is possible to conclude from this information that the temperature of 25°C yields the maximum net VFA production over the temperatures tested from 8 to 35°C in both the industrial-municipal system and the municipal-only system. It would also be appropriate to conclude that the industrial waste has the ability to increase VFA production at the aforementioned temperatures.

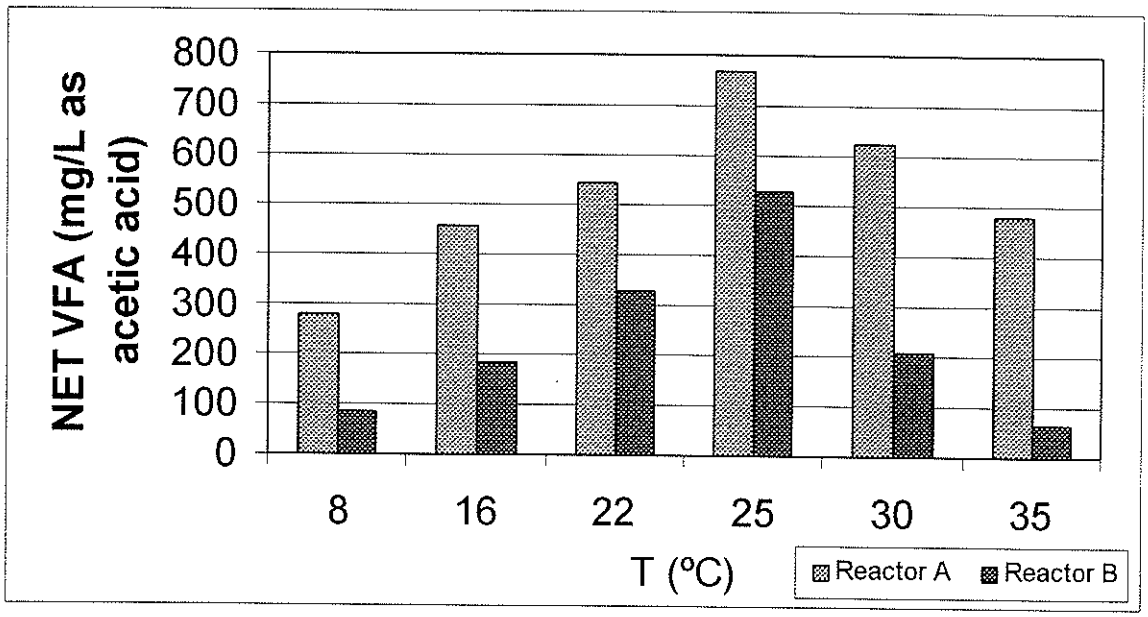

Figure 5.11: Net VFA concentration variation with temperature.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Other studies which have investigated the effects of temperature on acidogenesis include one by Skalsky and Daigger (1995) who found volatile acid production to be about 42% less at 14°C than at 21°C. Banister (1996, cited in Banister and Pretorius, 1998) also conducted experiments with temperature using batch reactors where a decrease in VFA yields of 45% was found at 12°C in comparison to ambient temperatures.

The specific VFA production rates at 25, 16 and 8°C are shown in Table 5.7. The production rate follows the same trend as the net VFA production (Figure 5.10) in that they decrease with temperature in both reactors A and B. The highest production rate also occurs at 25°C as did the net VFA production, and the rate at each temperature is always greater for reactor A. It is evident that the decrease in production rate is caused not by any decrease in VSS but by a decrease in net VFA production. The decline of the net VFA production is as mentioned earlier a function of temperature. As temperature decreases the acidogenic bacteria weaken in their ability to convert substrate to VFAs.

Temperature (°C)	VSS (mg/L)		VFA Production Rate (mg VFA/mg VSS*d)	
	Reactor A	Reactor B	Reactor A	Reactor B
25	14817	14467	0.0453	0.0306
16	13540	11428	0.0291	0.0132
8	14365	14280	0.0160	0.0048

Table 5.7: VFA production rates at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Table 5.8 reveals that there is no significant difference (according to the t-test) in VFAs between reactor contents and effluent for each of the temperature experiments. As mentioned with respect to the HRT experiments, small differences between reactor and effluent VFAs are due either to volatilization or an insignificant degree of acidogenesis

within the clarifiers. Once again the industrial and municipal system are subject to volatilization while the municipal-only system, with the exception of run 5, appears to be affected by acidogenesis due to the inferior operating characteristics of its clarifier.

Reactor	Run	Total VFA (mg/L as acetic acid)		Significant Difference ?
		Reactor	Effluent	
A	1	937 (124)	880 (84)	NO
	4	554 (94)	536 (90)	NO
	5	299 (102)	297 (133)	NO
B	1	681 (155)	731 (171)	NO
	4	252 (54)	269 (46)	NO
	5	117 (54)	103 (72)	NO

Table 5.8: Statistical significance between reactor and effluent concentrations for runs 1, 4 and 5 (using a 95% confidence level).
Note: Corresponding standard deviations are in parentheses.
Reactor A = industrial and municipal.
Reactor B = municipal only.

5.3.2b VFA SPECIATION

The relative distribution of the individual VFAs produced in reactor A as a function of temperature are shown in Figure 5.12. Acetic acid is by far the dominating species of VFA produced composing 56 to 68% of the total amount. N-butyric acid follows making up 14 to 19% of the mixture and propionic is close behind with a range of 13 to 18%. The remaining acids are only responsible for no more 5% each of the total VFA

concentration. Figure 5.12 shows that acetic acid decreases with temperature while propionic and n-butyric acids increase. The above trends are an indication that temperature may play a role in the selection of specific VFA formation pathways even though acetic, propionic and n-butyric acids all remain in relatively the same standing regardless of temperature, that is that acetic acid is always the most abundant followed by n-butyric and propionic acids.

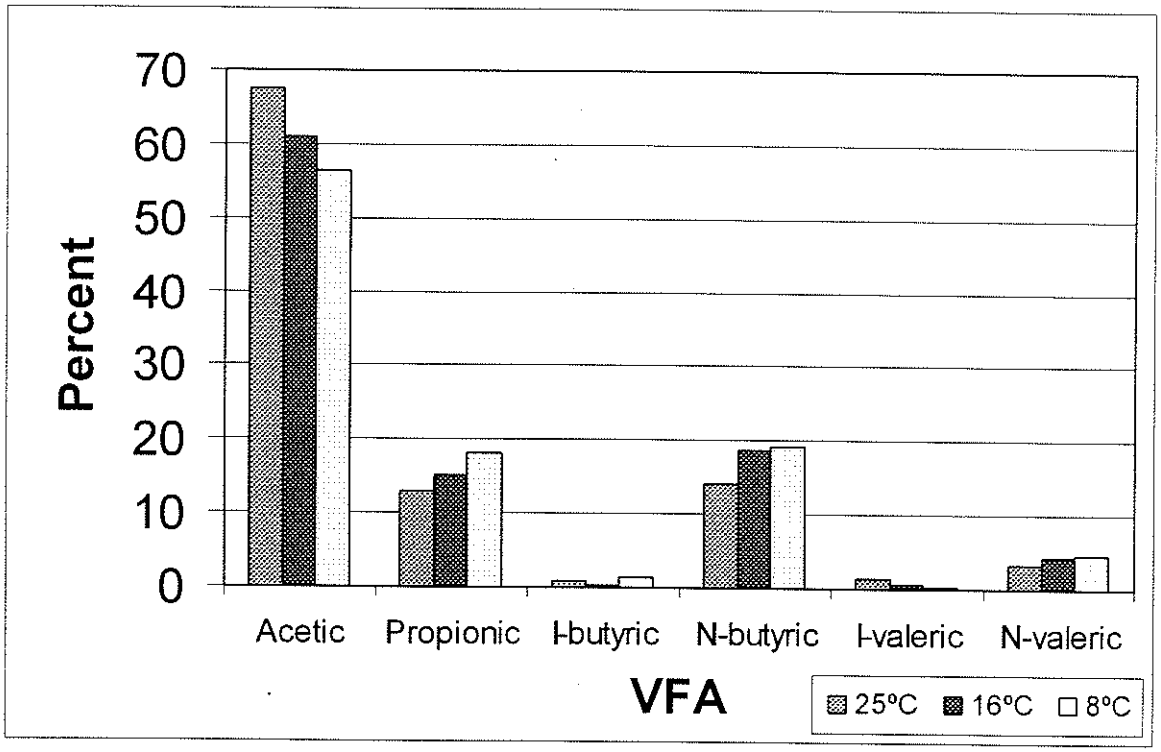

Figure 5.12: Distribution of VFAs in reactor A with temperature.

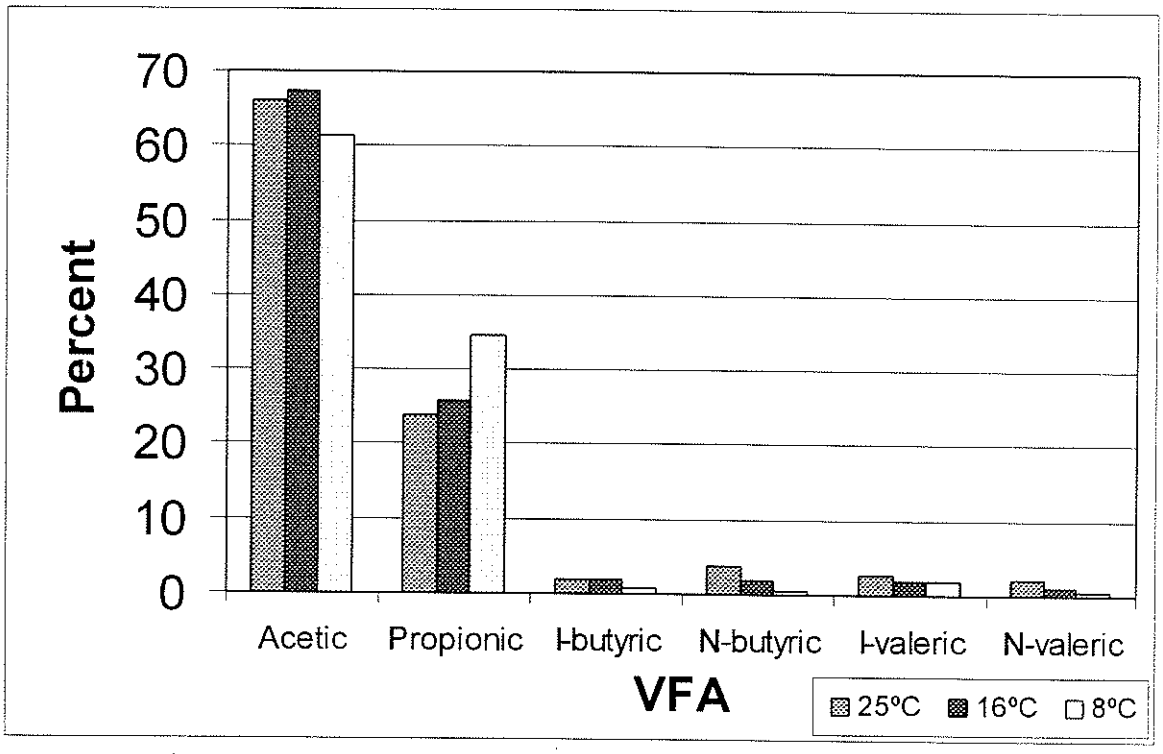

Figure 5.13: Distribution of VFAs in reactor B with temperature.

Figure 5.13 represents the distribution of VFAs that occurs within reactor B. Acetic acid is again the dominant VFA ranging from 61 to 67% of the total followed by propionic which makes up 24 to 35% of the total VFAs produced. The remaining acids are responsible for a maximum of 4% of the VFA concentration. The acetic acid distribution did not exhibit any specific trend with the decreasing temperature while the propionic acid levels did increase as the temperature decreased. The rest of the acids did show signs of decreasing as the temperature decreased except for the i-valeric acid which leveled off between 16 and 8°C. It should be noted that quantities of these remaining acids are small such that their respective trends should be interpreted with caution. It is therefore implied that temperature does have an effect on the selection of specific VFA

formation pathways, especially in the case of propionic acid (as seen in Figure 5.12 as well). The acetic, propionic and minor acids however all remain in relatively the same standing as temperature decreases.

One note of interest when comparing Figures 5.12 and 5.13 is the proportions of n-butyric acid in the industrial-municipal reactor compared to the municipal-only reactor. It would appear that the industrial wastewater plays a vital role in the creation of n-butyric acid as levels in this reactor are far greater than in the municipal-only reactor. This trend is not isolated to the runs occurring at 25, 16 and 8°C at an HRT of 30hrs but also occurs at HRTs of 48 and 60hrs at a temperature of 25°C. Therefore the increased levels of production for n-butyric acid in reactor A are not a function of HRT or temperature but is dependent on the use of the starch-rich industrial wastewater at a 1:1 ratio with primary sludge. The increased concentration of carbohydrates caused by the addition of the starch-rich wastewater would account for the increased production of n-butyric acid (Section 2.5.1).

It is also interesting to note that propionic levels are at least 10% greater in reactor B than in reactor A. The same trend was observed in the HRT experiments. The leads to the conclusion that the use of the industrial wastewater may cause an increase in n-butyric acid levels but also diminishes the production of propionic acid. The fact that 50% less primary sludge is used in the feed for reactor A could account for the decrease in propionic acid production as the primary sludge contains proteins which contribute to propionic acid formation (Section 2.5.3).

Banerjee (1997) conducted acidogenic experiments under similar conditions to those of this study, except higher temperatures of 22, 30 and 35°C were used. It was found as in this study that n-butyric acid decreased with higher temperatures when using industrial wastewater. It was also found in both experiments that propionic acid levels decreased with increasing temperature in the reactor using only municipal waste. The levels of propionic acid were also significantly higher in the reactor using only municipal waste while n-butyric concentrations were lower leading to the same conclusions about the use of the industrial wastewater as was mentioned in the previous paragraph of this study. Based on the results of the work done by Banerjee (1997) and in this study, it may be concluded that temperature does appear to play a role in selection the selection of VFA formation pathways.

5.3.2c SCOD PRODUCTION AND SS REDUCTION

The net SCOD production of reactors A and B as a function of temperature is shown in Figure 5.14. Both reactors when operated at 25°C produced the maximum amount of SCODs (1333mg/L in reactor A and 978mg/L in reactor B). Concentrations then decreased at 16°C and continued to do so at 8°C. The industrial and municipal reactor always produced more SCODs than the reactor operating on municipal waste alone. Overall, identical trends were observed in the net SCOD production as in the net VFA production (Figure 5.10).

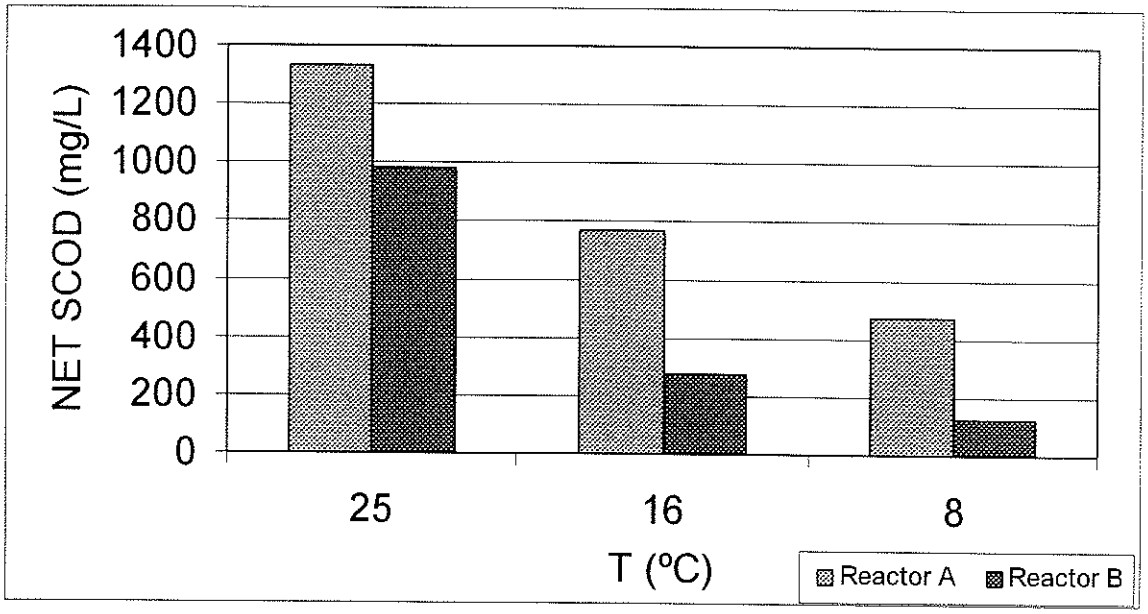

Figure 5.14: Net SCOD concentrations at 25,16 and 8°.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Temperature (°C)	VSS (mg/L)		SCOD Production Rate (mg SCOD/mg VSS*d)	
	Reactor A	Reactor B	Reactor A	Reactor B
25	14817	14467	0.0789	0.0537
16	13540	11428	0.0482	0.0187
8	14365	14280	0.0273	0.0074

Table 5.9: SCOD production rates at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

The specific SCOD production rates for reactors A and B are displayed in Table 5.9. They reveal the same trend as net SCOD production and the VFA production rates at 25, 16 and 8°C (Table 5.7). The highest production rates were achieved at 25°C and decreased with temperature at 16 and 8°C within both reactors. The combined industrial-

municipal reactor maintained a higher production rate than the municipal-only reactor at each of the given temperatures. The production rate in reactor A ranged from its maximum of 0.0789 to 0.0273mg SCOD/mg VSS*d and in reactor B the range was from 0.0537 to 0.0074mg SCOD/mg VSS*d. The remarkable decline in SCOD production rate was due to a decrease in net SCOD production, which is a function of the decreasing temperature.

Temperature (°C)	TSS Reduction (%)		VSS Reduction (%)	
	Reactor A	Reactor B	Reactor A	Reactor B
25	71.9	40.9	74.6	45.8
16	67.6	49.9	67.4	50.5
8	50.6	49.3	50.0	49.4

Table 5.10: SS reduction at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Table 5.10 represents the VSS reduction of reactors A and B as temperature decreases. It is apparent that there is a decrease in VSS reduction for the reactor using both the industrial and municipal wastewaters. There is however no statistically significant difference.in VSS reduction for the municipal-only reactor. For reactor A the trend in VSS reduction follows those of the net VFA and SCOD production and the specific VFA and SCOD production rates in that a maximum is achieved at 25°C and a gradual decrease is experienced at 16 and 8°C. Reactor B does not follow any previously observed trends and maintains a relatively stable VSS reduction level. The fact that the

amount of VSS destruction decreases with temperature in reactor A does not mean that the use of the industrial wastewater is detrimental. In spite of the decrease there is still a greater VSS reduction with the use of the industrial wastewater than without, at least until a temperature of 8°C is reached. The VSS reduction at 8°C in reactor A is comparable to those of reactor B at 25, 16 and 8°C. The TSS reduction results follow similar trends to those of the VSS reduction.

Banerjee et al. (1998) found in their experiments with a starch-rich industrial wastewater that increasing temperature above ambient conditions causes a decrease in VSS destruction. This study proved that decreasing temperatures below ambient conditions would also cause a decrease in VSS destruction. It may therefore be concluded that ambient temperatures yield the highest degree of VSS reduction when primary sludge and starch-rich industrial wastewaters are used in a 1:1 ratio at an HRT of 30hrs.

In conclusion, temperature has a significant effect on the production of VFAs. The maximum net VFA and SCOD productions, and specific VFA and SCOD production rates were attained at 25°C, and decreased with temperature from 16 to 8°C. Temperature was also found to play a significant role in VFA speciation. In reactor A, acetic acid decreased and propionic and n-butyric acids increased with a decrease in temperature. In reactor B, propionic acid levels increased as temperature decreased. The degree of VSS reduction in reactor A was also dependant on temperature in that a maximum was achieved at 25°C followed by a gradual decrease between 16 and 8°C. However, the VSS reduction in reactor B remained relatively stable regardless of temperature. Furthermore,

the net VFA and SCOD productions and the VFA and SCOD production rates were always higher in the combined industrial-municipal reactor.

5.3.3 VFA:SCOD RATIO

The VFA:SCOD ratio represents the amount of solubilized matter which is converted to VFAs. It basically measures the degree of success of the acidogenic phase. The fraction of VFAs composing the net SCOD concentration of reactors A and B at HRTs of 30, 48 and 60hrs are presented in Table 5.11. The VFA:SCOD ratio is a maximum at 60hrs in both reactors with 100% conversion. Considering that the 60hr HRT is the longest one investigated, it is reasonable that it produces the highest VFA:SCOD ratio as the acidogenic bacteria would have a longer period of time over the 30 and 48hr HRTs to convert the substrate and intermediates to VFAs. However, even at the lower HRTs conversion is relatively high with values near 0.8 or higher. It may therefore be concluded that the 30 and 48hr HRTs had no effect on the conversion of substrate to VFAs while the 60hr HRT resulted in 100% conversion. Also, the starch-rich industrial wastewater did not seem to have any effect on the VFA:SCOD ratio. The consistently high ratios do however indicate that hydrolysis is the rate limiting step at each of the HRTs investigated, the effects of which are intensified at the 60hr HRT.

Table 5.12 represents the VFA:SCOD ratios in reactors A and B at 25, 16 and 8°C. It would appear that the fraction of SCODs existing as VFAs is approximately 100% at low temperatures. Therefore it would be logical to say that at low temperatures such as 16 and 8°C, VFAs were produced while the production of intermediates and end products

was insignificant. Also, the starch-rich industrial wastewater had no effect on the VFA:SCOD ratio. More importantly though, the very high VFA:SCOD ratios indicate that hydrolysis appears to be the rate limiting step, regardless of temperature or HRT.

Reactor	HRT (hrs)	Net VFA (mg/L as COD)	Net SCOD (mg/L)	VFA/SCOD
A	30	1182	1333	0.89
	48	525	640	0.82
	60	677	642	1.05
B	30	765	978	0.78
	48	472	559	0.84
	60	337	307	1.10

Table 5.11: VFA:SCOD ratios at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Reactor	Temperature (°C)	Net VFA (mg/L as COD)	Net SCOD (mg/L)	VFA/SCOD
A	25	1182	1333	0.89
	16	767	765	1.00
	8	468	475	0.98
B	25	765	978	0.78
	16	271	271	1.00
	8	127	125	1.02

Table 5.12: VFA:SCOD ratios at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

The VFA:SCOD ratios found by Banerjee (1997) also show high levels of conversion with values near 0.86 at HRTs of 18 and 30hrs in the municipal-only reactor. The VFA:SCOD ratios attained in this study were similar with values of 0.78 and 0.84 at 30 and 48hrs, respectively (Table 5.11). It can therefore be said that HRTs between 18 and 48hrs do not appear to have any effect on the VFA:SCOD ratio when using primary sludge as a feed source. The same conclusion is implied by the results of the combined industrial-municipal reactor maintained by Banerjee (1997) and in this study. Furthermore, Elefsiniotis (1993) found that the VFA:SCOD ratio was independent of HRT above a certain minimum value. Complete conversion of the soluble portion of the substrate does however seem to occur at the 60hr HRT. In conclusion, acidogenesis was extremely successful in this study as indicated by the relatively high VFA:SCOD ratios attained regardless of HRT or temperature.

5.4 NITROGEN UTILIZATION

5.4.1 AMMONIA-NITROGEN

In anaerobic digestion, proteins contained in the wastewater can be converted to ammonia (Section 2.5.3). Figure 5.15 represents the net ammonia production in both reactors A and B at HRTs of 30, 48 and 60hrs. There is basically no net ammonia production in reactor A at 30 and 48hrs, but there is a substantial increase at 60hrs yielding 44mg/L of ammonia. Ammonia would still be produced at the lower HRTs in small amounts, but would be assimilated by the bacteria. The potential for ammonia volatilization is negligible due to the low pH levels within reactor A (pH<6.0).

The low ammonia production in reactor A may be attributed to the use of the starch-rich industrial wastewater. Previous studies have found that increasing concentrations of carbohydrates (ie. starch) retards the degradation of proteins (Breure et al., 1986a), and that bacteria adapted to easily fermentable sugars like glucose lost their ability to degrade proteins (Breure et al., 1986b). The increased ammonia production at the 60hr HRT occurred because enough time was allowed to overcome the potentially inhibitory effects of the industrial wastewater and to proceed with protein deamination.

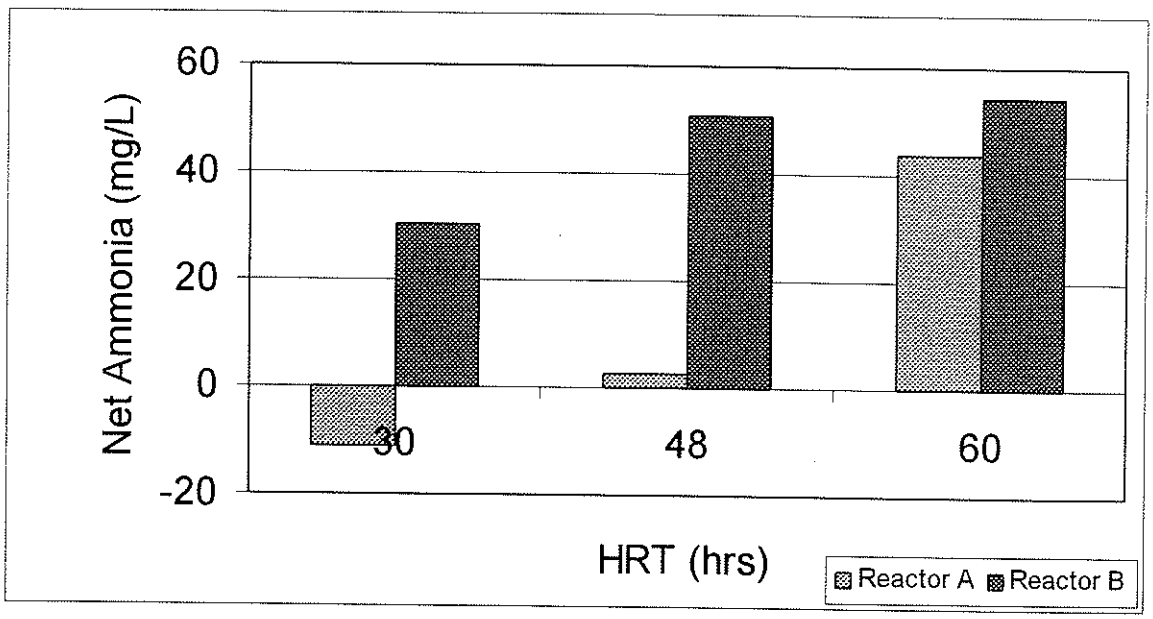

Figure 5.15: Net ammonia concentration at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

The net ammonia production in reactor B is far greater than that of reactor A, especially at the 30 and 48hr HRTs. It increases from 30 to 51 to 54mg/L at 30, 48 and 60hrs respectively. The minor increase from 51 to 54mg/L indicates that a maximum may have been approached. It is reasonable that a higher net production is experienced at

higher HRTs as more time is provided to complete the protein deamination process. The specific ammonia production rates are presented in Table 5.13 and support the findings regarding net ammonia production for both reactors A and B.

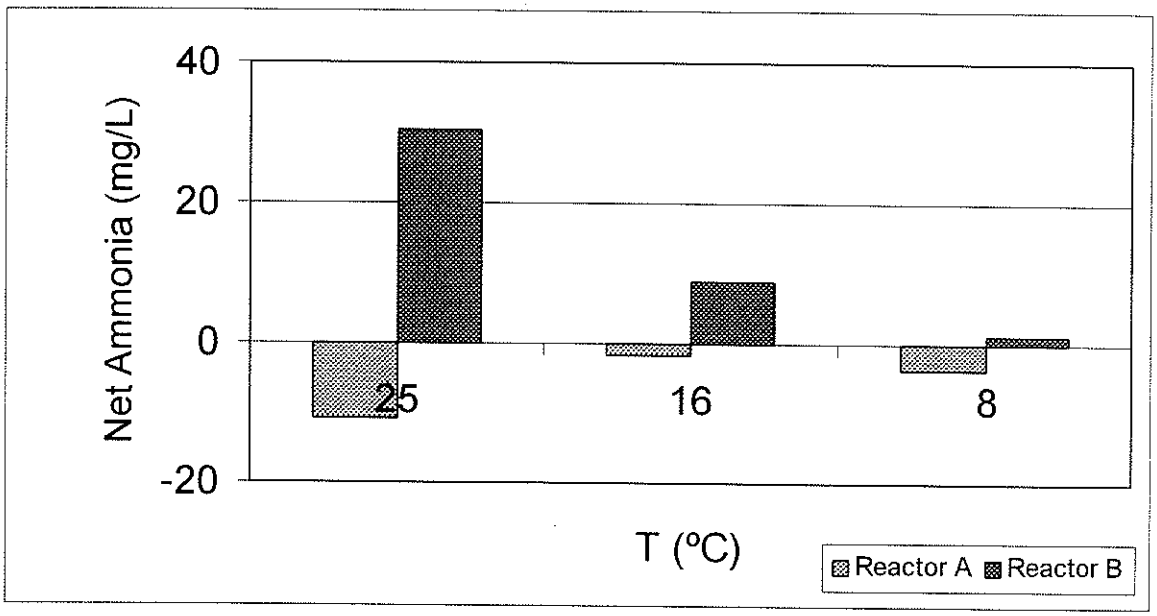

Figure 5.16: Net ammonia concentration at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Figure 5.16 reveals the net ammonia production for reactors A and B at temperatures of 25, 16 and 8°C. It is evident that there is no ammonia production within reactor A at these temperatures. Reasons for this lack of net production would be the same as discussed with regards to Figure 5.15. It is interesting to note that each of these temperature runs were conducted at the 30hr HRT, and each of them yields a net negative ammonia production. Therefore, net ammonia production does not appear to be as dependent on temperature as it is on HRT in the combined industrial-municipal system.

The net ammonia production for reactor B decreases with the decrease of temperature. There is a net production of 30, 9 and 1mg/L at 25, 16 and 8°C respectively. It would seem that as temperature decreases the ability of the bacteria to metabolize protein also decreases. It can therefore be concluded that temperature has a significant effect on the net ammonia production capabilities of systems fed with primary sludge. The specific ammonia production rates in Table 5.14 support this conclusion and those of reactor A.

HRT (hrs)	Ammonia Production Rate (mg NH_3-N/mg VSS*d)	
	Reactor A	Reactor B
30	-0.0006	0.0017
48	0.0002	0.0022
60	0.0038	0.0028

Table 5.13: Ammonia production rates at 30, 48 and 60hrs.
Reactor A = industrial and municipal.
Reactor B = municipal only.

Temperature (°C)	Ammonia Production Rate (mg NH_3-N/mg VSS*d)	
	Reactor A	Reactor B
25	-0.0006	0.0017
16	-0.0001	0.0006
8	-0.0002	0.0001

Table 5.14: Ammonia production rates at 25, 16 and 8°C.
Reactor A = industrial and municipal.
Reactor B = municipal only.

5.4.2 TOTAL KJELDAHL NITROGEN

The nitrogen within an anaerobic system may change forms but the total amount should be conserved throughout the system, assuming that denitrification is negligible. Mass balances were performed using the influent, reactor and effluent TKN concentrations, the amount wasted on the day the samples were drawn, and the average influent flow rate. Influent flow rates were averaged from the beginning of each run or from the day after the previous TKN sampling up to and including the day of the relevant TKN sampling.

According to Table 5.15, there is usually a significant reduction in nitrogen content within the system using both industrial and municipal wastes. The reasons for the reduction may be biochemical or mathematical, but the main cause can be attributed to analytical errors resulting from the nature of the solids of this system. It was virtually impossible to keep any of the samples well mixed for more than a few seconds as the solids seemed to settle quite rapidly, which was undoubtedly due to the dense nature of the starch solids. The volumes withdrawn with the use of a pipette from the sampling cups were therefore always short of solids. This effect was intensified in cases where reactor solids concentrations were lower as in the runs conducted at HRTs of 48 and 60hrs (@ 25°C) resulting in TKN reductions as high as 32.0 and 34.3% respectively. The runs performed at 16 and 8°C (@ 30hrs) showed an increase in reactor solids to levels nearing those of the 25°C (@ 30hrs) run resulting in a decrease in TKN reductions to approximately 21% for system A. The TKN reductions experienced in system B were reasonable indicating a good degree of nitrogen recovery with the exception of the last run conducted at 8°C and an HRT of 30hrs.

While the lack of TKN recovery in system A would be mainly due to the nature of the solid material within that system, it is possible that a small amount of the reduction is biochemically based. Van Loosdrecht and Jetten (1998) have mentioned an anaerobic ammonium oxidation reaction where ammonium is converted to nitrogen gas and nitrite is converted to nitrate. The equation is as follows (Van de Graag et al., 1996 cited in Van Loosdrecht and Jetten, 1998):

$$NH_4^+ + 1.3NO_2^- + 0.042CO_2 \rightarrow 0.042 \text{ biomass} + N_2 + 0.22NO_3^- + 0.08OH^- + 1.87H_2O$$

It is obvious that such a reaction would constitute only a minute amount of the TKN reduction as the concentration of nitrates within reactors A and B was insignificant (Table B27 – Appendix B). It is also possible that mathematical errors having to do with the assumption of an 'absolute' steady-state may have contributed to the TKN reductions experienced.

Conditions	TKN Reduction (%)	
	System A	System B
30hrs @ 25°C (run 1)	7.6	13.1
48hrs @ 25°C (run 2)	32.0	11.6
60hrs @ 25°C (run 3)	34.3	5.1
30hrs @ 16°C. (run 4)	21.3	4.5
30hrs @ 8°C (run 5)	21.4	27.5

Table 5.15: Percent TKN reduction.
System A = industrial and municipal.
System B = municipal only.

5.5 TOTAL COD CONSERVATION

The total chemical oxygen demand (TCOD) of an acidogenic anaerobic system should be conserved as long as no gases are produced. There should be no change in TCOD throughout the system, just a redistribution of the components which make up the TCOD concentration. Mass balances were performed to check TCOD conservation throughout systems A and B in the same manner described in Section 5.4.2. The results of these mass balances are presented in Table 5.16 and indicate a rather large reduction in TCODs throughout systems A and B.

With regards to system A, the nature of the solids and their tendency to settle so rapidly would contribute to the apparent reduction of TCODs just as described with respect to the TKN reductions. The use of the industrial wastewater is not however the only factor contributing to the lack of recovery of the TCODs. The analytical method in this case is also a large contributor which is the cause of the significant reductions in system B, and the intensified effect in system A. The fact that a syringe was used as opposed to a wide-mouthed pipette to withdraw the required volume of each sample would contribute to the reductions experienced as the syringe was unable to suck up some of the larger solid particles. The TCOD samples were also highly diluted, especially in the case of the reactor samples which were at times diluted to a 1:80 ratio with deionized water. At such high dilutions only a very small amount of sample was used (<0.6mL) which when combined with the high degree of dilution would most certainly contribute to a significant loss in the final TCOD concentration of the sample. A final evaluation of the TCODs leaving the system via the waste from the reactor would then be extremely

short of the actual amount contributing to an apparently large reduction in TCODs throughout both systems A and B.

Other factors which contribute to the reduction in TCODs include the production of carbon dioxide as a byproduct of metabolic activity. Carbon dioxide is produced through many metabolic pathways and is not included in TCOD measurements. It is possible that carbon dioxide production accounts for part of the TCOD reductions experienced in systems A and B. Mathematical assumptions having to do with the absolute steady-state of the systems may also partially account for the reductions in TCOD.

Conditions	TCOD Reduction (%)	
	System A	System B
30hrs @ 25°C (run 1)	30.5	16.0
48hrs @ 25°C (run 2)	49.7	38.1
60hrs @ 25°C (run 3)	53.1	42.5
30hrs @ 16°C (run 4)	37.3	42.9
30hrs @ 8°C (run 5)	20.0	21.8

Table 5.16: Percent TCOD reduction.
System A = industrial and municipal.
System B = municipal only.

5.6 GAS PRODUCTION

The main purpose of acid-phase anaerobic digestion is the production of VFAs. A minimal amount of gas production is expected in the form of carbon dioxide, nitrogen and hydrogen which are by-products of many of the metabolic pathways used in substrate conversion (Gottschalk, 1986). However, methane production has been found in acid-phase anaerobic digesters (Ghosh, 1987), and has been reported by many workers (Zhang and Noike, 1994).

In this study the amount of biogas produced by each reactor was negligible as indicated by the stable level of the gas retaining fluid in the gas collection apparatus (Table A3 – Appendix A). Furthermore, the amount of biogas in the headspace of each reactor was usually low, the majority of which regularly consisted of carbon dioxide (Table B29 – Appendix B). The presence of small amounts of methane does indicate the existence of small pockets of methane formers within the acid-phase. However, considering the healthy production of VFAs experienced in accordance with the variations of HRT and temperature, and the relatively minor production of biogases, it is clear that methanogenesis was suppressed in favor of acidogenesis.

5.7 VFA FORMATION PATHWAYS

The full range of each volatile fatty acid for runs 1 through 5 are displayed in Table 5.17. Acetic acid was the dominating VFA in reactors A and B. Such results are expected as acetic acid is formed from the three major organic groups (Sections 2.5.1 to 2.5.3), that is carbohydrates, lipids and proteins (Elefsiniotis, 1993). Propionic acid was

the next most abundant VFA in reactor B which is logical as it is produced mainly from carbohydrates (McCarty et al., 1963) which can make up a large percentage of municipal wastewaters. The propionic acid in reactor A was however produced in nearly the same quantity as the n-butyric acid. Butyric acid is usually derived from lipids and proteins, but it can be formed from the fermentation of carbohydrates (Gottschalk, 1986). Considering the large quantity of carbohydrates being fed into reactor A from the starch-rich industrial wastewater, activation of the biochemical pathway responsible for the degradation of carbohydrates to butyric acid would explain the increased production of n-butyric acid in reactor A over that of reactor B. The quantities of i-butyric, i-valeric and n-valeric acid were minimal in reactors A and B and since they are formed mainly from the fermentation of proteins (Elefsiniotis, 1993) it would be fair to assume that protein levels within both influents were relatively low.

Volatile Fatty Acid	Reactor A	Reactor B
Acetic	56.4 - 74.4	61.3 – 67.4
Propionic	10.4 - 18.1	23.9 – 34.7
I-butyric	0.8 - 2.7	0.9 – 3.6
N-butyric	9.0 - 19.4	0.7 – 3.7
I-valeric	0.4 - 4.1	2.0 – 5.6
N-valeric	2.3 - 4.5	0.5 – 2.0

Table 5.17: Overall distribution of VFAs (all values expressed as %).
Reactor A = industrial and municipal.
Reactor B = municipal only.

5.8 KINETICS OF VFA PRODUCTION

With respect to biological treatment processes, the role of HRT is very simple in that it merely dictates the amount of time which the feed spends in the reactor, or the period of time which the microorganisms have to assimilate and convert the substrate. VFA production can be used as a measure of a microorganism's ability to metabolize the substrate at different HRTs. Based on the results attained from systems A and B of this experiment and those conducted by Banerjee (1997), there is a definite relationship between HRT and VFA production.

Using the results of Banerjee's work and those of this experiment, it was found that there was a first order kinetic relationship between HRT and VFA production (Appendix C). A production rate (k) of 0.222days^{-1} was found in system A while the production rate in system B was found at 0.093days^{-1}. Similarly, the half-velocity constant (K_s) was 20% higher in system A. The significantly higher production rate in the combined industrial-municipal system coincides with the consistently higher VFA productions found over the municipal-only system in Sections 5.3.1a and 5.3.2a. The production rate in system A is also significantly greater than the typical rate of domestic sludge decay at 0.030days^{-1} (Metcalf and Eddy, 1991), which implies that the rate of substrate degradation is enhanced by the use of the starch-rich industrial wastewater. The production rates at 16 and 8°C were also calculated based on van't Hoff-Arrhenius' relationship (Appendix C). As expected, it was found that the production rates decreased with temperature.

5.9 CLARIFIER PERFORMANCE

Clarifier performance is important to the overall function of an acidogenic anaerobic digestion system in that it allows for the recycling of acclimated biomass back into the reactor. Clarifier A performed extremely well for the duration of the entire study. Settling within the clarifier was always excellent undoubtedly due the use of the starch-rich industrial wastewater. The dense nature of the solid particles promoted the rapid and efficient settling of matter within the clarifier. Also, whenever there actually was any scum formation it was only to an insignificant degree and resembled the scum which forms on heated milk.

The performance of clarifier B simply could not measure up to that of the industrial-municipal clarifier. The characteristics of the solids in this clarifier resulted in a less efficient settling process, as indicated by the significantly higher solids concentrations in effluent B (Table 5.18). At times the clarifier was stratified in that most of the solids would settle to the bottom, but there would still be a group of solids suspended higher up within the clarified liquid. Scum formation was also prevalent in clarifier B for the majority of the runs conducted which resulted in the loss of solids from the system and at times a decrease in SRT below the 10 day nominal value. Runs 1 through 3 (@ 25°C) produced a significant amount of scum formation which then decreased at the lower temperature run conducted at 16°C and disappeared with the 8°C run. The scum generated in this clarifier can be described as heavy and sometimes foamy. The foamy description comes from the fact that tiny gas bubbles were sometimes observed within the scum layer. In fact, gas bubbles had been occasionally observed deeper within this clarifier indicating that some solid materials were retained for a long enough period to

time to allow for the onset of methanogenesis. The fact that some particles were retained for such a significantly longer period of time than others also attests to the relative inefficiency of clarifier B.

Conditions	Effluent TS (mg/L)		Effluent VSS (mg/L)	
	System A	System B	System A	System B
30hrs @ 25°C (run 1)	1970	2848	677	1353
48hrs @ 25°C (run 2)	1275	2419	350	1370
60hrs @ 25°C (run 3)	1607	1873	595	1053
30hrs @ 16°C (run 4)	1922	3101	670	1687
30hrs @ 8°C (run 5)	1387	1745	352	505

Table 5.18: TS and VSS concentrations of effluents A and B.
System A = industrial and municipal.
System B = municipal only.

5.10 COLD STORAGE EVALUATION

The total VFA content of the undiluted primary sludge and starch-rich industrial wastewater was measured over time in order to determine the extent of degradation of each substrate during storage at 6°C (Table 5.19). The primary sludge was usually replaced every 14 days and fresh industrial wastewater was attained each month. In each case there was a certain degree of decomposition occurring over the respective time intervals, as indicated by the increase of total VFA content. The increase in VFA concentration would be largely due to the high concentration of solids in the undiluted substrates, especially in the industrial wastewater where TS levels were as high as 12.7%.

The high TS concentrations in the industrial wastewater combined with the easily fermentable starch material virtually ensure a relatively high degree of degradation by existing ubiquitous microorganisms. The amount of fermentation does however appear to drop significantly around 9 days in the primary sludge and at 13 days in the industrial wastewater. Regardless of the amount of fermentation which takes place prior to feeding, there would be no effect on the final results of this study as all relevant parameters were evaluated on a net production basis.

5.11 REPLICATION FEASIBILITY

To ensure that this study could be used in further research on the topic of acidogenic anaerobic digestion, an evaluation of the results between two separate runs and each reactor was conducted (Table 5.20). Both reactors A and B were operated at an HRT of 30hrs and a temperature of 25°C using primary sludge alone during the preliminary run (run P). Reactor B was again operated under the same conditions during run 1. According to the t-test (Moore, 1995) there was no significant difference in the results attained from reactors A and B during run P, or in the specific VFA and SCOD production rates of reactor B during runs P and 1. There were however discrepancies in the TSS and VSS reduction results for reactor B between runs P and 1 which can be attributed to a lack of complete stabilization of reactor solids during run P. In fact, the reactor solids of system B as well as for system A did not fully stabilize until well into run 1. However, the SS reduction results for run P between reactors A and B do not reveal any incongruities proving that even at a semi-stable level of operation reproduction is feasible.

Day	Total VFA (mg/L as acetic acid)	
	Primary Sludge	Starch-Rich Industrial Wastewater
0	1682	360
2	1904	703
4	2227	949
7	2199	1043
9	2611	1247
11	2557	1106
13	2639	1317
15	3036	1536
17		1296
20		1392
22		1692
24		1516
26		1612
28		1535
30		1716
Average	2357	1268
Standard Deviation	439	382

Table 5.19: Cold storage evaluation.

Parameter	Reactor A Run P	Reactor B Run P	Reactor B Run 1	Significant Difference?	
				Reactors A & B Run P	Reactor B Runs P & 1
VFA Production Rate	0.0317	0.0306	0.0306	NO	NO
SCOD Production Rate	0.0570	0.0472	0.0537	NO	NO
TSS Reduction (%)	67.6	66.4	40.9	NO	YES
VSS Reduction (%)	67.4	66.5	45.8	NO	YES

Table 5.20: Replication feasibility results.
Note: Specific production rates expressed as mg VFA or SCOD/mg VSS*d.
Reactor A = industrial and municipal.
Reactor B = municipal only.

5.12 APPLICATIONS REGARDING VFA PRODUCTION

The importance of VFA production cannot be emphasized enough with respect to biological nutrient removal. VFAs have the potential to prevent the eutrophication of so many of the earth's surface waters, since they can act as the carbon source needed during denitrification (Section 2.7.1) and phosphorus removal (Section 2.7.2). The fact that VFA production was significantly enhanced throughout the course of this study with the use of the starch-rich industrial wastewater and regardless of operating or environmental conditions could be extremely beneficial to nitrogen and phosphorus removal processes.

VFAs have been used successfully as a carbon source for denitrification (Hatziconstantinou, 1996; Brinch et al., 1994). There is also a direct relationship between the amount of VFAs used in phosphorus removal and the quantity of phosphorus removed. Therefore, information regarding optimal VFA production conditions which consisted of a 30hr HRT at 25°C in this study, could be remarkably important. Only 7 to

9mg of VFAs are needed to remove 1mg of phosphorus (Barnard, 1993). Therefore, VFA production would be useful even at the lowest net production level in this experiment, where 85mg/L (as acetic acid) of VFAs were produced at an HRT of 30hr and 8°C using municipal waste only. It is therefore possible to achieve significant phosphorus reductions even under the least productive conditions experienced in this study.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The changes in HRT and temperature imposed on the anaerobic systems used in this study had profound effects on their acidogenic characteristics. As such, the following conclusions can be made with respect to the results attained from the operational and environmental conditions investigated.

1) An acidogenic state was achieved and maintained throughout the entire study in both the industrial-municipal and municipal-only system, as indicated by the continual and healthy production of VFAs, and the low degree of gas production.
2) The maximum net VFA and SCOD concentrations were attained at an HRT of 30hrs. The net concentrations then decreased at 48 and 60hrs because of a drop in VSS concentrations.
3) The maximum specific VFA and SCOD production rates were also achieved at the 30hr HRT and decreased at 48 and 60hrs in accordance with the net VFA and SCOD concentrations.
4) The net VFA and SCOD concentrations and the specific VFA and SCOD production rates all varied with temperature in the same manner. A maximum was attained at 25°C and a decrease was observed at 16°C followed by a further decrease at 8°C.

5) The use of the starch-rich industrial wastewater consistently resulted in significantly higher net VFA and SCOD concentrations as well as higher specific VFA and SCOD production rates regardless of HRT or temperature.

6) Acetic acid was the dominant VFA produced in both reactors A and B with averages ranging from 56 to 74%. Propionic acid was the next most prevalent VFA averaging 10 to 18% in reactor A and 24 to 35% in reactor B. N-butyric acid was produced in approximately the same quantities as propionic acid in reactor A, and propionic acid production was at least 10 percentage points greater in reactor B than in reactor A. The use of the starch-rich industrial wastewater and therefore the increased concentration of carbohydrates obviously had a profound effect on VFA speciation such that n-butyric levels were significantly increased while propionic levels decreased. HRT does not appear to have any effect on VFA speciation, but a decrease in temperature causes a decrease in acetic acid while the quantities of propionic and n-butyric acid increase in reactor A. In reactor B, the decrease of temperature had no apparent effect on acetic acid concentrations but produced an increase in propionic acid concentrations.

7) The degree of VSS reduction remains statistically the same at the 30, 48 and 60hr HRTs indicating that VSS reduction is independent of HRT within the range investigated. VSS destruction did however decrease with temperature in reactor A, but remained relatively constant in reactor B. The use of the industrial wastewater significantly increased the degree of VSS reduction, even during its decrease with temperature. At its lowest point at 8°C, VSS destruction in the industrial-municipal reactor was comparable to that of the municipal-only reactor.

8) The maximum VFA:SCOD ratio was attained at the 60hr HRT indicating 100% conversion of SCODs to VFAs in both reactors A and B. Even at the lower HRTs of 30 and 48hrs conversion was still high with VFA:SCOD values nearing 0.8 or higher. Conversion was also approximately 100% at 16 and 8°C indicating the complete conversion of soluble organics to VFAs. The use of the starch-rich industrial wastewater had no apparent effect on the VFA:SCOD ratios. The high ratios attained do however indicate that acidogenesis was extremely successful, and that hydrolysis appears to be the rate limiting step regardless of HRT or temperature.

9) There was basically no net ammonia production in reactor A at the 30 and 48hr HRTs as a result of protein degradation inhibition by the starch from the industrial wastewater. Net ammonia production did however become apparent at the 60hr HRT in reactor A, and in reactor B production increased with HRT. There was again no net ammonia production in reactor A at 25, 16 and 8°C as these runs were all conducted at the 30hr HRT. The net production in reactor B simply decreased with the decrease in temperature.

10) VFA production appeared to follow a first order kinetic relationship with HRT in both the industrial-municipal and the municipal-only system.

11) Replication of the acid-phase anaerobic digestion observed in this study is feasible considering that the right operational and environmental conditions are provided.

6.2 RECOMMENDATIONS

Based on the findings of this study it is suggested that further research focus on the following areas:

1) It was proven during the course of this study that starch-rich industrial wastewater mixed with primary sludge at a 1:1 ratio has a positive effect on VFA production. Therefore the ratio of the industrial wastewater with primary sludge should be varied in order to determine the optimal mixture for VFA production.
2) Considering that a starch-rich industrial wastewater enhanced VFA production so significantly, the effects of using a wastewater rich in lipids or proteins or even a different form of carbohydrate should be investigated.
3) The use of process configurations other than the anaerobic contact process should be explored using a starch-rich industrial wastewater to determine if such a substrate is beneficial in different configurations.
4) The significance of maintaining an acidogenic anaerobic reactor is based on the fact that VFAs may be used in nutrient removal processes. An investigation which uses these VFAs in a denitrification or phosphorus removal study is therefore necessary to further evaluate the effectiveness of VFAs as a carbon source.
5) Large reductions in the TCOD were found in systems A and B throughout the course of this experiment due to the analytical method used. As such, an alternate method of determining TCOD concentration should be used when dealing with wastes like the primary sludge and the starch-rich industrial wastewater used in this study.

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APPENDIX A

OPERATIONAL AND ENVIRONMENTAL PARAMETERS

TABLE PAGE

A1: HRT and SRT for system A 110
A2: HRT and SRT for system B 116
A3: Temperature and gas production of systems A and B 122

Table A1: HRT and SRT for system A.					
RUN P:					
DATE	AMOUNT FED	TIME ELAPSED	FLOW	HRT	SRT
	(mL)	(hrs)	(mL/hr)	(hrs)	(days)
June 16	2125	23.5	90.4	33.2	
June 18	2500	25.0	100.0	30.0	
June 19	3000	25.0	120.0	25.0	
June 20	2500	24.0	104.2	28.8	10.0
June 22	5000	48.0	104.2	28.8	
June 23	2500	24.0	104.2	28.8	
June 24	2000	20.0	100.0	30.0	
June 25	3000	25.5	117.6	25.5	
June 28	2500	26.5	94.3	31.8	
June 30	5000	45.0	111.1	27.0	
July 1	2500	25.0	100.0	30.0	
July 2	2250	22.0	102.3	29.3	10.0
July 3	2400	22.0	109.1	27.5	
July 4	2500	24.5	102.0	29.4	
July 5	2500	25.0	100.0	30.0	
July 10	1500	22.5	66.7	45.0	
July 11	2500	22.5	111.1	27.0	
July 12	2700	27.5	98.2	30.6	
July 14	4000	43.5	92.0	32.6	10.0
July 15	2500	25.5	98.0	30.6	10.0
July 16	2340	25.0	93.6	32.1	10.0
July 17	2500	21.5	116.3	25.8	10.0
July 18	2500	24.5	102.0	29.4	
July 19	2667	27.0	98.8	30.4	
		AVERAGE:	101.5	29.9	10.0
		STD.DEV:	10.8	3.9	0.0
Table A1: Con't.					
RUN 1:					
DATE	AMOUNT FED	TIME ELAPSED	FLOW	HRT	SRT
	(mL)	(hrs)	(mL/hr)	(hrs)	(days)
July 21	4357	43.5	100.2	30.0	
July 22	2443	23.0	106.2	28.2	10.0
July 23	2400	25.0	96.0	31.3	10.0
July 24	1630	16.5	98.8	30.4	10.0
July 25	2600	25.5	102.0	29.4	
July 26	2733	26.0	105.1	28.5	
July 28	4500	50.5	89.1	33.7	
July 29	1834	18.5	99.1	30.3	10.0
July 30	1583	16.5	95.9	31.3	10.0
July 31	3193	28.5	112.0	26.8	10.0
Aug. 1	1867	21.5	86.8	34.5	10.0
Aug. 2	2550	24.5	104.1	28.8	10.0
Aug. 3	2429	24.0	101.2	29.6	
Aug. 5	4771	50.0	95.4	31.4	

Aug. 6	2310	24.0	96.3	31.2	10.0
Aug. 7	1700	18.0	94.4	31.8	10.0
Aug. 8	2800	26.0	107.7	27.9	
Aug. 9	2450	26.5	92.5	32.4	
Aug. 11	4875	49.0	99.5	30.2	
Aug. 12	1600	17.5	91.4	32.8	10.0
Aug. 13	2250	23.5	95.7	31.3	10.0
Aug. 14	2650	28.5	93.0	32.3	10.0
Aug. 15	2050	22.5	91.1	32.9	10.0
Aug. 16	3300	26.5	124.5	24.1	
Aug. 18	4150	41.0	101.2	29.6	
Aug. 19	3203	29.5	108.6	27.6	
Aug. 20	2714	26.5	102.4	29.3	
Aug. 21	1750	19.5	89.7	33.4	
Aug. 22	3167	28.0	113.1	26.5	10.0
Aug. 23	1667	17.5	95.3	31.5	10.0
Aug. 25	5583	50.0	111.7	26.9	10.0
Aug. 26	1667	20.5	81.3	36.9	
Aug. 28	4771	46.0	103.7	28.9	
Aug. 30	2557	27.0	94.7	31.7	10.0
Aug. 31	2500	24.5	102.0	29.4	10.0
Sept. 2	4458	43.5	102.5	29.3	10.0
Sept. 3	2750	25.0	110.0	27.3	
Sept. 4	2000	22.0	90.9	33.0	
Sept. 5	2500	24.5	102.0	29.4	10.0
Sept. 6	3300	28.0	117.9	25.5	10.0
Sept. 8	4200	43.0	97.7	30.7	10.0
Sept. 9	2333	27.0	86.4	34.7	10.0
Sept. 11	4750	45.5	104.4	28.7	10.0
Sept. 12	1762	19.0	92.7	32.3	
Sept. 13	2667	27.5	97.0	30.9	
Sept. 15	4233	45.5	93.0	32.2	
Sept. 16	2100	23.0	91.3	32.9	
		AVERAGE:	99.3	30.4	10.0
		STD.DEV:	8.5	2.5	0.0
Table A1: Con't.					
RUN 2:					
DATE	AMOUNT FED	TIME ELAPSED	FLOW	HRT	SRT
	(mL)	(hrs)	(mL/hr)	(hrs)	(days)
Sept. 17	1000	20.5	48.8	61.5	
Sept. 19	2250	47.0	47.9	62.7	
Sept. 22	1217	22.5	54.1	55.5	
Sept. 23	1783	27.0	66.0	45.4	
Sept. 24	1100	19.0	57.9	51.8	10.0
Sept. 25	1625	25.5	63.7	47.1	10.0
Sept. 26	1750	22.0	79.5	37.7	10.0
Sept. 27	1596	27.0	59.1	50.8	
Sept. 29	3166	51.0	62.1	48.3	
Sept. 30	1750	24.5	71.4	42.0	10.0

Oct. 1	750	16.5	45.5	66.0	10.0
Oct. 2	1690	24.0	70.4	42.6	
Oct. 3	1500	24.0	62.5	48.0	
Oct. 4	1500	25.5	58.8	51.0	
Oct. 6	2667	45.0	59.3	50.6	10.0
Oct. 7	2083	32.0	65.1	46.1	10.0
Oct. 8	1250	19.0	65.8	45.6	10.0
Oct. 9	1375	22.5	61.1	49.1	10.0
Oct. 10	1310	21.0	62.4	48.1	10.0
Oct. 11	1583	27.0	58.6	51.2	
Oct. 14	4583	68.5	66.9	44.8	
Oct. 15	1500	24.0	62.5	48.0	10.0
Oct. 17	2833	47.0	60.3	49.8	
Oct. 20	4500	72.5	62.1	48.3	
Oct. 21	1400	25.5	54.9	54.6	10.0
Oct. 22	1750	28.5	61.4	48.9	10.0
Oct. 23	1600	22.0	72.7	41.3	10.0
Oct. 24	1000	18.5	54.1	55.5	10.0
Oct. 25	2267	29.0	78.2	38.4	
Oct. 27	2950	50.0	59.0	50.8	
Oct. 28	1133	20.5	55.3	54.3	
Oct. 29	3833	23.5	163.1	18.4	10.0
Oct. 30	1500	19.0	78.9	38.0	10.0
Oct. 31	1357	23.5	57.7	52.0	10.0
Nov. 3	4500	71.0	63.4	47.3	
Nov. 4	1500	23.0	65.2	46.0	10.0
Nov. 5	1800	29.5	61.0	49.2	10.0
Nov. 6	1500	23.5	63.8	47.0	10.0
Nov. 7	900	18.0	50.0	60.0	10.0
Nov. 8	2300	30.0	76.7	39.1	10.0
Nov. 9	1267	19.5	65.0	46.2	
Nov. 10	1083	21.5	50.4	59.6	
Nov. 11	1500	26.5	56.6	53.0	
Nov. 12	1500	20.0	75.0	40.0	10.0
Nov. 13	1250	24.5	51.0	58.8	10.0
Nov. 14	1625	22.5	72.2	41.5	
		AVERAGE:	64.3	48.5	10.0
		STD.DEV:	17.0	8.0	0.0

Table A1: Con't.

RUN 3:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Nov. 15	833	24.0	34.7	86.4	
Nov. 17	2250	42.5	52.9	56.7	
Nov. 18	1143	29.0	39.4	76.1	
Nov. 19	1357	18.5	73.4	40.9	
Nov. 20	1400	26.5	52.8	56.8	
Nov. 21	1200	24.0	50.0	60.0	
Nov. 22	1300	24.5	53.1	56.5	

Nov. 24	2375	44.0	54.0	55.6	10.0
Nov. 25	1400	27.5	50.9	58.9	10.0
Nov. 26	1017	20.0	50.9	59.0	10.0
Nov. 28	2383	48.5	49.1	61.1	10.0
Nov. 29	1200	23.0	52.2	57.5	
Dec. 1	2500	47.5	52.6	57.0	
Dec. 2	1250	23.0	54.3	55.2	10.0
Dec. 3	1050	25.0	42.0	71.4	10.0
Dec. 5	2700	50.0	54.0	55.6	10.0
Dec. 7	2800	54.5	51.4	58.4	10.0
Dec. 10	3000	61.5	48.8	61.5	10.0
Dec. 11	1200	24.5	49.0	61.3	10.0
Dec. 12	1096	23.5	46.6	64.3	10.0
Dec. 13	1404	28.0	50.1	59.8	
Dec. 15	2067	45.5	45.4	66.0	
Dec. 16	1250	20.5	61.0	49.2	10.0
Dec. 17	1017	25.5	39.9	75.2	10.0
Dec. 18	1100	23.0	47.8	62.7	10.0
Dec. 19	1300	28.0	46.4	64.6	10.0
Dec. 20	1083	24.0	45.1	66.5	10.0
Dec. 22	2584	45.5	56.8	52.8	10.0
Dec. 23	1183	23.0	51.4	58.3	10.0
Dec. 24	1400	25.0	56.0	53.6	
Dec. 27	2833	74.0	38.3	78.4	
Dec. 29	2500	48.0	52.1	57.6	
Dec. 30	1333	23.5	56.7	52.9	10.0
Dec. 31	1417	22.0	64.4	46.6	10.0
Jan. 2	2050	50.5	40.6	73.9	10.0
Jan. 3	1300	25.5	51.0	58.8	10.0
Jan. 4	1233	24.0	51.4	58.4	
Jan. 5	1167	26.5	44.0	68.1	
Jan. 6	1300	23.0	56.5	53.1	10.0
Jan. 7	800	17.5	45.7	65.6	10.0
Jan. 8	900	22.5	40.0	75.0	10.0
Jan. 9	1417	29.0	48.9	61.4	10.0
		AVERAGE:	50.0	61.2	10.0
		STD.DEV:	7.2	8.9	0.0

Table A1: Con't.

RUN 4:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Jan. 10	3000	23.5	127.7	23.5	
Jan. 12	4500	49.5	90.9	33.0	
Jan. 13	1800	19.0	94.7	31.7	
Jan. 14	2450	27.0	90.7	33.1	
Jan. 15	2083	19.5	106.8	28.1	
Jan. 16	2050	22.5	91.1	32.9	10.0
Jan. 17	2533	26.0	97.4	30.8	10.0
Jan. 19	3917	46.5	84.2	35.6	10.0

Jan. 20	2250	25.0	90.0	33.3	10.0
Jan. 21	2869	23.5	122.1	24.6	10.0
Jan. 22	2314	22.5	102.8	29.2	10.0
Jan. 23	2200	22.0	100.0	30.0	
Jan. 25	4675	52.0	89.9	33.4	
Jan. 26	2467	20.5	120.3	24.9	10.0
Jan. 27	2500	27.5	90.9	33.0	10.0
Jan. 28	1667	21.5	77.5	38.7	10.0
Jan. 29	2333	25.0	93.3	32.1	10.0
Jan. 30	2625	20.5	128.0	23.4	10.0
Jan. 31	2042	23.5	86.9	34.5	10.0
Feb. 3	6666	76.0	87.7	34.2	10.0
Feb. 5	2725	23.5	116.0	25.9	10.0
Feb. 6	1500	17.5	85.7	35.0	10.0
Feb. 7	3067	30.0	102.2	29.3	
Feb. 9	4036	42.0	96.1	31.2	
Feb. 10	1917	23.5	81.6	36.8	
Feb. 11	2250	26.0	86.5	34.7	10.0
Feb. 12	2500	24.0	104.2	28.8	10.0
Feb. 13	2750	27.5	100.0	30.0	
Feb. 15	5800	43.5	133.3	22.5	
Feb. 16	1867	23.0	81.2	37.0	10.0
Feb. 17	2400	22.0	109.1	27.5	10.0
Feb. 18	2733	25.0	109.3	27.4	10.0
Feb. 19	3050	28.5	107.0	28.0	10.0
Feb. 20	2000	17.5	114.3	26.3	10.0
Feb. 21	2119	19.5	108.7	27.6	
Feb. 23	4631	46.0	100.7	29.8	
Feb. 24	2983	27.0	110.5	27.2	10.0
Feb. 25	1850	20.0	92.5	32.4	10.0
Feb. 26	2625	30.0	87.5	34.3	10.0
Feb. 27	1083	17.0	63.7	47.1	10.0
Feb. 28	2958	27.0	109.6	27.4	
Mar. 2	4675	44.0	106.3	28.2	
		AVERAGE:	99.5	30.8	10.0
		STD.DEV:	14.8	4.7	0.0

Table A1: Con't.

RUN 5:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Mar. 3	2450	24.5	100.0	30.0	
Mar. 4	2250	24.0	93.8	32.0	
Mar. 6	4967	45.5	109.2	27.5	
Mar. 7	2633	25.5	103.3	29.1	
Mar. 9	5100	45.0	113.3	26.5	10.0
Mar. 10	2700	28.5	94.7	31.7	10.0
Mar. 11	1783	20.0	89.2	33.7	10.0
Mar. 13	4400	47.0	93.6	32.0	10.0
Mar. 14	2200	22.0	100.0	30.0	10.0

Mar. 16	4000	47.5	84.2	35.6	10.0
Mar. 17	2083	22.0	94.7	31.7	10.0
Mar. 18	2000	23.0	87.0	34.5	10.0
Mar. 19	2900	27.5	105.5	28.4	10.0
Mar. 20	1533	18.5	82.9	36.2	10.0
Mar. 21	3292	28.0	117.6	25.5	
Mar. 23	4533	44.5	101.9	29.5	
Mar. 24	2100	21.5	97.7	30.7	10.0
Mar. 25	2500	26.5	94.3	31.8	10.0
Mar. 26	1900	23.0	82.6	36.3	10.0
Mar. 27	2500	28.5	87.7	34.2	10.0
Mar. 29	5133	46.0	111.6	26.9	10.0
Mar. 30	1983	19.0	104.4	28.7	10.0
Mar. 31	2600	25.5	102.0	29.4	
Apr. 1	2000	21.5	93.0	32.3	10.0
Apr. 2	2666	23.0	115.9	25.9	10.0
Apr. 3	2043	18.0	113.5	26.4	10.0
Apr. 4	2517	29.0	86.8	34.6	10.0
Apr. 6	3700	44.0	84.1	35.7	10.0
Apr. 7	2000	22.0	90.9	33.0	10.0
Apr. 8	1417	20.0	70.9	42.3	
Apr. 10	5050	48.5	104.1	28.8	
Apr. 11	2617	27.0	96.9	31.0	
Apr. 13	3800	42.0	90.5	33.2	
Apr. 14	2286	22.0	103.9	28.9	
Apr. 15	2114	19.5	108.4	27.7	
Apr. 16	2700	25.0	108.0	27.8	
Apr. 17	2567	25.0	102.7	29.2	
Apr. 18	2708	28.0	96.7	31.0	
Apr. 20	4512	43.0	104.9	28.6	
Apr. 21	2017	22.5	89.6	33.5	
Apr. 22	2233	23.5	95.0	31.6	
		AVERAGE:	97.7	31.1	10.0
		STD.DEV:	10.4	3.5	0.0

Table A2: HRT and SRT for system B.					
RUN P:					
DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
June 16	2000	23.5	85.1	35.3	
June 18					
June 19	3000	25.0	120.0	25.0	
June 20	1500	24.0	62.5	48.0	10.0
June 22	6500	48.0	135.4	22.2	
June 23	2500	24.0	104.2	28.8	
June 24	2000	20.0	100.0	30.0	
June 25	3000	25.5	117.6	25.5	
June 28	2500	26.5	94.3	31.8	
June 30	5000	45.0	111.1	27.0	
July 1	2500	25.0	100.0	30.0	
July 2	2000	22.0	90.9	33.0	10.0
July 3	2000	22.0	90.9	33.0	
July 4	2500	24.5	102.0	29.4	
July 5	2500	25.0	100.0	30.0	
July 10	1500	22.5	66.7	45.0	
July 11	2160	22.5	96.0	31.3	
July 12	2800	27.5	101.8	29.5	
July 14	4200	43.5	96.6	31.1	10.0
July 15	2000	25.5	78.4	38.3	10.0
July 16	2250	25.0	90.0	33.3	10.0
July 17	2420	21.5	112.6	26.7	10.0
July 18	2500	24.5	102.0	29.4	
July 19	2833	27.0	104.9	28.6	
		AVERAGE:	98.4	31.4	10.0
		STD.DEV:	16.2	5.9	0.0
Table A2: Con't.					
RUN 1:					
DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
July 21	4663	43.5	107.2	28.0	
July 22	2167	23.0	94.2	31.8	10.0
July 23	2333	25.0	93.3	32.1	10.0
July 24	1663	17.0	97.8	30.7	10.0
July 25	2667	25.5	104.6	28.7	
July 26	2750	25.5	107.8	27.8	
July 28	5083	50.5	100.7	29.8	
July 29	1667	18.5	90.1	33.3	10.0
July 30	2083	17.0	122.5	24.5	10.0
July 31	3250	28.5	114.0	26.3	10.0
Aug. 1	2333	21.5	108.5	27.6	10.0
Aug. 2	2667	24.5	108.9	27.6	10.0
Aug. 3	2250	24.0	93.8	32.0	
Aug 5	4850	50.0	97.0	30.9	

Aug. 6	2220	24.0	92.5	32.4	10.0
Aug. 7	1867	18.0	103.7	28.9	10.0
Aug. 8	2625	26.0	101.0	29.7	
Aug. 9	2675	26.5	100.9	29.7	
Aug. 11	4500	49.0	91.8	32.7	
Aug. 12	1500	17.5	85.7	35.0	10.0
Aug. 13	2500	23.5	106.4	28.2	10.0
Aug. 14	2750	28.5	96.5	31.1	10.0
Aug. 15	2250	22.5	100.0	30.0	10.0
Aug. 16	2333	26.5	88.0	34.1	
Aug 18	5000	41.0	122.0	24.6	
Aug 19	3334	29.5	113.0	26.5	
Aug. 20	2500	26.5	94.3	31.8	
Aug. 21	1833	19.5	94.0	31.9	
Aug. 22	2833	28.0	101.2	29.7	9.6
Aug. 23	1750	17.5	100.0	30.0	9.6
Aug. 25	6625	50.0	132.5	22.6	9.6
Aug. 26	2083	20.5	101.6	29.5	
Aug. 28	4667	47.5	98.3	30.5	
Aug. 30	2500	27.0	92.6	32.4	7.9
Aug. 31	2250	24.5	91.8	32.7	7.9
Sept. 2	4417	43.5	101.5	29.5	7.9
Sept. 3	2583	25.0	103.3	29.0	
Sept. 4	2367	22.0	107.6	27.9	
Sept. 5	2300	24.5	93.9	32.0	10.0
Sept. 6	2917	28.0	104.2	28.8	10.0
Sept. 8	4583	43.0	106.6	28.1	10.0
Sept. 9	2084	27.0	77.2	38.9	10.0
Sept. 11	4833	45.5	106.2	28.2	10.0
Sept. 12	1958	19.0	103.1	29.1	
Sept. 13	2917	27.5	106.1	28.3	
Sept. 15	4500	45.5	98.9	30.3	
Sept. 16	1933	23.0	84.0	35.7	
		AVERAGE:	100.9	30.0	9.7
		STD.DEV:	10.1	2.9	0.7

Table A2: Con't.

RUN 2:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Sept. 17	1166	20.5	56.9	52.7	
Sept. 19	3084	47.0	65.6	45.7	
Sept. 21	3333	51.0	65.4	45.9	
Sept. 22	1583	22.5	70.4	42.6	
Sept. 23	1500	26.5	56.6	53.0	
Sept. 24	1167	19.0	61.4	48.8	7.5
Sept. 25	1834	25.5	71.9	41.7	7.5
Sept. 26	1416	22.0	64.4	46.6	7.5
Sept. 27	1750	27.0	64.8	46.3	
Sept. 29	3000	51.0	58.8	51.0	

Sept. 30	1250	24.5	51.0	58.8	10.0
Oct. 1	1000	16.5	60.6	49.5	10.0
Oct. 2	1625	24.0	67.7	44.3	
Oct. 3	1667	24.0	69.5	43.2	
Oct. 4	1333	25.5	52.3	57.4	
Oct. 6	2750	45.0	61.1	49.1	10.0
Oct. 7	2083	32.0	65.1	46.1	10.0
Oct. 8	1167	19.0	61.4	48.8	10.0
Oct. 9	1600	22.5	71.1	42.2	10.0
Oct. 10	1175	21.0	56.0	53.6	10.0
Oct. 11	2042	27.0	75.6	39.7	
Oct. 14	4500	68.5	65.7	45.7	
Oct. 15	1450	24.0	60.4	49.7	10.0
Oct. 17	3250	47.0	69.1	43.4	
Oct. 20	4167	72.5	57.5	52.2	
Oct. 21	1333	25.5	52.3	57.4	10.0
Oct. 22	1667	28.5	58.5	51.3	10.0
Oct. 23	1667	22.0	75.8	39.6	10.0
Oct. 24	1033	18.5	55.8	53.7	10.0
Oct. 25	2167	29.0	74.7	40.1	
Oct. 27	2917	51.5	56.6	53.0	
Oct. 28	1083	20.5	52.8	56.8	
Oct. 29	1667	23.5	70.9	42.3	10.0
Oct. 30	1000	19.0	52.6	57.0	10.0
Oct. 31	1625	23.5	69.1	43.4	10.0
Nov. 3	4250	71.0	59.9	50.1	
Nov. 4	1292	23.0	56.2	53.4	10.0
Nov. 5	1917	29.5	65.0	46.2	10.0
Nov. 6	1700	23.5	72.3	41.5	10.0
Nov. 7	925	18.0	51.4	58.4	10.0
Nov. 8	2225	30.0	74.2	40.4	10.0
Nov. 9	1075	19.5	55.1	54.4	
Nov. 10	1300	21.5	60.5	49.6	
Nov. 11	1833	26.5	69.2	43.4	
Nov. 12	917	20.0	45.9	65.4	10.0
Nov. 13	1750	24.5	71.4	42.0	10.0
Nov. 14	1500	23.0	65.2	46.0	
		AVERAGE:	62.7	48.6	9.7
		STD.DEV:	7.6	6.1	0.8

Table A2: Con't.

RUN 3:					
DATE	AMOUNT FED	TIME ELAPSED	FLOW	HRT	SRT
	(mL)	(hrs)	(mL/hr)	(hrs)	(days)
Nov. 15	1167	24.0	48.6	61.7	
Nov. 17	2250	42.5	52.9	56.7	
Nov. 18	1333	29.0	46.0	65.3	
Nov. 19	1000	18.5	54.1	55.5	
Nov. 20	1417	26.5	53.5	56.1	
Nov. 21	1416	24.0	59.0	50.8	

Nov. 22	1000	24.5	40.8	73.5	
Nov. 24	2250	44.0	51.1	58.7	10.0
Nov. 25	1333	27.5	48.5	61.9	10.0
Nov. 26	917	20.0	45.9	65.4	10.0
Nov. 28	2833	48.5	58.4	51.4	10.0
Nov. 29	900	22.5	40.0	75.0	
Dec. 1	2250	47.5	47.4	63.3	
Dec. 2	1042	23.0	45.3	66.2	10.0
Dec. 3	1333	25.0	53.3	56.3	10.0
Dec. 5	2500	50.0	50.0	60.0	10.0
Dec. 7	2667	54.5	48.9	61.3	10.0
Dec. 10	3083	61.5	50.1	59.8	10.0
Dec. 11	1167	24.5	47.6	63.0	10.0
Dec. 12	1167	23.5	49.7	60.4	10.0
Dec. 13	1500	28.0	53.6	56.0	
Dec. 15	2333	45.5	51.3	58.5	
Dec. 16	1167	20.5	56.9	52.7	10.0
Dec. 17	1000	25.5	39.2	76.5	10.0
Dec. 18	1000	22.5	44.4	67.5	10.0
Dec. 19	1333	28.0	47.6	63.0	10.0
Dec. 20	1167	24.0	48.6	61.7	10.0
Dec. 22	2333	45.5	51.3	58.5	10.0
Dec. 23	1167	23.0	50.7	59.1	
Dec. 24	1533	25.0	61.3	48.9	
Dec. 27	3467	74.0	46.9	64.0	
Dec. 29	1916	48.0	39.9	75.2	
Dec. 30	1167	23.5	49.7	60.4	10.0
Dec. 31	1333	22.0	60.6	49.5	10.0
Jan. 2	2250	50.5	44.6	67.3	10.0
Jan. 3	1400	25.5	54.9	54.6	10.0
Jan. 4	1350	24.0	56.3	53.3	
Jan. 5	1250	26.5	47.2	63.6	
Jan. 6	1200	23.0	52.2	57.5	10.0
Jan. 7	800	17.5	45.7	65.6	10.0
Jan. 8	1167	22.5	51.9	57.8	10.0
Jan. 9	1416	29.0	48.8	61.4	10.0
		AVERAGE:	49.9	60.8	10.0
		STD.DEV:	5.3	6.6	0.0

Table A2: Con't.

RUN 4:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Jan. 10	2000	23.5	85.1	35.3	
Jan. 12	4750	49.5	96.0	31.3	
Jan. 13	1833	19.0	96.5	31.1	
Jan. 14	2417	27.0	89.5	33.5	
Jan. 15	1833	19.5	94.0	31.9	
Jan. 16	2167	22.5	96.3	31.1	10.0
Jan. 17	2667	26.0	102.6	29.2	10.0

Jan. 19	4333	46.5	93.2	32.2	10.0
Jan. 20	2167	25.0	86.7	34.6	10.0
Jan. 21	2500	23.5	106.4	28.2	10.0
Jan. 22	2417	22.5	107.4	27.9	10.0
Jan. 23	2417	22.5	107.4	27.9	
Jan. 25	5166	52.0	99.3	30.2	
Jan. 26	2800	20.5	136.6	22.0	7.6
Jan. 27	3033	27.5	110.3	27.2	7.6
Jan. 28	2083	21.5	96.9	31.0	7.6
Jan. 29	2084	25.0	83.4	36.0	7.6
Jan. 30	1917	20.5	93.5	32.1	7.6
Jan. 31	2375	23.5	101.1	29.7	7.6
Feb. 3	7375	76.0	97.0	30.9	7.6
Feb. 5	2333	23.5	99.3	30.2	7.6
Feb. 6	1916	17.5	109.5	27.4	7.6
Feb. 7	3000	30.0	100.0	30.0	
Feb. 9	3917	42.0	93.3	32.2	
Feb. 10	2250	23.5	95.7	31.3	
Feb. 11	2583	26.0	99.3	30.2	8.0
Feb. 12	2000	24.0	83.3	36.0	8.0
Feb. 13	3167	27.5	115.2	26.0	
Feb. 15	4667	43.5	107.3	28.0	
Feb. 16	2300	23.0	100.0	30.0	5.7
Feb. 17	2250	22.0	102.3	29.3	5.7
Feb. 18	2667	25.0	106.7	28.1	5.7
Feb. 19	3000	28.5	105.3	28.5	5.7
Feb. 20	1750	17.5	100.0	30.0	5.7
Feb. 21	2167	19.5	111.1	27.0	
Feb. 23	4167	46.0	90.6	33.1	
Feb. 24	2667	27.0	98.8	30.4	10.0
Feb. 25	1867	20.0	93.4	32.1	10.0
Feb. 26	3050	30.0	101.7	29.5	10.0
Feb. 27	1573	17.0	92.5	32.4	10.0
Feb. 28	2833	27.0	104.9	28.6	
Mar. 2	4834	44.0	109.9	27.3	
		AVERAGE:	100.0	30.3	8.2
		STD.DEV:	9.6	2.8	1.6

Table A2: Con't.

RUN 5:

DATE	AMOUNT FED (mL)	TIME ELAPSED (hrs)	FLOW (mL/hr)	HRT (hrs)	SRT (days)
Mar. 3	2533	24.5	103.4	29.0	
Mar. 4	2300	24.0	95.8	31.3	
Mar. 6	4467	45.5	98.2	30.6	
Mar. 7	2500	25.5	98.0	30.6	
Mar. 9	4250	45.0	94.4	31.8	10.0
Mar. 10	2917	28.5	102.4	29.3	10.0
Mar. 11	1750	19.5	89.7	33.4	10.0
Mar. 13	4300	47.0	91.5	32.8	10.0

Mar. 14	2275	22.0	103.4	29.0	10.0
Mar. 16	4350	47.5	91.6	32.8	10.0
Mar. 17	2083	22.0	94.7	31.7	10.0
Mar. 18	2084	23.0	90.6	33.1	10.0
Mar. 19	2833	27.5	103.0	29.1	10.0
Mar. 20	1833	18.5	99.1	30.3	10.0
Mar. 21	2700	28.0	96.4	31.1	
Mar. 23	4417	44.5	99.3	30.2	
Mar. 24	1733	21.5	80.6	37.2	10.0
Mar. 25	2967	26.5	112.0	26.8	10.0
Mar. 26	1583	18.0	87.9	34.1	10.0
Mar. 27	3000	28.5	105.3	28.5	10.0
Mar. 29	5667	46.0	123.2	24.4	10.0
Mar. 30	2250	19.0	118.4	25.3	10.0
Mar. 31	2500	25.5	98.0	30.6	
Apr. 1	2000	21.5	93.0	32.3	10.0
Apr. 2	2417	23.0	105.1	28.5	10.0
Apr. 3	1666	18.0	92.6	32.4	10.0
Apr. 4	2867	29.0	98.9	30.3	10.0
Apr. 6	4167	44.0	94.7	31.7	10.0
Apr. 7	1833	22.0	83.3	36.0	10.0
Apr. 8	2167	20.0	108.4	27.7	
Apr. 10	4583	41.0	111.8	26.8	
Apr. 11	3167	27.0	117.3	25.6	
Apr. 13	4350	42.0	103.6	29.0	
Apr. 14	1666	22.0	75.7	39.6	
Apr. 15	2067	19.5	106.0	28.3	
Apr. 16	2767	25.0	110.7	27.1	
Apr. 17	2333	25.0	93.3	32.1	
Apr. 18	2000	21.5	93.0	32.3	
Apr. 20	4417	43.0	102.7	29.2	
Apr. 21	2250	22.5	100.0	30.0	
Apr. 22	2250	23.5	95.7	31.3	
		AVERAGE:	99.1	30.6	10.0
		STD.DEV:	9.8	3.1	0.0

Table A3: Temperature and gas production of systems A and B.			
RUN P:			
DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
June 27	26.0	0	0
June 28	26.0	0	0
June 30	24.5	0	0
July 1	24.0	0	0
July 2	24.0	0	0
July 3	24.0	0	0
July 4	23.5	0	0
July 5	24.5	0	0
July 9	25.0	0	
July 10	25.0	0	0
July 11	25.0	0	0
July 12	26.0	0	0
July 14	25.5	0	0
July 15	26.0	0	0
July 16	26.5	0	0
July 17	26.0	0	0
July 18	27.0	0	
July 19	26.0		
AVERAGE:	25.3		
STD. DEV:	1.004		
Table A3: Con't.			
RUN 1:			
DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
July 21	25.0		
July 22	25.5		
July 23	25.5	0	0
July 24	25.5	0	0
July 25	26.0	0	0
July 26	25.5	0	0
July 28	26.5	0	
July 29	24.5	0	0
July 30	25.0	0	0
July 31	26.5	0	0
Aug. 1	25.5	0	0
Aug. 2	25.5	0	0
Aug. 3	25.5	0	0
Aug. 5	26.5	0	0
Aug. 6	27.0		0
Aug. 7	26.0		0
Aug. 8	26.5		0
Aug. 9	26.5		0

Aug. 11	25.0		0
Aug. 12	23.5		0
Aug. 13	23.5		0
Aug. 14	25.0		0
Aug. 15	25.0		~25
Aug. 16	23.5		0
Aug. 18	22.5		
Aug. 19	24.5	0	0
Aug. 20	26.0	0	0
Aug. 21	25.5	0	0
Aug. 22	25.5	0	0
Aug. 23	24.5	0	0
Aug. 25	27.0	0	0
Aug. 26	25.5	0	0
Aug. 28	25.5	0	0
Aug. 29	25.0	0	0
Aug. 30	26.5	0	0
Aug. 31	24.5	0	0
Sept. 2	24.5	0	0
Sept. 3	24.0	0	0
Sept. 4	23.5	0	0
Sept. 5	25.0	0	0
Sept. 6	24.5	0	0
Sept. 8	23.5	0	0
Sept. 9	24.5	0	0
Sept. 11	26.0	0	0
Sept. 12	25.5	0	0
Sept. 13	26.0	0	0
Sept. 15	24.5	0	0
Sept. 16	25.0	0	0
AVERAGE:	25.2		
STD.DEV:	1.014		

Table A3: Con't.

RUN 2:			
DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
Sept. 17	24.5	0	0
Sept. 19	23.5	0	0
Sept. 21	23.0	0	0
Sept. 22	24.5	0	0
Sept. 23	24.5	0	0
Sept. 24	23.5	0	0
Sept. 25	25.5	0	0
Sept. 26	25.5	0	0
Sept. 27	27.5	0	0
Sept. 29	25.5	0	0
Sept. 30	25.5	0	0
Oct. 1	27.0	0	0

Oct. 2	26.0	0	0
Oct. 3	27.0	0	0
Oct. 4	25.0	0	0
Oct. 6	23.0	0	0
Oct. 7	26.0	0	0
Oct. 8	26.0	0	0
Oct. 9	24.0	0	0
Oct. 10	21.5	0	0
Oct. 11	24.5	0	0
Oct. 14	21.0	0	0
Oct. 15	23.0	0	0
Oct. 17	21.0	0	0
Oct. 20	24.0	0	0
Oct. 21	25.5	0	0
Oct. 22	26.5	0	0
Oct. 23	24.5	0	0
Oct. 24	23.5	0	0
Oct. 25	23.5	0	0
Oct. 27	27.0	0	0
Oct. 28	28.0	0	0
Oct. 29	25.0	0	0
Oct. 30	25.0	0	0
Oct. 31	25.0	0	0
Nov. 3	25.0	0	0
Nov. 4	25.0	0	0
Nov. 5	25.0	0	0
Nov. 6	25.0	0	0
Nov. 7	25.0	0	0
Nov. 8	25.0	0	0
Nov. 9	25.0	0	0
Nov. 10	25.0	0	0
Nov. 11	25.0	0	0
Nov. 12	25.0	0	0
Nov. 13	25.0	0	0
Nov. 14	25.0	0	0
AVERAGE:	24.8		
STD.DEV.	1.477		

Table A3: Con't.

RUN 3:			
DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
Nov. 15	25.0	0	0
Nov. 17	25.0	0	0
Nov. 18	25.5	0	
Nov. 19	25.5	0	
Nov. 20	25.5	0	0
Nov. 21	25.0	0	0
Nov. 22	25.0	0	0

Nov. 24	25.0	0	0
Nov. 25	25.0	0	0
Nov. 26	25.0	0	0
Nov. 28	25.5	0	0
Nov. 29	25.0	0	0
Dec. 1	25.0	0	0
Dec. 2	25.0	0	0
Dec. 3	25.0	0	0
Dec. 5	25.0	0	0
Dec. 7	25.0		
Dec. 10	25.0	0	0
Dec. 11	25.0	0	0
Dec. 12	25.0	0	0
Dec. 13	25.0	0	0
Dec. 15	25.5	0	0
Dec. 16	25.0	0	0
Dec. 17	25.0	0	0
Dec. 18	25.0	0	0
Dec. 19	25.0	0	0
Dec. 20	25.0	0	0
Dec. 22	25.0	0	0
Dec. 23	25.0	0	0
Dec. 24	25.0	0	0
Dec. 27	25.0	0	0
Dec. 29	25.0	0	0
Dec. 30	25.0	0	0
Dec. 31	25.0	0	0
Jan. 2	25.0	0	0
Jan. 3	25.0	0	0
Jan. 4	25.0	0	0
Jan. 5	25.0	0	0
Jan. 6	25.0	0	0
Jan. 7	25.0	0	0
Jan. 8	25.0	0	0
Jan. 9	25.0	0	0
AVERAGE:	25.1		
STD.DEV:	0.164		

Table A3: Con't.

RUN 4:			
DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
Jan. 10	21.0	0	0
Jan. 12	20.5	0	0
Jan. 13	18.5	0	0
Jan. 14	17.0	0	0
Jan. 15	17.0	0	0
Jan. 16	15.5	0	0
Jan. 17	16.0	0	0

Jan. 19	16.0	0	0
Jan. 20	16.0	0	0
Jan. 21	16.0	0	0
Jan. 22	16.0	0	0
Jan. 23	16.0	0	0
Jan. 25		0	
Jan. 26	16.0	0	
Jan. 27	16.0	0	
Jan. 28	16.0	0	
Jan. 29	16.0	0	0
Jan. 30	16.0	0	0
Jan. 31	16.0	0	0
Feb. 3	16.0	0	0
Feb. 5	16.0	0	0
Feb. 6	16.0	0	0
Feb. 7	16.0	0	0
Feb. 9	16.0	0	0
Feb. 10	16.0	0	0
Feb. 11	16.0	0	0
Feb. 12	16.0	0	0
Feb. 13	16.0	0	0
Feb. 15	16.0	0	0
Feb. 16	16.0	0	0
Feb. 17	16.0	0	0
Feb. 18	16.0	0	0
Feb. 19	16.0	0	0
Feb. 20	16.0	0	0
Feb. 21	16.0	0	0
Feb. 23	16.0	0	0
Feb. 24	16.0	0	0
Feb. 25	16.0	0	0
Feb. 26	16.0	0	0
Feb. 27	16.0	0	0
Feb. 28	16.0	0	0
Mar. 2	16.0	0	0
AVERAGE:	16.0		
STD.DEV:	0.083		

Table A3: Con't.

RUN 5:

DATE	TEMPERATURE	GAS PRODUCTION	
		SYSTEM A	SYSTEM B
	(°C)	(mL)	(mL)
Mar. 3	12.5	0	0
Mar. 4	11.5	0	0
Mar. 6	6.5	0	0
Mar. 7	8.0	0	0
Mar. 9	8.0	0	0
Mar. 10	8.0	0	0
Mar. 11	8.0	0	0

Mar. 13	8.0	0	0
Mar. 14	8.0	0	0
Mar. 16	7.5	0	0
Mar. 17	7.0	0	0
Mar. 18	7.0	0	0
Mar. 19	6.5	0	0
Mar. 20	7.5	0	0
Mar. 21	7.5	0	0
Mar. 23	7.5	0	0
Mar. 24	7.5	0	0
Mar. 25	7.5	0	0
Mar. 26	7.0	0	0
Mar. 27	7.5	0	0
Mar. 29	7.5	0	0
Mar. 30	7.5	0	0
Mar. 31	7.0	0	0
Apr. 1	7.5	0	0
Apr. 2	7.5	0	0
Apr. 3	7.5	0	0
Apr. 4	7.5	0	0
Apr. 6	7.5	0	0
Apr. 7	7.5	0	0
Apr. 8	7.5	0	0
Apr. 10	7.5	0	0
Apr. 11		0	0
Apr. 13		0	0
Apr. 14	7.5	0	0
Apr. 15	7.5	0	0
Apr. 16	7.5	0	0
Apr. 17	7.5	0	0
Apr. 18	7.5	0	0
Apr. 20	7.5	0	0
Apr. 21	7.5	0	0
Apr. 22	7.5	0	0
AVERAGE:	7.5		
STD.DEV:	0.309		

APPENDIX B

EXPERIMENTAL RESULTS

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Table B1: pH, alkalinity and solids for influent A.

RUN P:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
June 16	7.20	230	5603	4043	5500	4425
June 19	7.03	210	5235	3945	4550	3525
June 30	7.08	305	6842	5435	6200	4850
July 2	7.23	305	6891	5623	6050	4750
July 14	7.28	320	4907	3718	4425	3450
July 15	7.25	325	4846	3617	4750	3600
July 17	7.25	360	5984	4334	5475	3300
AVERAGE:	7.19	294	5758	4388	5279	3986
STD.DEV:	0.10	54	852	815	715	664

Table B1: Con't.

RUN 1:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
July 22	7.15	290	6704	5567	6350	5325
July 24	7.08	315	6836	5620	6450	5400
July 29	7.18	320	9720	8110	10975	9100
Aug. 2	7.15	285	9180	7910	9325	8250
Aug. 5	6.90	255	8960	7840	9125	8300
Aug. 7	6.63	200	5600	4810	5675	4900
Aug. 12	6.30	185	6110	5340	5450	4925
Aug. 14	5.98	155	6350	5520	5800	5150
Aug. 21	5.98	155	5610	4970	5125	4750
Aug. 25	5.90	150	6020	5170	6175	5550
Aug. 28	6.05	140	5460	4780	5100	4625
Sept. 2	6.05	140	5500	4870	6025	5400
Sept. 5	6.03	135	5480	4840	5000	4625

Sept. 9	6.35	155	5330	4560	5475	4725
Sept. 11	5.98	105	5830	5090	5775	5100
AVERAGE:	6.45	199	6579	5666	6522	5742
STD.DEV:	0.51	73	1479	1225	1797	1493

Table B1: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	6.20	150	5490	4730	5700	4950
Sept. 26	5.78	140	5630	4910	5850	5025
Sept. 29	5.85	150	5240	4490	5025	4350
Oct. 1	5.55	145	5440	4820	5425	5150
Oct. 6	6.08	185	5460	4750	5125	4650
Oct. 9	5.63	150	8950	8190	5575	5050
Oct. 15	5.70	185	5260	4520	5025	4500
Oct. 21	5.25	145	5710	4850	5325	4625
Oct. 24	5.00	130	5850	4890	5425	4650
Oct. 28	6.58	170	4580	4030	4375	3925
Oct. 30	6.78	195	4410	3930	4275	3875
Nov. 4	6.90	185	5500	4840	5550	4975
Nov. 7	6.78	150	5860	5120	5400	4825
Nov. 11	6.03	125	5000	4370	4450	3975
Nov. 13	5.40	90	4440	3880	4300	3800
AVERAGE:	5.97	153	5521	4821	5122	4555
STD.DEV:	0.59	28	1061	1006	533	467

Table B1: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	5.53	130	4720	4090	4250	3875
Nov. 26	5.20	120	4830	4170	4150	3775

Nov. 28	5.23	130	5660	4890	4675	4150
Dec. 1	5.85	150	5110	4360	4350	3750
Dec. 11	5.55	160	5970	5040	5275	4675
Dec. 15	5.35	155	5000	4310	4325	3875
Dec. 17	5.55	125	4750	4130	4225	3900
Dec. 19	6.15	170	5330	4540	4825	4250
Dec. 22	5.88	135	5300	4570	4875	4250
Dec. 29	6.13	175	5210	4480	4750	4200
Dec. 31	5.45	110	5010	4380	4425	3950
Jan. 2	5.30	135	5340	4630	5150	4175
Jan. 5	5.63	140	6150	5260	5300	4700
Jan. 7	6.25	175	6490	5610	6025	5350
Jan. 9	6.40	215	5710	4890	5100	4475
AVERAGE:	5.70	148	5372	4623	4780	4223
STD.DEV:	0.39	27	527	438	523	433

Table B1: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	6.73	195	5370	4710	5075	4675
Jan. 19	7.00	285	5850	5180	5400	4825
Jan. 22	6.80	230	4930	4300	4475	4025
Jan. 26	6.70	220	4990	4380	4650	4250
Jan. 30	6.60	180	4790	4140	4550	4050
Feb. 3	6.68	155	6020	5140	5450	4750
Feb. 6	6.18	140	5360	4525	5350	4725
Feb. 10	5.98	110	4590	4000	4375	3975
Feb. 12	5.95	120	5200	4470	4625	4100

Feb. 16	6.15	120	5370	4480	4825	4050
Feb. 18	6.40	165	5530	4590	5275	4475
Feb. 20	6.35	160	5470	4490	5200	4375
Feb. 23	6.25	155	5430	4070	4900	4025
Feb. 25	6.55	175	5760	4500	5250	4175
Feb. 27	6.68	170	6770	5270	5725	4625
AVERAGE:	6.47	172	5429	4550	5008	4340
STD.DEV:	0.31	46	539	387	411	311

Table B1: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	6.45	175	4840	3780	4350	3500
Mar. 13	6.40	165	5550	4520	4875	3875
Mar. 17	6.65	170	5020	3890	4475	3375
Mar. 20	6.60	145	5490	4330	4825	3875
Mar. 24	6.35	155	4490	3710	4075	3375
Mar. 26	6.73	155	5880	4790	4975	4000
Mar. 30	6.48	170	5100	4040	4400	3425
Apr. 1	6.63	160	5460	4380	4925	4000
Apr. 3	6.63	180	4690	3960	4175	3425
Apr. 7	6.68	160	4300	3530	3875	3225
Apr. 10	6.55	160	5140	4300	4375	3725
Apr. 14	6.55	165	4570	3600	3975	3125
Apr. 16	6.33	145	4410	3510	3975	3150
Apr. 18	6.50	160	5980	4830	4925	3800
Apr. 21	6.40	160	5860	4590	5275	4175
AVERAGE:	6.53	162	5119	4117	4498	3603
STD.DEV:	0.12	10	564	450	440	338

Table B2: pH, alkalinity and solids for influnet B.

RUN P:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
June 16	7	280	5475	4175	5550	4575
June 19	7.025	210	5678	4518	5225	4275
June 30	7.075	320	7144	5497	6100	4875
July 2	7.25	340	7106	5450	6275	4825
July 14	7.225	330	5579	4200	5150	4025
July 15	7.325	335	5381	4023	6525	4750
July 17	7.3	365	6691	4790	5650	4150
AVERAGE:	7.17	311	6151	4665	5782	4496
STD.DEV:	0.13	52	795	608	529	345

Table B2: Con't.

RUN 1:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 22	7.13	420	6939	4886	7125	5075
July 24	7.13	450	6252	4307	5975	4200
July 29	7.20	450	6590	4540	6575	4550
Aug. 2	7.35	380	6260	4580	5900	4525
Aug. 5	7.15	365	5880	4490	6050	4675
Aug. 7	6.70	315	4800	3550	4700	3625
Aug. 12	6.80	345	5360	4190	3550	3050
Aug. 14	6.73	320	5270	4230	3700	2900
Aug. 22	6.78	300	5070	3990	3975	3300
Aug. 25	6.53	295	4820	3680	4725	3800
Aug. 28	6.73	290	4900	3800	4550	3700
Sept. 2	6.73	280	4790	3620	4825	3750
Sept. 5	6.80	285	4800	3760	4050	3225

Sept. 9	6.68	290	5150	3740	4900	3725
Sept. 11	6.93	275	4560	3390	4700	3700
AVERAGE:	6.89	337	5429	4050	5020	3853
STD.DEV:	0.24	62	758	446	1072	633

Table B2: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	6.68	310	4700	3590	4650	3400
Sept. 26	7.05	270	4570	3550	4325	3150
Sept. 29	6.73	310	4740	3660	4800	3500
Oct. 1	7.10	315	5180	4310	5125	4425
Oct. 6	6.65	325	5810	4490	5475	4325
Oct. 9	7.10	330	5300	4030	5125	4000
Oct. 15	6.50	285	5330	4040	5400	4150
Oct. 21	6.73	305	5260	3960	4900	3650
Oct. 24	6.93	305	5210	3880	4750	3575
Oct. 28	6.60	285	5070	3870	4750	3750
Oct. 30	6.90	270	4560	3610	4350	3625
Nov. 4	7.00	295	5020	3900	4600	3650
Nov. 7	7.30	290	4810	3740	4450	3525
Nov. 11	6.98	280	5020	3910	4725	3700
Nov. 13	7.30	300	5850	4550	5875	4550
AVERAGE:	6.90	298	5095	3939	4887	3798
STD.DEV:	0.25	18	393	310	439	403

Table B2: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	6.98	280	5180	4020	4950	3950
Nov. 26	7.05	295	5300	4110	4500	3550

Nov. 28	6.95	290	5470	4190	5075	3925
Dec. 1	6.75	300	5180	3940	4650	3575
Dec. 11	7.25	325	5620	4350	4950	3800
Dec. 15	7.13	325	5290	4060	4100	3150
Dec. 17	6.90	280	4840	3740	4825	3850
Dec. 19	7.05	275	4940	3790	4950	3750
Dec. 22	6.75	265	5550	4280	4825	3650
Dec. 29	6.85	270	5280	4070	4375	3275
Dec. 31	6.73	260	4570	3680	4075	3125
Jan. 2	6.80	260	5150	4090	4700	3225
Jan. 5	6.90	275	5140	3940	4575	3575
Jan. 7	6.95	275	5390	4170	4500	3350
Jan. 9	6.85	280	6170	4810	4550	3575
AVERAGE:	6.93	284	5271	4083	4640	3555
STD.DEV:	0.15	20	368	276	303	276

Table B2: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	7.10	320	5180	4040	4625	3800
Jan. 19	7.20	275	4620	3610	3750	2875
Jan. 22	6.90	300	5230	4200	4700	3775
Jan. 26	7.30	320	4850	3800	4400	3675
Jan. 30	6.93	260	4970	3850	4650	3750
Feb. 3	7.00	255	6530	5200	5325	3925
Feb. 6	6.80	220	6050	4840	5400	4450
Feb. 10	6.75	230	4650	3590	4425	3550
Feb. 12	6.85	240	5190	4070	4625	3675

Feb. 16	6.80	245	4800	3400	5125	3750
Feb. 18	6.93	245	6610	4870	5250	3875
Feb. 20	6.85	280	5140	3440	4650	3225
Feb. 23	6.98	285	5330	3480	5075	3275
Feb. 25	7.03	285	14940	5600	4350	3350
Feb. 27	6.85	245	33810	12280	5050	3900
AVERAGE:	6.95	267	5319	4030	4760	3657
STD.DEV:	0.15	31	664	596	446	369
			*Not included in average.			

Table B2: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	6.85	245	5630	3640	5050	3275
Mar. 13	6.68	200	5880	3960	5700	3600
Mar. 17	6.70	205	5630	3690	5000	3125
Mar. 20	6.75	220	4770	3160	4875	3400
Mar. 24	6.65	200	4870	3400	4100	2700
Mar. 26	6.73	175	6270	4290	5125	3425
Mar. 30	6.80	230	4110	2720	3425	2300
Apr. 1	6.85	220	5860	4210	5475	3550
Apr. 3	6.85	250	4120	2930	3525	2450
Apr. 7	6.90	235	5850	4160	4600	3175
Apr. 10	6.90	240	4920	3550	4425	3050
Apr. 14	6.80	235	4990	3120	4575	2800
Apr. 16	6.73	240	5710	3660	5250	3400
Apr. 18	6.60	185	6090	3990	4750	3200
Apr. 21	6.70	220	5540	3710	5400	3400
AVERAGE:	6.77	220	5349	3613	4752	3123
STD.DEV:	0.09	23	678	475	668	395

Table B3: pH, alkalinity and solids for reactor A.						
RUN P:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
June 16	5.9	340	8086	5448	7725	5525
June 19	5.65	330	18803	12015	17350	11000
June 30	6.05	290	11422	7774	9800	6775
July 2	5.9	345	14704	10700	16725	12075
July 14	5.5	350	17661	13034	14425	10850
July 15	5.4	250	24325	18090	24600	18375
July 17	5.55	360	31830	22975	44600	32125
AVERAGE:	5.71	323.57	18119	12862	19318	13818
STD.DEV:	0.24	39.45	8004	5998	12427	9074

Table B3: Con't.						
RUN 1:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 22	5.10	270	25788	18819	34575	25200
July 24	5.18	340	26382	19174	32475	23500
July 29	4.78	195	20980	15250	27600	20250
Aug. 2	4.73	180	19810	14870	23225	17725
Aug. 5	4.55	75	19920	15360	22025	17050
Aug. 7	4.55	90	16520	12720	13675	10750
Aug. 12	4.48	0	15450	12620	12925	10900
Aug. 14	4.35	0	15960	13080	10750	8950
Aug. 21	4.30	0	14850	12530	9825	8425
Aug. 25	4.20	0	15510	13440	14875	12875
Aug. 28	4.30	0	17030	14570	12975	11300
Sept. 2	4.30	0	16890	14820	17525	15475
Sept. 5	4.30	0	14360	12630	13700	12225

Sept. 9	4.25	0	14800	13110	17400	15625
Sept. 11	4.05	0	15090	13250	13325	12000
AVERAGE:	4.49	77	17956	14416	18458	14817
STD.DEV:	0.33	115	3871	2115	7822	5107

Table B3: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	4.38	0	9710	8130	14750	12325
Sept. 26	4.55	50	9090	7700	9225	8025
Sept. 29	4.58	80	9080	7670	8350	7275
Oct. 1	4.65	80	8880	7620	8025	7075
Oct. 6	4.50	0	8850	7560	8500	7450
Oct. 9	4.60	60	7500	6350	7125	6275
Oct. 15	4.68	70	5710	4730	5325	4450
Oct. 21	4.60	65	7160	5910	6625	5650
Oct. 24	4.55	50	7000	5730	7200	6050
Oct. 28	4.80	95	6400	5260	6300	5350
Oct. 30	4.70	75	6950	5670	6400	5375
Nov. 4	5.00	125	5400	4410	5325	4575
Nov. 7	4.85	95	5110	4130	4875	4100
Nov. 11	4.50	0	6200	5140	5850	5050
Nov. 13	4.35	0	6770	5610	6275	5525
AVERAGE:	4.62	56	7321	6108	7343	6303
STD.DEV:	0.17	40	1478	1323	2411	2032

Table B3: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	4.45	0	6840	5610	6325	5400
Nov. 26	4.45	0	6520	5350	6200	5250

Nov. 28	4.45	0	6330	5230	5900	5100
Dec. 1	4.75	100	6240	5070	5900	5000
Dec. 11	4.68	100	6670	5320	5850	4850
Dec. 15	4.63	65	6290	5070	6125	5150
Dec. 17	4.70	105	5780	4640	5200	4425
Dec. 19	4.85	140	5400	4330	5875	4925
Dec. 22	5.00	170	6250	4930	5650	4600
Dec. 29	5.30	230	6150	4920	6250	5200
Dec. 31	5.10	200	5720	4630	5175	4275
Jan. 2	5.15	195	5380	4220	4875	3625
Jan. 5	5.23	205	5210	4040	4325	3425
Jan. 7	5.25	205	5190	4050	4750	3700
Jan. 9	5.40	210	5640	4420	5000	4075
AVERAGE:	4.89	128	5974	4789	5560	4600
STD.DEV:	0.33	83	537	499	624	647

Table B3: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	4.83	100	10200	8360	10625	8975
Jan. 19	4.70	90	10980	9300	10850	9325
Jan. 22	4.68	65	10700	9170	10925	9450
Jan. 26	4.70	85	12770	11050	12525	11125
Jan. 30	4.75	105	12980	11450	14675	13000
Feb. 3	4.65	85	15220	13570	14525	13100
Feb. 6	4.55	60	17390	15450	17475	15750
Feb. 10	4.65	75	17470	15590	15800	14250
Feb. 12	4.78	110	16350	13940	15225	13725

Feb. 16	4.98	145	18490	16430	17625	15800
Feb. 18	5.10	190	17980	15950	18075	16300
Feb. 20	4.90	145	17580	15510	17200	15525
Feb. 23	5.00	190	17680	15410	18250	15925
Feb. 25	5.05	195	18740	16230	17325	15150
Feb. 27	5.05	195	18760	16080	17950	15700
AVERAGE:	4.82	122	15553	13566	15270	13540
STD.DEV:	0.18	50	3149	2900	2816	2628

Table B3: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	5.75	210	18630	15740	18025	15425
Mar. 13	5.63	220	19770	16810	19675	16800
Mar. 17	5.38	260	19300	15880	18425	15350
Mar. 20	5.50	210	17470	14410	16800	14050
Mar. 24	5.43	195	17850	14860	17375	14475
Mar. 26	5.50	220	17840	15020	17500	14750
Mar. 30	5.45	200	17520	14620	16850	14350
Apr. 1	5.50	200	17180	14370	16925	14050
Apr. 3	5.45	190	17630	14900	16875	14450
Apr. 7	5.43	195	17500	14820	16575	14225
Apr. 10	5.50	200	19010	16270	18500	15900
Apr. 14	5.03	220	14360	11850	13225	11125
Apr. 16	5.25	185	15940	13440	15075	12775
Apr. 18	5.38	185	16500	14050	15400	13250
Apr. 21	5.33	195	17400	14790	16850	14500
AVERAGE:	5.43	206	17593	14789	16938	14365
STD.DEV:	0.16	19	1349	1189	1550	1338

Table B4: pH, alkalinity and solids for reactor B.						
RUN P:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
June 16	6	480	12490	8259	11500	8300
June 19	5.825	355	22329	16531	21950	16125
June 30	5.5	315	14349	11879	18750	15850
July 2	5.55	375	24757	19331	18625	14575
July 14	5.45	335	27337	22269	22400	18525
July 15	5.4	340	24116	19123	29525	23675
July 17	5.45	365	31830	22975	22000	17600
AVERAGE:	5.60	366	22458	17195	20679	16379
STD.DEV:	0.23	54	6890	5416	5428	4622

Table B4: Con't.						
RUN 1:						
DATE	pH	ALKALINITY	TS	VS	TSS	VSS
		(mg/L as $CaCO_3$)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 22	5.50	425	29105	21816	43175	32475
July 24	5.53	440	25284	18470	27250	19800
July 29	5.25	355	23940	16260	29750	20150
Aug. 2	5.55	455	22830	15160	23850	16050
Aug. 5	5.60	445	23320	15800	23675	16000
Aug. 7	5.60	400	21740	14300	21125	13925
Aug. 12	5.63	440	19860	13480	18525	12725
Aug. 14	.5.60	375	20810	14370	15475	10850
Aug. 21	5.55	365	17920	12620	14275	10325
Aug. 25	5.53	340	16440	11870	16400	11675
Aug. 28	5.45	335	15910	11120	15900	11200
Sept. 2	5.55	295	16090	11570	15875	11375
Sept. 5	5.53	330	16970	12240	14525	10550

Sept. 9	5.65	340	15350	11020	15275	11150
Sept. 11	5.50	270	13420	9580	11750	8750
AVERAGE:	5.53	374	19933	13978	20455	14467
STD.DEV:	0.09	58	4409	3201	8167	6039

Table B4: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	5.65	300	15140	10870	15575	11025
Sept. 26	5.70	350	14340	10290	14450	10500
Sept. 29	5.88	380	15720	11230	13850	10150
Oct. 1	5.90	395	15420	11240	14050	10475
Oct. 6	5.83	365	16110	11790	17050	12425
Oct. 9	5.78	400	16210	11750	18125	13275
Oct. 15	5.78	405	16530	12040	16700	12125
Oct. 21	5.70	400	16140	11420	13775	9900
Oct. 24	5.78	375	15370	10630	18525	12750
Oct. 28	5.80	395	16360	11480	15225	10875
Oct. 30	5.95	440	16100	11400	16150	11500
Nov. 4	5.98	460	15550	11030	16800	12025
Nov. 7	6.13	515	15300	10750	15275	10650
Nov. 11	6.15	510	14680	10390	19000	13525
Nov. 13	6.23	495	15560	10970	15525	10975
AVERAGE:	5.88	412	15635	11152	16005	11478
STD.DEV:	0.17	61	623	514	1679	1146

Table B4: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	6.23	585	15010	10400	15000	10500
Nov. 26	6.23	545	13340	9210	13775	9400

Nov. 28	6.20	530	12100	8380	11750	8250
Dec. 1	6.23	595	13400	9150	14450	9875
Dec. 11	6.35	630	12570	8530	12825	8775
Dec. 15	6.40	605	9920	6810	15400	10725
Dec. 17	6.30	580	9800	6830	10325	7200
Dec. 19	6.30	540	9570	6500	10800	7425
Dec. 22	6.18	470	9770	6630	9375	6400
Dec. 29	6.00	420	9190	6430	9150	6400
Dec. 31	6.23	430	8830	6250	8600	5925
Jan. 2	6.30	445	8900	6120	11750	7825
Jan. 5	6.30	445	8470	5830	9525	6600
Jan. 7	6.20	465	8720	6080	9725	6725
Jan. 9	6.20	450	9020	6200	8975	6300
AVERAGE:	6.24	516	10574	7290	11428	7888
STD.DEV:	0.09	72	2110	1440	2343	1615

Table B4: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	6.20	415	12080	9210	11975	9250
Jan. 19	6.20	390	12940	9770	13125	9925
Jan. 22	6.10	400	14540	11040	14625	11075
Jan. 26	6.28	395	12890	10050	12675	10050
Jan. 30	6.20	390	13400	10440	12950	10125
Feb. 3	6.10	385	15660	12010	13975	10775
Feb. 6	6.10	355	15100	12040	14750	11750
Feb. 10	5.93	325	16240	12610	16125	12675
Feb. 12	6.00	330	18830	14610	15850	12475

Feb. 16	6.05	330	17260	13070	16875	12700
Feb. 18	6.05	330	15760	11720	15575	11875
Feb. 20	6.00	350	15830	11450	16225	12175
Feb. 23	6.00	360	17110	12140	17450	12300
Feb. 25	6.03	375	17290	11890	16825	11775
Feb. 27	5.98	375	17980	12380	17750	12500
AVERAGE:	6.08	367	15527	11629	15117	11428
STD.DEV:	0.10	29	2025	1382	1843	1144

Table B4: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	6.28	400	21840	14600	23625	16200
Mar. 13	6.08	315	21870	14930	23300	16100
Mar. 17	6.13	350	24200	15960	24175	15925
Mar. 20	6.20	360	23730	15310	23275	15250
Mar. 24	6.18	350	25290	16550	26200	17350
Mar. 26	6.20	325	23700	15860	21750	14725
Mar. 30	6.35	365	22800	15120	22975	15425
Apr. 1	6.28	365	22800	15400	21950	14725
Apr. 3	6.35	370	21290	14520	21675	14950
Apr. 7	6.30	340	20170	13560	19850	13350
Apr. 10	6.35	345	20390	14560	20325	14225
Apr. 14	6.03	335	18080	11720	17750	11500
Apr. 16	6.33	335	18150	12050	17650	11925
Apr. 18	6.35	320	16940	11700	14975	10475
Apr. 21	6.40	335	17730	11990	17800	12075
AVERAGE:	6.25	347	21265	14255	21152	14280
STD.DEV:	0.11	22	2608	1649	3048	1995

Table B5: pH, alkalinity and solids for effluent A.

RUN P:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
June 16	5.95	360	2436	1519	1150	825
June 19	5.7	280	2538	1709	1050	775
June 30	5.925	195	3927	2737	2850	2200
July 2	6.25	350	2125	1520	1050	800
July 14	6.4	395	2116	1462	800	650
July 15	6.525	400	2070	1363	775	500
July 17	6.525	365	1989	1347	1100	800
AVERAGE:	6.18	335	2457	1665	1254	936
STD.DEV:	0.33	73	679	488	719	569

Table B5: Con't.

RUN 1:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
July 22	6.50	380	2159	1405	1175	875
July 24	5.95	285	1924	1320	650	525
July 29	5.73	340	1900	1220	875	575
Aug. 2	5.13	260	2470	1670	950	625
Aug. 5	5.15	260	2380	1600	950	750
Aug. 7	4.85	160	2120	1440	750	475
Aug. 12	4.58	60	2000	1400	1150	900
Aug. 14	4.55	60	1850	1310	825	600
Aug. 21	4.40	0	1680	1210	825	675
Aug. 25	4.43	0	1950	1410	875	625
Aug. 28	4.45	0	2220	1660	1225	875
Sept. 2	4.35	0	1790	1310	850	800
Sept. 5	4.35	0	1600	1200	525	525

Sept. 9	4.28	0	1740	1280	800	650
Sept. 11	4.18	0	1760	1340	875	675
AVERAGE:	4.86	120	1970	1385	887	677
STD.DEV:	0.70	144	255	153	188	136

Table B5: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	4.43	0	1460	1070	775	350
Sept. 26	4.85	85	1400	1100	325	400
Sept. 29	5.20	130	1260	910	50	50
Oct. 1	5.80	185	1270	960	675	450
Oct. 6	5.63	170	1500	1110	700	550
Oct. 9	5.55	160	1350	1020	575	425
Oct. 15	5.15	120	1200	910	350	275
Oct. 21	5.50	150	1390	850	475	200
Oct. 24	5.48	145	1300	900	500	275
Oct. 28	5.90	205	1350	970	525	400
Oct. 30	5.90	165	1090	800	375	350
Nov. 4	6.45	175	920	590	350	275
Nov. 7	6.55	190	960	640	450	275
Nov. 11	5.68	135	950	750	350	325
Nov. 13	5.45	130	1720	1210	800	650
AVERAGE:	5.57	143	1275	919	485	350
STD.DEV:	0.55	50	223	174	200	143

Table B5: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	4.55	45	1640	1230	875	725
Nov. 26	4.60	60	1580	1190	700	650

Nov. 28	4.68	80	1500	1160	500	475
Dec. 1	5.28	150	1420	920	675	425
Dec. 11	5.58	175	1560	1130	675	450
Dec. 15	5.40	170	1930	1470	675	500
Dec. 17	5.93	205	1600	1160	625	575
Dec. 19	6.20	240	1380	890	450	325
Dec. 22	6.25	265	2050	1400	1200	950
Dec. 29	6.45	280	1600	1210	800	625
Dec. 31	6.55	290	1290	990	325	275
Jan. 2	6.68	315	1420	910	1000	450
Jan. 5	6.68	310	2280	1680	2100	1600
Jan. 7	6.65	280	1390	990	550	425
Jan. 9	6.73	315	1460	1000	650	475
AVERAGE:	5.88	212	1607	1155	787	595
STD.DEV:	0.81	95	275	225	423	324

Table B5: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	5.50	190	1720	1340	750	700
Jan. 19	5.10	150	2360	1820	1450	1175
Jan. 22	4.85	100	3030	2410	1750	1375
Jan. 26	4.70	75	1950	1520	1025	850
Jan. 30	4.70	65	1700	1380	650	650
Feb. 3	4.80	105	1700	1300	675	625
Feb. 6	4.83	110	2750	2220	1075	850
Feb. 10	4.80	115	1900	1490	825	775
Feb. 12	4.90	140	1930	1560	700	650

Feb. 16	5.30	185	1490	1100	375	300
Feb. 18	5.33	170	1590	1230	525	450
Feb. 20	5.30	175	1540	1110	475	450
Feb. 23	5.20	200	1730	1290	525	450
Feb. 25	5.30	195	1730	1210	650	400
Feb. 27	5.50	205	1710	1120	550	350
AVERAGE:	5.07	145	1922	1473	800	670
STD.DEV:	0.29	47	448	395	380	303

Table B5: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	6.08	190	1160	800	175	100
Mar. 13	6.18	195	1080	790	475	400
Mar. 17	5.70	245	1540	1010	650	275
Mar. 20	5.90	215	1350	940	475	225
Mar. 24	6.00	190	1220	860	425	425
Mar. 26	6.05	200	1330	900	450	400
Mar. 30	5.90	200	1310	920	475	400
Apr. 1	6.00	190	1290	920	425	225
Apr. 3	5.93	190	1340	940	675	325
Apr. 7	5.88	185	1440	856	725	425
Apr. 10	5.88	185	1450	1190	775	700
Apr. 14	4.98	235	2140	1470	575	325
Apr. 16	5.45	205	1660	1200	550	325
Apr. 18	5.88	195	1260	880	425	350
Apr. 21	5.75	185	1230	850	400	375
AVERAGE:	5.84	200	1387	968	512	352
STD.DEV:	0.29	18	255	184	152	132

Table B6: pH, alkalinity and solids for effluent B.

RUN P:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
June 16	6.45	390	2670	1664	1150	775
June 19	6.05	315	2752	1725	1250	800
June 30	5.95	350	3585	2625	1650	1350
July 2	6.225	440	2763	1876	900	675
July 14	6.4	400	1940	1354	825	675
July 15	6.6	420	2055	1380	1050	700
July 17	6.4	370	2294	1641	1100	875
AVERAGE:	6.30	384	2580	1752	1132	836
STD.DEV:	0.21	39	514	395	270	221

Table B6: Con't.

RUN 1:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
July 22	6.28	430	2324	1573	925	600
July 24	6.20	435	2644	1884	1375	1100
July 29	5.73	380	2440	1580	1475	900
Aug. 2	5.98	335	2900	1980	1800	1200
Aug. 5	5.95	355	2750	1800	1325	875
Aug. 7	6.30	325	2480	1680	1225	800
Aug. 12	6.25	375	2750	1850	1925	1375
Aug. 14	6.23	380	2530	1800	1500	1075
Aug. 21	6.05	295	1780	1140	850	675
Aug. 25	5.85	330	3680	2550	3300	2175
Aug. 28	5.65	315	3880	2730	3025	2125
Sept. 2	6.03	270	2620	1910	1850	1425
Sept. 5	5.98	280	2930	2170	2025	1625

Sept. 9	6.03	280	3510	2560	3125	2375
Sept. 11	5.70	220	3500	2550	2750	1975
AVERAGE:	6.01	334	2848	1984	1898	1353
STD.DEV:	0.21	60	571	447	799	580

Table B6: Con't.

RUN 2:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Sept. 24	6.40	310	2390	1740	1800	1100
Sept. 26	6.25	310	5710	4220	5975	4650
Sept. 29	6.55	355	2080	1460	1150	900
Oct. 1	6.63	360	2350	1700	1850	1425
Oct. 6	6.73	320	2700	2090	1700	1350
Oct. 9	6.65	345	2070	1430	1500	1050
Oct. 15	6.48	330	2030	1520	1025	800
Oct. 21	6.60	345	1880	1170	1175	650
Oct. 24	6.60	365	2530	1770	2075	1425
Oct. 28	6.68	355	2180	1570	1600	1175
Oct. 30	6.95	350	2090	1510	1325	1075
Nov. 4	6.93	305	1580	1080	800	575
Nov. 7	6.85	355	2750	1950	2675	1975
Nov. 11	6.90	370	1830	1320	1225	1050
Nov. 13	6.95	340	2120	1510	1750	1350
AVERAGE:	6.68	341	2419	1736	1842	1370
STD.DEV:	0.21	21	964	737	1235	972

Table B6: Con't.

RUN 3:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Nov. 24	7.35	395	2300	1640	1875	1425
Nov. 26	7.18	380	1790	1320	1175	1025

Nov. 28	6.88	395	1400	1020	825	650
Dec. 1	7.00	365	1510	1020	1325	1000
Dec. 11	7.15	475	1910	1310	1425	1050
Dec. 15	7.03	360	1730	1190	1225	900
Dec. 17	7.13	495	5520	3850	6525	4600
Dec. 19	7.25	420	1110	670	650	450
Dec. 22	7.10	410	1820	1190	1125	875
Dec. 29	7.05	445	1640	1140	1050	700
Dec. 31	6.95	380	1130	840	525	400
Jan. 2	7.30	405	1390	880	1375	575
Jan. 5	7.20	410	1390	980	800	600
Jan. 7	7.83	400	1540	1090	925	625
Jan. 9	7.30	425	1920	1280	1325	925
AVERAGE:	7.18	411	1873	1295	1477	1053
STD.DEV:	0.22	38	1057	744	1438	1017

Table B6: Con't.

RUN 4:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Jan. 16	6.58	325	1940	1470	1175	975
Jan. 19	6.60	345	2410	1820	1575	1175
Jan. 22	6.55	365	2190	1610	1000	850
Jan. 26	6.15	325	1950	1470	1000	775
Jan. 30	6.35	290	3120	2390	2200	1800
Feb. 3	6.05	290	2680	2020	1950	1600
Feb. 6	6.33	305	4660	3620	3950	2925
Feb. 10	6.40	300	3810	2880	3050	2450
Feb. 12	6.33	310	3040	2390	1850	1500

Feb. 16	6.23	285	3250	2440	2025	1550
Feb. 18	6.18	300	7540	5610	7550	5625
Feb. 20	6.33	265	2090	1460	1100	825
Feb. 23	6.20	305	2520	1860	1600	1125
Feb. 25	6.33	305	3220	2190	2175	1500
Feb. 27	6.60	275	2100	1430	950	625
AVERAGE:	6.35	306	3101	2311	2210	1687
STD.DEV:	0.17	26	1444	1099	1692	1260

Table B6: Con't.

RUN 5:

DATE	pH	ALKALINITY (mg/L as $CaCO_3$)	TS (mg/L)	VS (mg/L)	TSS (mg/L)	VSS (mg/L)
Mar. 9	6.60	270	2010	1340	650	375
Mar. 13	6.50	240	1840	1300	975	650
Mar. 17	6.48	280	1740	1160	900	400
Mar. 20	6.55	240	1790	1170	850	475
Mar. 24	6.60	225	1620	1100	700	575
Mar. 26	6.60	220	1670	1080	650	525
Mar. 30	6.63	245	1580	1020	575	375
Apr. 1	6.68	260	2040	1370	1225	725
Apr. 3	6.70	260	1630	1080	825	625
Apr. 7	6.68	275	1560	1040	800	350
Apr. 10	6.70	250	1540	1140	700	525
Apr. 14	6.40	320	2080	1390	925	500
Apr. 16	6.70	275	1940	1360	825	525
Apr. 18	6.73	245	1690	1140	875	475
Apr. 21	6.65	240	1450	920	675	475
AVERAGE:	6.61	256	1745	1174	810	505
STD.DEV:	0.09	25	198	145	164	107

Table B7: VFA content of influent A.

RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	(mg/L as
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	acetic acid)
June 16	16.98	8.02	3.76	6.94	4.93	6.98	16.98	6.55	2.57	4.73	2.90	4.10	37.83
June 19	48.02	16.63	7.79	11.88	11.66	8.62	48.02	13.59	5.31	8.10	6.86	5.07	86.95
June 30	115.68	10.64	8.35	8.91	9.70	2.63	115.68	8.70	5.70	6.07	5.70	1.55	143.40
July 2	11.35	6.80	1.78	4.44	3.09	2.76	11.35	5.56	1.22	3.03	1.82	1.62	24.59
July 14	84.83	5.95	5.57	5.58	12.01	2.12	84.83	4.86	3.80	3.81	7.06	1.25	105.60
July 15	17.98	5.78	1.85	4.85	3.50	2.81	17.98	4.72	1.26	3.31	2.06	1.65	30.98
July 17	12.90	5.73	1.40	3.66	1.93	1.96	12.90	4.68	0.96	2.49	1.13	1.15	23.31
AVERAGE:	43.96	8.51	4.36	6.61	6.69	3.98	43.96	6.95	2.97	4.51	3.93	2.34	64.67
STD.DEV:	41.35	3.99	2.92	2.91	4.30	2.67	41.35	3.26	1.99	1.98	2.53	1.57	47.51

Table B7: Con't.

RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	(mg/L as
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	acetic acid)
July 22	66.43	1.72	0.96	2.36	0.93	0.41	66.43	1.40	0.66	1.61	0.55	0.24	70.88
July 24	101.77	12.77	8.50	8.60	9.52	1.81	101.77	10.44	5.79	5.86	5.60	1.06	130.53
July 29	11.92	5.32	1.35	3.40	1.99	1.16	11.92	4.35	0.92	2.32	1.17	0.68	21.36
Aug. 2	15.21	8.52	1.98	2.65	3.87	1.78	15.21	6.96	1.35	1.81	2.27	1.05	28.66
Aug. 5	107.42	14.10	1.78	2.79	5.98	0.99	107.42	11.52	1.21	1.90	3.52	0.58	126.15

Aug.7	99.91	22.61	3.36	6.75	5.34	2.11	99.91	18.47	2.29	4.60	3.14	1.24	129.65
Aug. 12	140.75	47.37	7.84	16.45	11.75	4.53	140.75	38.70	5.34	11.22	6.91	2.66	205.58
Aug 14	120.86	51.74	9.38	13.72	10.75	5.74	120.86	42.27	6.39	9.35	6.32	3.38	188.57
Aug. 21	174.64	48.42	9.00	20.46	10.21	9.39	174.64	39.56	6.14	13.95	6.00	5.52	245.81
Aug. 25	211.71	58.15	9.19	23.61	11.52	12.83	211.71	47.50	6.27	16.10	6.78	7.54	295.91
Aug. 28	156.79	33.46	8.08	22.63	10.59	15.25	156.79	27.34	5.51	15.43	6.22	8.97	220.27
Sept. 2	185.46	31.86	8.80	17.59	11.81	16.17	185.46	26.03	6.00	12.00	6.94	9.51	245.94
Sept. 5	163.05	28.89	8.12	16.96	9.88	12.69	163.05	23.60	5.54	11.57	5.81	7.46	217.03
Sept. 9	130.52	32.44	8.54	19.27	12.46	13.07	130.52	26.51	5.82	13.14	7.33	7.69	191.01
Sept. 11	152.88	18.60	7.27	14.46	10.68	7.77	152.88	15.19	4.96	9.86	6.28	4.57	193.74
AVERAGE:	122.62	27.73	6.28	12.78	8.48	7.05	122.62	22.66	4.28	8.72	4.99	4.14	167.41
STD.DEV:	57.84	17.84	3.29	7.68	3.82	5.74	57.84	14.58	2.25	5.24	2.24	3.37	80.90

Table B7: Con't.

RUN 2:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	(mg/L as
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	acetic acid)
Sept. 24	165.38	40.29	13.74	27.78	17.55	17.49	165.38	32.92	9.37	18.95	10.32	10.29	247.22
Sept. 26	209.29	31.02	12.41	27.25	17.86	10.94	209.29	25.34	8.46	18.58	10.50	6.43	278.62
Sept. 29	181.73	32.87	16.04	51.02	22.78	18.79	181.73	26.86	10.94	34.80	13.39	11.05	278.76
Oct. 1	161.13	21.23	9.49	42.54	12.42	8.86	161.13	17.34	6.47	29.01	7.30	5.21	226.47

Oct. 6	194.08	37.88	15.04	31.90	19.22	11.93	194.08	30.95	10.26	21.76	11.30	7.02	275.36
Oct. 9	184.05	22.73	12.28	31.02	15.48	7.54	184.05	18.57	8.37	21.16	9.10	4.43	245.69
Oct. 15	81.18	46.12	10.43	21.37	18.11	7.06	81.18	37.68	7.11	14.57	10.65	4.15	155.35
Oct. 21	475.13	28.40	16.71	4.30	13.57	1.13	475.13	23.20	11.39	2.94	7.98	0.66	521.30
Oct. 24	389.33	26.90	11.47	2.04	11.48	1.08	389.33	21.98	7.82	1.39	6.75	0.63	427.91
Oct. 28	32.96	18.93	4.98	12.65	7.30	4.68	32.96	15.47	3.40	8.63	4.29	2.75	67.49
Oct. 30	35.93	1.23	4.26	2.51	4.58	0.82	35.93	1.01	2.90	1.71	2.69	0.48	44.72
Nov. 4	18.96	0.00	2.21	0.45	3.10	0.00	18.96	0.00	1.51	0.31	1.82	0.00	22.60
Nov. 7	2.34	0.00	1.36	0.00	0.00	0.00	2.34	0.00	0.93	0.00	0.00	0.00	3.26
Nov. 11	96.63	30.23	8.13	33.90	4.88	3.52	96.63	24.70	5.54	23.12	2.87	2.07	154.93
Nov. 13	132.93	35.10	14.77	83.70	5.44	2.81	132.93	28.68	10.08	57.08	3.20	1.65	233.62
AVERAGE:	157.40	24.86	10.22	24.83	11.58	6.44	157.40	20.31	6.97	16.93	6.81	3.79	212.22
STD.DEV:	131.94	14.54	5.03	23.08	6.96	6.15	131.94	11.88	3.43	15.74	4.09	3.61	144.67

Table B7: Con't.

RUN 3:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Nov. 24	197.22	23.89	12.64	70.83	8.20	4.48	197.22	19.52	8.62	48.31	4.82	2.63	281.12
Nov. 26	172.53	16.08	10.39	81.21	4.74	6.11	172.53	13.13	7.09	55.39	2.78	3.59	254.52
Nov. 28	190.22	11.20	11.98	74.47	5.38	1.96	190.22	9.15	8.17	50.79	3.16	1.15	262.65
Dec. 1	126.96	11.69	8.32	65.34	6.07	6.47	126.96	9.55	5.68	44.56	3.57	3.81	194.13

Dec. 11	182.70	26.64	18.34	174.77	13.68	10.07	182.70	21.77	12.51	119.20	8.04	5.92	350.14
Dec. 15	180.33	27.60	15.15	142.15	13.57	9.16	180.33	22.55	10.33	96.95	7.98	5.38	323.52
Dec. 17	181.20	30.68	14.38	104.76	16.12	14.50	181.20	25.06	9.81	71.44	9.48	8.53	305.52
Dec. 19	178.54	10.32	14.29	56.42	16.60	8.98	178.54	8.43	9.74	38.48	9.76	5.28	250.23
Dec. 22	201.42	19.71	11.75	17.15	11.26	3.10	201.42	16.11	8.01	11.70	6.62	1.82	245.68
Dec. 29	253.47	26.33	18.15	19.08	15.67	6.16	253.47	21.51	12.38	13.01	9.21	3.62	313.21
Dec. 31	226.75	57.37	15.06	31.69	14.38	16.73	226.75	46.87	10.27	21.61	8.46	9.84	323.81
Jan. 2	244.56	55.79	14.48	20.99	14.42	10.57	244.56	45.58	9.88	14.32	8.48	6.21	329.03
Jan. 5	261.70	43.23	15.20	8.23	13.89	3.85	261.70	35.32	10.37	5.61	8.17	2.26	323.43
Jan. 7	208.61	10.78	12.97	5.21	14.04	0.00	208.61	8.81	8.85	3.56	8.25	0.00	238.07
Jan. 9	46.07	23.88	3.74	11.20	8.66	6.56	46.07	19.51	2.55	7.64	5.09	3.86	84.72
AVERAGE:	190.15	26.35	13.12	58.90	11.78	7.25	190.15	21.53	8.95	40.17	6.93	4.26	271.98
STD.DEV:	53.03	15.21	3.70	51.15	4.08	4.54	53.03	12.43	2.52	34.88	2.40	2.67	67.66

Table B7: Con't.

RUN 4:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	114.22	3.76	3.29	1.78	7.29	1.91	114.22	3.07	2.24	1.21	4.29	1.13	126.16
Jan. 19	7.04	0.00	0.00	0.00	2.16	0.00	7.04	0.00	0.00	0.00	1.27	0.00	8.31
Jan. 22	110.15	5.38	3.99	0.00	5.14	0.00	110.15	4.40	2.72	0.00	3.02	0.00	120.29

Jan. 26	97.98	10.80	4.45	4.84	7.66	3.89	97.98	8.82	3.03	3.30	4.50	2.29	119.93
Jan. 30	77.61	8.51	1.81	0.00	3.16	0.00	77.61	6.95	1.23	0.00	1.86	0.00	87.65
Feb. 3	48.78	32.59	0.00	4.33	0.00	0.00	48.78	26.62	0.00	2.96	0.00	0.00	78.36
Feb. 6	132.41	23.79	5.71	1.73	6.94	0.00	132.41	19.44	3.90	1.18	4.08	0.00	161.00
Feb. 10	138.43	16.48	5.27	0.00	6.80	0.00	138.43	13.46	3.59	0.00	4.00	0.00	159.48
Feb. 12	133.05	17.30	4.65	2.71	8.87	0.00	133.05	14.13	3.17	1.85	5.22	0.00	157.42
Feb. 16	99.84	7.47	0.00	0.00	5.37	0.00	99.84	6.10	0.00	0.00	3.16	0.00	109.10
Feb. 18	11.52	10.12	0.00	0.00	2.69	0.00	11.52	8.27	0.00	0.00	1.58	0.00	21.38
Feb. 20	95.41	11.07	1.86	0.00	4.88	0.00	95.41	9.04	1.27	0.00	2.87	0.00	108.58
Feb. 23	119.43	15.69	1.91	0.00	5.53	0.00	119.43	12.82	1.31	0.00	3.25	0.00	136.80
Feb. 25	38.12	7.57	0.00	0.00	3.99	0.00	38.12	6.19	0.00	0.00	2.35	0.00	46.66
Feb. 27	4.82	4.05	0.00	0.00	0.00	0.00	4.82	3.31	0.00	0.00	0.00	0.00	8.13
AVERAGE:	81.92	11.64	2.20	1.03	4.70	0.39	81.92	9.51	1.50	0.70	2.76	0.23	96.62
STD.DEV:	47.74	8.45	2.18	1.69	2.69	1.09	47.74	6.90	1.49	1.15	1.58	0.64	53.37

Table B7: Con't.

RUN 5:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Mar. 9	2.81	2.20	0.00	0.00	0.00	0.00	2.81	1.80	0.00	0.00	0.00	0.00	4.61
Mar. 13	1.21	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.00	0.00	0.00	0.00	1.21
Mar. 17	4.38	3.03	0.00	0.00	0.00	0.00	4.38	2.48	0.00	0.00	0.00	0.00	6.86

Mar. 20	2.79	2.21	0.00	0.00	0.00	0.00	2.79	1.81	0.00	0.00	0.00	0.00	4.59
Mar. 24	16.55	4.11	0.00	0.00	1.58	0.00	16.55	3.36	0.00	0.00	0.93	0.00	20.83
Mar. 26	1.74	1.51	0.00	0.00	0.00	0.00	1.74	1.24	0.00	0.00	0.00	0.00	2.98
Mar. 30	6.90	4.91	0.00	0.00	1.21	0.00	6.90	4.01	0.00	0.00	0.71	0.00	11.63
Apr. 1	2.94	1.27	0.00	0.00	0.00	0.00	2.94	1.04	0.00	0.00	0.00	0.00	3.98
Apr. 3	37.52	3.79	0.00	0.00	1.94	0.00	37.52	3.09	0.00	0.00	1.14	0.00	41.75
Apr. 7	1.60	0.00	1.07	0.00	0.00	0.47	1.60	0.00	0.73	0.00	0.00	0.28	2.60
Apr. 10	1.40	0.00	1.52	0.00	0.00	0.00	1.40	0.00	1.04	0.00	0.00	0.00	2.43
Apr. 14	52.46	15.79	2.81	2.78	3.82	1.01	52.46	12.90	1.92	1.90	2.25	0.59	72.01
Apr. 16	38.14	4.20	0.00	0.43	2.19	0.00	38.14	3.43	0.00	0.29	1.29	0.00	43.15
Apr. 18	17.79	17.51	1.24	0.56	0.00	0.00	17.79	14.31	0.85	0.38	0.00	0.00	33.32
Apr. 21	48.36	5.89	0.00	0.82	2.32	0.71	48.36	4.81	0.00	0.56	1.37	0.42	55.51
AVERAGE:	15.77	4.43	0.44	0.31	0.87	0.15	15.77	3.62	0.30	0.21	0.51	0.09	20.50
STD.DEV:	18.73	5.29	0.84	0.73	1.23	0.32	18.73	4.33	0.58	0.50	0.72	0.19	22.96

Table B8: VFA content of influent B.

RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
June 16	12.04	4.65	2.29	3.71	2.41	3.79	12.04	3.79	1.56	2.53	1.42	2.23	23.57
June 19	19.97	8.62	5.24	7.03	6.82	5.68	19.97	7.04	3.57	4.79	4.01	3.34	42.73
June 30	145.43	21.80	9.97	15.52	10.05	2.40	145.43	17.81	6.80	10.58	5.91	1.41	187.95
July 2	33.13	2.34	5.41	2.13	6.41	1.49	33.13	1.91	3.69	1.46	3.77	0.88	44.84
July 14	94.66	3.48	5.02	4.20	11.10	1.40	94.66	2.85	3.43	2.86	6.53	0.82	111.14
July 15	7.01	2.01	0.85	2.14	5.97	1.31	7.01	1.64	0.58	1.46	3.51	0.77	14.97
July 17	4.80	1.69	0.78	1.27	2.15	1.12	4.80	1.38	0.53	0.87	1.27	0.66	9.51
AVERAGE:	45.29	6.37	4.22	5.14	6.42	2.46	45.29	5.20	2.88	3.51	3.77	1.44	62.10
STD.DEV:	53.95	7.21	3.24	4.95	3.41	1.70	53.95	5.89	2.21	3.38	2.00	1.00	65.05

Table B8: Con't.

RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
July 22	134.75	2.49	5.63	2.36	1.50	0.51	134.75	2.04	3.84	1.61	0.88	0.30	143.42
July 24	166.53	27.59	16.78	21.49	18.13	3.76	166.53	22.54	11.44	14.66	10.66	2.21	228.04
July 29	133.23	5.76	5.04	3.63	16.14	1.06	133.23	4.70	3.44	2.47	9.49	0.62	153.95
Aug. 2	20.26	3.87	1.93	1.93	12.31	1.16	20.26	3.16	1.32	1.32	7.24	0.68	33.98
Aug.5	81.49	3.50	3.31	1.65	9.07	0.62	81.49	2.86	2.26	1.12	5.33	0.36	93.42

Aug. 7	70.68	40.58	7.41	23.15	9.80	5.10	70.68	33.15	5.05	15.79	5.76	3.00	133.43
Aug. 12	108.02	29.13	10.78	18.83	14.99	5.89	108.02	23.80	7.35	12.84	8.81	3.46	164.30
Aug. 14	107.16	17.19	11.35	10.75	14.11	4.52	107.16	14.04	7.74	7.33	8.30	2.66	147.23
Aug. 21	94.03	25.10	8.89	15.02	14.08	5.10	94.03	20.51	6.06	10.24	8.28	3.00	142.12
Aug. 25	119.13	52.96	8.88	30.39	15.28	9.86	119.13	43.27	6.06	20.73	8.98	5.80	203.97
Aug. 28	106.15	16.10	8.72	13.01	12.13	6.86	106.15	13.15	5.95	8.87	7.13	4.04	145.29
Sept. 2	121.64	20.55	7.94	13.21	13.79	6.76	121.64	16.79	5.42	9.01	8.11	3.97	164.93
Sept. 5	111.75	26.92	8.09	19.15	15.76	9.21	111.75	21.99	5.51	13.06	9.27	5.42	167.01
Sept. 9	104.77	50.75	7.56	35.26	13.21	16.17	104.77	41.46	5.16	24.05	7.77	9.51	192.71
Sept. 11	129.73	9.41	12.04	7.57	13.94	5.47	129.73	7.69	8.21	5.16	8.20	3.22	162.20
AVERAGE:	107.29	22.13	8.29	14.49	12.95	5.47	107.29	18.08	5.65	9.89	7.61	3.22	151.73
STD.DEV:	33.35	16.43	3.65	10.36	3.93	4.16	33.35	13.42	2.49	7.07	2.31	2.44	45.30

Table B8: Con't.

RUN 2:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Sept. 24	98.20	47.84	8.32	26.46	12.27	11.12	98.20	39.08	5.67	18.05	7.21	6.54	174.76
Sept. 26	75.52	11.84	6.98	2.34	8.25	1.36	75.52	9.67	4.76	1.60	4.85	0.80	97.20
Sept. 29	85.57	37.70	9.14	23.45	19.03	8.81	85.57	30.80	6.24	15.99	11.19	5.18	154.96
Oct. 1	110.40	22.78	9.59	8.32	13.82	2.64	110.40	18.61	6.54	5.68	8.13	1.55	150.91

Oct. 6	144.11	61.97	14.03	41.33	21.22	14.92	144.11	50.63	9.57	28.19	12.48	8.77	253.74
Oct. 9	154.70	33.29	18.05	11.06	17.86	3.67	154.70	27.19	12.31	7.54	10.50	2.16	214.40
Oct. 15	271.78	10.92	13.20	18.52	13.83	2.95	271.78	8.92	9.00	12.63	8.13	1.74	312.21
Oct. 21	68.72	26.24	11.20	1.23	20.60	0.26	68.72	21.44	7.64	0.84	12.12	0.15	110.90
Oct. 24	64.53	16.16	7.63	0.72	17.20	0.00	64.53	13.21	5.21	0.49	10.11	0.00	93.54
Oct. 28	70.81	39.89	8.31	19.65	11.93	6.94	70.81	32.59	5.67	13.40	7.01	4.08	133.56
Oct. 30	106.02	20.33	9.59	4.38	9.05	1.63	106.02	16.61	6.54	2.98	5.32	0.96	138.43
Nov. 4	78.90	10.42	5.51	1.44	10.01	0.93	78.90	8.51	3.76	0.99	5.89	0.55	98.59
Nov. 7	2.27	0.00	1.30	0.00	5.18	0.00	2.27	0.00	0.88	0.00	3.05	0.00	6.20
Nov. 11	104.14	39.35	12.81	13.98	12.47	5.23	104.14	32.15	8.74	9.54	7.33	3.08	164.97
Nov. 13	1.68	0.35	0.53	3.13	1.21	0.00	1.68	0.29	0.36	2.14	0.71	0.00	5.17
AVERAGE:	95.82	25.27	9.08	11.74	12.93	4.03	95.82	20.65	6.19	8.00	7.60	2.37	140.64
STD.DEV:	64.31	17.86	4.59	12.09	5.69	4.55	64.31	14.59	3.13	8.25	3.35	2.68	81.49

Table B8: Con't.

RUN 3:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Nov. 24	60.78	4.50	2.12	1.47	6.96	0.00	60.78	3.68	1.45	1.00	4.09	0.00	71.00
Nov. 26	27.50	0.00	0.00	0.00	2.47	0.00	27.50	0.00	0.00	0.00	1.45	0.00	28.95
Nov. 28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec. 1	116.83	35.70	13.02	3.59	7.06	0.00	116.83	29.17	8.88	2.45	4.15	0.00	161.48

Dec. 11	71.39	5.41	0.00	1.86	9.88	0.00	71.39	4.42	0.00	1.27	5.81	0.00	82.89
Dec. 15	74.79	1.51	0.00	1.37	8.89	0.00	74.79	1.24	0.00	0.93	5.23	0.00	82.18
Dec. 17	58.63	0.00	0.00	1.42	6.47	0.00	58.63	0.00	0.00	0.97	3.80	0.00	63.40
Dec. 19	8.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	8.00
Dec. 22	110.03	24.89	5.26	0.00	6.65	0.00	110.03	20.34	3.59	0.00	3.91	0.00	137.87
Dec. 29	5.33	0.00	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	5.33
Dec. 31	129.62	34.45	10.78	0.00	10.33	0.00	129.62	28.15	7.35	0.00	6.07	0.00	171.19
Jan. 2	136.70	16.52	3.01	0.00	6.34	0.00	136.70	13.50	2.05	0.00	3.73	0.00	155.97
Jan. 5	61.99	3.96	0.00	0.00	5.47	0.00	61.99	3.24	0.00	0.00	3.22	0.00	68.45
Jan. 7	10.62	0.00	0.00	0.00	0.00	0.00	10.62	0.00	0.00	0.00	0.00	0.00	10.62
Jan. 9	15.59	3.34	0.00	0.00	0.00	0.00	15.59	2.73	0.00	0.00	0.00	0.00	18.32
AVERAGE:	59.19	8.69	2.28	0.65	4.70	0.00	59.19	7.10	1.55	0.44	2.76	0.00	71.04
STD.DEV:	47.48	12.82	4.22	1.07	3.90	0.00	47.48	10.47	2.88	0.73	2.29	0.00	60.80

Table B8: Con't.

RUN 4:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	52.46	3.81	0.00	2.97	6.92	0.00	52.46	3.11	0.00	2.03	4.07	0.00	61.67
Jan. 19	5.27	0.00	0.00	0.00	0.00	0.00	5.27	0.00	0.00	0.00	0.00	0.00	5.27
Jan. 22	217.49	34.81	11.15	1.94	12.95	0.00	217.49	28.44	7.60	1.32	7.62	0.00	262.46

Jan. 26	24.92	3.15	0.00	0.00	3.91	0.00	24.92	2.58	0.00	0.00	2.30	0.00	29.79
Jan. 30	99.42	16.06	2.91	0.00	4.32	0.00	99.42	13.12	1.99	0.00	2.54	0.00	117.06
Feb. 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb. 6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb. 10	118.29	4.60	0.00	0.00	7.18	0.00	118.29	3.76	0.00	0.00	4.22	0.00	126.27
Feb. 12	35.62	0.00	0.00	0.00	3.38	0.00	35.62	0.00	0.00	0.00	1.99	0.00	37.61
Feb. 16	56.67	1.17	0.00	0.00	4.41	0.00	56.67	0.96	0.00	0.00	2.59	0.00	60.22
Feb. 18	1.81	0.00	0.00	0.00	0.00	0.00	1.81	0.00	0.00	0.00	0.00	0.00	1.81
Feb. 20	129.66	18.18	7.79	1.01	8.16	0.49	129.66	14.85	5.31	0.69	4.80	0.29	155.61
Feb. 23	104.99	1.92	1.65	0.82	8.42	0.00	104.99	1.57	1.12	0.56	4.95	0.00	113.19
Feb. 25	18.81	0.00	0.00	0.00	4.49	0.00	18.81	0.00	0.00	0.00	2.64	0.00	21.44
Feb. 27	5.20	0.00	0.00	0.00	0.00	0.00	5.20	0.00	0.00	0.00	0.00	0.00	5.20
AVERAGE:	58.04	5.58	1.57	0.45	4.28	0.03	58.04	4.56	1.07	0.31	2.51	0.02	66.51
STD.DEV;	63.67	9.94	3.37	0.90	3.92	0.13	63.67	8.12	2.30	0.61	2.31	0.07	75.34

Table B8: Con't.

RUN 5:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Mar. 9	23.23	0.00	0.00	0.00	2.88	0.00	23.23	0.00	0.00	0.00	1.70	0.00	24.93
Mar. 13	1.43	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	0.00	0.00	0.00	1.43
Mar. 17	3.02	0.00	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	0.00	0.00	3.02

Mar. 20	2.73	0.00	0.00	0.00	0.00	0.00	2.73	0.00	0.00	0.00	0.00	0.00	2.73
Mar. 24	2.91	0.00	0.00	0.00	0.00	0.00	2.91	0.00	0.00	0.00	0.00	0.00	2.91
Mar. 26	1.96	0.00	0.00	0.00	0.00	0.00	1.96	0.00	0.00	0.00	0.00	0.00	1.96
Mar. 30	61.10	2.11	2.15	0.00	3.75	0.00	61.10	1.72	1.47	0.00	2.21	0.00	66.50
Apr. 1	3.32	0.00	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00	0.00	0.00	3.32
Apr. 3	95.98	15.06	4.92	1.07	4.28	0.40	95.98	12.31	3.35	0.73	2.52	0.24	115.12
Apr. 7	0.73	0.00	0.62	0.00	0.00	0.00	0.73	0.00	0.42	0.00	0.00	0.00	1.15
Apr. 10	37.47	1.31	0.00	0.00	3.08	0.21	37.47	1.07	0.00	0.00	1.81	0.12	40.47
Apr. 14	96.09	16.26	4.78	0.94	6.89	0.22	96.09	13.28	3.26	0.64	4.05	0.13	117.45
Apr. 16	60.96	1.29	0.52	0.38	5.33	0.00	60.96	1.06	0.35	0.26	3.13	0.00	65.77
Apr. 18	2.02	0.00	0.92	0.00	0.00	0.00	2.02	0.00	0.63	0.00	0.00	0.00	2.64
Apr. 21	26.17	0.61	0.00	0.00	2.11	0.27	26.17	0.50	0.00	0.00	1.24	0.16	28.07
AVERAGE:	27.94	2.44	0.93	0.16	1.89	0.07	27.94	2.00	0.63	0.11	1.11	0.04	31.83
STD.DEV:	34.70	5.41	1.70	0.36	2.35	0.13	34.70	4.42	1.16	0.24	1.38	0.08	41.14

Table B9: VFA content of reactor A.

RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
June 16	260.27	158.93	5.62	13.99	6.28	5.93	260.27	129.84	3.83	9.54	3.69	3.49	410.66
June 19	319.03	144.17	6.02	21.76	6.30	7.08	319.03	117.79	4.11	14.84	3.70	4.16	463.62
June 30	256.98	134.71	10.63	15.17	12.77	4.84	256.98	110.06	7.25	10.35	7.51	2.85	394.99
July 2	224.68	148.50	10.62	17.03	14.58	9.09	224.68	121.33	7.24	11.61	8.57	5.35	378.78
July 14	443.61	206.85	15.34	26.18	20.97	17.28	443.61	168.99	10.46	17.86	12.33	10.16	663.42
July 15	534.64	231.28	13.96	31.95	21.10	18.51	534.64	188.96	9.52	21.79	12.41	10.88	778.20
July 17	371.16	192.42	11.19	30.64	13.72	18.94	371.16	157.21	7.63	20.90	8.07	11.14	576.10
AVERAGE:	344.34	173.84	10.48	22.39	13.67	11.67	344.34	142.02	7.15	15.27	8.04	6.86	523.68
STD.DEV:	112.88	36.54	3.65	7.37	6.04	6.31	112.88	29.85	2.49	5.02	3.55	3.71	153.29

Table B9: Con't.

RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
July 22	626.90	187.30	12.57	8.62	111.58	25.84	626.90	153.02	8.57	5.88	65.61	15.20	875.17
July 24	605.21	184.06	13.38	176.44	15.98	32.63	605.21	150.37	9.13	120.33	9.40	19.19	913.62
July 29	636.24	209.11	8.61	198.36	10.37	43.61	636.24	170.85	5.87	135.28	6.10	25.64	979.98
Aug. 2	678.39	174.65	9.63	241.14	13.21	59.07	678.39	142.69	6.56	164.46	7.77	34.73	1034.60
Aug. 5	495.94	143.04	5.66	213.44	10.33	35.42	495.94	116.87	3.86	145.57	6.07	20.83	789.14

Aug. 7	592.95	155.96	7.51	223.30	9.81	49.43	592.95	127.42	5.12	152.29	5.77	29.07	912.61
Aug. 12	561.80	112.55	11.84	205.93	17.22	45.73	561.80	91.95	8.07	140.45	10.12	26.89	839.28
Aug. 14	550.91	123.63	13.21	207.55	17.85	52.13	550.91	101.00	9.01	141.55	10.49	30.65	843.62
Aug. 21	628.59	155.24	13.17	207.76	14.84	68.28	628.59	126.83	8.98	141.69	8.72	40.15	954.97
Aug.25	893.73	196.27	13.41	208.02	13.90	85.02	893.73	160.36	9.14	141.87	8.17	49.99	1263.26
Aug. 28	773.13	172.60	10.80	179.66	9.77	75.14	773.13	141.02	7.37	122.53	5.75	44.19	1093.97
Sept. 2	697.43	128.89	10.56	141.79	11.71	55.99	697.43	105.30	7.20	96.70	6.89	32.92	946.44
Sept. 5	622.52	111.98	8.97	204.22	10.06	56.27	622.52	91.49	6.12	139.28	5.91	33.08	898.40
Sept. 9	487.40	75.75	8.25	231.29	71.14	29.61	487.40	61.88	5.62	157.74	41.83	17.41	771.89
Sept. 11	648.36	105.07	10.05	232.74	12.19	49.38	648.36	85.84	6.85	158.73	7.17	29.03	935.98
AVERAGE:	633.30	149.07	10.51	192.02	23.33	50.90	633.30	121.79	7.17	130.96	13.72	29.93	936.86
STD.DEV:	102.96	38.66	2.42	56.52	28.78	16.72	102.96	31.59	1.65	38.55	16.92	9.83	124.42

Table B9: Con't.

RUN 2:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Sept. 24	574.52	66.48	16.21	13.32	15.34	10.53	574.52	54.32	11.06	9.08	9.02	6.19	664.19
Sept. 26	446.58	52.60	11.15	24.53	14.61	5.50	446.58	42.98	7.60	16.73	8.59	3.23	525.71
Sept. 29	414.73	62.58	17.89	78.25	25.11	21.24	414.73	51.13	12.20	53.37	14.76	12.49	558.69
Oct. 1	347.63	53.81	13.75	62.56	15.53	15.29	347.63	43.96	9.37	42.67	9.13	8.99	461.77

Oct. 6	509.50	86.12	27.35	102.29	26.62	36.52	509.50	70.36	18.65	69.76	15.65	21.47	705.40
Oct. 9	452.87	77.30	18.88	71.17	21.96	16.89	452.87	63.16	12.88	48.54	12.91	9.93	600.28
Oct. 15	401.87	65.73	16.36	56.41	22.83	16.42	401.87	53.70	11.16	38.47	13.42	9.65	528.28
Oct. 21	515.56	83.72	20.18	64.83	22.83	21.69	515.56	68.40	13.76	44.21	13.43	12.76	668.11
Oct. 24	534.33	83.92	17.28	66.13	22.44	20.09	534.33	68.56	11.78	45.10	13.20	11.81	684.79
Oct. 28	412.41	78.73	16.56	28.41	22.55	15.44	412.41	64.32	11.29	19.37	13.26	9.08	529.73
Oct. 30	322.99	76.94	12.94	108.65	15.63	25.39	322.99	62.86	8.82	74.10	9.19	14.93	492.89
Nov. 4	294.21	75.91	11.75	46.11	16.31	24.75	294.21	62.02	8.01	31.45	9.59	14.55	419.83
Nov. 7	319.17	76.26	10.20	35.82	13.12	18.50	319.17	62.30	6.96	24.43	7.72	10.88	431.45
Nov. 11	421.88	88.66	16.77	178.65	21.55	45.52	421.88	72.43	11.44	121.84	12.67	26.77	667.02
Nov. 13	536.86	87.60	17.07	217.67	17.14	45.37	536.86	71.57	11.64	148.45	10.08	26.68	805.28
AVERAGE:	433.67	74.42	16.29	76.99	19.57	22.61	433.67	60.80	11.11	52.50	11.51	13.29	582.89
STD.DEV:	87.74	11.67	4.23	56.39	4.32	11.62	87.74	9.54	2.88	38.46	2.54	6.83	112.78

Table B9: Con't.

RUN 3:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	(mg/L as
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	acetic acid)
Nov. 24	508.16	74.59	19.13	185.65	12.11	32.49	508.16	60.94	13.05	126.61	7.12	19.10	734.98
Nov. 26	392.44	61.55	14.79	175.72	5.27	37.72	392.44	50.29	10.09	119.84	3.10	22.18	597.93
Nov. 28	410.51	64.14	16.95	212.63	7.23	43.97	410.51	52.40	11.56	145.01	4.25	25.85	649.59
Dec. 1	317.60	66.29	16.14	143.00	11.46	37.24	317.60	54.16	11.01	97.52	6.74	21.90	508.93

Dec. 11	421.61	109.37	32.41	244.71	35.30	50.83	421.61	89.35	22.10	166.89	20.76	29.89	750.60
Dec. 15	439.18	99.58	30.57	228.46	32.21	48.92	439.18	81.36	20.85	155.81	18.94	28.76	744.90
Dec. 17	443.78	101.35	27.05	164.88	37.82	53.46	443.78	82.80	18.45	112.45	22.24	31.44	711.16
Dec. 19	443.21	99.70	27.20	148.90	44.40	48.01	443.21	81.46	18.55	101.55	26.11	28.23	699.11
Dec. 22	330.75	90.53	23.34	114.69	36.76	36.82	330.75	73.96	15.92	78.22	21.62	21.65	542.11
Dec. 29	403.34	143.29	36.90	110.02	279.69	52.43	403.34	117.06	25.16	75.04	164.46	30.83	815.89
Dec. 31	407.88	160.55	34.42	105.27	52.01	50.64	407.88	131.17	23.48	71.80	30.58	29.77	694.67
Jan. 2	366.56	150.77	25.86	85.93	33.26	43.15	366.56	123.18	17.64	58.61	19.56	25.37	610.91
Jan. 5	388.80	147.46	27.30	78.33	33.80	43.45	388.80	120.47	18.62	53.42	19.88	25.55	626.74
Jan. 7	379.68	148.11	30.14	79.07	37.99	38.47	379.68	121.01	20.56	53.92	22.34	22.62	620.13
Jan. 9	400.46	143.32	27.38	71.32	38.40	38.24	400.46	117.09	18.67	48.64	22.58	22.49	629.93
AVERAGE:	403.60	110.71	25.97	143.24	46.52	43.72	403.60	90.45	17.71	97.69	27.35	25.71	662.51
STD.DEV:	46.88	35.42	6.73	57.24	66.03	6.68	46.88	28.94	4.59	39.04	38.83	3.93	83.36

Table B9: Con't.

RUN 4:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	373.22	114.33	14.94	211.83	15.61	37.93	373.22	93.41	10.19	144.47	9.18	22.30	652.77
Jan. 19	378.06	112.91	0.00	243.61	8.30	45.46	378.06	92.25	0.00	166.14	4.88	26.73	668.07
Jan. 22	404.95	137.48	0.00	193.61	3.05	52.91	404.95	112.32	0.00	132.04	1.80	31.11	682.22

Jan. 26	347.89	111.04	0.00	204.48	0.00	48.62	347.89	90.72	0.00	139.45	0.00	28.59	606.65
Jan. 30	330.22	96.52	0.00	168.99	0.00	38.43	330.22	78.86	0.00	115.25	0.00	22.60	546.92
Feb. 3	420.91	129.68	0.00	175.73	0.00	71.47	420.91	105.95	0.00	119.85	0.00	42.02	688.73
Feb. 6	338.94	119.54	4.65	221.48	0.00	54.91	338.94	97.66	3.17	151.05	0.00	32.29	623.11
Feb. 10	375.75	100.24	0.00	146.41	0.00	38.73	375.75	81.90	0.00	99.85	0.00	22.77	580.27
Feb. 12	333.64	85.08	0.00	86.30	0.00	23.39	333.64	69.51	0.00	58.86	0.00	13.75	475.77
Feb. 16	309.80	73.05	5.41	85.62	6.13	18.47	309.80	59.68	3.69	58.39	3.60	10.86	446.02
Feb. 18	278.37	89.28	7.36	91.41	8.87	24.24	278.37	72.94	5.02	62.34	5.22	14.25	438.14
Feb. 20	301.80	87.99	6.58	112.16	7.11	24.77	301.80	71.89	4.49	76.49	4.18	14.56	473.41
Feb. 23	307.09	89.85	5.64	95.57	8.36	30.02	307.09	73.41	3.85	65.18	4.92	17.65	472.09
Feb. 25	277.88	89.60	2.54	107.03	9.13	37.85	277.88	73.21	1.73	72.99	5.37	22.26	453.44
Feb. 27	303.35	97.60	2.48	121.61	7.58	47.89	303.35	79.74	1.69	82.94	4.46	28.16	500.33
AVERAGE:	338.79	102.28	3.31	151.06	4.94	39.67	338.79	83.56	2.25	103.02	2.91	23.33	553.86
STD.DEV:	44.10	17.97	4.24	54.95	4.88	14.33	44.10	14.68	2.89	37.47	2.87	8.43	93.75

Table B9: Con't.

RUN 5:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Mar. 9	107.12	55.51	5.24	21.52	0.00	6.73	107.12	45.35	3.58	14.68	0.00	3.96	174.68
Mar. 13	109.88	58.12	5.39	28.05	0.00	8.28	109.88	47.49	3.68	19.13	0.00	4.87	185.05
Mar. 17	241.71	91.12	7.64	136.04	5.54	42.67	241.71	74.44	5.21	92.78	3.26	25.09	442.49

Mar. 20	152.39	56.90	7.49	67.96	0.00	16.34	152.39	46.49	5.11	46.35	0.00	9.61	259.94
Mar. 24	150.06	63.11	6.36	74.97	0.00	11.59	150.06	51.56	4.34	51.13	0.00	6.82	263.90
Mar. 26	142.07	64.66	5.94	70.87	0.00	13.24	142.07	52.83	4.05	48.33	0.00	7.78	255.07
Mar. 30	153.64	58.91	5.38	76.46	0.00	12.85	153.64	48.13	3.67	52.14	0.00	7.56	265.14
Apr. 1	132.54	57.96	7.67	67.40	0.00	15.17	132.54	47.35	5.23	45.97	0.00	8.92	240.01
Apr. 3	158.95	53.79	6.24	86.17	2.99	16.48	158.95	43.95	4.25	58.77	1.76	9.69	277.37
Apr. 7	148.57	64.25	6.11	76.70	0.00	20.66	148.57	52.49	4.16	52.31	0.00	12.15	269.68
Apr. 10	134.64	58.08	6.50	76.96	2.62	15.18	134.64	47.45	4.43	52.49	1.54	8.92	249.48
Apr. 14	303.54	124.88	6.60	171.25	7.49	74.70	303.54	102.03	4.50	116.79	4.40	43.92	575.19
Apr. 16	213.85	67.08	2.45	96.06	3.63	29.25	213.85	54.81	1.67	65.51	2.13	17.20	355.17
Apr. 18	189.11	62.93	2.72	115.78	2.55	38.77	189.11	51.41	1.85	78.96	1.50	22.80	345.63
Apr. 21	188.47	55.86	3.55	105.52	2.13	21.94	188.47	45.64	2.42	71.97	1.25	12.90	322.65
AVERAGE:	168.44	66.21	5.69	84.78	1.80	22.92	168.44	54.09	3.88	57.82	1.06	13.48	298.76
STD.DEV:	52.18	18.53	1.64	37.72	2.37	17.67	52.18	15.14	1.12	25.72	1.39	10.39	101.52

Table B10: VFA rpoduction of reactor A.						
RUN P:						
DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
June 16	431.21	37.83	372.83	5525	1.25	0.0540
June 19	490.42	86.95	376.67	11000	1.25	0.0274
June 30	422.95	143.40	251.59	6775	1.25	0.0297
July 2	411.56	24.59	354.19	12075	1.25	0.0235
July 14	714.23	105.60	557.82	10850	1.25	0.0411
July 15	832.80	30.98	747.22	18375	1.25	0.0325
July 17	623.83	23.31	552.79	32125	1.25	0.0138
AVERAGE:	561.00	64.67	459.02	13818	1.25	0.0317
STD.DEV:	165.59	47.51	168.24	9074	0.00	0.0129

Table B10: Con't.						
RUN 1:						
DATE	TOTAL VFA (mg/L as acetic acid)	INFLUENT VFA (mg/L as acetic acid)	NET VFA (mg/L as acetic acid)	REACTOR VSS (mg/L)	HRT (days)	PRODUCTION RATE (mg VFA/mg VSS*d)
July 22	970.43	70.88	804.29	25200	1.25	0.0255
July 24	1071.66	130.53	783.09	23500	1.25	0.0267
July 29	1152.86	21.36	958.62	20250	1.25	0.0379
Aug. 2	1248.12	28.66	1005.94	17725	1.25	0.0454
Aug. 5	965.46	126.15	662.99	17050	1.25	0.0311

Aug. 7	1104.85	129.65	782.96	10750	1.25	0.0583
Aug. 12	1024.81	205.58	633.70	10900	1.25	0.0465
Aug. 14	1035.33	188.57	655.05	8950	1.25	0.0586
Aug. 21	1154.52	245.81	709.16	8425	1.25	0.0673
Aug.25	1472.44	295.91	967.35	12875	1.25	0.0601
Aug. 28	1273.80	220.27	873.70	11300	1.25	0.0619
Sept. 2	1090.15	245.94	700.50	15475	1.25	0.0362
Sept. 5	1082.80	217.03	681.37	12225	1.25	0.0446
Sept. 9	994.49	191.01	580.88	15625	1.25	0.0297
Sept. 11	1137.76	193.74	742.24	12000	1.25	0.0495
AVERAGE:	1118.63	167.41	769.46	14817	1.25	0.0453
STD.DEV:	133.61	80.90	130.55	5107	0.00	0.0138

Table B10: Con't.

RUN 2:

DATE	TOTAL VFA (mg/L as acetic acid)	INFLUENT VFA (mg/L as acetic acid)	NET VFA (mg/L as acetic acid)	REACTOR VSS (mg/L)	HRT (days)	PRODUCTION RATE (mg VFA/mg VSS*d)
Sept. 24	699.54	247.22	416.97	12325	2.00	0.0169
Sept. 26	561.86	278.62	247.09	8025	2.00	0.0154
Sept. 29	651.51	278.76	279.93	7275	2.00	0.0192
Oct. 1	531.93	226.47	235.30	7075	2.00	0.0166

Oct. 6	830.94	275.36	430.04	7450	2.00	0.0289
Oct. 9	684.54	245.69	354.59	6275	2.00	0.0283
Oct. 15	600.98	155.35	372.93	4450	2.00	0.0419
Oct. 21	752.27	521.30	146.81	5650	2.00	0.0130
Oct. 24	766.68	427.91	256.88	6050	2.00	0.0212
Oct. 28	582.74	67.49	462.24	5350	2.00	0.0432
Oct. 30	599.92	44.72	448.17	5375	2.00	0.0417
Nov. 4	483.43	22.60	397.23	4575	2.00	0.0434
Nov. 7	481.43	3.26	428.19	4100	2.00	0.0522
Nov. 11	839.74	154.93	512.09	5050	2.00	0.0507
Nov. 13	1002.13	233.62	571.66	5525	2.00	0.0517
AVERAGE:	671.31	212.22	370.67	6303	2.00	0.0323
STD.DEV:	146.62	144.67	116.38	2032	0.00	0.0146

Table B10: Con't.

RUN 3:

DATE	TOTAL VFA (mg/L as acetic acid)	INFLUENT VFA (mg/L as acetic acid)	NET VFA (mg/L as acetic acid)	REACTOR VSS (mg/L)	HRT (days)	PRODUCTION RATE (mg VFA/mg VSS*d)
Nov. 24	900.87	281.12	453.86	5400	2.50	0.0336
Nov. 26	753.13	254.52	343.41	5250	2.50	0.0262
Nov. 28	836.27	262.65	386.94	5100	2.50	0.0303
Dec. 1	646.10	194.13	314.80	5000	2.50	0.0252

Dec. 11	990.24	350.14	400.46	4850	2.50	0.0330
Dec. 15	969.26	323.52	421.38	5150	2.50	0.0327
Dec. 17	895.73	305.52	405.64	4425	2.50	0.0367
Dec. 19	873.55	250.23	448.88	4925	2.50	0.0365
Dec. 22	679.52	245.68	296.43	4600	2.50	0.0258
Dec. 29	1111.38	313.21	502.68	5200	2.50	0.0387
Dec. 31	850.30	323.81	370.86	4275	2.50	0.0347
Jan. 2	732.08	329.03	281.88	3625	2.50	0.0311
Jan. 5	744.21	323.43	303.31	3425	2.50	0.0354
Jan. 7	739.56	238.07	382.06	3700	2.50	0.0413
Jan. 9	742.31	84.72	545.21	4075	2.50	0.0535
AVERAGE:	830.97	271.99	390.52	4600	2.50	0.0343
STD.DEV:	128.48	67.66	76.48	647	0.00	0.0071

Table B10: Con't.

RUN 4:

DATE	TOTAL VFA (mg/L as acetic acid)	INFLUENT VFA (mg/L as acetic acid)	NET VFA (mg/L as acetic acid)	REACTOR VSS (mg/L)	HRT (days)	PRODUCTION RATE (mg VFA/mg VSS*d)
Jan. 16	838.91	126.16	526.61	8975	1.25	0.0469
Jan. 19	865.82	8.31	659.76	9325	1.25	0.0566
Jan. 22	847.17	120.29	561.93	9450	1.25	0.0476

Jan. 26	774.69	119.93	486.72	11125	1.25	0.0350
Jan. 30	684.76	87.65	459.27	13000	1.25	0.0283
Feb. 3	850.60	78.36	610.37	13100	1.25	0.0373
Feb. 6	809.62	161.00	462.11	15750	1.25	0.0235
Feb. 10	702.89	159.48	420.79	14250	1.25	0.0236
Feb. 12	548.38	157.42	318.35	13725	1.25	0.0186
Feb. 16	522.55	109.10	336.92	15800	1.25	0.0171
Feb. 18	524.97	21.38	416.76	16300	1.25	0.0205
Feb. 20	573.13	108.58	364.83	15525	1.25	0.0188
Feb. 23	563.68	136.80	335.29	15925	1.25	0.0168
Feb. 25	555.79	46.66	406.78	15150	1.25	0.0215
Feb. 27	617.57	8.13	492.20	15700	1.25	0.0251
AVERAGE:	685.37	96.62	457.25	13540	1.25	0.0291
STD.DEV:	134.47	53.37	101.79	2628	0.00	0.0127

Table B10: Con't.

RUN 5:

DATE	TOTAL VFA (mg/L as acetic acid)	INFLUENT VFA (mg/L as acetic acid)	NET VFA (mg/L as acetic acid)	REACTOR VSS (mg/L)	HRT (days)	PRODUCTION RATE (mg VFA/mg VSS*d)
Mar. 9	196.89	4.61	170.07	15425	1.25	0.0088
Mar. 13	212.73	1.21	183.84	16800	1.25	0.0088
Mar. 17	568.82	6.86	435.63	15350	1.25	0.0227

Mar. 20	321.00	4.59	255.35	14050	1.25	0.0145
Mar. 24	326.19	20.83	243.07	14475	1.25	0.0134
Mar. 26	315.23	2.98	252.09	14750	1.25	0.0137
Mar. 30	328.51	11.63	253.51	14350	1.25	0.0141
Apr. 1	300.14	3.98	236.03	14050	1.25	0.0134
Apr. 3	351.83	41.75	235.62	14450	1.25	0.0130
Apr. 7	338.31	2.60	267.08	14225	1.25	0.0150
Apr. 10	316.86	2.43	247.05	15900	1.25	0.0124
Apr. 14	744.81	72.01	503.18	11125	1.25	0.0362
Apr. 16	441.68	43.15	312.02	12775	1.25	0.0195
Apr. 18	450.74	33.32	312.31	13250	1.25	0.0189
Apr. 21	411.19	55.51	267.14	14500	1.25	0.0147
AVERAGE:	374.99	20.50	278.26	14365	1.25	0.0160
STD.DEV:	137.78	22.96	87.08	1338	0.00	0.0067

Table B11: VFA content of reactor B.

RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
June 16	304.57	209.17	11.01	20.24	17.80	7.65	304.57	170.89	7.51	13.81	10.46	4.50	511.73
June 19	305.10	205.03	8.78	27.71	13.21	7.69	305.10	167.51	5.99	18.89	7.77	4.52	509.78
June 30	426.03	259.02	9.49	28.58	9.45	11.25	426.03	211.62	6.47	19.49	5.56	6.62	675.79
July 2	461.88	256.04	11.60	34.06	12.57	19.69	461.88	209.18	7.91	23.23	7.39	11.58	721.18
July 14	416.90	242.74	13.70	27.04	19.05	18.02	416.90	198.32	9.34	18.44	11.20	10.60	664.80
July 15	503.24	314.70	16.18	37.70	25.13	24.71	503.24	257.11	11.04	25.71	14.78	14.53	826.41
July 17	401.79	285.69	12.34	37.88	19.10	27.18	401.79	233.41	8.42	25.83	11.23	15.98	696.66
AVERAGE:	402.79	253.20	11.87	30.46	16.61	16.60	402.79	206.86	8.10	20.77	9.77	9.76	658.05
STD.DEV:	74.74	39.26	2.52	6.43	5.25	7.93	74.74	32.08	1.72	4.38	3.09	4.66	113.71

Table B11: Con't.

RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
July 22	583.97	307.14	22.40	8.16	49.14	33.68	583.97	250.93	15.28	5.57	28.90	19.80	904.45
July 24	570.94	301.86	21.98	56.38	30.76	31.26	570.94	246.62	14.99	38.45	18.09	18.38	907.46
July 29	592.46	350.71	30.55	64.55	42.58	33.58	592.46	286.53	20.84	44.02	25.04	19.75	988.63
Aug. 2	459.56	290.39	31.27	58.88	55.73	41.41	459.56	237.25	21.33	40.16	32.77	24.35	815.42
Aug. 5	367.43	187.72	16.32	35.52	32.30	18.37	367.43	153.37	11.13	24.22	18.99	10.80	585.95

Aug. 7	381.71	165.39	12.75	30.61	19.40	17.61	381.71	135.12	8.70	20.88	11.41	10.35	568.17
Aug. 12	424.71	140.52	23.69	40.67	36.88	17.16	424.71	114.81	16.16	27.73	21.69	10.09	615.19
Aug. 14	410.88	124.42	20.81	40.66	26.90	16.84	410.88	101.65	14.19	27.73	15.82	9.90	580.18
Aug. 21	403.28	109.51	15.25	29.41	21.21	15.92	403.28	89.47	10.40	20.06	12.47	9.36	545.04
Aug. 25	510.02	156.19	12.93	36.10	22.26	20.52	510.02	127.60	8.82	24.62	13.09	12.07	696.22
Aug. 28	476.06	207.68	17.98	45.65	26.82	26.64	476.06	169.67	12.26	31.14	15.77	15.67	720.56
Sept. 2	424.95	177.62	13.55	20.03	19.44	19.00	424.95	145.11	9.24	13.66	11.43	11.17	615.57
Sept. 5	441.54	184.63	15.61	34.86	24.06	23.28	441.54	150.84	10.64	23.78	14.15	13.69	654.64
Sept. 9	312.57	141.10	12.98	25.99	21.07	16.68	312.57	115.28	8.85	17.73	12.39	9.81	476.62
Sept. 11	372.48	141.29	16.68	31.15	25.88	20.84	372.48	115.43	11.37	21.25	15.22	12.25	548.00
AVERAGE:	448.84	199.08	18.98	37.24	30.30	23.52	448.84	162.65	12.95	25.40	17.81	13.83	681.47
STD.DEV:	83.94	76.13	6.04	14.87	11.19	7.94	83.94	62.20	4.12	10.14	6.58	4.67	154.66

Table B11: Con't.

RUN 2:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Sept. 24	416.30	155.30	16.00	22.42	23.34	18.83	416.30	126.88	10.91	15.29	13.72	11.07	594.17
Sept. 26	372.65	156.96	14.61	17.42	25.88	6.61	372.65	128.24	9.96	11.88	15.21	3.89	541.84
Sept. 29	312.65	133.39	22.69	32.76	45.55	18.14	312.65	108.98	15.48	22.34	26.79	10.67	496.91
Oct. 1	338.50	101.59	17.88	26.71	30.65	12.55	338.50	83.00	12.19	18.21	18.02	7.38	477.30

Oct. 6	372.12	101.57	14.76	18.70	16.85	13.07	372.12	82.98	10.06	12.76	9.91	7.68	495.51
Oct. 9	357.30	125.34	19.04	23.21	23.75	9.31	357.30	102.40	12.99	15.83	13.97	5.48	507.96
Oct. 15	365.34	143.26	24.70	36.17	44.82	14.40	365.34	117.04	16.85	24.67	26.36	8.47	558.73
Oct. 21	347.15	179.65	24.58	30.53	38.19	15.80	347.15	146.78	16.76	20.82	22.46	9.29	563.25
Oct. 24	271.83	137.54	16.64	20.27	27.21	10.64	271.83	112.37	11.35	13.82	16.00	6.25	431.62
Oct. 28	255.97	150.31	17.48	15.67	242.98	10.24	255.97	122.80	11.92	10.69	142.87	6.02	550.27
Oct. 30	220.00	143.01	14.92	11.82	20.65	8.37	220.00	116.84	10.17	8.06	12.14	4.92	372.14
Nov. 4	193.41	135.16	12.80	15.94	19.33	12.16	193.41	110.42	8.73	10.87	11.37	7.15	341.95
Nov. 7	133.73	116.67	19.56	26.45	30.76	12.52	133.73	95.32	13.34	18.04	18.09	7.36	285.87
Nov. 11	107.16	107.73	15.85	29.24	22.13	12.43	107.16	88.01	10.81	19.94	13.01	7.31	246.25
Nov. 13	103.15	114.54	15.75	22.65	23.05	6.81	103.15	93.58	10.74	15.45	13.55	4.01	240.48
AVERAGE:	277.82	133.47	17.82	23.33	42.34	12.13	277.82	109.04	12.15	15.91	24.90	7.13	446.95
STD.DEV:	104.24	22.45	3.66	6.94	56.19	3.66	104.24	18.34	2.50	4.73	33.04	2.15	120.29

Table B11: Con't.

RUN 3:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Nov. 24	200.15	115.39	14.84	8.51	26.27	4.50	200.15	94.27	10.12	5.81	15.44	2.65	328.44
Nov. 26	146.14	110.44	15.61	8.30	19.80	6.28	146.14	90.23	10.65	5.66	11.64	3.69	268.01
Nov. 28	167.48	72.00	16.51	9.20	24.03	2.96	167.48	58.82	11.26	6.28	14.13	1.74	259.71
Dec. 1	123.20	102.38	19.27	11.32	23.41	6.34	123.20	83.64	13.14	7.72	13.77	3.73	245.19

Dec. 11	66.22	97.04	20.05	8.55	20.62	2.91	66.22	79.28	13.68	5.83	12.12	1.71	178.84
Dec. 15	92.21	84.07	19.83	9.78	23.27	2.49	92.21	68.69	13.52	6.67	13.68	1.47	196.24
Dec. 17	152.21	96.33	15.72	10.11	27.58	3.38	152.21	78.71	10.72	6.89	16.22	1.99	266.74
Dec. 19	184.56	94.89	14.76	7.91	25.07	7.04	184.56	77.53	10.07	5.39	14.74	4.14	296.43
Dec. 22	220.50	67.83	13.03	7.68	22.37	5.14	220.50	55.41	8.88	5.24	13.15	3.02	306.21
Dec. 29	293.24	66.64	15.32	10.85	21.63	4.34	293.24	54.44	10.45	7.40	12.72	2.55	380.80
Dec. 31	243.84	47.34	13.74	5.76	20.76	2.22	243.84	38.68	9.37	3.93	12.21	1.31	309.33
Jan. 2	213.17	56.28	8.98	4.78	14.47	4.11	213.17	45.98	6.13	3.26	8.51	2.42	279.46
Jan. 5	224.53	91.58	13.03	6.36	20.73	5.72	224.53	74.82	8.89	4.34	12.19	3.37	328.12
Jan. 7	231.72	91.00	14.22	7.70	20.43	6.64	231.72	74.35	9.70	5.25	12.01	3.91	336.93
Jan. 9	255.59	99.17	15.04	5.28	21.89	8.51	255.59	81.03	10.25	3.60	12.87	5.00	368.34
AVERAGE:	187.65	86.16	15.33	8.14	22.16	4.84	187.65	70.39	10.46	5.55	13.03	2.85	289.92
STD.DEV:	62.97	19.91	2.87	1.97	3.11	1.88	62.97	16.27	1.95	1.34	1.83	1.10	56.95

Table B11: Con't.

RUN 4:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	188.93	45.32	7.39	8.09	10.08	3.99	188.93	37.03	5.04	5.52	5.93	2.34	244.78
Jan. 19	165.87	65.05	3.42	6.82	6.23	2.02	165.87	53.14	2.33	4.65	3.66	1.19	230.85
Jan. 22	292.21	110.65	16.70	18.48	15.19	8.64	292.21	90.40	11.39	12.60	8.93	5.08	420.61

Jan. 26	206.77	69.21	8.39	11.23	9.28	4.62	206.77	56.55	5.72	7.66	5.46	2.72	284.86
Jan. 30	182.39	81.15	7.50	9.79	9.18	4.04	182.39	66.30	5.12	6.68	5.40	2.38	268.26
Feb. 3	185.82	87.81	9.96	8.23	9.25	6.69	185.82	71.74	6.79	5.61	5.44	3.93	279.33
Feb. 6	141.28	67.84	8.19	9.32	11.01	6.29	141.28	55.42	5.58	6.36	6.47	3.70	218.81
Feb. 10	188.61	61.25	8.49	7.88	10.97	4.70	188.61	50.04	5.79	5.37	6.45	2.77	259.03
Feb. 12	157.12	65.21	4.40	4.73	6.89	4.77	157.12	53.27	3.00	3.23	4.05	2.80	223.48
Feb. 16	145.52	73.05	4.67	3.68	5.52	2.13	145.52	59.68	3.18	2.51	3.25	1.25	215.39
Feb. 18	125.90	77.15	4.14	3.13	5.24	5.22	125.90	63.03	2.82	2.14	3.08	3.07	200.05
Feb. 20	138.73	99.13	7.21	4.97	8.07	3.87	138.73	80.99	4.92	3.39	4.75	2.28	235.05
Feb. 23	164.21	109.57	6.24	5.13	9.08	3.72	164.21	89.52	4.25	3.50	5.34	2.19	269.01
Feb. 25	138.39	87.13	3.69	2.78	6.26	7.09	138.39	71.19	2.52	1.90	3.68	4.17	221.84
Feb. 27	120.01	91.10	1.38	1.19	4.21	6.35	120.01	74.43	0.94	0.81	2.47	3.73	202.40
AVERAGE:	169.45	79.37	6.78	7.03	8.43	4.94	169.45	64.85	4.63	4.79	4.96	2.91	251.58
STD.DEV:	42.64	18.38	3.63	4.28	2.83	1.82	42.64	15.01	2.48	2.92	1.67	1.07	54.10

Table B11: Con't.

RUN 5:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	acetic	propionic	i-butyric	n-butyric	i-valeric	n-valeric	(mg/L as
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	acetic acid)
Mar. 9	79.59	43.10	0.00	0.00	4.37	1.01	79.59	35.21	0.00	0.00	2.57	0.59	117.97
Mar. 13	50.79	38.83	0.00	0.00	0.00	0.79	50.79	31.73	0.00	0.00	0.00	0.46	82.98
Mar. 17	78.28	79.73	3.50	2.08	4.66	2.80	78.28	65.14	2.38	1.42	2.74	1.65	151.61

Mar. 20	51.98	43.80	0.00	0.87	2.97	1.71	51.98	35.78	0.00	0.60	1.75	1.01	91.11
Mar. 24	59.66	50.97	0.00	0.90	3.22	1.50	59.66	41.64	0.00	0.61	1.89	0.88	104.68
Mar. 26	51.88	42.52	0.00	0.00	2.60	0.60	51.88	34.74	0.00	0.00	1.53	0.35	88.50
Mar. 30	90.00	54.71	3.71	3.00	5.73	0.00	90.00	44.69	2.53	2.05	3.37	0.00	142.65
Apr. 1	64.33	46.04	1.92	2.03	3.63	0.00	64.33	37.61	1.31	1.39	2.14	0.00	106.77
Apr. 3	93.43	59.71	5.41	3.29	5.71	1.43	93.43	48.79	3.69	2.24	3.35	0.84	152.34
Apr. 7	62.09	49.50	0.94	1.03	3.59	1.25	62.09	40.44	0.64	0.70	2.11	0.74	106.72
Apr. 10	64.23	40.69	0.67	0.84	3.98	0.60	64.23	33.24	0.46	0.57	2.34	0.35	101.21
Apr. 14	151.87	142.49	5.61	1.28	7.86	1.35	151.87	116.41	3.83	0.87	4.62	0.79	278.40
Apr. 16	89.34	32.62	1.18	0.90	4.93	0.43	89.34	26.65	0.80	0.61	2.90	0.25	120.55
Apr. 18	44.02	10.87	0.70	0.28	3.18	0.50	44.02	8.88	0.48	0.19	1.87	0.29	55.73
Apr. 21	43.84	9.05	0.00	0.49	2.09	0.00	43.84	7.39	0.00	0.33	1.23	0.00	52.79
AVERAGE:	71.69	49.64	1.58	1.13	3.90	0.93	71.69	40.56	1.07	0.77	2.29	0.55	116.93
STD.DEV:	27.72	30.98	2.01	1.04	1.82	0.77	27.72	25.31	1.37	0.71	1.07	0.45	53.65

Table B12: VFA production of reactor B.						
RUN P:						
DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
June 16	548.01	23.57	488.16	8300	1.25	0.0471
June 19	546.95	42.73	467.05	16125	1.25	0.0232
June 30	713.93	187.95	487.84	15850	1.25	0.0246
July 2	771.29	44.84	676.34	14575	1.25	0.0371
July 14	714.38	111.14	553.66	18525	1.25	0.0239
July 15	892.47	14.97	811.44	23675	1.25	0.0274
July 17	758.12	9.51	687.15	17600	1.25	0.0312
AVERAGE:	706.45	62.10	595.95	16379	1.25	0.0306
STD.DEV:	123.92	65.05	130.97	4622	0.00	0.0088

Table B12: Con't.						
RUN 1:						
DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
July 22	973.99	143.42	761.03	32475	1.25	0.0187
July 24	997.36	228.04	679.42	19800	1.25	0.0275
July 29	1098.28	153.95	834.68	20150	1.25	0.0331
Aug. 2	934.02	33.98	781.44	16050	1.25	0.0390
Aug. 5	651.10	93.42	492.53	16000	1.25	0.0246

Aug. 7	619.50	133.43	434.74	13925	1.25	0.0250
Aug. 12	690.86	164.30	450.89	12725	1.25	0.0283
Aug. 14	647.82	147.23	432.95	10850	1.25	0.0319
Aug. 21	597.33	142.12	402.92	10325	1.25	0.0312
Aug. 25	754.82	203.97	492.25	11675	1.25	0.0337
Aug. 28	795.39	145.29	575.27	11200	1.25	0.0411
Sept. 2	661.07	164.93	450.64	11375	1.25	0.0317
Sept. 5	716.90	167.01	487.63	10550	1.25	0.0370
Sept. 9	525.39	192.71	283.91	11150	1.25	0.0204
Sept. 11	608.09	162.20	385.80	8750	1.25	0.0353
AVERAGE:	751.46	151.73	529.74	14467	1.25	0.0306
STD.DEV:	171.59	45.30	161.90	6039	0.00	0.0065

Table B12: Con't.

RUN 2:

DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
Sept. 24	645.17	174.76	419.41	11025	2.00	0.0190
Sept. 26	582.78	97.20	444.64	10500	2.00	0.0212
Sept. 29	572.18	154.96	341.95	10150	2.00	0.0168
Oct. 1	533.11	150.91	326.39	10475	2.00	0.0156

Oct. 6	535.91	253.74	241.77	12425	2.00	0.0097
Oct. 9	556.22	214.40	293.56	13275	2.00	0.0111
Oct. 15	635.07	312.21	246.52	12125	2.00	0.0102
Oct. 21	632.58	110.90	452.35	9900	2.00	0.0228
Oct. 24	479.05	93.54	338.08	12750	2.00	0.0133
Oct. 28	721.77	133.56	416.71	10875	2.00	0.0192
Oct. 30	407.44	138.43	233.71	11500	2.00	0.0102
Nov. 4	380.07	98.59	243.36	12025	2.00	0.0101
Nov. 7	342.70	6.2	279.67	10650	2.00	0.0131
Nov. 11	297.32	164.97	81.28	13525	2.00	0.0030
Nov. 13	284.23	5.17	235.31	10975	2.00	0.0107
AVERAGE:	507.04	140.64	306.31	11478	2.00	0.0137
STD.DEV:	135.94	81.49	100.59	1146	0.00	0.0053

Table B12: Con't.

RUN 3:

DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
Nov. 24	362.46	71.00	257.44	10500	2.50	0.0098
Nov. 26	299.66	28.95	239.06	9400	2.50	0.0102
Nov. 28	293.12	0.00	259.71	8250	2.50	0.0126
Dec. 1	283.55	161.48	83.71	9875	2.50	0.0034

Dec. 11	212.18	82.89	95.95	8775	2.50	0.0044
Dec. 15	231.58	82.18	114.06	10725	2.50	0.0043
Dec. 17	302.56	63.40	203.34	7200	2.50	0.0113
Dec. 19	330.77	8.00	288.43	7425	2.50	0.0155
Dec. 22	336.50	137.87	168.34	6400	2.50	0.0105
Dec. 29	413.92	5.33	375.47	6400	2.50	0.0235
Dec. 31	336.15	171.19	138.14	5925	2.50	0.0093
Jan. 2	299.76	155.97	123.49	7825	2.50	0.0063
Jan. 5	356.90	68.45	259.67	6600	2.50	0.0157
Jan. 7	367.80	10.62	326.31	6725	2.50	0.0194
Jan. 9	400.07	18.32	350.02	6300	2.50	0.0222
AVERAGE:	321.80	71.04	218.88	7888	2.50	0.0119
STD.DEV:	56.00	60.80	94.91	1615	0.00	0.0063

Table B12: Con't.

RUN 4:

DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
Jan. 16	263.62	61.67	183.11	9250	1.25	0.0158
Jan. 19	242.68	5.27	225.58	9925	1.25	0.0182
Jan. 22	458.61	262.46	158.15	11075	1.25	0.0114

Jan. 26	306.41	29.79	255.07	10050	1.25	0.0203
Jan. 30	287.83	117.06	151.20	10125	1.25	0.0119
Feb. 3	301.10	0.00	279.33	10775	1.25	0.0207
Feb. 6	240.92	0.00	218.81	11750	1.25	0.0149
Feb. 10	279.41	126.27	132.76	12675	1.25	0.0084
Feb. 12	236.56	37.61	185.87	12475	1.25	0.0119
Feb. 16	225.58	60.22	155.17	12700	1.25	0.0098
Feb. 18	211.16	1.81	198.24	11875	1.25	0.0134
Feb. 20	250.39	155.61	79.44	12175	1.25	0.0052
Feb. 23	284.28	113.19	155.82	12300	1.25	0.0101
Feb. 25	234.11	21.44	200.40	11775	1.25	0.0136
Feb. 27	210.36	5.20	197.20	12500	1.25	0.0126
AVERAGE:	268.87	66.51	185.08	11428	1.25	0.0132
STD.DEV:	60.87	75.34	49.74	1144	0.00	0.0043

Table B12: Con't.

RUN 5:

DATE	TOTAL VFA	INFLUENT VFA	NET VFA	REACTOR VSS	HRT	PRODUCTION RATE
	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L as acetic acid)	(mg/L)	(days)	(mg VFA/mg VSS*d)
Mar. 9	121.13	24.93	93.04	16200	1.25	0.0046
Mar. 13	83.45	1.43	81.55	16100	1.25	0.0041
Mar. 17	159.81	3.02	148.59	15925	1.25	0.0075

Mar. 20	94.46	2.73	88.38	15250	1.25	0.0046
Mar. 24	108.07	2.91	101.77	17350	1.25	0.0047
Mar. 26	90.38	1.96	86.54	14725	1.25	0.0047
Mar. 30	150.59	66.50	76.15	15425	1.25	0.0039
Apr. 1	111.60	3.32	103.45	14725	1.25	0.0056
Apr. 3	162.47	115.12	37.22	14950	1.25	0.0020
Apr. 7	110.91	1.15	105.57	13350	1.25	0.0063
Apr. 10	104.93	40.47	60.74	14225	1.25	0.0034
Apr. 14	288.51	117.45	160.95	11500	1.25	0.0112
Apr. 16	125.12	65.77	54.78	11925	1.25	0.0037
Apr. 18	58.57	2.64	53.09	10475	1.25	0.0041
Apr. 21	54.35	28.07	24.72	12075	1.25	0.0016
AVERAGE:	121.62	31.83	85.10	14280	1.25	0.0048
STD.DEV:	56.18	41.14	37.28	1995	0.00	0.0023

Table B13: VFA content of effluent A.

RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
June 16	291.25	223.21	7.08	19.60	8.21	7.64	291.25	182.36	4.83	13.37	4.82	4.49	501.13
June 19	378.36	180.64	5.40	27.82	6.03	7.56	378.36	147.58	3.68	18.97	3.54	4.45	556.58
June 30	382.31	267.75	12.67	28.25	15.68	12.27	382.31	218.75	8.64	19.27	9.22	7.21	645.41
July 2	287.73	164.54	12.27	23.89	19.00	11.91	287.73	134.43	8.37	16.29	11.17	7.00	464.99
July 14	423.08	200.72	21.57	34.63	31.46	24.20	423.08	163.99	14.71	23.62	18.50	14.23	658.13
July 15	501.66	225.92	24.02	41.86	35.86	24.11	501.66	184.58	16.38	28.55	21.08	14.18	766.43
July 17	434.72	201.86	17.22	33.08	21.46	22.10	434.72	164.92	11.75	22.56	12.62	12.99	659.56
AVERAGE:	385.59	209.23	14.32	29.88	19.67	15.68	385.59	170.94	9.76	20.38	11.57	9.22	607.46
STD.DEV:	77.28	33.77	7.00	7.36	11.09	7.54	77.28	27.59	4.78	5.02	6.52	4.43	105.03

Table B13: Con't.

RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
July 22	584.39	197.69	18.07	7.15	68.58	26.56	584.39	161.51	12.32	4.88	40.33	15.62	819.04
July 24	702.43	194.51	14.73	165.13	23.49	32.74	702.43	158.91	10.04	112.62	13.81	19.25	1017.07
July 29	601.95	208.87	11.55	196.69	16.21	48.08	601.95	170.64	7.88	134.14	9.53	28.27	952.42
Aug. 2	608.78	170.80	11.71	229.24	20.37	62.03	608.78	139.54	7.99	156.34	11.98	36.47	961.10
Aug. 5	499.98	137.45	6.12	200.85	11.80	34.66	499.98	112.30	4.17	136.98	6.94	20.38	780.75

Aug. 7	520.68	151.42	6.00	214.76	7.98	43.66	520.68	123.71	4.09	146.47	4.69	25.67	825.31
Aug. 12	529.91	110.20	9.10	189.99	13.49	42.22	529.91	90.03	6.21	129.58	7.93	24.83	788.49
Aug. 14	525.96	117.09	10.81	207.96	13.21	44.09	525.96	95.66	7.37	141.83	7.77	25.92	804.51
Aug. 21	610.97	139.77	11.67	195.60	13.23	62.61	610.97	114.19	7.96	133.40	7.78	36.81	911.10
Aug. 25	733.80	164.47	11.68	150.79	10.17	61.01	733.80	134.37	7.96	102.84	5.98	35.87	1020.83
Aug. 28	648.42	160.45	9.37	164.59	8.70	66.71	648.42	131.08	6.39	112.25	5.11	39.22	942.48
Sept. 2	670.20	131.10	8.97	136.87	9.24	54.35	670.20	107.11	6.12	93.34	5.43	31.96	914.16
Sept. 5	579.13	117.26	9.03	167.74	8.82	53.07	579.13	95.80	6.16	114.40	5.19	31.20	831.88
Sept. 9	567.07	91.22	9.09	173.63	8.89	45.41	567.07	74.53	6.20	118.41	5.23	26.70	798.14
Sept. 11	572.55	101.60	9.20	202.26	9.11	44.37	572.55	83.01	6.27	137.94	5.35	26.09	831.22
AVERAGE:	597.08	146.26	10.47	173.55	16.22	48.10	597.08	119.49	7.14	118.36	9.54	28.29	879.90
STD.DEV:	68.11	36.27	3.06	52.50	15.18	11.81	68.11	29.63	2.09	35.80	8.93	6.94	83.88

Table B13: Con't.

RUN 2:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Sept. 24	577.19	63.22	15.08	5.94	13.63	6.40	577.19	51.65	10.28	4.05	8.01	3.76	654.95
Sept. 26	495.45	52.07	9.12	15.40	12.32	2.92	495.45	42.54	6.22	10.50	7.24	1.71	563.67
Sept. 29	347.69	58.07	14.48	53.26	21.30	13.45	347.69	47.44	9.88	36.32	12.53	7.91	461.77
Oct. 1	270.74	47.25	12.42	49.64	14.56	11.69	270.74	38.61	8.47	33.85	8.56	6.87	367.10

Oct. 6	490.17	72.73	23.96	91.13	28.68	30.03	490.17	59.42	16.34	62.15	16.86	17.66	662.60
Oct. 9	421.10	75.53	17.03	72.90	22.14	15.16	421.10	61.71	11.61	49.72	13.02	8.91	566.07
Oct. 15	386.45	74.81	16.54	36.69	22.24	16.73	386.45	61.12	11.28	25.02	13.08	9.84	506.79
Oct. 21	310.52	71.88	14.26	102.14	18.71	26.13	310.52	58.72	9.73	69.66	11.00	15.37	475.00
Oct. 24	516.03	84.79	18.28	71.11	24.08	20.89	516.03	69.27	12.47	48.50	14.16	12.29	672.71
Oct. 28	384.95	74.56	17.49	38.61	23.99	18.29	384.95	60.92	11.93	26.33	14.11	10.76	508.99
Oct. 30	304.22	72.76	13.36	95.71	17.98	23.80	304.22	59.45	9.11	65.28	10.57	13.99	462.63
Nov. 4	254.57	68.97	11.69	51.24	18.06	23.48	254.57	56.35	7.97	34.94	10.62	13.81	378.27
Nov. 7	310.84	77.20	11.15	41.21	14.68	18.37	310.84	63.07	7.61	28.10	8.63	10.80	429.06
Nov. 11	406.07	86.63	14.90	165.98	20.96	42.27	406.07	70.78	10.16	113.20	12.33	24.86	637.40
Nov. 13	498.96	84.22	15.48	204.19	18.14	41.68	498.96	68.81	10.56	139.26	10.67	24.51	752.76
AVERAGE:	398.33	70.98	15.02	73.01	19.43	20.75	398.33	57.99	10.24	49.79	11.43	12.20	539.98
STD.DEV:	99.45	11.51	3.53	53.65	4.52	11.19	99.45	9.41	2.41	36.59	2.66	6.58	116.07

Table B13: Con't.

RUN 3:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Nov. 24	520.36	76.60	19.60	206.50	12.33	35.87	520.36	62.58	13.36	140.83	7.25	21.09	765.49
Nov. 26	396.41	62.60	15.73	187.79	5.67	39.57	396.41	51.14	10.73	128.07	3.33	23.26	612.95
Nov. 28	367.02	41.72	15.27	183.76	6.72	38.01	367.02	34.08	10.41	125.32	3.95	22.35	563.14
Dec. 1	301.59	39.11	14.74	139.71	10.75	36.88	301.59	31.95	10.05	95.28	6.32	21.68	466.87

Dec. 11	390.44	104.28	33.45	224.50	30.82	44.22	390.44	85.20	22.81	153.11	18.12	26.00	695.68
Dec. 15	379.32	94.52	29.30	228.41	33.44	46.46	379.32	77.23	19.98	155.78	19.66	27.32	679.29
Dec. 17	463.29	101.42	25.53	174.74	40.80	51.51	463.29	82.86	17.41	119.17	23.99	30.29	737.01
Dec. 19	398.49	99.65	25.52	146.24	41.45	47.63	398.49	81.41	17.41	99.73	24.37	28.01	649.42
Dec. 22	335.24	82.13	22.23	109.26	37.18	37.88	335.24	67.10	15.16	74.51	21.86	22.27	536.15
Dec. 29	378.23	124.14	31.82	103.21	48.99	49.35	378.23	101.42	21.70	70.39	28.81	29.02	629.56
Dec. 31	354.71	144.47	32.14	95.00	48.11	46.32	354.71	118.03	21.92	64.79	28.29	27.24	614.98
Jan. 2	383.20	158.02	27.37	90.24	34.38	43.67	383.20	129.10	18.67	61.55	20.22	25.68	638.41
Jan. 5	369.25	140.88	26.61	76.45	38.02	41.51	369.25	115.10	18.15	52.14	22.36	24.41	601.41
Jan. 7	397.08	143.63	29.77	83.82	37.96	41.29	397.08	117.35	20.30	57.16	22.32	24.28	638.49
Jan. 9	325.30	115.43	25.55	57.18	32.43	34.12	325.30	94.31	17.42	39.00	19.07	20.06	515.16
AVERAGE:	383.99	101.91	24.97	140.45	30.60	42.29	383.99	83.26	17.03	95.79	17.99	24.86	622.93
STD.DEV:	53.11	36.94	6.22	57.12	14.55	5.26	53.11	30.18	4.24	38.95	8.56	3.09	80.50

Table B13: Con't.

RUN 4:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	359.99	112.58	7.43	179.35	18.33	37.74	359.99	91.98	5.07	122.31	10.78	22.19	612.32
Jan. 19	392.23	112.62	5.86	219.97	9.89	40.72	392.23	92.01	4.00	150.02	5.82	23.94	668.01
Jan. 22	395.43	134.77	12.06	169.00	6.87	45.86	395.43	110.10	8.22	115.26	4.04	26.97	660.02

Jan. 26	368.78	121.37	0.00	207.52	0.00	47.64	368.78	99.16	0.00	141.53	0.00	28.01	637.48
Jan. 30	325.08	102.32	0.00	186.89	0.00	40.38	325.08	83.59	0.00	127.46	0.00	23.74	559.87
Feb. 3	387.63	117.60	0.00	130.56	0.00	61.19	387.63	96.08	0.00	89.04	0.00	35.98	608.74
Feb. 6	334.12	116.31	0.00	168.00	0.00	50.43	334.12	95.03	0.00	114.57	0.00	29.65	573.37
Feb. 10	335.35	107.08	0.00	158.96	0.00	42.97	335.35	87.49	0.00	108.41	0.00	25.27	556.52
Feb. 12	331.81	90.27	0.00	93.78	0.00	27.99	331.81	73.75	0.00	63.96	0.00	16.46	485.97
Feb. 16	289.14	65.56	2.79	68.51	6.51	17.23	289.14	53.57	1.90	46.72	3.83	10.13	405.29
Feb. 18	276.12	78.51	3.07	71.35	8.28	19.09	276.12	64.15	2.09	48.66	4.87	11.23	407.11
Feb. 20	293.60	83.65	0.00	102.32	7.58	25.83	293.60	68.34	0.00	69.78	4.46	15.19	451.37
Feb. 23	295.17	84.50	2.85	99.49	8.11	33.56	295.17	69.03	1.94	67.85	4.77	19.73	458.50
Feb. 25	306.27	88.54	5.30	109.84	9.51	38.34	306.27	72.34	3.61	74.91	5.59	22.54	485.27
Feb. 27	288.14	96.00	2.77	107.95	8.09	47.86	288.14	78.44	1.89	73.62	4.75	28.14	474.98
AVERAGE:	331.92	100.78	2.81	138.23	5.54	38.46	331.92	82.34	1.91	94.27	3.26	22.61	536.32
STD.DEV:	40.81	18.90	3.56	49.05	5.41	12.06	40.81	15.44	2.43	33.45	3.18	7.09	89.55

Table B13: Con't.

RUN 5:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Mar. 9	98.45	39.65	5.07	12.78	0.00	4.51	98.45	32.40	3.46	8.71	0.00	2.65	145.67
Mar. 13	102.68	47.34	5.21	16.31	0.00	5.86	102.68	38.68	3.55	11.12	0.00	3.45	159.48
Mar. 17	252.44	113.46	9.18	143.23	6.22	42.86	252.44	92.70	6.26	97.68	3.66	25.20	477.93

Mar. 20	148.18	57.45	6.16	71.09	0.00	19.56	148.18	46.93	4.20	48.48	0.00	11.50	259.30
Mar. 24	144.38	54.34	7.10	71.22	0.00	11.92	144.38	44.39	4.85	48.57	0.00	7.01	249.20
Mar. 26	139.26	63.70	6.12	66.46	0.00	11.62	139.26	52.04	4.18	45.32	0.00	6.83	247.64
Mar. 30	142.60	55.55	5.76	61.19	0.00	11.03	142.60	45.39	3.93	41.73	0.00	6.49	240.14
Apr. 1	117.63	47.75	6.71	50.98	2.89	10.57	117.63	39.02	4.58	34.77	1.70	6.22	203.91
Apr. 3	136.71	48.58	7.73	56.59	3.59	12.19	136.71	39.69	5.27	38.60	2.11	7.17	229.54
Apr. 7	148.14	59.71	6.14	63.71	3.41	16.27	148.14	48.78	4.19	43.45	2.00	9.56	256.13
Apr. 10	130.56	49.31	6.01	69.13	3.09	12.74	130.56	40.29	4.10	47.15	1.82	7.49	231.40
Apr. 14	330.91	156.70	7.54	176.65	9.55	87.45	330.91	128.02	5.14	120.48	5.62	51.42	641.58
Apr. 16	227.99	79.96	1.45	107.76	4.47	43.23	227.99	65.33	0.99	73.49	2.63	25.42	395.85
Apr. 18	178.66	220.10	2.08	76.46	2.94	23.62	178.66	179.82	1.42	52.14	1.73	13.89	427.66
Apr. 21	176.99	51.54	3.25	86.13	1.93	18.76	176.99	42.11	2.22	58.74	1.14	11.03	292.22
AVERAGE:	165.04	76.34	5.70	75.31	2.54	22.15	165.04	62.37	3.89	51.36	1.49	13.02	297.18
STD.DEV:	62.20	50.25	2.09	42.15	2.78	21.43	62.20	41.05	1.43	28.75	1.63	12.60	133.29

Table B14: VFA content of effluent B.													
RUN P:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
June 16	239.83	153.26	11.66	21.87	17.88	7.99	239.83	125.22	7.95	14.92	10.51	4.70	403.13
June 19	281.40	208.03	11.08	32.26	16.87	9.04	281.40	169.96	7.55	22.00	9.92	5.32	496.15
June 30	504.91	486.56	10.33	39.24	11.23	9.65	504.91	397.52	7.04	26.76	6.60	5.67	948.51
July 2	495.29	263.37	13.99	35.67	15.40	23.28	495.29	215.17	9.54	24.33	9.06	13.69	767.08
July 14	251.42	185.38	23.32	30.67	34.65	23.93	251.42	151.46	15.91	20.92	20.38	14.07	474.14
July 15	501.05	278.64	22.72	44.12	34.62	29.78	501.05	227.65	15.49	30.09	20.35	17.51	812.14
July 17	413.08	259.35	18.71	42.11	30.16	30.60	413.08	211.89	12.76	28.72	17.73	17.99	702.18
AVERAGE:	383.85	262.09	15.97	35.13	22.97	19.18	383.85	214.12	10.89	23.96	13.51	11.28	657.62
STD.DEV:	122.77	109.03	5.56	7.65	9.85	10.01	122.77	89.07	3.79	5.21	5.79	5.88	202.88

Table B14: Con't.													
RUN 1:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
July 22	494.63	259.99	26.75	6.52	49.41	31.65	494.63	212.41	18.24	4.45	29.05	18.61	777.40
July 24	629.03	327.32	25.82	67.31	41.11	31.33	629.03	267.42	17.61	45.90	24.17	18.42	1002.56
July 29	705.60	403.51	35.30	74.79	45.06	36.90	705.60	329.67	24.07	51.01	26.50	21.70	1158.54
Aug. 2	497.03	346.79	33.14	68.82	59.22	46.99	497.03	283.33	22.60	46.94	34.82	27.63	912.35
Aug. 5	436.99	230.45	19.97	53.68	35.69	24.91	436.99	188.28	13.62	36.61	20.99	14.65	711.13

Aug. 7	422.30	205.07	17.01	40.09	23.78	23.24	422.30	167.54	11.60	27.34	13.98	13.67	656.43
Aug. 12	415.06	161.61	23.47	46.72	35.52	19.03	415.06	132.04	16.01	31.87	20.89	11.19	627.06
Aug. 14	381.34	140.14	21.40	49.93	30.41	19.31	381.34	114.50	14.59	34.05	17.88	11.36	573.72
Aug. 21	380.32	129.52	15.21	37.71	22.85	15.23	380.32	105.82	10.38	25.72	13.44	8.96	544.63
Aug. 25	482.38	164.85	14.53	43.52	24.89	19.44	482.38	134.68	9.91	29.68	14.63	11.43	682.72
Aug. 28	500.55	224.03	17.56	53.82	29.00	27.69	500.55	183.04	11.97	36.70	17.05	16.28	765.60
Sept. 2	404.79	196.64	14.09	32.64	21.44	20.37	404.79	160.66	9.61	22.26	12.61	11.98	621.90
Sept. 5	427.89	219.37	18.70	39.87	27.73	23.58	427.89	179.23	12.76	27.19	16.30	13.87	677.24
Sept. 9	426.56	204.27	14.37	37.49	26.74	22.23	426.56	166.89	9.80	25.57	15.72	13.07	657.62
Sept. 11	393.64	176.19	14.61	32.67	26.26	20.05	393.64	143.94	9.96	22.28	15.44	11.79	597.06
AVERAGE:	466.54	225.98	20.79	45.71	33.27	25.46	466.54	184.63	14.18	31.17	19.56	14.97	731.06
STD.DEV:	92.22	78.56	6.84	17.06	11.03	8.31	92.22	64.18	4.67	11.63	6.48	4.89	171.02

Table B14: Con't.

RUN 2:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Sept. 24	524.10	233.88	18.55	36.01	29.58	23.44	524.10	191.08	12.65	24.56	17.39	13.78	783.56
Sept. 26	423.88	179.94	14.05	21.68	25.11	7.85	423.88	147.01	9.58	14.79	14.77	4.62	614.65
Sept. 29	364.06	166.90	23.45	40.75	43.73	17.43	364.06	136.35	15.99	27.79	25.71	10.25	580.17
Oct. 1	322.40	120.19	19.40	36.15	40.02	12.44	322.40	98.20	13.23	24.65	23.53	7.31	489.32

Oct. 6	368.22	122.75	19.08	22.49	23.79	13.49	368.22	100.28	13.01	15.34	13.99	7.93	518.78
Oct. 9	321.42	133.06	18.43	22.78	22.32	7.15	321.42	108.71	12.57	15.54	13.12	4.20	475.56
Oct. 15	412.51	172.58	28.61	42.07	49.37	18.94	412.51	141.00	19.51	28.69	29.03	11.14	641.89
Oct. 21	384.29	204.63	27.11	34.31	41.84	17.37	384.29	167.18	18.49	23.40	24.60	10.21	628.18
Oct. 24	323.28	175.62	20.72	29.01	35.95	14.16	323.28	143.49	14.13	19.79	21.14	8.32	530.15
Oct. 28	272.73	149.05	16.15	14.08	23.83	9.32	272.73	121.78	11.02	9.60	14.01	5.48	434.61
Oct. 30	248.99	160.06	16.64	11.70	23.14	8.67	248.99	130.77	11.35	7.98	13.61	5.10	417.79
Nov. 4	207.66	134.77	13.27	13.93	18.69	11.23	207.66	110.10	9.05	9.50	10.99	6.61	353.92
Nov. 7	142.59	136.18	15.88	25.27	28.52	15.31	142.59	111.26	10.83	17.23	16.77	9.00	307.69
Nov. 11	101.77	126.87	17.14	18.82	24.88	7.80	101.77	103.65	11.69	12.84	14.63	4.59	249.16
Nov. 13	110.72	112.11	17.09	17.53	24.05	5.97	110.72	91.59	11.65	11.95	14.14	3.51	243.57
AVERAGE:	301.91	155.24	19.04	25.77	30.32	12.70	301.91	126.83	12.98	17.58	17.83	7.47	484.60
STD.DEV:	121.69	34.20	4.39	10.05	9.40	5.08	121.69	27.94	2.99	6.85	5.53	2.99	154.22

Table B14: Con't.

RUN 3:													
DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Nov. 24	169.93	125.99	14.66	7.40	25.33	3.96	169.93	102.93	10.00	5.05	14.90	2.33	305.13
Nov. 26	144.04	107.49	15.25	5.17	21.94	7.44	144.04	87.82	10.40	3.53	12.90	4.38	263.06
Nov. 28	139.98	65.77	14.03	4.67	19.32	5.73	139.98	53.73	9.57	3.18	11.36	3.37	221.20
Dec. 1	122.77	82.49	16.39	8.58	20.06	2.84	122.77	67.39	11.18	5.85	11.80	1.67	220.66

Dec. 11	48.94	96.32	20.96	10.06	17.66	2.75	48.94	78.69	14.29	6.86	10.38	1.62	160.79
Dec. 15	80.67	83.93	18.39	11.06	19.09	2.42	80.67	68.57	12.54	7.54	11.22	1.43	181.97
Dec. 17	124.08	90.04	15.07	10.24	24.40	3.08	124.08	73.56	10.28	6.99	14.35	1.81	231.07
Dec. 19	136.94	76.81	12.81	7.93	22.53	7.82	136.94	62.75	8.73	5.41	13.25	4.60	231.69
Dec. 22	198.52	58.83	12.01	7.52	21.71	5.94	198.52	48.06	8.19	5.13	12.76	3.49	276.16
Dec. 29	241.06	69.67	15.40	11.10	20.50	3.79	241.06	56.92	10.50	7.57	12.05	2.23	330.34
Dec. 31	189.62	40.82	12.28	6.72	17.82	0.00	189.62	33.35	8.37	4.58	10.48	0.00	246.40
Jan. 2	167.87	52.94	8.66	4.33	13.32	4.72	167.87	43.25	5.90	2.95	7.83	2.78	230.58
Jan. 5	176.51	75.53	10.72	5.09	18.08	5.34	176.51	61.71	7.31	3.47	10.63	3.14	262.76
Jan. 7	182.69	80.01	12.53	6.62	20.64	6.89	182.69	65.37	8.54	4.52	12.14	4.05	277.31
Jan. 9	184.10	72.21	12.11	0.00	19.26	7.88	184.10	58.99	8.26	0.00	11.32	4.63	267.30
AVERAGE:	153.85	78.59	14.08	7.10	20.11	4.71	153.85	64.21	9.60	4.84	11.82	2.77	247.09
STD.DEV:	48.09	21.29	3.07	3.00	2.95	2.29	48.09	17.39	2.09	2.04	1.73	1.35	43.74

Table B14: Con't.

RUN 4:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Jan. 16	155.85	57.29	8.56	4.42	9.32	2.30	155.85	46.80	5.84	3.02	5.48	1.35	218.34
Jan. 19	156.20	62.62	8.21	4.78	7.60	2.63	156.20	51.16	5.60	3.26	4.47	1.55	222.23
Jan. 22	246.12	115.42	16.54	11.27	14.59	5.59	246.12	94.30	11.28	7.69	8.58	3.29	371.25

Jan. 26	186.91	68.19	8.44	7.37	10.84	5.35	186.91	55.71	5.75	5.02	6.37	3.15	262.92
Jan. 30	191.89	100.19	4.80	8.50	10.40	8.59	191.89	81.85	3.27	5.80	6.12	5.05	293.99
Feb. 3	171.23	63.86	3.90	0.00	9.07	14.91	171.23	52.18	2.66	0.00	5.34	8.77	240.17
Feb. 6	147.68	81.39	9.79	6.34	12.76	7.17	147.68	66.50	6.68	4.32	7.50	4.22	236.90
Feb. 10	173.24	95.54	11.75	9.75	15.18	5.09	173.24	78.06	8.01	6.65	8.93	2.99	277.87
Feb. 12	171.31	83.67	6.18	3.52	8.12	6.85	171.31	68.36	4.22	2.40	4.77	4.03	255.09
Feb. 16	192.05	117.83	6.60	5.39	8.36	3.81	192.05	96.27	4.50	3.67	4.91	2.24	303.64
Feb. 18	181.38	139.58	6.50	3.54	8.88	2.51	181.38	114.04	4.43	2.42	5.22	1.48	308.97
Feb. 20	142.62	127.09	7.47	4.71	8.48	2.77	142.62	103.83	5.09	3.21	4.99	1.63	261.38
Feb. 23	197.98	139.34	7.38	5.45	10.37	4.12	197.98	113.84	5.03	3.72	6.10	2.42	329.10
Feb. 25	146.21	103.82	4.89	1.26	8.05	9.20	146.21	84.82	3.33	0.86	4.73	5.41	245.36
Feb. 27	114.94	99.92	3.38	0.00	4.70	7.30	114.94	81.63	2.30	0.00	2.77	4.29	205.93
AVERAGE:	171.71	97.05	7.63	5.09	9.78	5.88	171.71	79.29	5.20	3.47	5.75	3.46	268.88
STD.DEV:	30.66	27.33	3.33	3.28	2.73	3.35	30.66	22.33	2.27	2.24	1.61	1.97	45.52

Table B14: Con't.

RUN 5:

DATE	VFA CONCENTRATION						VFA CONCENTRATION AS ACETIC ACID						TOTAL VFA
	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	acetic (mg/L)	propionic (mg/L)	i-butyric (mg/L)	n-butyric (mg/L)	i-valeric (mg/L)	n-valeric (mg/L)	(mg/L as acetic acid)
Mar. 9	59.93	20.87	0.00	0.00	3.99	0.00	59.93	17.05	0.00	0.00	2.34	0.00	79.32
Mar. 13	30.56	18.65	0.00	0.00	1.39	0.84	30.56	15.24	0.00	0.00	0.81	0.49	47.10
Mar. 17	79.47	94.50	4.16	0.00	5.19	2.58	79.47	77.20	2.83	0.00	3.05	1.52	164.07

Mar. 20	40.98	28.22	0.00	0.00	2.69	1.99	40.98	23.06	0.00	0.00	1.58	1.17	66.80
Mar. 24	42.80	37.05	0.00	0.00	3.19	1.63	42.80	30.27	0.00	0.00	1.87	0.96	75.90
Mar. 26	31.21	24.32	0.00	0.00	2.19	0.62	31.21	19.87	0.00	0.00	1.29	0.36	52.73
Mar. 30	72.59	41.35	3.64	0.00	5.10	0.00	72.59	33.78	2.49	0.00	3.00	0.00	111.85
Apr. 1	57.34	28.93	2.37	0.00	3.63	0.78	57.34	23.64	1.61	0.00	2.13	0.46	85.19
Apr. 3	63.57	39.94	4.20	0.91	4.67	1.69	63.57	32.63	2.87	0.62	2.75	1.00	103.43
Apr. 7	67.69	40.25	1.25	0.00	3.72	1.20	67.69	32.89	0.85	0.00	2.19	0.71	104.32
Apr. 10	53.33	27.99	0.50	0.00	3.45	0.66	53.33	22.87	0.34	0.00	2.03	0.39	78.95
Apr. 14	167.74	184.44	4.60	3.03	7.83	3.05	167.74	150.68	3.14	2.07	4.60	1.79	330.02
Apr. 16	99.73	53.07	2.21	0.77	5.26	0.42	99.73	43.36	1.51	0.53	3.09	0.24	148.46
Apr. 18	41.92	3.57	2.16	0.00	2.51	0.78	41.92	2.92	1.47	0.00	1.47	0.46	48.24
Apr. 21	39.52	3.40	0.00	0.00	1.82	0.21	39.52	2.78	0.00	0.00	1.07	0.12	43.50
AVERAGE:	63.23	43.10	1.67	0.31	3.77	1.10	63.23	35.22	1.14	0.21	2.22	0.64	102.66
STD.DEV:	34.63	44.73	1.78	0.81	1.66	0.92	34.63	36.54	1.21	0.55	0.98	0.54	72.26

Table B15: COD content of influent A.

RUN P:			RUN 2:			RUN 4:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD (mg/L)	TCOD (mg/L)		SCOD (mg/L)	TCOD (mg/L)		SCOD (mg/L)	TCOD (mg/L)
June 16	250.0		Sept. 24	502.5		Jan. 16	450.0	
June 19	625.0		Sept. 26	600.0		Jan. 19	300.0	
June 30	375.0		Sept. 29	555.0	5875.0	Jan. 22	290.0	5937.5
July 2	187.5	6750.0	Oct. 1	615.0		Jan. 26	260.0	
July 14	440.0		Oct. 6	600.0		Jan. 30	240.0	
July 15	200.0		Oct. 9	690.0	7125.0	Feb. 3	260.0	6625.0
July 17	250.0	6150.0	Oct. 15	525.0		Feb. 6	330.0	
			Oct. 21	840.0		Feb. 10	370.0	
AVG:	332.5	6450.0	Oct. 24	720.0	6600.0	Feb. 12	400.0	7187.5
STD.DEV:	158.7	424.3	Oct. 28	180.0		Feb. 16	210.0	
			Oct. 30	165.0		Feb. 18	140.0	
			Nov. 4	140.0	6125.0	Feb. 20	210.0	5312.5
			Nov. 7	175.0		Feb. 23	260.0	
			Nov. 11	380.0		Feb. 25	140.0	
			Nov. 13	540.0	4875.0	Feb. 27	80.0	5500.0
			AVG:	481.8	6120.0	AVG:	262.7	6112.5
			STD.DEV:	223.3	844.2	STD.DEV:	100.6	784.9

RUN 1:			RUN 3:			RUN 5:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD (mg/L)	TCOD (mg/L)		SCOD (mg/L)	TCOD (mg/L)		SCOD (mg/L)	TCOD (mg/L)
July 22	262.5		Nov. 24	615.0		Mar. 9	50.0	
July 24	420.0		Nov. 26	675.0		Mar. 13	60.0	
July 29	330.0		Nov. 28	730.0	6750.0	Mar. 17	120.0	5312.5
Aug. 2	200.0		Dec. 1	590.0		Mar. 20	105.0	
Aug. 5	390.0		Dec. 11	945.0		Mar. 24	137.5	
Aug. 7	330.0	6000.0	Dec. 15	697.5	7125.0	Mar. 26	80.0	4300.0
Aug. 12	540.0		Dec. 17	870.0		Mar. 30	125.0	
Aug. 14	630.0	7500.0	Dec. 19	570.0		Apr. 1	135.0	
Aug. 21	555.0		Dec. 22	472.5	6500.0	Apr. 3	165.0	3800.0
Aug. 25	660.0	6875.0	Dec. 29	622.5		Apr. 7	115.0	
Aug. 28	450.0		Dec. 31	682.5		Apr. 10	87.5	
Sept. 2	502.5	6750.0	Jan. 2	840.0	6125.0	Apr. 14	190.0	3675.0
Sept. 5	465.0		Jan. 5	645.0		Apr. 16	100.0	
Sept. 9	405.0		Jan. 7	525.0		Apr. 18	187.5	
Sept. 11	412.5	7750.0	Jan. 9	420.0	6562.5	Apr. 21	150.0	3675.0
AVG:	436.8	6975.0	AVG:	660.0	6612.5	AVG:	120.5	4152.5
STD.DEV:	128.3	686.9	STD.DEV:	144.5	365.5	STD.DEV:	42.0	697.8

Table B16: COD content of influent B.

RUN P:			RUN 2:			RUN 4:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
June 16	400.0		Sept. 24	420.0		Jan. 16	N/A	
June 19	2750.0		Sept. 26	450.0		Jan. 19	250.0	
June 30	475.0		Sept. 29	480.0	7875.0	Jan. 22	600.0	7625.0
July 2	275.0	5250.0	Oct. 1	577.5		Jan. 26	220.0	
July 14	440.0		Oct. 6	675.0		Jan. 30	260.0	
July 15	300.0		Oct. 9	640.0	6875.0	Feb. 3	190.0	6875.0
July 17	300.0	6000.0	Oct. 15	380.0		Feb. 6	150.0	
			Oct. 21	550.0		Feb. 10	275.0	
AVG:	705.7	5625.0	Oct. 24	420.0	7200.0	Feb. 12	170.0	5375.0
STD.DEV:	904.7	530.3	Oct. 28	515.0		Feb. 16	260.0	
			Oct. 30	285.0		Feb. 18	220.0	
			Nov. 4	275.0	6500.0	Feb. 20	355.0	6000.0
			Nov. 7	185.0		Feb. 23	340.0	
			Nov. 11	355.0		Feb. 25	225.0	
			Nov. 13	140.0	6875.0	Feb. 27	267.5	6125.0
			AVG:	423.2	7065.0	AVG:	270.2	6400.0
			STD.DEV:	157.5	516.2	STD.DEV:	110.8	867.8

RUN 1:			RUN 3:			RUN 5:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
July 22	450.0		Nov. 24	235.0		Mar. 9	165.0	
July 24	690.0		Nov. 26	245.0		Mar. 13	150.0	
July 29	555.0		Nov. 28	175.0	6375.0	Mar. 17	165.0	4750.0
Aug. 2	360.0		Dec. 1	425.0		Mar. 20	135.0	
Aug. 5	450.0		Dec. 11	262.5		Mar. 24	155.0	
Aug. 7	435.0	5400.0	Dec. 15	262.5	6000.0	Mar. 26	120.0	4100.0
Aug. 12	570.0		Dec. 17	352.5		Mar. 30	205.0	
Aug. 14	487.5	6750.0	Dec. 19	450.0		Apr. 1	155.0	
Aug. 21	480.0		Dec. 22	330.0	6500.0	Apr. 3	325.0	3600.0
Aug. 25	555.0	6250.0	Dec. 29	160.0		Apr. 7	137.5	
Aug. 28	450.0		Dec. 31	380.0		Apr. 10	160.0	
Sept. 2	525.0	6000.0	Jan. 2	380.0	5750.0	Apr. 14	300.0	3975.0
Sept. 5	622.5		Jan. 5	575.0		Apr. 16	215.0	
Sept. 9	510.0		Jan. 7	425.0		Apr. 18	125.0	
Sept. 11	465.0	6625.0	Jan. 9	420.0	6250.0	Apr. 21	150.0	4650.0
AVG:	507.0	6205.0	AVG:	338.5	6175.0	AVG:	177.5	4215.0
STD.DEV:	82.4	539.8	STD.DEV:	114.4	301.0	STD.DEV:	60.7	480.8

Table B17: COD content of reactor A.						
RUN P:						
DATE	SCOD CONC.			TCOD CONC.		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
June 16	800.0	250.0	550.0			
June 19	1300.0	625.0	675.0			
June 30	1187.5	375.0	812.5			
July 2	950.0	187.5	762.5	16250.0	6750.0	9500.0
July 14	1250.0	440.0	810.0			
July 15	1125.0	200.0	925.0			
July 17	1200.0	250.0	950.0	40000.0	6150.0	33850.0
AVERAGE:	1116.1	332.5	783.6	28125.0	6450.0	21675.0
STD.DEV:	178.6	158.7	139.1	16793.8	424.3	17218.1

Table B17: Con't.						
RUN 1:						
DATE	SCOD CONC.			TCOD CONC.		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 22	1575.0	262.5	1312.5			
July 24	1650.0	420.0	1230.0			
July 29	1950.0	330.0	1620.0			
Aug. 2	1650.0	200.0	1450.0			
Aug. 5	1950.0	390.0	1560.0			
Aug. 7	1800.0	330.0	1470.0	24600.0	6000.0	18600.0
Aug. 12	1687.5	540.0	1147.5			
Aug. 14	1800.0	630.0	1170.0	18000.0	7500.0	10500.0
Aug. 21	1850.0	550.0	1300.0			
Aug. 25	2125.0	660.0	1465.0	23437.5	6875.0	16562.5
Aug. 28	1875.0	450.0	1425.0			
Sept. 2	1500.0	502.5	997.5	24750.0	6750.0	18000.0
Sept. 5	1500.0	465.0	1035.0			
Sept. 9	1825.0	405.0	1420.0			
Sept. 11	1800.0	412.5	1387.5	26625.0	7750.0	18875.0
AVERAGE:	1769.2	436.5	1332.7	23482.5	6975.0	16507.5
STD.DEV:	175.9	128.0	184.6	3270.7	686.9	3475.1

Table B17: Con't.						
RUN 2:						
DATE	SCOD CONC.			TCOD CONC.		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Sept. 24	1000.0	502.5	497.5			
Sept. 26	1150.0	600.0	550.0			
Sept. 29	975.0	555.0	420.0	11250.0	5875.0	5375.0

Oct. 1	1025.0	615.0	410.0			
Oct. 6	1275.0	600.0	675.0			
Oct. 9	1160.0	690.0	470.0	10875.0	7125.0	3750.0
Oct. 15	920.0	525.0	395.0			
Oct. 21	1260.0	840.0	420.0			
Oct. 24	1120.0	720.0	400.0	11625.0	6600.0	5025.0
Oct. 28	1080.0	180.0	900.0			
Oct. 30	1170.0	165.0	1005.0			
Nov. 4	810.0	140.0	670.0	7150.0	6125.0	1025.0
Nov. 7	810.0	175.0	635.0			
Nov. 11	1350.0	380.0	970.0			
Nov. 13	1725.0	540.0	1185.0	10725.0	4875.0	5850.0
AVERAGE:	1122.0	481.8	640.2	10325.0	6120.0	4205.0
STD.DEV:	230.8	223.3	258.2	1808.9	844.2	1940.8

Table B17: Con't.

RUN 3:

DATE	SCOD CONC.			TCOD CONC.		
	REACTOR (mg/L)	INFLUENT (mg/L)	NET (mg/L)	REACTOR (mg/L)	INFLUENT (mg/L)	NET (mg/L)
Nov. 24	1425.0	615.0	810.0			
Nov. 26	1290.0	675.0	615.0			
Nov. 28	1455.0	730.0	725.0	11050.0	6750.0	4300.0
Dec. 1	1230.0	590.0	640.0			
Dec. 11	1575.0	945.0	630.0			
Dec. 15	1440.0	697.5	742.5	8937.5	7125.0	1812.5
Dec. 17	1350.0	870.0	480.0			
Dec. 19	1425.0	570.0	855.0			
Dec. 22	1125.0	472.5	652.5	8775.0	6500.0	2275.0
Dec. 29	1275.0	622.5	652.5			
Dec. 31	1260.0	682.5	577.5			
Jan. 2	1275.0	840.0	435.0	7800.0	6125.0	1675.0
Jan. 5	1140.0	645.0	495.0			
Jan. 7	1140.0	525.0	615.0			
Jan. 9	1125.0	420.0	705.0	11375.0	6562.5	4812.5
AVERAGE:	1302.0	660.0	642.0	9587.5	6612.5	2975.0
STD.DEV:	139.7	144.5	116.9	1550.2	365.5	1471.7

Table B17: Con't.

RUN 4:

DATE	SCOD CONC.			TCOD CONC.		
	REACTOR (mg/L)	INFLUENT (mg/L)	NET (mg/L)	REACTOR (mg/L)	INFLUENT (mg/L)	NET (mg/L)
Jan. 16	1350.0	450.0	900.0			
Jan. 19	1200.0	300.0	900.0			
Jan. 22	1230.0	290.0	940.0	14700.0	5937.5	8762.5
Jan. 26	1050.0	260.0	790.0			

Jan. 30	990.0	240.0	750.0			
Feb. 3	1125.0	260.0	865.0	23100.0	6625.0	16475.0
Feb. 6	1200.0	330.0	870.0			
Feb. 10	1110.0	370.0	740.0			
Feb. 12	840.0	400.0	440.0	24600.0	7187.5	17412.5
Feb. 16	825.0	210.0	615.0			
Feb. 18	840.0	140.0	700.0			
Feb. 20	840.0	210.0	630.0	24750.0	5312.5	19437.5
Feb. 23	930.0	260.0	670.0			
Feb. 25	900.0	140.0	760.0			
Feb. 27	990.0	80.0	910.0	24300.0	5500.0	18800.0
AVERAGE:	1028.0	262.7	765.3	22290.0	6112.5	16177.5
STD.DEV:	168.3	100.6	138.9	4292.2	784.9	4304.1

Table B17: Con't.

RUN 5:						
DATE	SCOD CONC.			TCOD CONC.		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mar. 9	465.0	50.0	415.0			
Mar. 13	420.0	60.0	360.0			
Mar. 17	880.0	120.0	760.0	24600.0	5312.5	19287.5
Mar. 20	480.0	105.0	375.0			
Mar. 24	550.0	137.5	412.5			
Mar. 26	480.0	80.0	400.0	21000.0	4300.0	16700.0
Mar. 30	480.0	125.0	355.0			
Apr. 1	555.0	135.0	420.0			
Apr. 3	585.0	165.0	420.0	19800.0	3800.0	16000.0
Apr. 7	487.5	115.0	372.5			
Apr. 10	465.0	87.5	377.5			
Apr. 14	1125.0	190.0	935.0	15000.0	3675.0	11325.0
Apr. 16	645.0	100.0	545.0			
Apr. 18	750.0	187.5	562.5			
Apr. 21	570.0	150.0	420.0	18600.0	3675.0	14925.0
AVERAGE:	595.8	120.5	475.3	19800.0	4152.5	15647.5
STD.DEV:	190.6	42.0	165.9	3498.6	697.8	2902.1

Table B18: COD content of reactor B.						
RUN P:						
DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
June 16	1200.0	400.0	800.0			
June 19	1450.0	2750.0				
June 30	1125.0	475.0	650.0			
July 2	1250.0	275.0	975.0	28750.0	5250.0	23500.0
July 14	1275.0	440.0	835.0			
July 15	1300.0	300.0	1000.0			
July 17	1400.0	300.0	1100.0	22250.0	6000.0	16250.0
AVERAGE:	1285.7	705.7	893.3	25500.0	5625.0	19875.0
STD.DEV:	111.7	904.7	162.5	4596.2	530.3	5126.5

Table B18: Con't.						
RUN 1:						
DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 22	1800.0	450.0	1350.0			
July 24	1650.0	690.0	960.0			
July 29	3225.0	555.0	2670.0			
Aug. 2	2100.0	360.0	1740.0			
Aug. 5	1650.0	450.0	1200.0			
Aug. 7	1200.0	435.0	765.0	28500.0	5400.0	23100.0
Aug. 12	1275.0	570.0	705.0			
Aug. 14	1275.0	487.5	787.5	24000.0	6750.0	17250.0
Aug. 21	1125.0	480.0	645.0			
Aug. 25	1100.0	555.0	545.0	21750.0	6250.0	15500.0
Aug. 28	1375.0	450.0	925.0			
Sept. 2	1000.0	525.0	475.0	23250.0	6000.0	17250.0
Sept. 5	1175.0	622.5	552.5			
Sept. 9	1375.0	510.0	865.0			
Sept. 11	950.0	465.0	485.0	19875.0	6625.0	13250.0
AVERAGE:	1485.0	507.0	978.0	23475.0	6205.0	17270.0
STD.DEV:	576.2	82.4	584.2	3221.5	539.8	3649.8

Table B18: Con't.						
RUN 2:						
DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Sept. 24	1000.0	420.0	580.0			
Sept. 26	1150.0	450.0	700.0			
Sept. 29	950.0	480.0	470.0	18750.0	7875.0	10875.0

Oct. 1	900.0	577.5	322.5			
Oct. 6	825.0	675.0	150.0			
Oct. 9	1120.0	640.0	480.0	23250.0	6875.0	16375.0
Oct. 15	2460.0	380.0	2080.0			
Oct. 21	1120.0	550.0	570.0			
Oct. 24	820.0	420.0	400.0	19125.0	7200.0	11925.0
Oct. 28	840.0	515.0	325.0			
Oct. 30	735.0	285.0	450.0			
Nov. 4	705.0	275.0	430.0	18850.0	6500.0	12350.0
Nov. 7	855.0	185.0	670.0			
Nov. 11	630.0	355.0	275.0			
Nov. 13	615.0	140.0	475.0	17875.0	6875.0	11000.0
AVERAGE:	981.7	423.2	558.5	19570.0	7065.0	12505.0
STD.DEV:	442.6	157.5	445.6	2109.8	516.2	2250.5

Table B18: Con't.

RUN 3:

DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Nov. 24	720.0	235.0	485.0			
Nov. 26	637.5	245.0	392.5			
Nov. 28	892.5	175.0	717.5	15600.0	6375.0	9225.0
Dec. 1	630.0	425.0	205.0			
Dec. 11	450.0	262.5	187.5			
Dec. 15	637.5	262.5	375.0	11375.0	6000.0	5375.0
Dec. 17	690.0	352.5	337.5			
Dec. 19	615.0	450.0	165.0			
Dec. 22	600.0	330.0	270.0	12187.5	6500.0	5687.5
Dec. 29	675.0	160.0	515.0			
Dec. 31	540.0	380.0	160.0			
Jan. 2	570.0	380.0	190.0	11375.0	5750.0	5625.0
Jan. 5	540.0	575.0	-35.0			
Jan. 7	570.0	425.0	145.0			
Jan. 9	570.0	420.0	150.0	11050.0	6250.0	4800.0
AVERAGE:	622.5	338.5	306.8	12317.5	6175.0	6142.5
STD.DEV:	100.9	114.4	172.9	1882.5	301.0	1758.4

Table B18: Con't.

RUN 4:

DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Jan. 16	555.0	N/A	N/A			
Jan. 19	N/A	250.0	N/A			
Jan. 22	750.0	600.0	150.0	18900.0	7625.0	11275.0
Jan. 26	585.0	220.0	365.0			

Jan. 30	510.0	260.0	250.0			
Feb. 3	525.0	190.0	335.0	27750.0	6875.0	20875.0
Feb. 6	487.5	150.0	337.5			
Feb. 10	525.0	275.0	250.0			
Feb. 12	600.0	170.0	430.0	21750.0	5375.0	16375.0
Feb. 16	420.0	260.0	160.0			
Feb. 18	435.0	220.0	215.0			
Feb. 20	420.0	355.0	65.0	24000.0	6000.0	18000.0
Feb. 23	870.0	340.0	530.0			
Feb. 25	555.0	225.0	330.0			
Feb. 27	375.0	267.5	107.5	19200.0	6125.0	13075.0
AVERAGE:	543.8	270.2	271.2	22320.0	6400.0	15920.0
STD.DEV:	133.0	110.8	133.3	3676.4	867.8	3832.6

Table B18: Con't.

RUN 5:						
DATE	SCOD CONC.			TCOD		
	REACTOR	INFLUENT	NET	REACTOR	INFLUENT	NET
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mar. 9	262.5	165.0	97.5			
Mar. 13	262.5	150.0	112.5			
Mar. 17	325.0	165.0	160.0	26250.0	4750.0	21500.0
Mar. 20	190.0	135.0	55.0			
Mar. 24	310.0	155.0	155.0			
Mar. 26	180.0	120.0	60.0	27900.0	4100.0	23800.0
Mar. 30	270.0	205.0	65.0			
Apr. 1	275.0	155.0	120.0			
Apr. 3	390.0	325.0	65.0	23250.0	3600.0	19650.0
Apr. 7	312.5	137.5	175.0			
Apr. 10	275.0	160.0	115.0			
Apr. 14	620.0	300.0	320.0	15750.0	3975.0	11775.0
Apr. 16	350.0	215.0	135.0			
Apr. 18	270.0	125.0	145.0			
Apr. 21	245.0	150.0	95.0	19200.0	4650.0	14550.0
AVERAGE:	302.5	177.5	125.0	22470.0	4215.0	18255.0
STD.DEV:	103.2	60.7	66.2	5005.8	480.8	4973.4

Table B19: COD content of effluent A.

RUN P:			RUN 2:			RUN 4:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
June 16	1250.0		Sept. 24	1140.0		Jan. 16	1200.0	
June 19	1250.0		Sept. 26	1000.0		Jan. 19	1440.0	
June 30	1125.0		Sept. 29	820.0	2100.0	Jan. 22	1170.0	3950.0
July 2	1000.0	7500.0	Oct. 1	920.0		Jan. 26	1110.0	
July 14	1375.0		Oct. 6	1240.0		Jan. 30	975.0	
July 15	1350.0		Oct. 9	1245.0	1875.0	Feb. 3	960.0	2400.0
July 17	1200.0	2400.0	Oct. 15	1080.0		Feb. 6	1125.0	
			Oct. 21	1065.0		Feb. 10	1110.0	
AVG:	1221.4	4950.0	Oct. 24	1155.0	1875.0	Feb. 12	900.0	2550.0
STD.DEV:	129.4	3606.2	Oct. 28	915.0		Feb. 16	810.0	
			Oct. 30	840.0		Feb. 18	780.0	
			Nov. 4	795.0	1150.0	Feb. 20	825.0	2000.0
			Nov. 7	855.0		Feb. 23	840.0	
			Nov. 11	1125.0		Feb. 25	840.0	
			Nov. 13	1245.0	1875.0	Feb. 27	900.0	1875.0
			AVG:	1029.3	1775.0	AVG:	999.0	2555.0
			STD.DEV:	162.4	362.7	STD.DEV:	187.2	827.7

RUN 1:			RUN 3:			RUN 5:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
July 22	1300.0		Nov. 24	1560.0		Mar. 9	225.0	
July 24	1700.0		Nov. 26	1245.0		Mar. 13	375.0	
July 29	1875.0		Nov. 28	1275.0	2100.0	Mar. 17	940.0	1625.0
Aug. 2	2600.0		Dec. 1	1125.0		Mar. 20	460.0	
Aug. 5	1750.0		Dec. 11	1530.0		Mar. 24	460.0	
Aug. 7	1750.0	3250.0	Dec. 15	1410.0	2250.0	Mar. 26	480.0	1100.0
Aug. 12	1625.0		Dec. 17	1410.0		Mar. 30	450.0	
Aug. 14	1700.0	3375.0	Dec. 19	1650.0		Apr. 1	570.0	
Aug. 21	1800.0		Dec. 22	1125.0	2200.0	Apr. 3	480.0	1125.0
Aug. 25	1800.0	3200.0	Dec. 29	1560.0		Apr. 7	480.0	
Aug. 28	1840.0		Dec. 31	1200.0		Apr. 10	450.0	
Sept. 2	1680.0	3400.0	Jan. 2	1440.0	1750.0	Apr. 14	1320.0	2135.0
Sept. 5	1680.0		Jan. 5	1140.0		Apr. 16	720.0	
Sept. 9	1680.0		Jan. 7	1050.0		Apr. 18	645.0	
Sept. 11	1720.0	3600.0	Jan. 9	1050.0	1625.0	Apr. 21	495.0	1137.5
AVG:	1766.7	3365.0	AVG:	1318.0	1985.0	AVG:	570.0	1424.5
STD.DEV:	265.4	155.7	STD.DEV:	202.7	280.4	STD.DEV:	262.9	453.4

Table B20: COD content of effluent B.

RUN P:			RUN 2:			RUN 4:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
June 16	900.0		Sept. 24	1400.0		Jan. 16	N/A	
June 19	1400.0		Sept. 26	1200.0		Jan. 19	450.0	
June 30	1700.0		Sept. 29	1220.0	3000.0	Jan. 22	637.5	2950.0
July 2	1450.0	3750.0	Oct. 1	1100.0		Jan. 26	555.0	
July 14	1350.0		Oct. 6	1020.0		Jan. 30	765.0	
July 15	1375.0		Oct. 9	1080.0	2625.0	Feb. 3	480.0	3900.0
July 17	1350.0	4200.0	Oct. 15	1140.0		Feb. 6	510.0	
			Oct. 21	1245.0		Feb. 10	675.0	
AVG:	1360.7	3975.0	Oct. 24	915.0	3150.0	Feb. 12	945.0	3375.0
STD.DEV:	237.1	318.2	Oct. 28	930.0		Feb. 16	562.5	
			Oct. 30	780.0		Feb. 18	585.0	
			Nov. 4	810.0	2500.0	Feb. 20	465.0	2625.0
			Nov. 7	915.0		Feb. 23	630.0	
			Nov. 11	600.0		Feb. 25	450.0	
			Nov. 13	540.0	2600.0	Feb. 27	540.0	2250.0
			AVG:	993.0	2775.0	AVG:	589.3	3020.0
			STD.DEV:	241.9	282.8	STD.DEV:	137.4	643.1

RUN 1:			RUN 3:			RUN 5:		
DATE	CONC.		DATE	CONC.		DATE	CONC.	
	SCOD	TCOD		SCOD	TCOD		SCOD	TCOD
	(mg/L)	(mg/L)		(mg/L)	(mg/L)		(mg/L)	(mg/L)
July 22	1700.0		Nov. 24	660.0		Mar. 9	135.0	
July 24	1800.0		Nov. 26	630.0		Mar. 13	165.0	
July 29	2150.0		Nov. 28	787.5	2000.0	Mar. 17	350.0	1625.0
Aug. 2	1800.0		Dec. 1	600.0		Mar. 20	160.0	
Aug. 5	1600.0		Dec. 11	450.0		Mar. 24	410.0	
Aug. 7	1350.0	3250.0	Dec. 15	480.0	2000.0	Mar. 26	130.0	1550.0
Aug. 12	1375.0		Dec. 17	562.5		Mar. 30	225.0	
Aug. 14	1250.0	4000.0	Dec. 19	540.0		Apr. 1	190.0	
Aug. 21	1160.0		Dec. 22	540.0	1700.0	Apr. 3	310.0	1450.0
Aug. 25	1680.0	5000.0	Dec. 29	720.0		Apr. 7	305.0	
Aug. 28	1400.0		Dec. 31	487.5		Apr. 10	235.0	
Sept. 2	1300.0	4000.0	Jan. 2	420.0	1875.0	Apr. 14	737.5	2030.0
Sept. 5	1400.0		Jan. 5	510.0		Apr. 16	450.0	
Sept. 9	1400.0		Jan. 7	600.0		Apr. 18	275.0	
Sept. 11	1100.0	5325.0	Jan. 9	465.0	2375.0	Apr. 21	225.0	1330.0
AVG:	1497.7	4315.0	AVG:	563.5	1990.0	AVG:	286.8	1597.0
STD.DEV:	284.2	839.9	STD.DEV:	103.8	247.9	STD.DEV:	157.7	266.2

Table B21: Ammonia and TKN content of influent A.								
RUN P:			RUN 2:			RUN 4:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
July 4	38.63	243.43	Oct. 2	14.15	180.82	Feb. 10	8.70	126.96
July 18	50.81	339.76	Oct. 14	16.16	200.68	Feb. 17	1.85	130.00
AVERAGE:	44.72	291.59	Nov. 3	12.10	164.40	Feb. 26	0.42	105.11
STD.DEV:	8.61	68.12						
			Nov. 9	8.51	173.16	Feb. 28	6.94	101.96
			Nov. 14	7.95	140.92	Mar. 2	0.86	142.13
			AVERAGE:	11.77	172.00	AVERAGE:	3.75	121.23
			STD.DEV:	3.55	21.94	STD.DEV:	3.80	17.16
RUN 1:			RUN 3:			RUN 5:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
Aug. 18	29.56	131.28	Dec. 23	6.86	169.59	Apr. 2	14.23	107.86
Aug. 30	13.24	129.18	Dec. 31	15.73	155.09	Apr. 8	5.28	75.31
Sept. 4	11.10	80.17	Jan. 4	7.23	63.85	Apr. 15	6.63	86.49
Sept. 8	7.71	152.33	Jan. 7	3.61	170.93	Apr.17	0.14	87.90
Sept. 15	10.13	137.41	Jan. 8	3.61	187.40	Apr. 22	0.01	114.95
AVERAGE:	14.35	126.08	AVERAGE:	7.41	149.37	AVERAGE:	5.26	94.50
STD.DEV:	8.73	27.21	STD.DEV:	4.96	49.16	STD.DEV:	5.83	16.38

Table B22: Ammonia and TKN content of influent B.								
RUN P:			RUN 2:			RUN 4:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
July 4	37.30	270.05	Oct. 2	51.98	250.70	Feb. 10	37.90	204.59
July 18	49.20	354.77	Oct. 14	49.44	289.60	Feb. 17	20.23	238.00
AVERAGE:	43.25	312.41	Nov. 3	25.53	245.76	Feb. 26	15.12	164.68
STD.DEV:	8.41	59.90						
			Nov. 9	25.01	247.67	Feb. 28	24.13	156.68
			Nov. 14	27.25	264.33	Mar. 2	22.93	176.47
			AVERAG	35.84	259.61	AVERAG	24.06	188.08
			STD.DEV:	13.63	18.27	STD.DEV:	8.48	33.29
RUN 1:			RUN 3:			RUN 5:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
Aug. 18	50.63	201.23	Dec. 23	39.37	227.23	Apr. 2	36.71	173.58
Aug. 30	49.71	206.15	Dec. 31	50.96	234.69	Apr. 8	19.88	143.69
Sept. 4	48.23	205.29	Jan. 4	34.31	111.57	Apr. 15	19.74	167.30
Sept. 8	41.60	240.05	Jan. 7	25.28	232.78	Apr.17	7.94	191.32
Sept. 15	43.92	220.61	Jan. 8	23.49	237.03	Apr. 22	4.67	167.56
AVERAGE:	46.82	214.67	AVERAG	34.68	208.66	AVERAG	17.79	168.69
STD.DEV:	3.89	15.97	STD.DEV:	11.19	54.40	STD.DEV:	12.60	17.06

Table B23: Ammonia and TKN content of reactor A.

RUN P:

DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	INFLUENT CONC. NH_3-N (mg/L)	INFLUENT CONC. TKN (mg/L)	NET CONC. NH_3-N (mg/L)	NET CONC. TKN (mg/L)
July 4	57.84	508.15	38.63	243.43	19.21	264.72
July 18	64.45	726.60	50.81	339.76	13.64	386.84
AVERAGE:	61.15	617.38	44.72	291.60	16.43	325.78
STD.DEV:	4.68	154.47	8.61	68.12	3.94	86.35

Table B23: Con't.

RUN 1:

DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	INFLUENT CONC. NH_3-N (mg/L)	INFLUENT CONC. TKN (mg/L)	NET CONC. NH_3-N (mg/L)	NET CONC. TKN (mg/L)
Aug. 18	3.66	498.93	29.56	131.28	-25.90	367.65
Aug. 30	2.97	426.24	13.24	129.18	-10.27	297.06
Sept. 4	2.41	405.27	11.10	80.17	-8.69	325.10
Sept. 8	4.02	481.33	7.71	152.33	-3.69	329.00
Sept. 15	4.21	408.42	10.13	137.41	-5.92	271.01
AVERAGE:	3.45	444.04	14.35	126.07	-10.89	317.96
STD.DEV:	0.75	43.28	8.73	27.21	8.76	36.34

Table B23: Con't.

RUN 2:

DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	INFLUENT CONC. NH_3-N (mg/L)	INFLUENT CONC. TKN (mg/L)	NET CONC. NH_3-N (mg/L)	NET CONC. TKN (mg/L)
Oct. 2	8.08	283.48	14.15	180.82	-6.07	102.66
Oct. 14	18.84	326.98	16.16	200.68	2.68	126.30
Nov. 3	20.62	301.23	12.10	164.40	8.52	136.83
Nov. 9	14.35	289.65	8.51	173.16	5.84	116.49

Nov. 14	9.86	299.97	7.95	140.92	1.91	159.05
AVERAGE:	14.35	300.26	11.77	172.00	2.58	128.27
STD.DEV:	5.45	16.65	3.54	21.94	5.50	21.33

Table B23: Con't.

RUN 3:

DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Dec. 23	41.00	344.33	6.86	169.59	34.14	174.74
Dec. 31	61.63	341.33	15.73	155.09	45.90	186.24
Jan. 4	50.20	221.02	7.23	63.85	42.97	157.17
Jan. 7	51.75	276.77	3.61	170.93	48.14	105.84
Jan. 8	50.05	295.29	3.61	187.40	46.44	107.89
AVERAGE:	50.93	295.75	7.41	149.37	43.52	146.38
STD.DEV:	7.33	50.95	4.96	49.16	5.57	37.53

Table B23: Con't.

RUN 4:

DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Feb. 10	2.45	494.08	8.70	126.96	-6.25	367.12
Feb. 17	3.36	480.00	1.85	130.00	1.51	350.00
Feb. 26	0.64	388.56	0.42	105.11	0.22	283.45
Feb. 28	2.44	375.58	6.94	101.96	-4.51	273.62
Mar. 2	1.42	374.90	0.86	142.13	0.56	232.78
AVERAGE:	2.06	422.62	3.75	121.23	-1.69	301.39
STD.DEV:	1.05	59.26	3.80	17.16	3.46	55.87

Table B23: Con't.						
RUN 5:						
DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Apr. 2	3.65	370.74	14.23	107.86	-10.58	262.88
Apr. 8	0.14	307.80	5.28	75.31	-5.14	232.49
Apr. 15	3.30	323.40	6.63	86.49	-3.33	236.91
Apr.17	0.15	327.50	0.14	87.90	0.01	239.60
Apr. 22	0.06	341.56	0.01	114.95	0.06	226.60
AVERAGE:	1.46	334.20	5.26	94.50	-3.80	239.70
STD.DEV:	1.84	23.71	5.83	16.38	4.40	13.86

Table B24: Ammonia and TKN content of reactor B.						
RUN P:						
DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
July 4	58.92	389.10	37.30	270.05	21.62	119.05
July 18	73.28	759.27	49.20	354.77	24.08	404.50
AVERAGE:	66.10	574.19	43.25	312.41	22.85	261.78
STD.DEV:	10.16	261.75	8.41	59.91	1.74	201.84

Table B24: Con't.						
RUN 1:						
DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Aug. 18	91.09	666.81	50.63	201.23	40.46	465.58
Aug. 30	77.30	599.12	49.71	206.15	27.59	392.97
Sept. 4	67.22	586.71	48.23	205.29	18.99	381.42
Sept. 8	70.78	633.85	41.60	240.05	29.18	393.80
Sept. 15	78.98	621.82	43.92	220.61	35.06	401.21
AVERAGE:	77.07	621.66	46.82	214.67	30.26	407.00
STD.DEV:	9.18	31.29	3.89	15.97	8.10	33.50

Table B24: Con't.						
RUN 2:						
DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Oct. 2	82.18	648.39	51.98	250.70	30.20	397.69
Oct. 14	102.26	786.27	49.44	289.60	52.82	496.67
Nov. 3	66.74	744.63	25.53	245.76	41.21	498.87
Nov. 9	91.88	724.78	25.01	247.67	66.87	477.11

Nov. 14	88.76	716.85	27.25	264.33	61.51	452.52
AVERAGE:	86.37	724.18	35.84	259.61	50.52	464.57
STD.DEV:	13.15	50.18	13.63	18.27	14.94	41.78

Table B24: Con't.

RUN 3:

DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	INFLUENT CONC. NH_3-N (mg/L)	INFLUENT CONC. TKN (mg/L)	NET CONC. NH_3-N (mg/L)	NET CONC. TKN (mg/L)
Dec. 23	89.51	543.12	39.37	227.23	50.14	315.89
Dec. 31	84.42	551.58	50.96	234.69	33.46	316.89
Jan. 4	81.44	441.36	34.31	111.57	47.13	329.79
Jan. 7	95.74	461.62	25.28	232.78	70.46	228.84
Jan. 8	93.54	455.74	23.49	237.03	70.05	218.71
AVERAGE:	88.93	490.68	34.68	208.66	54.25	282.02
STD.DEV:	6.01	52.34	11.19	54.40	15.91	53.58

Table B24: Con't.

RUN 4:

DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	INFLUENT CONC. NH_3-N (mg/L)	INFLUENT CONC. TKN (mg/L)	NET CONC. NH_3-N (mg/L)	NET CONC. TKN (mg/L)
Feb. 10	51.85	570.03	37.90	204.59	13.95	365.44
Feb. 17	30.21	570.00	20.23	238.00	9.98	332.00
Feb. 26	26.51	458.40	15.12	164.68	11.40	293.72
Feb. 28	24.79	507.67	24.13	156.68	0.66	350.98
Mar. 2	30.62	500.83	22.93	176.47	7.69	324.36
AVERAGE:	32.80	521.39	24.06	188.08	8.74	333.30
STD.DEV:	10.93	48.24	8.48	33.29	5.05	27.36

Table B24: Con't.						
RUN 5:						
DATE	NH_3-N	TKN	INFLUENT CONC.		NET CONC.	
	CONC.	CONC.	NH_3-N	TKN	NH_3-N	TKN
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Apr. 2	30.32	487.81	36.71	173.58	-6.39	314.22
Apr. 8	19.56	422.33	19.88	143.69	-0.32	278.65
Apr. 15	20.41	420.73	19.74	167.30	0.67	253.44
Apr.17	15.11	446.44	7.94	191.32	7.17	255.12
Apr. 22	9.40	428.56	4.67	167.56	4.73	261.00
AVERAGE:	18.96	441.17	17.79	168.69	1.17	272.48
STD.DEV:	7.71	27.99	12.60	17.06	5.20	25.38

Table B25: Ammonia and TKN content of effluent A.								
RUN P:			RUN 2:			RUN 4:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
July 4	61.93	155.65	Oct. 2	10.23	65.29	Feb. 10	2.34	75.05
July 18	54.71	160.84	Oct. 14	18.96	81.90	Feb. 17	1.57	60.25
AVERAGE:	58.32	158.25	Nov. 3	8.96	81.70	Feb. 26	0.93	53.76
STD.DEV:	5.10	3.67						
			Nov. 9	11.88	98.08	Feb. 28	2.88	64.22
			Nov. 14	8.08	87.52	Mar. 2	2.34	58.18
			AVERAGE:	11.62	82.90	AVERAGE:	2.01	62.29
			STD.DEV:	4.34	11.88	STD.DEV:	0.76	8.07
RUN 1:			RUN 3:			RUN 5:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
Aug. 18	5.14	96.70	Dec. 23	26.66	80.72	Apr. 2	0.78	50.36
Aug. 30	1.84	95.93	Dec. 31	39.07	95.63	Apr. 8	0.12	46.24
Sept. 4	1.04	80.64	Jan. 4	28.71	15.29	Apr. 15	2.33	51.60
Sept. 8	4.13	100.22	Jan. 7	29.42	46.59	Apr.17	0.59	37.91
Sept. 15	3.30	81.71	Jan. 8	23.17	74.67	Apr. 22	0.19	32.00
AVERAGE:	3.09	91.04	AVERAGE:	29.41	62.58	AVERAGE:	0.80	43.62
STD.DEV:	1.67	9.16	STD.DEV:	5.92	31.86	STD.DEV:	0.90	8.42

Table B26: Ammonia and TKN content of effluent B.								
RUN P:			RUN 2:			RUN 4:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
July 4	56.51	189.78	Oct. 2	69.28	231.74	Feb. 10	42.70	201.01
July 18	65.83	186.17	Oct. 14	75.35	152.13	Feb. 17	27.35	230.00
AVERAGE:	61.17	187.98	Nov. 3	51.29	166.64	Feb. 26	24.00	142.08
STD.DEV:	6.59	2.56						
			Nov. 9	66.07	177.73	Feb. 28	16.40	168.01
			Nov. 14	58.24	160.11	Mar. 2	20.88	107.78
			AVERAGE:	64.04	177.67	AVERAGE:	26.26	169.78
			STD.DEV:	9.43	31.65	STD.DEV:	10.04	48.00
RUN 1:			RUN 3:			RUN 5:		
DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)	DATE	NH_3-N CONC. (mg/L)	TKN CONC. (mg/L)
Aug. 18	78.37	174.48	Dec. 23	64.39	208.03	Apr. 2	21.64	101.70
Aug. 30	65.56	208.55	Dec. 31	55.80	83.97	Apr. 8	17.78	90.69
Sept. 4	48.23	199.44	Jan. 4	59.42	111.15	Apr. 15	16.04	97.51
Sept. 8	61.50	170.56	Jan. 7	59.52	71.93	Apr.17	12.84	87.90
Sept. 15	64.19	116.37	Jan. 8	69.61	174.38	Apr. 22	9.13	72.47
AVERAGE:	63.57	173.88	AVERAGE:	61.75	129.89	AVERAGE:	15.48	90.05
STD.DEV:	10.76	35.97	STD.DEV:	5.35	58.96	STD.DEV:	4.77	11.24

Table B27: Nitrate and ORP values for systems A and B.					
INFLUENT A			INFLUENT B		
DATE	NITRATE CONC. (mg/L)	ORP (mV)	DATE	NITRATE CONC. (mg/L)	ORP (mV)
Apr. 15	0.4055	N/A	Apr. 15	0.2363	N/A
Apr. 17	0.3632	-129	Apr. 17	0.4760	-78
Apr. 22	0.3115	-32	Apr. 22	0.3444	-41
AVERAGE:	0.3601	-81	AVERAGE:	0.3522	-60
STD.DEV:	0.0471	69	STD.DEV:	0.1200	26
REACTOR A			REACTOR B		
DATE	NITRATE CONC. (mg/L)	ORP (mV)	DATE	NITRATE CONC. (mg/L)	ORP (mV)
Apr. 15	0.4102	N/A	Apr. 15	0.3585	N/A
Apr. 17	0.4666	-151	Apr. 17	0.5277	-193
Apr. 22	0.1846	97	Apr. 22	0.3256	82
AVERAGE:	0.3538	-27	AVERAGE:	0.4039	-56
STD.DEV:	0.1492	175	STD.DEV:	0.1084	194
EFFLUENT A			EFFLUENT B		
DATE	NITRATE CONC. (mg/L)	ORP (mV)	DATE	NITRATE CONC. (mg/L)	ORP (mV)
Apr. 15	0.1564	N/A	Apr. 15	0.1846	N/A
Apr. 17	0.4478	-93	Apr. 17	0.3632	-77
Apr. 22	0.3491	-70	Apr. 22	0.4102	-142
AVERAGE:	0.3178	-82	AVERAGE:	0.3193	-110
STD.DEV:	0.1482	16	STD.DEV:	0.1190	46

Table B28: Mass balance calculation example (reactor A, run 1)									
RUN 1:									
DATE	INFLUENT FLOW	WASTE	EFFLUENT FLOW	INFLUENT VSS	WASTE VSS	EFFLUENT VSS	RATE IN	RATE OUT	REDUCTION
	(L/d)	(L/d)	(L/d)	(mg/L)	(mg/L)	(mg/L)	(g/d)	(g/d)	(%)
July 22	2.48	0.016	2.46	5325	25200	875	13.19	2.57	80.5
July 24	2.34	0.017	2.32	5400	23500	525	12.62	1.61	87.3
July 29	2.37	0.017	2.35	9100	20250	575	21.58	1.70	92.1
Aug. 2	2.39	0.230	2.16	8250	17725	625	19.75	5.43	72.5
Aug. 5	2.36	0.224	2.14	8300	17050	750	19.58	5.42	72.3
Aug. 7	2.29	0.234	2.05	4900	10750	475	11.21	3.49	68.9
Aug. 12	2.35	0.194	2.15	4925	10900	900	11.56	4.05	64.9
Aug. 14	2.26	0.195	2.07	5150	8950	600	11.66	2.99	74.4
Aug. 21	2.47	0.119	2.35	4750	8425	675	11.73	2.59	77.9
Aug. 25	2.56	0.119	2.44	5550	12875	625	14.21	3.06	78.5
Aug. 28	2.22	0.119	2.10	4625	11300	875	10.27	3.18	69.0
Sept. 2	2.39	0.154	2.24	5400	15475	800	12.93	4.18	67.7
Sept. 5	2.42	0.154	2.27	4625	12225	525	11.21	3.07	72.6
Sept. 9	2.42	0.150	2.27	4725	15625	650	11.41	3.82	66.6
Sept. 11	2.51	0.150	2.36	5100	12000	675	12.78	3.39	73.5
			AVERAGE:	5742	14817	677	13.71	3.37	74.6
			STD.DEV:	1493	5107	136	3.57	1.11	7.6

Table B29: Gas production of systems A and B.							
GAS COMPOSITION							
DATE	SYSTEM	CH_4&CO_2 IN HEADSPACE (%)		CH_4 (%)		CO_2 (%)	
		MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
Nov. 10	A	5.1	9.9	16.9	32.7	67.3	83.1
	B	32.0	40.4	60.5	76.4	23.6	39.5
Jan. 9	A	12.0	22.5	46.2	86.9	13.1	53.8
	B	13.9	19.4	45.8	63.8	36.2	54.2
Feb. 27	A	10.7	13.7	18.6	23.9	76.1	81.4
	B	5.5	11.2	22.7	46.6	53.4	77.3
Apr. 17	A	12.7	13.1	14.9	15.4	84.6	85.1
	B	6.1	9.3	21.2	31.9	68.1	78.8

APPENDIX C

KINETICS

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C2: Kinetic relationship between VFA production and HRT in reactor B 227

KINETIC EQUATIONS

A first order kinetic relationship for the bench-scale reactors used in this study was established by operating the units at several different HRTs. The following equation was then used to calculate the production rate of each system (Metcalf and Eddy, 1991):

$$\frac{X*HRT}{S-S_o} = \frac{K_s}{k}\frac{1}{S} + \frac{1}{k} \qquad (C1)$$

X = reactor VSS (mg/L)
HRT = hydraulic retention time (hrs)
S = effluent VFA concentration (mg/L as acetic acid)
S_o = influent VFA concentration (mg/L as acetic acid)
K_s = half-velocity constant, VFA concentration at half the maximum production rate (mg/L as acetic acid)
k = production rate ($time^{-1}$)

The production rates attained from equation C1 are valid at ambient temperatures (@ 22 to 25°C). Using these production rates and the following equation which is an approximation of the van't Hoff-Arrhenius relationship, the production rates at 16 and 8°C were calculated (Metcalf and Eddy, 1991):

$$k_{T2} = k_{T1} * \theta^{(T2-T1)} \qquad (C2)$$

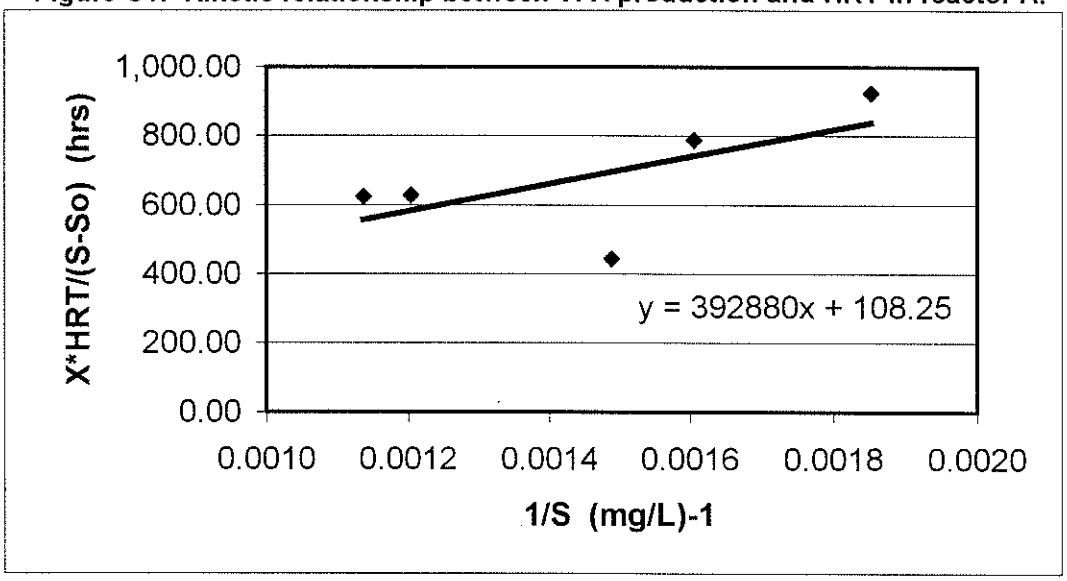
k_{T2} = production rate at T2 (°C)
k_{T1} = production rate at T1 (ie. 25°C)
θ = temperature-activity coefficient
T2, T1 = temperatures (°C)

A temperature-activity coefficient for a trickling filter at a value of 1.035 (Metcalf and Eddy, 1991) was used in Table C3. The trickling filter has an anaerobic layer and as such was assumed to have a θ value close to that of an anaerobic digester.

Table C1: System A kinetics (22 to 25°C).

HRT	VFA (mg/L as acetic acid)		Reactor VSS (X)	S-So	X*HRT	X*HRT/(S-So)	1/S
(hrs)	Influent (So)	Effluent (S)	(mg/L)				
18	294.19	671.81	9312	378	167616	443.87	0.0015
30	325.46	830.83	10553	505	316590	626.45	0.0012
30	167.41	879.9	14817	712	444510	623.88	0.0011
48	212.22	539.98	6303	328	302544	923.07	0.0019
60	271.98	622.93	4600	351	276000	786.44	0.0016

Figure C1: Kinetic relationship between VFA production and HRT in reactor A.



Based on Equation C1and the relationship derived from Figure C1:

$$K_s/k = 392880;\ 1/k = 108.25$$

Therefore,

$$k = 0.0092 hrs^{-1} = 0.222 days^{-1}$$

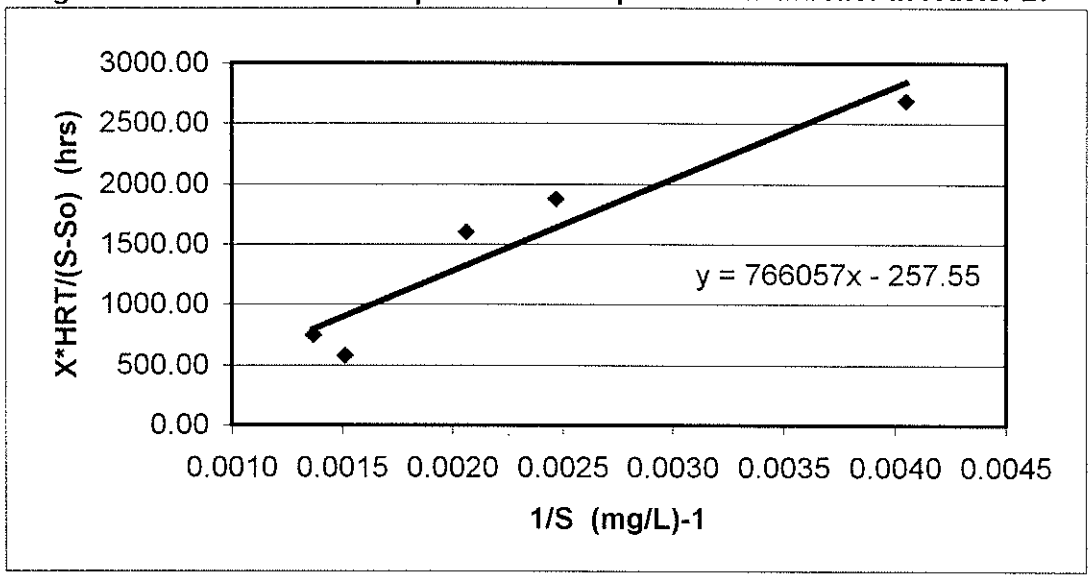
and

$$K_s = 392880 * k = 3629 mg/L$$

Table C2: System B kinetics (22 to 25°C).

HRT	VFA (mg/L as acetic acid)		Reactor VSS (X)	S-So	X*HRT	X*HRT/(S-So)	1/S
(hrs)	Influent (So)	Effluent (S)	(mg/L)				
18	255.09	660.82	12984	405.73	233712	576.03	0.0015
30	84.28	404.98	20063	320.7	601890	1876.80	0.0025
30	151.73	731.06	14467	579.33	434010	749.16	0.0014
48	140.64	484.6	11478	343.96	550944	1601.77	0.0021
60	71.04	247.09	7888	176.05	473280	2688.33	0.0040

Figure C2: Kinetic relationship between VFA production and HRT in reactor B.



Based on Equation C1 and the relationship derived from Figure C2:

$$|k| = 0.0039 hrs^{-1} = 0.093 days^{-1}$$

and

$$|K_s| = 2974 mg/L$$

* Calculations have been demonstrated with respect to reactor A.

Table C3: Kinetic production rates at 25, 16 and 8°C.

Temperature (°C)	k ($days^{-1}$)	
	Reactor A	Reactor B
25	0.222	0.093
16	0.162	0.069
8	0.123	0.052

Example calculation (reactot A at 16°C):

Based on Equation C2 :

$$k_{16} = k_{25} * 1.035^{(16-25)}$$

$$k_{16} = 0.222 * 1.035^{-9}$$

$$k_{16} = 0.162 days^{-1}$$

APPENDIX D

CONVERSION FACTORS

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Table D1: VFA conversion factors.

ACID	MOLECULAR WEIGHT	CONVERSION (mg acetic acid/mg VFA)
acetic	60.05	1.000
propionic	74.08	0.811
butyric	88.10	0.682
valeric	102.13	0.588

Table D2: VFA:SCOD conversion factors.

COD TYPE	CONVERSION FACTOR (mg/mg acid)	VFA
acetic acid	1.067	acetic
propionic acid	1.514	propionic
butyric acid	1.818	butyric
valeric acid	2.039	valeric