# USING A PARTIAL-MIX, SINGLE-JET MIXING SYSTEM TO IMPROVE SOLIDS RETENTION IN ANAEROBIC SEQUENCING BATCH REACTORS


By

HERNAN FERNANDEZ-BARRIALES LOPEZ

Superior Engineer in Chemical Engineering

Universidade de Santiago de Compostela

Santiago de Compostela, Spain

2012


Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2016

USING A PARTIAL-MIX, SINGLE-JET MIXING

SYSTEM TO IMPROVE SOLIDS RETENTION IN

ANAEROBIC SEQUENCING BATCH REACTORS

Thesis Approved:

Dr. Douglas W. Hamilton

Thesis Adviser

Dr. Gregory Wilber

Dr. Mark Wilkins

ACKNOWLEDGEMENTS

I would like to thank Dr. Douglas W. Hamilton for the opportunity to work in the research that led to the writing of this thesis. I would also like to thank Dr. Emilia Paloma Cuesta Alonso for the advice and support provided during my studies at Oklahoma State University.

I would also like to thank Dr. Gregory Wilber and Dr. Mark Wilkins for being part of my committee and for their teachings in the field of wastewater treatment and bioreactors that were of great help during my research.

Thanks to my family (Pilar, Jose, Marcos, Mar and Iago) for their support overseas, to Oscar for his support on-site, and to Harshini for everything.

Name: HERNAN FERNANDEZ-BARRIALES LOPEZ

Date of Degree: JULY, 2016

Title of Study: USING A PARTIAL-MIX, SINGLE JET MIXING SYSTEM TO IMPROVE SOLIDS RETENTION IN ANAEROBIC SEQUENCING BATCH REACTORS

Major Field: BIOSYSTEMS AND AGRICULTURAL ENGINEERING

Abstract: A mixing design for Anaerobic Sequencing Batch Reactors (ASBR) was evaluated to increase solids retention while treating dilute wastewater such as swine manure. The concept behind the proposed design consists in partially mixing the reactor contents to maintain two separate regions: a solids-concentrated layer at the bottom and a solids-free layer near the top of the reactor. Injection of clarified liquid to the bottom of the reactor provides reactor mixing. This results in a less aggressive mixing system, which prevents aggregate disruption and particle size reduction increasing effluent quality and the solid retention time. The partial-mix design provided improvement in effluent quality, organic matter removal efficiency, and solids retention time, while maintaining stable operation. The partial-mix system was able to effectively decouple the hydraulic and solids retention times, which allows the treatment at higher organic loading rates and improved reactor volumetric efficiency. Fed a mixture of dilute swine manure and raw glycerol, and operating at 35°C, a 6-day HRT, and a loading rate of 0.87 g COD $L^{-1}$ reactor $day^{-1}$, solids retention times up to 700 days were achieved, along with organic matter removal efficiencies above 90% COD and 80%VS. Effluent VSS concentration decreased 67% compared to a fully mixed ASBR design. While biogas yield did not show a significant increase, the increased ability to retain solids in the reactor using partial-mix design allowed maintaining high organic matter removal efficiencies while operating under low HRTs.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

# CHAPTER I

## INTRODUCTION

Waste generated by agricultural industries is characterized as having a large fraction of organic matter (OM) and a high concentration of plant nutrients such as nitrogen and phosphorus. Treatment of these wastes is essential to prevent water contamination, reduce eutrophication in lakes and reservoirs, and control odor generation. Biological treatment of agricultural waste is favored over physical (filtration, sedimentation) and chemical treatments (chemical oxidation), since biological treatment can effectively reduce OM while operating at near ambient temperature and pressure, avoiding excessive maintenance operations and reducing operation costs. There are two biological treatment approaches: aerobic and anaerobic digestion. The difference between these processes is the terminal electron acceptor available for the microorganisms to carry out the digestion. If oxygen is available, the favored process is aerobic digestion; while in absence of oxygen, anaerobic digestion process is favored. Equations 1 and 2 are simplified formulas for aerobic and anaerobic digestion.

$$Organic\ matter + O_2 + nutrients \xrightarrow[microorganisms]{aerobic} CO_2 + NH_3 + New\ cells \qquad \text{Eq. 1}$$

$$Organic\ matter + nutrients \xrightarrow[microorganisms]{anaerobic} CH_4 + CO_2 + NH_3 + New\ cells \qquad \text{Eq. 2}$$

Organic matter present in wastewater is the source of both energy and nutrients required by microorganisms to survive and generate new cell material. Both aerobic and anaerobic microorganisms use the energy available in OM for growing new cells, which results in the production of sludge. While the fast growing rate of aerobic microorganisms leads to large amounts of sludge production, anaerobic microorganisms grow at a considerably lower rate, reducing sludge generation. Most of the energy available in OM is stored in the form of methane ($CH_4$) released in biogas during anaerobic digestion. Methane is a valuable by-product of anaerobic digesters that can be burned in order to produce heat and electricity. Table 1 provides a summary of the benefits and the drawbacks for both aerobic and anaerobic digestion.

Table 1. Pros and Cons for Aerobic and Anaerobic Digestion.

| | **Pros** | **Cons** |
|---|---|---|
| **Aerobic Digestion** | Low retention times<br>Low temperature dependence<br>Capable of treating relatively large quantities of wastewater | Large sludge volume<br>Aeration required<br>OM energy wasted to atmosphere as $CO_2$ and heat |
| **Anaerobic Digestion** | Reduced sludge volume<br>Aeration is not required<br>OM energy stored as flammable $CH_4$ | Slower growing microorganisms<br>Relatively larger reactor volumes<br>Heating required |

### 1.1. Anaerobic Reactors

Anaerobic digestion of wastewater has been studied for over 150 years (Burton et al., 2013), and different approaches to maximize the OM removal and biogas production have been considered. It must be noted that even though the characteristics of agricultural wastewater and other kinds of waste may differ, the concept of anaerobic digestion applies to all of them in the same way.

### 1.1.1. Passive Reactors

The first anaerobic reactors developed simply consisted of providing oxygen-free conditions for a given volume of waste, and allowed the anaerobic microorganisms to grow and digest without any mechanical or energetic input. Examples of this type of reactors are the septic tank and anaerobic lagoons, which are shown in Figures 1 and 2. Septic tanks are widely used in households that are not connected to a centralized sewer system. Anaerobic lagoons are used to treat manure on large livestock farms, but have also been used in limited numbers for domestic sewage treatment. Anaerobic lagoons can either be open or covered. Open lagoons release biogas directly to the atmosphere; whereas, biogas is collected for further use under the impermeable cover of a covered lagoon.

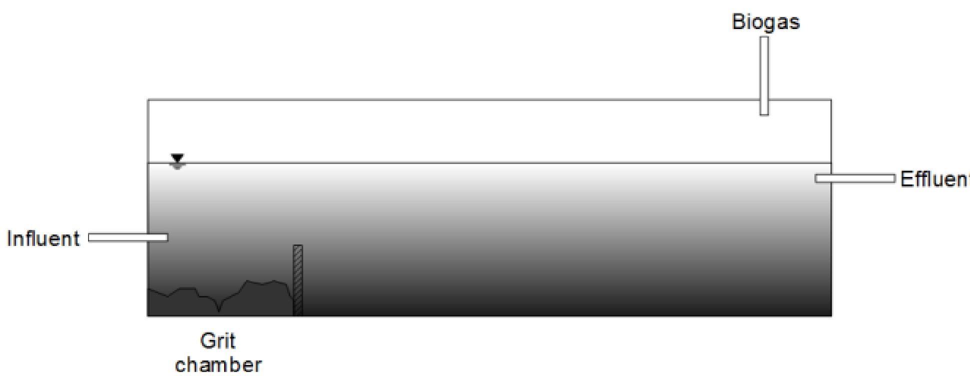



Figure 1. Passive Reactor: Septic Tank.

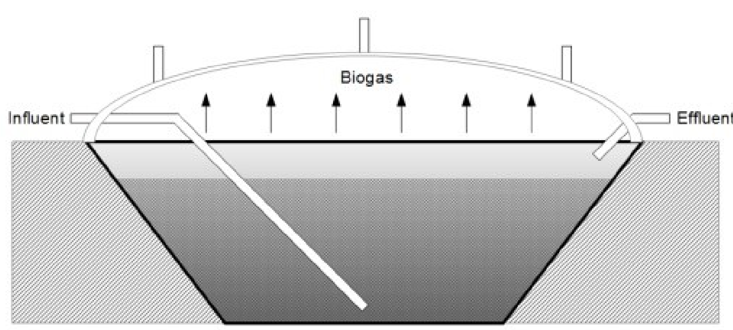



Figure 2. Passive Reactor: Covered Lagoon.

### 1.1.2. Completely Stirred Tank Reactors

This type of reactor is continuously mixed to enhance contact between microorganisms and OM (Figure 3). Influent wastewater is fed continuously, and an effluent stream equal in flow to the influent is withdrawn, maintaining a constant volume. When this type of reactor operates under completely mix conditions, the effluent has the same solids concentration as the contents of the reactor.

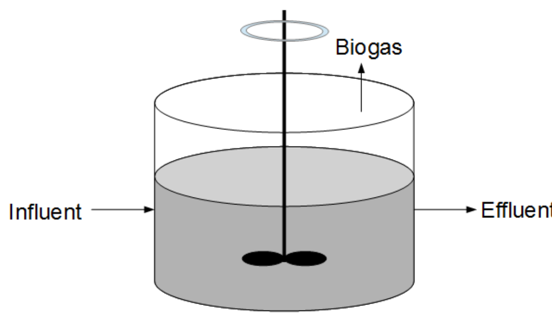



Figure 3. Completely Stirred Tank Reactor (CSTR).

### 1.1.3. Contact Stabilization Reactors

A combination of degasifier and clarifier unit can be located downstream of a CSTR in order to increase the effluent quality and reduce the loss of untreated OM (Figure 4). This type of reactor is called a Contact Stabilization Reactor. A fraction of the solids settled by the clarifier is recirculated to the anaerobic digester, while part of it is wasted in order to keep steady state conditions. This allows obtaining high retention of solids while reducing the required liquid retention. Liquid is withdrawn from the top of the clarifier unit as effluent.

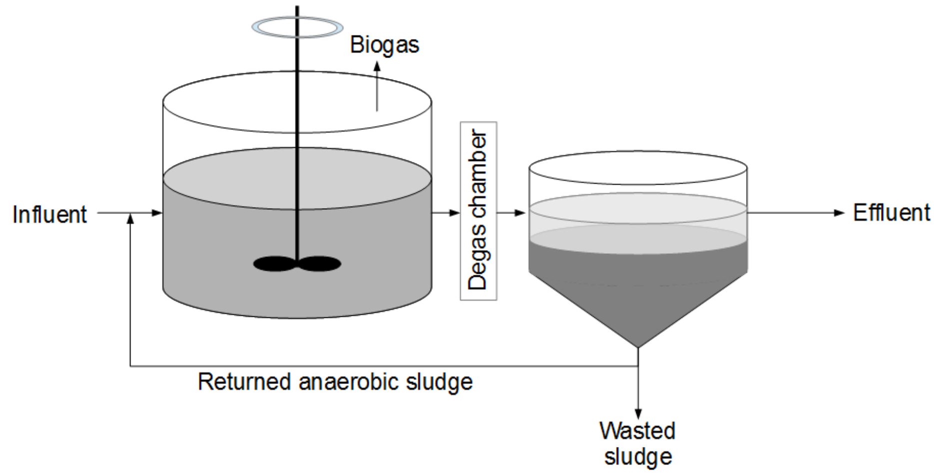



Figure 4. Contact Stabilization Reactor.

### 1.1.4. Sludge Bed Reactors

In these reactors, wastewater is injected in the bottom of the unit, creating a sludge bed. Flow through the sludge bed keeps anaerobic microorganisms in contact with digestible OM. The summation of forces pulling particles upwards (liquid flow) and downwards (gravity) generates a concentration gradient that results in a fairly suspended particle free effluent. Many different configurations have been proposed based on the same principle, with the Upflow Anaerobic Sludge Blanket reactor (UASB, Figure 5) and the Expanded Granular Sludge Bed reactor (EGSB, Figure 6) being two common designs used.

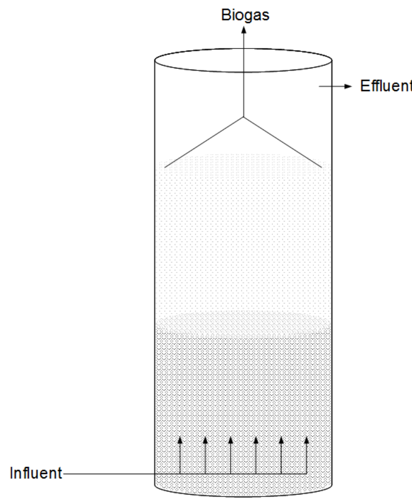



Figure 5. Upflow Anaerobic Sludge Blanket Reactor (UASB).

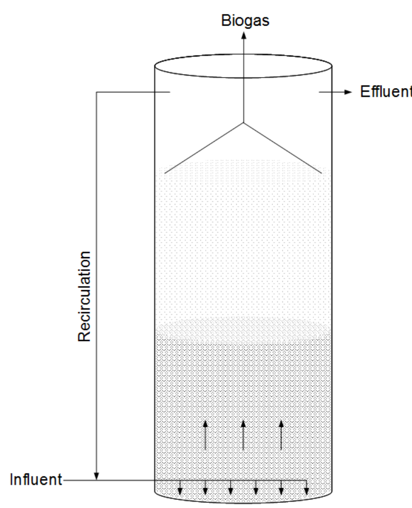



Figure 6. Expanded Granular Sludge Bed Reactor (EGSB).

Both UASB and EGSB have similar characteristics; a high height-to-diameter ratio, influent injected through the bottom of the reactor, and effluent discharge after passing through the sludge blanket. The main difference between the two reactor designs lies in the presence of effluent recirculation in the EGSB reactor. Also, the direction in which the influent is injected through the bottom of the reactor varies (injected upwards for UASBs and aimed at the bottom for EGSBs).

### 1.1.5. Membrane/Filter Reactors

Membrane and filter reactors make use of solid matrices to provide support for the growth of anaerobic microorganisms and retain solid matter by physical means (i.e. filtering). The addition of a physical separation process increases the efficiency of the process by enhancing solid retention, but care must be taken to avoid filter clogging or biofouling. In general, membranes are added to stand-alone digesters, such as CSTR and sludge blanket reactors to form a named digestion package. An UASB reactor combined with a filter is known as the Anaerobic Hybrid Process, ANHYB (Figure 7). A CSTR reactor combined with a filter is the Anaerobic Membrane Process, ANMBR.

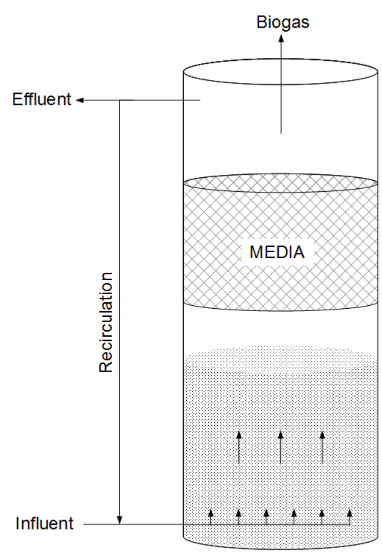



Figure 7. Combination of UASB and Filter Reactor with Recirculation in an Anaerobic Hybrid Process (ANHYB).

### 1.1.6. Anaerobic Sequencing Batch Reactors

Developed in the early 1990s, the Anaerobic Sequencing Batch Reactor (ASBR) design consists of combining a CSTR with a clarifier unit in the same vessel. This is achieved by carrying out the operation in a cycle consisting of four phases as shown in Figure 8. The main benefit of an ASBR is its ability to retain the solid particles by settling. Solids retention provides time for slow growing methanogens to remain in the reactor and digest solid OM particles, while reducing the overall time liquids remain in the reactor.

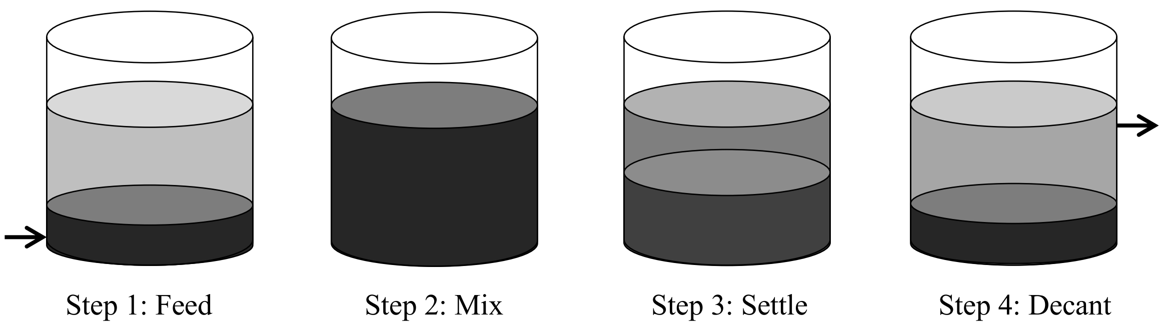



Figure 8. Four Phases of an ASBR Cycle.

## 1.2. Reactor Selection

There are several factors to be taken into consideration when selecting a reactor design. Depending on each particular situation, some factors will be more important than others, and one or more designs will be favored over the rest. The final choice usually depends on cost, integration with the farm or factory design, and preferences of the designer and clients.

### 1.2.1. Wastewater Characteristics

Agricultural waste varies considerably during the year as changes take place in livestock population, diet composition, meteorological conditions and farm cleaning procedures. Despite this variability, based on regular operation conditions, an estimate of the average characteristics of the wastewater must be calculated in order to select the best option for the reactor design.

Wastewater dilution defines the concentration of solids present in the stream to be treated. Solids concentration is usually measured as percentage of Total Solids (TS). In the case of agricultural waste, TS depends mainly on type of livestock housed and the volume of water used for flushing or cleaning livestock facilities. Poultry manure contains fairly high solids as excreted (25% TS); while cattle and swine manures are considerably more dilute (15 and 10% TS as excreted, respectively) (Hamilton, 2011).

Wastewater strength depends on the amount of OM present and can be measured in terms of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), or percentage of Volatile Solids (VS). Organic Matter is potential energy stored in the wastewater and must be removed to avoid environmental issues such as pathogen growth, eutrophication of reservoirs, odor generation, and vector attraction. Other wastewater characteristics to take into account are temperature, inorganic fraction, nutrient concentration, the presence of antibiotic and chemical compounds, and viscosity (Burton et al., 2013).

### 1.2.2. Treatment Requirements

Specific regulations require effluent discharged from a farm meets certain quality limits. In the case of agricultural waste in the US, current regulations are based on recycling plant nutrients released to the environment (nitrogen and phosphorus).

### 1.2.3. Volumetric Flow

The volume of wastewater generated plays a major role in the selection of the reactor to be used. Some designs are more suitable to treat larger amounts of waste, while other designs work better under discontinuous loads such as periodic flushing of livestock housings.

### 1.2.4. Economic Constraints

Every industry must manage a budget in order to maintain a profitable operation, and agricultural industries are no different. Building an anaerobic reactor is an important investment, and its operation will generate additional costs that must be integrated into the farm budget. These two constraints (initial investment and operation costs) must be taken into consideration at the moment of deciding which type of reactor will optimize the farm's operation.

### 1.2.5. Space Availability

It is typical to have a limited amount of land available to build a wastewater treatment reactor. Some set-ups allow the treatment of large quantities of wastewater in small reactor volumes, therefore, reducing the space needed for treatment units. Increasing reactor efficiency can reduce the number of processing units downstream of the reactor; therefore, optimizing the space used.

### 1.2.6. Summary

Table 2 is a summary of design factors and how they apply to available anaerobic treatment technologies.

Table 2. Summary of Factors Evaluated for Reactor Selection. Adapted from Burton et al. (2013)

| **Reactor type** | **Wastewater characteristics (Feed strength) (Loading rate)** | **HRT (Volume per flowrate) (days)** | **Space requirements** |
|---|---|---|---|
| ***Passive*** | Diluted-concentrated <2 kg COD $m^{-3}$ $day^{-1}$ | High 20 – 50 | High |
| ***CSTR*** | Moderately concentrated <4 kg COD $m^{-3}$ $day^{-1}$ | High 15 – 30 | Relatively High |
| ***Contact Stabilization*** | Moderately concentrated 2 – 5 kg COD $m^{-3}$ $day^{-1}$ | Relatively Low 10-20 | Relatively High |
| ***Sludge Bed*** | Diluted 20 – 50 kg COD $m^{-3}$ $day^{-1}$ | Low 0.16 – 0.33 | Low |
| ***Membrane Filter*** | Diluted – concentrated 5 – 20 kg COD $m^{-3}$ $day^{-1}$ | Low 1 – 3 | Low |
| ***ASBR*** | Diluted 1 – 3 kg COD $m^{-3}$ $day^{-1}$ | Relatively Low 5 – 15 | Low |

# CHAPTER II

## LITERATURE REVIEW

### 2.1. Fundamentals of Anaerobic Digestion

The process by which OM is converted into biogas involves a number of microbial communities conducting a series of processes that, when linked together, result in what is called the Anaerobic Digestion Process. The interactions between the chemical species produced in each stage of anaerobic digestion are shown schematically in Figure 9. Since all of the steps are interconnected, the rate at which the entire process takes place depends on the slowest step, known as the rate-limiting step. Many studies have been conducted to determine the rate-limiting step of anaerobic digestion under various conditions. The general conclusion is for complex organic substrates, the rate-limiting step is hydrolysis; while for readily biodegradable substrates, the limiting step is methanogenesis (Adekunle and Okolie, 2015).

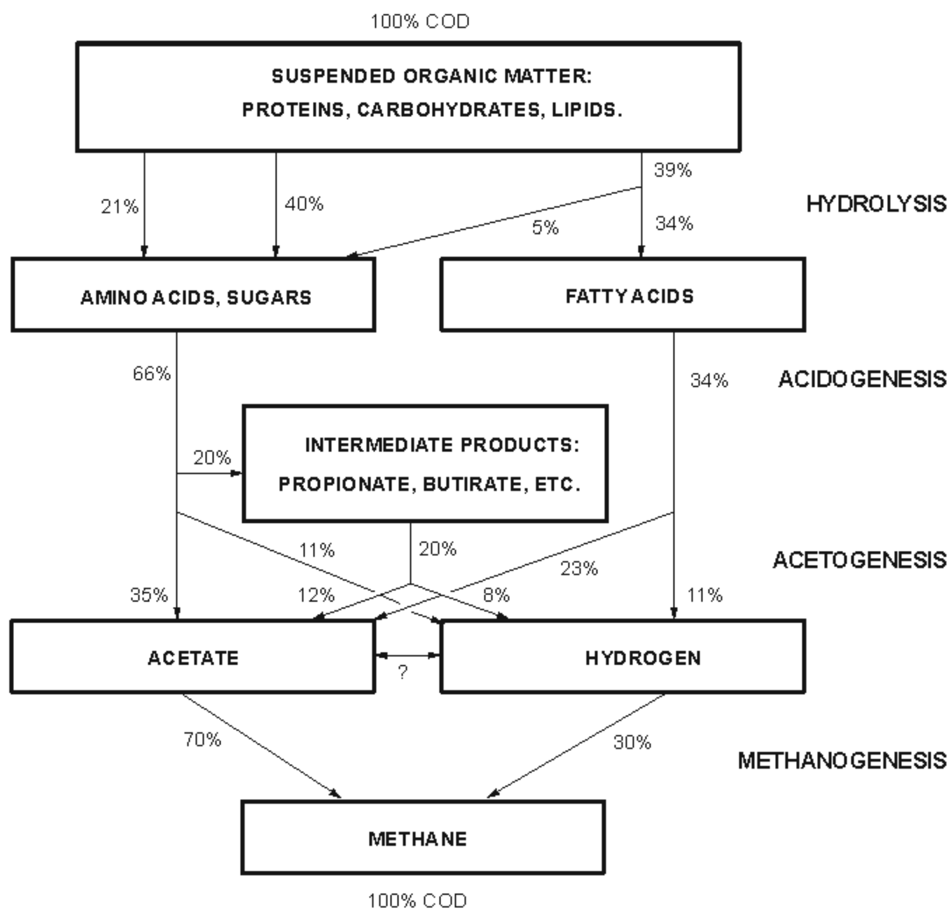



Figure 9. Steps in Anaerobic Digestion and their Intermediate Chemical Species (van Haandel and van der Lubbe, 2012).

### 2.1.1. Hydrolysis

The first step in converting OM to biogas is to transform insoluble OM (complex carbohydrates, lipids, fats, and proteins) into soluble compounds that can be easily converted into energy or used as a carbon source by microorganisms (i.e. amino acids, monosaccharides). This process is carried out by enzymes secreted by microorganisms (both strict and facultative anaerobes), which can effectively break bonds of larger OM particles (Adekunle and Okolie, 2015).

### 2.1.2. Acidogenesis

Small-sized compounds (monomers) generated in the hydrolysis step are further treated by acidogens (facultative and anaerobic microorganisms) to obtain volatile fatty acids, alcohols, Carbon dioxide ($CO_2$) and Hydrogen ($H_2$) (Adekunle and Okolie, 2015).

### 2.1.3. Acetogenesis

The acetogenesis step provides the necessary substrates for methanogenesis. Volatile fatty acids with more than two carbon atoms (i.e. propionic, butyric, valeric acids) are broken into acetic acid, $H_2$, and $CO_2$. The concentration of $H_2$ must remain relatively low in order to maintain a stable process. Excess $H_2$ produced in acetogenesis must be removed during methanogenesis (Adekunle and Okolie, 2015).

### 2.1.4. Methanogenesis

Acetic acid, $CO_2$, and $H_2$ are converted to $CH_4$ during methanogensis. These gases combined with traces of hydrogen sulfide ($H_2S$) generated in previous steps, constitute the bulk of gases contained in biogas. Methanogenesis is the slowest biochemical reaction in anaerobic digestion with easily degradable substrates (Adekunle and Okolie, 2015).

## 2.2. Environmental Factors

The biological nature of anaerobic digestion makes it highly dependent on environmental factors such as temperature, pH and alkalinity. The adequate selection of operation values for these environmental variables is of great importance to operate an anaerobic process at efficient and stable conditions.

### 2.2.1. Temperature

Anaerobic microorganisms are very sensitive to temperature; therefore, temperature must be maintained at a fairly constant set point to achieve optimal operation.

A maximum variation of 0.5 °C $day^{-1}$ has been recommended by the Water Environment Federation to avoid reactor shocks (Water Environment Federation, 2009). Depending on the temperature selected, the growth of different communities of microorganisms will be favored. Three groups are named based on their preferred temperature range: psychrophilic (10 – 20 °C), mesophilic (30 – 38 °C) and thermophilic (50 – 57 °C) (Burton et al., 2013). It must be noted that these ranges vary depending on the author. There are no sharp limits after which a particular microorganism will automatically disappear, but regions in which a set of microorganisms are more predominant. Numerous studies have been conducted using different temperatures in order to determine the optimum operation point for a given influent wastewater and reactor type. A number of these studies are summarized in Table 3.

Table 3. Summary of Temperature Influence Results Found in the Literature.

| Authors | Type of Reactor | Wastewater | Feed Strength (% TS) | Temperature | $CH_4$ Yield (L $kgCOD_{fed}^{-1}$) | OM Reduction (% COD) |
|---|---|---|---|---|---|---|
| Rudolfs (1927) | Not specified | Sewage sludge | Not specified | 10 | 130 (OM) | |
| | | | | 18 | 250 | |
| | | | | 24 | 320 | |
| Hatfield et al. (1928) | Not specified | Sewage sludge | Not specified | 11.5 | 400 (OM) | |
| | | | | 18.7 | 500 | |
| | | | | 25.3 | 552 | |
| | | | | 31.4 | 572 | |
| | | | | 35.2 | 566 | |
| Fair and Moore (1932, 1934 and 1937) | Not specified | Sewage sludge | Not specified | 10 | 450 (OM) | |
| | | | | 15 | 530 | |
| | | | | 20 | 610 | |
| | | | | 25 | 710 | |
| | | | | 30 | 760 | |
| Viel (1951) | Not specified | Sewage sludge | Not specified | 16.1 | 417 (OM) | |
| | | | | 25 | 512 | |
| | | | | 38 | 508 | |
| | | | | 57.1 | 534 | |
| Malý and Fadrus (1971) | Not specified | Sewage sludge | 4-6 | 20 | 376 (OM) | 46% (OM) |
| | | | | 30 | 382 | 49% (OM) |
| | | | | 50 | 386 | 50% (OM) |
| Hansen et al. (1998) | CSTR | Swine manure | Not specified | 37 | 188 | |
| | | | | 45 | 141 | |
| | | | | 55 | 67 | |
| | | | | 60 | 22 | |

Table 3 (Cont.). Summary of Temperature Influence Results Found in the Literature.

| Authors | Type of Reactor | Wastewater | Feed Strength (%TS) | Temperature | $CH_4$ Yield (L $kgCOD_{fed}^{-1}$) | OM Reduction (% COD) |
|---|---|---|---|---|---|---|
| Kim et al. (2006) | Three stage, unmixed | Food waste | 12.38 | 40 | 154 (CODdegraded) | 77% |
| | | | | 45 | 187 | 78% |
| | | | | 50 | 223 | 79% |
| | | | | 55 | 129 | 77% |
| Chae et al. (2008) | Batch, unmixed | Swine manure | 5 | 25 | 114 | 80% |
| | | | | 30 | 143 | 76% |
| | | | | 35 | 163 | 72% |
| Ndegwa et al. (2008) | ASBR | Swine manure | 0.3-0.4 | 20 | 120 | 85% |
| | | | | 35 | | 75% |
| Nges and Liu (2010) | CSTR | Sewage sludge | 8-12 | 37 | 307 | 55 % (VS) |
| | | | | 50 | 325 | 56 % (VS) |
| Kinnunen et al. (2014) | AVR, unmixed | WW-grown algae | 2 | Ambient | 83 (L $kgVS_{fed}^{-1}$) | 47% (VS) |
| | | | | 20 | 103 | 36% (VS) |
| | | | | 37 | 225 | 24% (VS) |
| Moset et al. (2015) | Not specified | Cattle manure | 7.1 | 35 | 154 | 34% (VS) |
| | | | | 50 | 209 | 37% (VS) |
| | | | 8.5 | 35 | 151.2 | 30% (VS) |
| | | | | 50 | 185.1 | 37% (VS) |
| | | | 8.5 | 35 | 155 | 28% (VS) |
| | | | | 50 | 177 | 34% (VS) |

The effect of temperature in anaerobic digestion has been studied since the early stages of the technology. Malý and Fadrus (1971) compiled a set of studies carried out since the decade of 1920s, and developed their own experiments to determine the influence of temperature on biogas production and OM reduction from sewage sludge The results of these early studies indicated that even though temperatures as low as 10 °C could be used while still producing biogas, with biogas production increasing with an increasing temperature. Hansen et al. (1998) studied the effect of different temperatures in CSTRs treating swine manure. The temperatures used were 37, 45, 55 and 60 °C, and it was found that the biogas production was severely inhibited as temperature was raised. At the same time, $CH_4$ concentration in biogas decreased dramatically when increasing the temperature (from 71 to 40%) in the studied range. Kim et al. (2006) conducted research on food waste anaerobic digestion at temperatures in the mesophilic and thermophilic ranges to determine the optimum operation temperature for soluble COD removal and biogas production using a three stage unmixed reactor. The researchers claimed that thermophilic temperatures promoted removal of soluble organics and increased gas yield, with an optimum temperature of 50 °C.

Ndegwa et al. (2008) studied the temperature effect on ASBRs treating dilute swine manure. No significant difference in gas production was observed between the two studied temperatures (20 and 35 °C), but better stabilization of the waste was observed at 20 °C. This result was explained by the authors by stating that while biogas yield remains constant, settleability of the suspended solids decreases with the temperature increase. Chae et al. (2008) developed a series of experiments to find out the optimum temperature for swine manure digestion in an unmixed batch reactor. Temperatures of 25, 30 and 35 °C were evaluated, resulting in an increase in gas production at higher temperatures, and a slight decrease in OM removal. The effect of temperature shocks was also studied by applying sharp changes of temperature (5 °C decrease and 2 °C increase). The 5 °C decrease shock produced a more drastic change in biogas production, for which the reactor took longer to recover (40h) ). Kinnunen et al. (2014)

determined that for an unmixed reactor treating wastewater-grown microalgae, twice as much biogas can be produced at 37°C than at 20 °C. Also, little improvement was observed when keeping the temperature set at 20 °C versus letting the reactor operate at ambient conditions. Moset et al. (2015) compared different operation parameters of anaerobic digestion in cattle manure under mesophilic (35 °C) and thermophilic (50 °C) conditions, reaching the conclusion that the thermophilic conditions provided slightly better results in terms of $CH_4$ yield and OM removal.  .

### 2.2.2. pH, Alkalinity and Volatile Fatty Acids

Microorganisms carrying out anaerobic digestion are sensitive to pH conditions. The high diversity of microorganisms involved in anaerobic digestion makes it hard to set an optimum pH value, since each of species of organism has its own favored conditions. As a general rule, the anaerobic digestion operates most successfully at pH 6 to 8. Alkalinity is a measure of a solution's ability to resist change in pH. This variable accounts for the concentration of hydroxides, carbonates and bicarbonates present in solution, which form salts with common elements in the wastewater (i.e. magnesium, calcium, sodium) and are of basic nature. Volatile fatty acids (VFAs) are short hydrocarbon chains with a carboxylic tail, which are important precursors of biogas. Acetic, propionic, and butyric are the most common acids in anaerobic digestion processes, and contribute to the acidification of the reactor. It is very important to keep an appropriate ratio between concentration of carbonates and VFA to maintain the pH within the optimum rage of operation. In cases where reactor pH drops below 6 or rises above 8, addition of acidic or basic species may be needed to keep the microbial communities in balance. McCarty (1964) established a relationship between bicarbonate alkalinity, pH and $CO_2$ content of biogas (Figure 10). The author stated that an increase in alkalinity always leads to an increase in pH (the medium becomes more basic). For a given pH, a larger concentration of bicarbonates resulted in an increased carbon dioxide content in the biogas. Therefore, it is optimum to keep low concentrations of bicarbonates at moderately high pH values to reduce the carbon dioxide content, therefore increasing the $CH_4$ content.

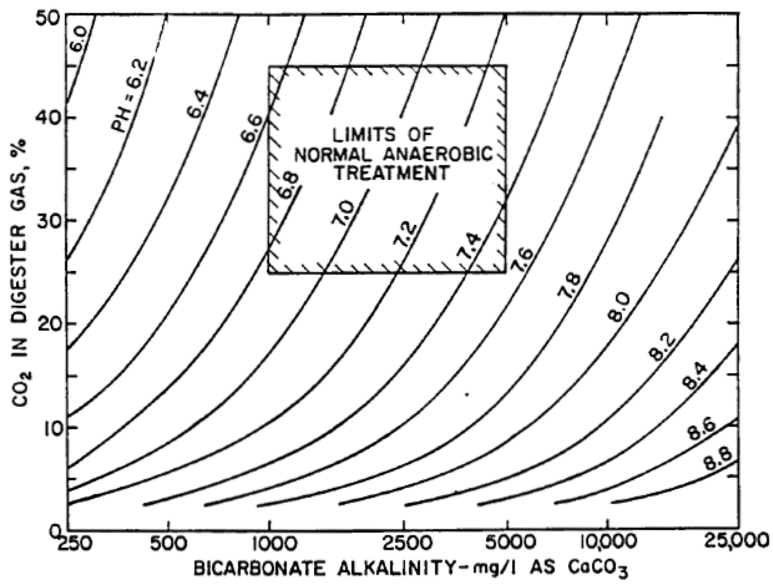



Figure 10. Relationship between Alkalinity, pH and $CO_2$ Content at 35 ºC. (McCarty, 1964)

Zhang et al. (2015) conducted experiments for determining the pH influence on the thermophilic co-digestion of solid state swine manure and maize stalk. It was observed that at pH 8, $CH_4$ yield decreased sharply, while $CH_4$ yield peaked at pH 7.0. The ratio between concentrations of VFAs (as equivalent moles of acetic acid per liter) and alkalinity (as equivalent moles of calcium bicarbonate per liter) is said to be optimum between 0.1 and 0.3, followed by an instability region covering ratios between 0.3 to 0.8, after which digestion is completely inhibited (Zhang et al., 2015).

Latif et al. (2015) proposed conducting anaerobic digestion at unusually low pH (5.5 to 7) to enhance phosphorous release within the reactor. The observed drop in biogas production was explained by the difficulty of hydrolyzing OM rather than by inhibition of $CH_4$ forming microorganisms. Furthermore, $CH_4$ content in the biogas laid below 50% for values of pH under 7. In exchange for this decrease in $CH_4$ production, release of phosphorous was multiplied by 4 compared to regular operation conditions. Finally, it was observed that only at pH lower than 6 are significant amounts of propionic and butyric acids found in solution, while acetic acid is always present. The behavior of 2 to 6-carbon VFA in the anaerobic digestion process was studied by Wang et al. (1999). This study described how the larger-chain VFAs need to be converted to acetic acid prior to its conversion into biogas by methanogens. Acetic and propionic acids tended to accumulate as they are the end products of larger VFA destruction (being propionic acid the end product of odd-C chains). A limit of 1,400 mg $L^{-1}$ of acetic acid was observed, after which the degradation rate of propionic acid decreased considerably (Wang et al., 1999).

Two full-scale anaerobic digesters located in Austria were studied by Franken-Whittle et al. (2014) to evaluate the relationship between VFA and overall operation. The reactors had working volumes of 173 and 110 $m^3$, and were operated using loading rates ranging from 2.8 to 5.2 kg VS $m^{-3}$ $day^{-1}$ and hydraulic retention times between 26 and 57 days. One of the reactors was operated in the mesophilic region, and the other one operated with thermophilic conditions. The researchers observed that the concentration of VFA oscillated greatly, going from periods of low VFA concentration to periods of high VFA without affecting the biogas production or pH of the reactor. The evaluation of their results confirms the findings of Wang et al. (1999), as when levels of acetic acid exceeded 1,000 mg $L^{-1}$, the concentration of propionic acid were extremely high (between 4,000 and 8,000 mg $L^{-1}$).

## 2.3. Control Parameters

The operation of an anaerobic digester can be controlled using parameters related to three basic concepts; the time liquid and solid phases remain in the reactor, the load of OM that is fed, and reactor mixing.

### 2.3.1. Solids Content

The solids content of wastewater can be classified as suspended or dissolved, and as fixed or volatile. The distinction between Suspended Solids (SS) and Dissolved Solids (DS) is based on their ability to settle. For ease of testing, if a particle passes through a Whatman glass fiber filter having 1.58 μm openings it is considered to be DS, if it is retained on the filter it is considered SS (APHA, 2005). Similarly, a distinction can be made between Fixed Solids (FS) and Volatile Solids (VS). In this case, the solids that combust at high temperatures (550 °C for 2 hours) are considered VS, while those remaining after subjected to high temperature conditions called FS (APHA, 2005). It is usual to assume all OM is represented by VS content, neglecting the fraction of such OM which belongs to the FS species.

The solids content of each reactor stream (Substrate, Effluent, Reactor Contents) plays a major role in the operation of an anaerobic digester. Generally speaking, a greater content of VS in the feed will result in a larger amount of OM that needs to be treated for a given volume fed, and, therefore, a larger potential for biogas production. But, at the same time, if the solids content in the feed exceeds the treatment capability it can result in an excess of pollutants being discharged or even in the reactor breakdown. In sludge bed and ASBR reactors, accumulating solids inside the reactor provides a longer time for treatment to be carried out; nevertheless, in order to maintain the operability of the reactor, a certain amount of solids must be removed periodically (operation known as solids wasting). Finally, the solids content of effluent is an indicator of how efficiently treatment is taking place. Low effluent VS content indicates OM destruction or retention within the digester.

### 2.3.2. Hydraulic Retention Time

The average time a unit of volume of liquid remains in a reactor is the Hydraulic Retention Time (HRT). A higher HRT is translated into an increased time provided for the stabilization of liquid substrate, but also means that a larger reactor volume is needed in order to treat a given influent flow rate. Equation 3 is used to determine HRT in a continuous reactor, with $Q^{eff}$ being the effluent flow rate, and $V^R$ the reactor volume. For ASBR reactors, the formula is modified slightly (Equation 4) by introducing the volume present in the reactor during the decant phase on day i, $V^R_{react,i}$, and the volume decanted on day i, $V^D_i$ (Hamilton and Steele, 2014).

$$HRT = \frac{V^R}{Q^{eff}} \qquad \text{Eq. 3}$$

$$HRT_{ASBR} = \frac{V^R_{react,i}}{V^D_i} \qquad \text{Eq. 4}$$

For CSTR reactors, in which the HRT is the time microorganisms are held in the reactor, there should be a lower limit to HRT as enough time must be provided for microorganisms to conduct the conversion of OM into biogas. Rincón et al. (2008) studied the performance of a CSTR reactor treating olive mill solid waste under different loading rates and HRT at mesophilic conditions. A limit of 17 days HRT was observed; below such limit, COD removal efficiencies dropped alarmingly and pH conditions became unstable. Kim et al. (2006) performed experiments to determine the influence of temperature and HRT on the digestion process of food waste in a modified three-stage fermenter. It was observed by the researchers that the lowest HRT tested (8 days) provided unstable operation of when treating the concentrated waste used (12% TS). Wang et al. (1997) studied the influence of lowering the HRT in concentrated waste activated sludge anaerobic digestion. They found that the maximum gas production per reactor volume was steadily increased as the HRT was lowered from 10 to 4 days. At 3-day HRT, a sharp decrease in gas production was observed.

### 2.3.3. Solids Retention Time

The average time a solid particle spends inside a reactor is called the Solids Retention Time (SRT). It is a very important variable, because it is a rough measure of the time microorganisms are held in the reactor and allowed to grow, reproduce, and digest OM. Equation 5 shows how SRT is calculated based on the total mass of solids inside the reactor, $m_s^R$, the effluent solid concentration, $C_s^{eff}$, and the effluent flowrate, $Q^{eff}$. Equation 6 is used to calculate SRT in ASBR digesters, with $V_{react,i}^R$ being the volume present inside the reactor during the react phase on day i, $[VSS]_{R,i}$ the concentration of VSS inside the reactor during the react phase on day i, $V_i^D$ the volume decanted from the reactor on day I, $[VSS]_D$ the concentration of VSS in decanted effluent on day i, $V_j^{SW}$ the volume of sludge wasted on day j, $[VSS]_{sw}$ the concentration of VSS in the sludge wasted on day j, n the number of days in an evaluation period, and x the number of sludge wasting events in the evaluation period lasting n days (Hamilton and Steele, 2014).

$$SRT = \frac{m_s^R}{C_s^{eff} \cdot Q^{eff}} \qquad \text{Eq. 5}$$

$$SRT_{ASBR} = \frac{\frac{\sum_1^n \left(V_{react,i}^R \cdot [VSS]_{R,i}\right)}{n}}{\sum_1^n \left(V_i^D \cdot [VSS]_D\right) + \sum_1^x \left(V_j^{SW} \cdot [VSS]_{sw}\right)} \qquad \text{Eq. 6}$$

Four full-scale mesophilic anaerobic digesters operating in Italy were studied by Bolzonella et al. (2005) to determine the relationship between SRT and biogas production. The reactors operated as CSTRs without a clarifying unit, and were fed waste activated sludge ranging from 2.5 to 4 %TS. A relationship between the expected biogas yield ($Y_{biogas}$ in L g$^{-1}$VS) and the SRT in a range covering from 8 to 45 days was obtained (Equation 7). This relationship suggests that biogas yield is maximized at lower SRTs.

$$Y_{biogas}\left(\frac{liters}{g\,VS_{fed}}\right) = 0.23 \cdot e^{-0.028 \cdot SRT\ (days)} \qquad \text{Eq. 7}$$

Nges and Liu (2010) studied a broad selection of SRTs (ranging from 3 to 35 days) for CSTRs treating sewage sludge under mesophilic and thermophilic conditions. Because of the characteristics of the CSTRs studied, a decrease in SRT resulted in an increase in the loading rate. The researchers observed that decreasing SRTs resulted in an increase in biogas production and a decrease in the OM removal efficiency. The overall effect was that biogas yield increased and volumetric reactor efficiency decreased when SRT was increased. A limit of 9 day SRT was observed, below which excessive foaming and a sharp decrease in biogas production occurred. The most favorable SRT was 30 days. It must be noted that the results obtained by Nges and Liu (2010) clearly contradicts the observations of Bolzonella et al. (2005). Lee et al. (2011) reached similar conclusions to Nges and Liu (2010) after operating a bench scale CSTR treating a combination of primary and waste activated sludge. They observed that organic removal efficiencies and biogas yield increased steadily with increasing SRT. Below 10 days SRT, the removal efficiencies decreased considerably, explained by a reduced ability to hydrolyze OM.

### 2.3.4. Food-to-Microorganism Ratio

The Food-to-Microorganism ratio (F/M) indicates how much substrate is supplied per mass of microorganisms available to digest the substrate. It is common to use mass of VSS to indicate mass of organisms, as it is difficult to measure the actual mass of viable cells. The amount of substrate added is usually expressed in terms of oxygen demand, most commonly Chemical Oxygen Demand (COD). Therefore, the magnitude of the F/M will depend on the strength of the feed, the volumetric feeding rate, and the SRT. Equation 8 is used to calculate F/M, with $Q^{in}$ being the flowrate of the influent, $[OM]^{in}$ the concentration of OM in the influent, $[VSS]_{react}$ the concentration of VSS within the reactor and $V^R$ the reactor volume.

$$F/M = \frac{Q^{in} \cdot [OM]^{in}}{[VSS]_{react} \cdot V^R} \qquad \text{Eq. 8}$$

Pérez et al. (1999) described the effect of F/M for a thermophilic fluidized bed reactor treating industrial wastewater. A relationship between OM removal efficiency and F/M was observed, dropping from above 95% at F/M of 0.05 kg COD $kg^{-1}$ VS $day^{-1}$ to 80% for F/M of 0.55 kg COD $kg^{-1}$ VS $day^{-1}$. Methane yield and volumetric reactor efficiency was increased until a F/M of 0.30 kg $kg^{-1}$ $day^{-1}$ was achieved, after which further increases in F/M did not affect $CH_4$ yield or volumetric reactor efficiency. A study was conducted by Kafle et al. (2014) to determine the influence of F/M on the anaerobic batch digestion of Chinese cabbage waste under mesophilic and thermophilic conditions. Food to Microogranism ratios of 0.5, 1 and 2 (substrate concentrations of 2.5, 5 and 10 g VS $L^{-1}$, respectively) measured as g substrate $g^{-1}$ inoculum added were tested. Under mesophilic conditions, the $CH_4$ content in the biogas decreased with larger F/M (62.8 to 57.3%), while under thermophilic conditions the opposite behavior was observed (28.9 to 51.3%). The removal efficiencies were largely favored by higher F/M, increasing from 59.4% to 75.6% in mesophilic conditions, and from 63.5 to 78.3% in thermophilic conditions favoring the higher F/M. Siddique et al. (2016) carried out experiments to determine the effect of altering the F/M in the co-digestion of petrochemical wastewater with manure in a batch CSTR. Food to Microogranism ratios were reported in terms of g $VS_{fed}$ per gVS in the reactor, and varied from 0.25 to 2. Under mesophilic conditions, the increase in F/M resulted in a $CH_4$ content drop from 79% to 58%, while OM removal efficiencies increased steadily from 55 to 77% as F/M increased. The $CH_4$ generation per gram of VS had a peak at F/M 0.5, and another peak at F/M of 2. A similar behavior was observed when using the same F/M range in thermophilic conditions.

### 2.3.5. Organic Loading Rate

The amount of OM fed per volume of reactor is the reactors Organic Loading Rate (OLR). This variable is related to the HRT (lower HRT results in higher OLR) and the wastewater strength (higher influent OM concentration translates into higher OLR). The most common units used are in terms of mass of COD or VS fed to the reactor per volume of reactor per time (kg COD $m^{-3}$ $day^{-1}$). The generic formula for OLR is presented in Equation 9, while equation 10 shows how to calculate it for ASBRs (Hamilton and Steele, 2014).

$$OLR = \frac{Q^{in} \cdot [OM]^{in}}{V^R} \quad \text{Eq. 9}$$

$$OLR_{ASBR} = \frac{V_i^{in} \cdot [OM]_i^{in}}{V_{react,i}^R} \quad \text{Eq. 10}$$

Anaerobic digesters operate under a broader range of OLRs than aerobic digesters, and OLR varies greatly depending on the type of reactor used. Babaee and Shayegan (2011) carried out experiments in a pilot scale, 70L CSTR to determine the influence of OLR on the production of $CH_4$ from municipal solid waste. It was found that the highest organic removal efficiencies and $CH_4$ yields were achieved at the lowest OLR studied (1.4 kgVS $m^{-3}$ $day^{-1}$). Increasing the OLR to 2 and 2.75 kgVS $m^{-3}$ $day^{-1}$ reduced the reactor OM removal efficiency, lowered the pH and alkalinity, and reduced the biogas $CH_4$ content. Borja et al. (1995) studied the effect of OLR on anaerobic treatment of slaughterhouse wastewater using a fluidized-bed reactor. The OLR was increased from 2.9 to 54 gCOD $L^{-1}$ $day^{-1}$, which provided a linear response in biogas produced per day. The $CH_4$content decreased considerably when OLR was increased (from 78% to 59%), which was attributed in the paper to a possible methanogen inhibition. The VFA concentration in the reactor increased considerably, and the OM removal efficiency was reduced when OLR was increased. Sánchez et al. (2005) tested the stability and performance of a UASB reactor treating swine manure. Operating conditions were varied from 1 to 8.1 g COD $L^{-1}$ $day^{-1}$. At OLRs above 1 g COD $L^{-1}$ $day^{-1}$ provided removal efficiencies below 80% in SS and COD, and kept decreasing as the OLR was increased. VFAs experienced a continued increase while alkalinity dropped under increasing loadings, causing a decrease in pH. Finally, $CH_4$ content was severely decreased at higher OLRs (66% at 1, 47% at 4.1, 33.3% $CH_4$ at 8.1 gCOD $L^{-1}$ $day^{-1}$). Wijekoon et al. (2011) studied the impact of OLR on a VFA production in a two-stage thermophilic anaerobic membrane reactor. Organic loading rates ranged from 5 to 12 kg COD $m^{-3}$ $day^{-1}$. Volatile fatty acids accumulated and the predominant VFA species switched from acetic to n-butyric acid as OLR was increased.

### 2.3.6. Mixing

Mixing plays a major role in most of processes involving chemical or biological reactions. Homogenization of a reactor's contents achieves a better contact between the species participating in the reaction. Several studies have been conducted to determine the best option for mixing an anaerobic digester in terms of mixing design, mixing intensity and mixing frequency, but the specificity of each application makes it hard to come up with general rules.

#### *2.3.6.1. Mixing Type*

Three basic types of mixing are used in anaerobic digesters; mechanical, hydraulic, and pneumatic. In mechanical mixing, force is transmitted to the fluid by a rotating impeller. Hydraulic and pneumatic systems provide the mixing force by recirculating reactor liquids and gases, respectively. Each particular type of mixing has benefits and drawbacks, and should be selected based on the reactor design to enhance its operation (Lindmark et al., 2014).

#### *2.3.6.2. Mixing Intensity*

High mixing intensity increases the shear stress on the medium, preventing aggregation of solids. This has been reported to cause gas production inhibition by several researchers including Stroot et al. (2001) and Kim et al. (2002). Vavilin and Angelidaki (2005) showed that stress applied to the microorganisms conducting hydrolysis, acidogenesis, acetogenesis, and methanogenesis cause inhibition of biogas production (Vavilin and Angelidaki, 2005) . The US EPA provided a guideline for the design of mixing systems for anaerobic digesters in which it was recommended to use mixing intensities between 5 and 8 W $m^{-3}$ (Lindmark et al., 2014).

#### *2.3.6.3. Mixing Frequency*

Three different schemes of operation can be differentiated; continuous, intermittent, and unmixed. A compromise between increase in biogas production and energy demanded by the mixing system must be reached to optimize the reactor's operation; therefore the benefits of mixing frequency must be closely evaluated. Mills (1979) developed experiments to optimize the energy balance of a mesophilic anaerobic digester, and found out that up to 70% of the biogas produced was released while the mixing system was operating. Several researchers determined that similar biogas production could be achieved than that of a continuously mixed reactor by operating in mixing/settling cycles of variable times (Lindmark et al., 2014). At the same time, other researchers claimed that mixing a reactor either in a continuous or an intermittent mode did not provide any benefit when compared to an unmixed reactor unless a particularly high OLR was used (Karim et al., 2005). The lack of a consensus is likely a result of the high variability in the operational parameters used in each study (i.e. OLR, HRT, SRT, feedstock, reactor design, mixing type, mixing intensity). In general, it is accepted that intermittent mixing provides better energy efficiency than continuous mixing due to savings in mixing energy, as the biogas production does not change between the intermittent and continuous mixing (Kaparaju et al., 2008).

## 2.4. Performance Parameters

The operation of an anaerobic digester is usually evaluated based on two parameters; OM removal efficiency and biogas production.

### 2.4.1. Organic Matter Removal Efficiency

The extent to which a given reactor digests the OM present in the influent wastewater is indicative of its treatment efficiency. A mass balance between the OM of the influent and OM of the effluent can provide sufficient data to assess process efficiency. The most common measures of OM strength are VS and oxygen demand (either COD, or BOD). Equations 11 and 12 are used to calculate removal efficiencies for VS and COD, and analogous equations are used for VSS and BOD. Organic matter removal efficiencies refer only to volatile species (VS, VSS, BOD, and COD), but it is not uncommon to find other removal efficiencies reported in the literature (i.e. TS, DS, FS), therefore it is very important to always report which variable is being evaluated.

$$\eta_{VS} = \frac{VS_{in} - VS_{out}}{VS_{in}} \cdot 100 \qquad \text{Eq. 11}$$

$$\eta_{COD} = \frac{COD_{in} - COD_{out}}{COD_{in}} \cdot 100 \qquad \text{Eq. 12}$$

### 2.4.2. Biogas Production

The general reaction of anaerobic digestion (Eq. 2) converts OM into a mixture of $CH_4$ and $CO_2$, along with traces of other gases ($H_2$, $H_2S$). As more OM is digested, a higher volume of biogas is produced. The most important biogas variable is the ratio between $CH_4$ and $CO_2$. Since $CH_4$ is the gas that can be combusted, keeping the $CH_4$ content high in the biogas is desirable. Table 4 provides typical values for the $CH_4$ content based on the type of waste digested.

Table 4. Approximate $CH_4$ Percentage in Biogas for Different Substrates
(adapted from Burton et al. (2013) and Swedish Gas Centre (2012))

| ***Substrate*** | **$CH_4$ %** |
|---|---|
| **Wastewater treatment plant sludge** | 65 |
| **Fish waste** | 71 |
| **Straw** | 70 |
| **Sorted food waste** | 63 |
| **Liquid cattle manure** | 65 |
| **Potato stems** | 56 |
| **Slaughterhouse waste** | 63 |
| **Liquid pig slurry** | 65 |
| ***Compound*** | $CH_4$ % |
| **Lipid (approx. $C_{18}H_{33}O_2$)** | 70 |
| **Carbohydrate (approx. $C_6H_{10}O_5$)** | 50 |
| **Protein (approx. $C_{11}H_{24}O_5N_4$)** | 66 |

Another important factor used to assess how efficiently the reactor operates is the gas yield. Yields can refer to either total biogas or $CH_4$ volume. The most common yields are expressed in terms of gas produced per mass of VS or per mass of COD fed to the reactor. Equations 13 and 14 are used for calculating the gas yields by dividing the volume of gas produced ($V_{gas}$) by the mass of OM fed in terms of COD ($m_{COD}^{fed}$) or VS ($m_{VS}^{fed}$).

$$Y_{gas}^{COD} = \frac{V_{gas}}{m_{COD}^{fed}} \quad \text{Eq. 13}$$

$$Y_{gas}^{VS} = \frac{V_{gas}}{m_{VS}^{fed}} \quad \text{Eq. 14}$$

The ultimate $CH_4$ yield of COD can be determined through stoichiometry as the volume of CH4 that can be produced from a given mass of oxygen demand (Burton et al., 2013)

$$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O + heat \quad \text{Eq. 15}$$

$$\left(16 + 2 \cdot 32 \Rightarrow 44 + 2 \cdot 18\right)\ grams \quad \text{Eq. 16}$$

Focusing on the left side of the combustion equation for $CH_4$, it is seen that 2 moles of $O_2$ are consumed in the combustion of one mole of $CH_4$, or 64 grams of $O_2$ are demanded per 16 grams of $CH_4$. Therefore:

$$Maximum\ CH_4\ yield\ (35\ ℃, 1\ bar):\ \frac{16\ g\ CH_4}{64\ g\ COD} \cdot \frac{1}{0.627 \frac{g\ CH_4}{L\ CH_4}} = 0.399 \frac{L\ CH_4}{g\ COD} \quad \text{Eq. 17}$$

Equation 17 provides an upper limit to how much $CH_4$ can be produced per mass of oxygen demand. The volume generated is highly dependent on the temperature and pressure at which the biogas is produced. The relationship between VS destroyed and the biogas produced is more variable than COD given the different nature of different types of OM. A typical range of values is from 0.75 to 1.12 L of biogas per g of VSS destroyed (Burton et al., 2013).

Another way of assessing the biogas production of an anaerobic digester relates to the volume of gas that can be produced per volume of reactor per day. This variable receives the name of volumetric reactor efficiency (VRE), and can be expressed in terms of volume of biogas or $CH_4$ produced.

### 2.5. Past Work on ASBR Digesters

The concept of ASBR was developed by Richard Dague at Iowa State University (Habben, 1991). A set of experiments were conducted to determine the capability of an anaerobic reactor to conduct internal settling. It was concluded that the proposed reactor design effectively settled solids without using an external unit or a degasifier. In addition, a maximum concentration of mixed liquor TSS between 12,000 and 13,000 mg $L^{-1}$ was observed, above which solids settling was impeded. A patent for the ASBR design was issued in 1993 (Dague, 1993). In the patent, the design is specified (Figure 11) and data is provided for different experiments conducted to test the patented design. The following claims were attached to the patent document:

- A wide range of OLRs can be treated while maintaining high OM removal efficiencies.

- Intermittent mixing favors biogas production (2 minutes mix per hour provides better results than continuous mixing).

- The design can be used with all types of mixing, but it is recommended to avoid aggressive methods that sheer flocculent and granular biomass solids and keeping them from settling.

- The separation of solid particles from the liquid matrix can be enhanced by creating vacuum conditions prior to settling, removing gas bubbles that tend to lift solid particles reducing the effluent quality.

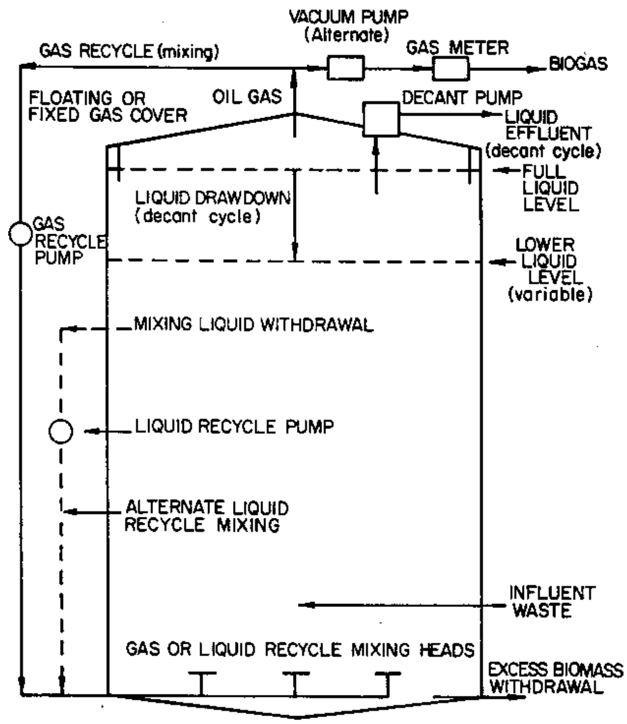



Figure 11. Patented ASBR design (Dague, 1993).

Ndon and Dague (1997) conducted a series of experiments to evaluate the influence of temperature and HRTs on the operation of ASBRs treating low strength wastewater. Studied temperatures ranged from 15 to 35 °C. The influent COD was adjusted to 400, 600, 800 and 1,000 mg $L^{-1}$. The HRTs used were extremely low (12 to 48 h), yet COD removal efficiencies above 80% were achieved in all experiments. It was concluded that low temperatures and higher influent strength provided poorer results in terms of removal efficiency. Solids retention time could be maintained in a range between 50 days (at 12 hour HRT) and 300 days (at 48 hour HRT).

Masse and Masse (2000) applied the ASBR technology to slaughterhouse wastewater by using four 42-L mesophilic reactors operated at 30 °C. After a start-up period in which high concentrations of solids were lost in the effluent, steady-state conditions were achieved under variable OLRs ranging from 2 to 5 kg COD $m^{-3}$ $day^{-1}$ and an HRT of 2 days. COD removal efficiencies of above 90% were achieved. Average effluent quality was reported to be 364 mg TSS $L^{-1}$.

Shizas and Bagley (2002) studied the impact of influent concentration, total cycle time and fill time to cycle time ratio on a lab-scale ASBR treating a glucose solution. They proposed that increasing the feeding time considerably (up to 75% of the total cycle time) could avoid process destabilization caused by sudden changes in the reactor environment (peaks of substrate concentration). This operation was especially recommended by the authors when treating easily digestible materials. Shorter cycles with lower initial substrate concentration were also suggested to work better for ASBRs.

Massé et al. (2003) operated an ASBR at psychrophilic conditions to evaluate the possibility of operating under ambient conditions to avoid the application of heating energy. A decrease in $CH_4$ yield was observed when operation temperature was lowered from 20 to 10 °C (0.218 and 0.080 L $gCOD_{fed}^{-1}$, respectively) along with a considerably lower organic removal efficiency (94.2% and 60.4% COD removal).

Ndegwa et al. (2005) studied the application of the ASBR technology to dilute swine manure at 20 and 35 °C with HRTs between 4 and 12 days. Biogas yield was slightly improved at the higher temperature (0.14 L g $COD^{-1}$ at 20 °C and 0.16 L g $COD^{-1}$ at 35°C and 6-day HRT). OM removal efficiencies were improved at 20°C (90%) compared to 35°C (84%). The improvement in removal efficiency at the lower temperature was explained by the authors by an increased settleability of solids at 20 °C overcame the higher reaction rate at 35°C.

Sarti et al. (2007) evaluated the performance of three, 1.2 $m^3$, pilot-scale ASBRs with different geometries and mixing types. At OLRs ranging from 0.6 to 1.2 kgCOD $m^{-3}$ $day^{-1}$, the two reactors operating with a sludge recirculation system achieved very low OM removal efficiencies (around

40% COD and 60% VSS removals). The reactor operating with mechanical mixing provided considerably better results (60% COD and 80% VSS removals), which lead the authors to the conclusion that the particle size reduction caused by the hydraulic mixing prevents the proper operation of ASBRs due to settleability loss.

Pinheiro et al. (2008) used hydraulic-mixed ASBRs operating in 6 hour cycles at 30 °C in order to treat a diluted synthetic wastewater consisting of a mixture of carbohydrates, lipids, proteins and metal traces. An optimum liquid recirculation velocity was determined to be 7 m $h^{-1}$, which provided the best combination of mass transfer enhancement and shear stress reduction. Also, the cycle length was evaluated compared to the two different influent concentrations; for the 500 mg COD $L^{-1}$ feed, cycle length could be reduced up to 2 h, while for the 1,000 and 1,500 mg COD $L^{-1}$ feed the cycle length lower limit was found to be 3.5 h.

The cycle frequency and operation temperature of ASBRs treating dilute swine manure was further analyzed by Ndegwa et al. (2008), leading to results similar to their previous studies. Temperature of 20 °C was favored in terms of OM removal efficiency, odor control (VFA degradation) and effluent biostabilization. When comparing the operation of ASBRs at 1 and 3 cycles per day, it was concluded that a long, single cycle provided greater biogas production while maintaining the same $CH_4$ concentration and lower presence of solids in the effluent, while the VFA reduction was not affected by the cycle frequency.

Extremely low strength domestic wastewater (290 to 500 mg COD $L^{-1}$) was treated using ASBRs at variable OLRs, HRTs, and temperatures ranging from 10 to 25 °C in a study conducted by Kayranli and Ugurlu (2011). A considerable decrease in organic removal efficiency was observed when using lower temperatures and HRTs. Methane yields of 0.20, 0.18 and 0.15 L $g^{-1}$ COD were obtained for 25, 15 and 10 °C, respectively. The experiments conducted at 25°C obtained good organic removal efficiencies even at HRTs as low as 11 h, but as the temperature dropped the need for longer HRTs became obvious. Hamilton and Steele (2014) operated a 400 $m^3$ ASBR treating diluted swine manure at 20 and 5 day HRTs, with operating temperatures held at minimum of 22 °C but otherwise following the daily ambient temperatures. Removal efficiencies of 73% COD and 62% VS, and $CH_4$ yields of 0.55 $m^3$ $CH_4$ kg $VS^{-1}$ were achieved operating under the 20-day HRT. The reduction of HRT to 5 days resulted in lower removal efficiencies (57% COD and 55% VS) and $CH_4$ yield (0.38 $m^3$ $kgVS^{-1}$). The overall VRE remained constant at 0.18 $m^3CH_4$ $m^{-3}$ $day^{-1}$. Hamilton and Steele (2014) determined that solids washout related to the decrease in feed solids concentration and HRT resulted in a coupling of SRT and HRT in the 400$m^3$ ASBR reactor (Figure 12). The authors surmised that more solids were being decanted than those being fed daily, resulting in the overall reduction of mass retained within the ASBR. Solids began accumulating once more as decant solids concentration reached a level lower than influent solids.

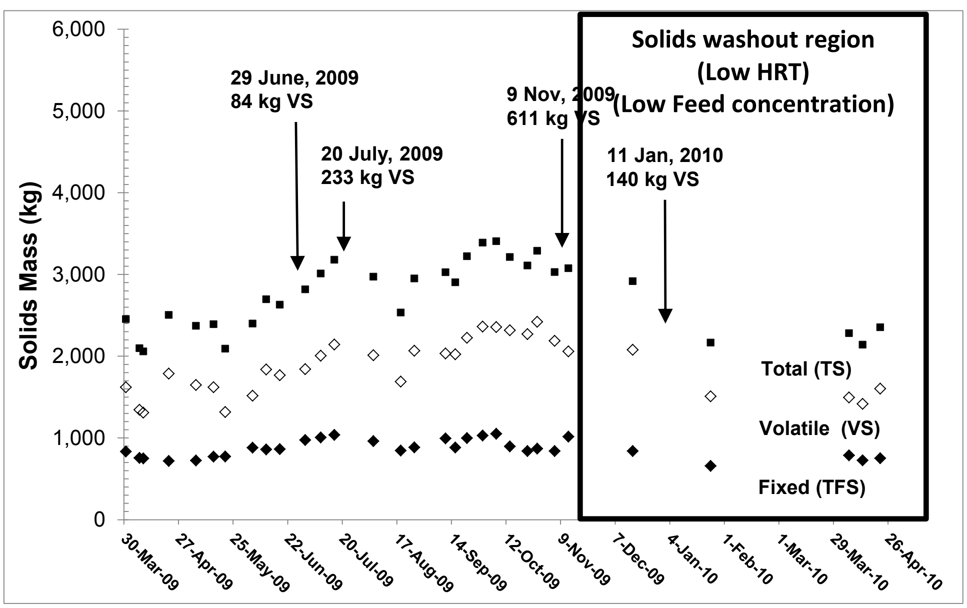
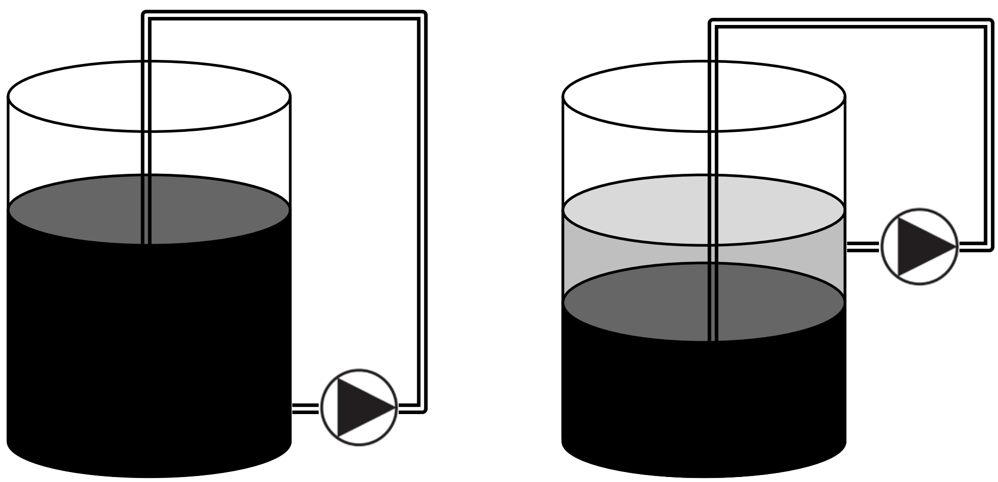



Figure 12. Solids Washout Observed during Operation of Full-Scale ASBR (Hamilton and Steele, 2014).

# CHAPTER III

## OBJECTIVES

The purpose of the work described in this thesis is to improve the operation of ASBRs treating dilute wastewater by increasing their ability to retain solids. An alternative mixing scheme (Figure 13b) was tested to avoid solids washout problems.



a. Typical Full-Mix ASBR Mixing Scheme b. Proposed Partial-Mix ASBR Mixing Scheme

Figure 13. Comparison between Typical and Proposed Mixing Schemes.

### 3.1. Evaluation of the Hypothesis

The performance of the proposed alternative mixing scheme for ASBRs was then tested in three experimental trials:

1. In the first trial, a simultaneous comparison between a fully-mixed ASBR and a partially-mixed reactor was performed. Operating conditions were kept constant (temperature, OLR, HRT and mixing times), and the performance of both reactors (Operation stability, retained OM, VSS accumulation rate, effluent quality, OM removal efficiency, biogas production, and SRT) were evaluated to determine the adequacy of the proposed mixing design.

2. In the second trial, five reactors were changed from fully-mixed ASBR to partially-mixed ASBR while maintaining the same operating conditions. Comparisons were made before and after mixing systems were changes. Performance was evaluated based on the same parameters of the first trial.

3. The third trial evaluated the impact of decreasing the HRT (and the subsequent increasing OLR) on six reactors operating under the partially-mixed scheme. Comparisons were made before and after the HRT reduction. Performance was evaluated based on the same parameters of the first trial.

## 3.2. Evaluation Criteria

### 3.2.1. Evaluation of Operation Stability

The VFA concentration, alkalinity and pH of the reactors were closely followed. In particular, VFA-to-alkalinity ratio and pH are reported on a weekly basis.

### 3.2.2. Evaluation of Mass of Organic Matter and Accumulation Rate

The mass of OM present in the reactors and its accumulation rate was determined to provide an estimate of the ability to retain digestible material and to grow microorganisms within the reactor. This was values were obtained by sampling reactor profiles and determining the VSS content at different depths.

### 3.2.3. Evaluation of Effluent Quality

The quality of the reactor effluent was tested in terms of solids concentration. In particular, total, volatile, suspended and dissolved solids present in the decanted phase were determined in order to evaluate the effect of each treatment applied to the reactors.

### 3.2.4. Evaluation of Organic Matter Removal Efficiency

The relationship between OM fed to the reactor and OM leaving the reactor in the decanted effluent was used to determine the OM removal efficiencies of the system. OM in the form of VS, VSS and COD was evaluated to determine the three different OM removal efficiencies tested in this work.

### 3.2.5. Evaluation of Biogas Production

The biogas production was closely followed and different operation parameters daily biogas production rate, biogas yield, and VRE were computed.

### 3.2.6. Evaluation of Solids Retention Ability

The ability to capture solids in a reactor was computed through the determination of SRT, and this provided a measurement of how much time an average particle of OM spent in the reactor.

# CHAPTER IV

# MATERIALS AND METHODS

Experiments were conducted at the Oklahoma State University BAE West Lab in in Stillwater, Oklahoma.

## 4.1. Experimental Setup

The research was conducted using a set of six identical bench-scale ASBRs operating in parallel as shown in Figures 14 and 15.

### 4.1.1. Hydraulic Installation

The hydraulic installation was designed to allow an automated operation of the six reactors, while ensuring that all reactors were fed a mixture of swine manure and glycerol with the same characteristics. Figure 14 shows the schematic design of the hydraulic system used. For a better understanding of the process, the hydraulic installation can be separated into three different operation systems that are independent of each other; feeding, mixing of reactor contents, and decanting the treated effluent.

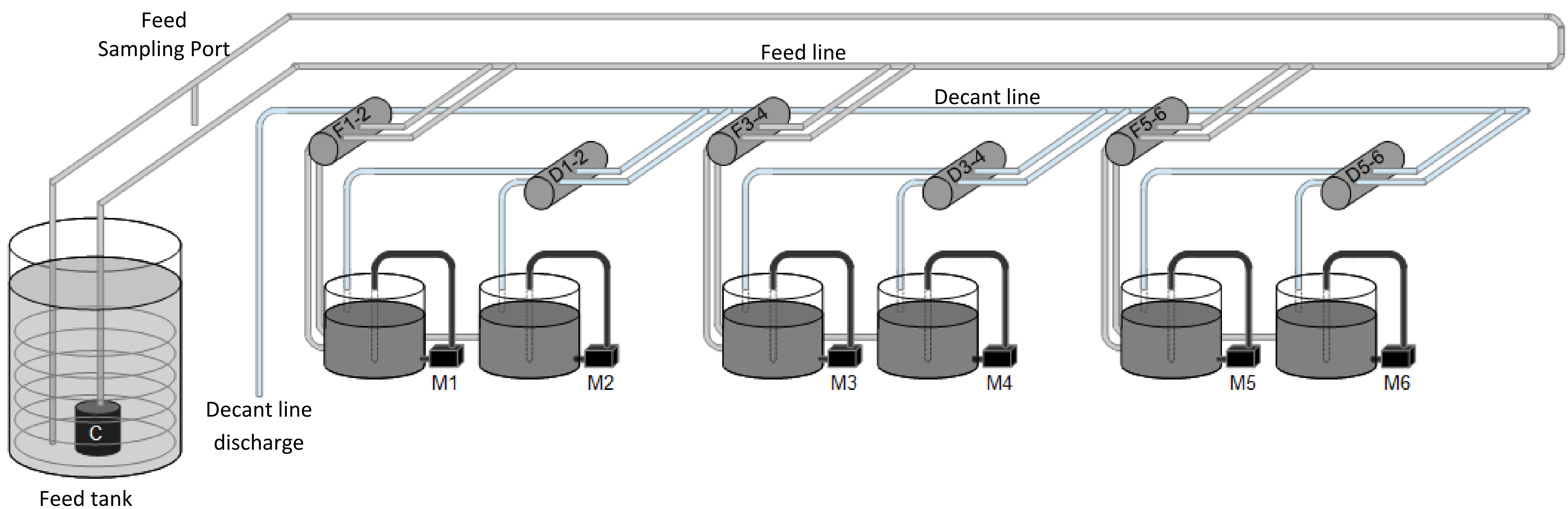



Figure 14. Experimental Setup: Hydraulic Installation.

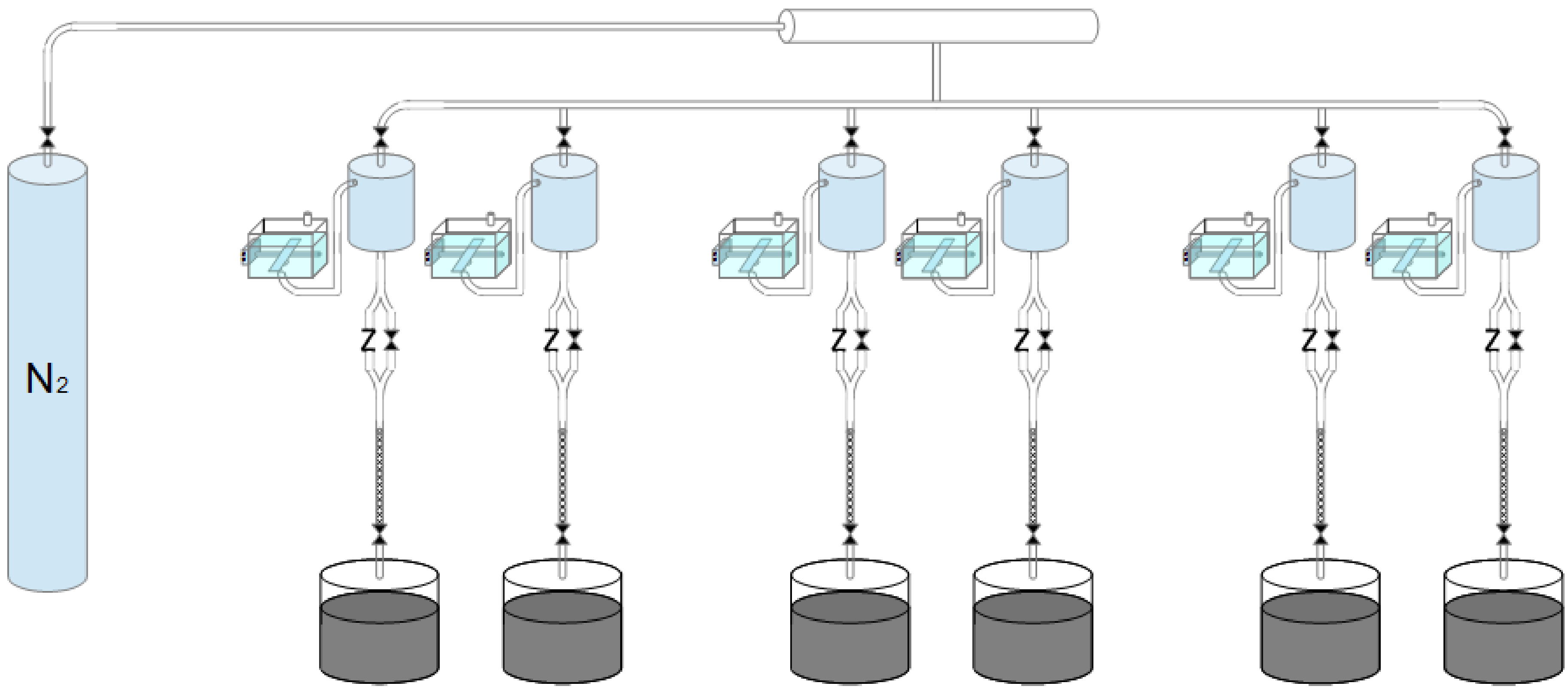



Figure 15. Gas Handling System.

The feeding operation consisted of transferring a given amount of volume from the reservoir where the feed was contained (Feed tank, 180 L PE) to each of the six reactors. This took place once or twice per day (depending on the cycle time used), and was carried out as follows. First, the circulation pump (C, UTILITECH submersible pump, 1/6hp) located at the bottom of the feed tank was switched on, and feed was circulated through the feed line. Then, the feed pump (F, MASTERFLEX Model 7553-70) for a pair of reactors was switched on for a set amount of time (time of feeding depends on the chosen HRT), injecting the required amount of feed inside the reactors connected to such pump.

The decanting operation took place at the end of each cycle, and was responsible for removing the same amount of feed added to the reactor at the beginning of the cycle. The decant pump (D, MASTERFLEX Model 7553-70) operated for the same amount of time as the feed pump to maintain steady state conditions over time. Both decant and feed pumps for each pair of reactors were calibrated weekly to adjust their respective flow rates, so the liquid fed and decanted would remain constant. The reactors were mixed intermittently through each cycle, in intervals of 90 min mixing followed by 90 min settling. Right after feeding a pair of reactors, the mixing pumps (M, LITTLE GIANT 1EUAA-MD for full-mix, MASTERFLEX Model 7553-70 for partial-mix) started to operate for 90 min, after which the mixing was interrupted for the same amount of time. Depending on the cycle length, 4 or 8 mixing-settling processes took place between feeding and decanting a reactor in each cycle. It must be noted that the reactors were arranged to operate in pairs, as each feeding and decanting pump was used for two reactors at the same time. The lines were independent, but the pumping equipment for feeding and decanting was shared. All hydraulic operations were programmed with a set of 10 timers that activated and deactivated the different pumps of the installation. Table 5 provides the timers set up for the whole installation to operate with two cycles per day, and 6 days HRT. Note that the decant pump and feed pump were activated with some minutes of difference (decant at X:26 and feed at X:30).

Table 5. Timer Setup to Operate the Whole Installation at 6-day HRT and 2 Cycles per Day.

| | Feed tank | Reactors 1&2 | | | Reactors 3&4 | | | Reactors 5&6 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Time** | **C** | **F** | **D** | **M** | **F** | **D** | **M** | **F** | **D** | **M** |
| **08:30** | 10 min | 2 min | 2 min | | | | | | | |
| **09:00** | | | | 90 min | | | | | | |
| **09:30** | 10 min | | | | 2 min | 2 min | | | | |
| **10:00** | | | | | | | 90 min | | | |
| **10:30** | 10 min | | | | | | | 2 min | 2 min | |
| **11:00** | | | | | | | | | | 90 min |
| **11:30** | | | | | | | | | | |
| **12:00** | | | | 90 min | | | | | | |
| **12:30** | | | | | | | | | | |
| **13:00** | | | | | | | 90 min | | | |
| **13:30** | | | | | | | | | | |
| **14:00** | | | | | | | | | | 90 min |
| **14:30** | | | | | | | | | | |
| **15:00** | | | | 90 min | | | | | | |
| **15:30** | | | | | | | | | | |
| **16:00** | | | | | | | 90 min | | | |
| **16:30** | | | | | | | | | | |
| **17:00** | | | | | | | | | | 90 min |
| **17:30** | | | | | | | | | | |
| **18:00** | | | | 90 min | | | | | | |
| **18:30** | | | | | | | | | | |
| **19:00** | | | | | | | 90 min | | | |
| **19:30** | | | | | | | | | | |
| **20:00** | | | | | | | | | | 90 min |
| **20:30** | 10 min | 2 min | 2 min | | | | | | | |
| **21:00** | | | | 90 min | | | | | | |
| **21:30** | 10 min | | | | 2 min | 2 min | | | | |
| **22:00** | | | | | | | 90 min | | | |
| **22:30** | 10 min | | | | | | | 2 min | 2 min | |
| **23:00** | | | | | | | | | | 90 min |
| **23:30** | | | | | | | | | | |
| **00:00** | | | | 90 min | | | | | | |
| **00:30** | | | | | | | | | | |
| **01:00** | | | | | | | 90 min | | | |
| **01:30** | | | | | | | | | | |
| **02:00** | | | | | | | | | | 90 min |
| **02:30** | | | | | | | | | | |
| **03:00** | | | | 90 min | | | | | | |
| **03:30** | | | | | | | | | | |
| **04:00** | | | | | | | 90 min | | | |
| **04:30** | | | | | | | | | | |
| **05:00** | | | | | | | | | | 90 min |
| **05:30** | | | | | | | | | | |
| **06:00** | | | | 90 min | | | | | | |
| **06:30** | | | | | | | | | | |
| **07:00** | | | | | | | 90 min | | | |
| **07:30** | | | | | | | | | | 90 min |
| **08:00** | | | | | | | | | | |

Another part of the hydraulic installation is the heating system. Water was warmed a laboratory water baths (Julabo D7790 MV-BASIS) and circulated through heating coils in each reactor at 35 °C. The heating stream was conducted through a piping system that connected to each reactor's heating coil, effectively maintaining mesophilic operating conditions. A cooling system was also connected to the feed tank cooling coils to prevent OM degradation by keeping liquid temperature as low as possible (2$^{o}$C). All piping (i.e. feed line, decant line, water-bath line) was constructed using PVC SCH40 1/2" pipes. All tubing for the reactor mixing and feeding lines was made out of 3/8" ID vinyl using plastic connectors. Tubing for the gas handling system was made out with 1/4" ID vinyl using plastic connectors.

### 4.1.2. Gas Handling System

A schematic drawing of the gas handling system used in the experimental setup is presented in Figure 15. Gas leaving each reactor traveled through an iron-based filter to remove $H_2S$, after which it crossed a check valve. Then, it reached a gas meter (Figure 16) that accounted for the volume of biogas produced. Finally, biogas coming out of the gas meter was conducted outside the reactor room and vented.

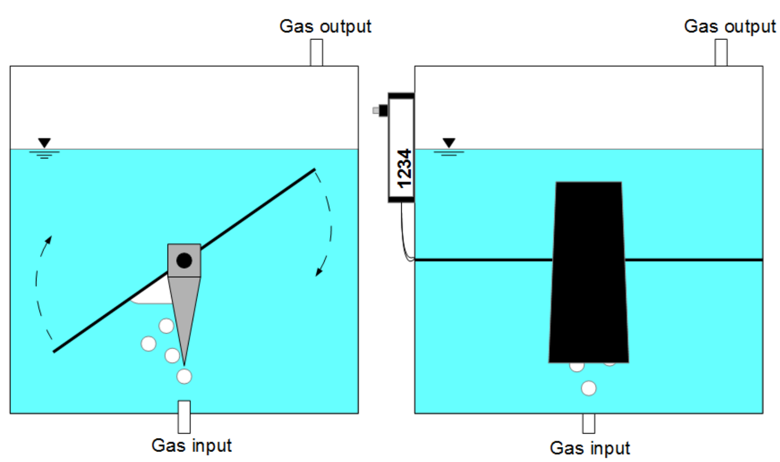



Figure 16. Tipping Bucket Gas Meter.

The gas meter kept track of the number of bubbles of a set volume passing through the balance pole submerged in a body of water. Since the volume of water contained in the gas meter was constant (2.5L), the volume of gas that could be trapped beneath the balance before being lifted remained constant as well. When enough gas accumulated beneath the lower end of the balance, it generated enough force to lift it. Each of these tips had a fixed volume that depends on the water volume and certain construction parameters of the equipment. By locating a magnet associated to the balance, we could account the number of tips in a meter, and recorded them using a tip-meter. Then, the total volume of biogas produced in each reactor was calculated by using the calibration data provided in Table 6. This data was obtained by measuring the number of tips generated in each gas meter over a known flow rate and time.

Table 6. Calibration Data for Gas Meters.

| Reactor | Volume of biogas per tip (ml) |
|---|---|
| **1** | 10.89 |
| **2** | 11.15 |
| **3** | 10.91 |
| **4** | 10.50 |
| **5** | 10.81 |
| **6** | 11.62 |

A nitrogen tank was connected to the gas handling system to allow maintaining anaerobic conditions in the case one or more reactors needed to be taken off-line. In addition, it was used to locate gas leaks by pressurizing the reactors and checking each of the joints of the gas handling system individually. This was done by opening the appropriate valves and applying soap water to observe if soap bubbles formed.

### 4.1.3. Single Reactor Set-Up

Both full and partial-mix reactors were constructed using 12-inch Sch40 PVC pipe (Figures 17 and 18). Two end-caps were glued to both ends of the pipe's section. The vessel was then perforated at the top and on the sides to accommodate a decant port, a sampling port, two mixing ports, a gas outlet, and a purge port. The heating coil required two extra holes to be drilled into the vessel.

#### *4.1.3.1. Full-Mix Reactor Design*

In the full-mix reactor (Figure 17), the withdrawal port for the mix line was located on the lower end of the reactor's side, and the feed port lied in another side of the reactor. The contents of the reactor were mixed using a centrifugal pump (LITTLE GIANT 1EUAA-MD).

#### *4.1.3.2. Partial-Mix Reactor Design*

In the partial-mix reactor scheme (Figure 18), the feed and the mixing lines were combined. To achieve a better control of the mixing intensity, the centrifugal pump used in the full-mix scheme was replaced by a peristaltic pump in the partial-mix setup (MASTERFLEX Model 7553-70). Furthermore, to prevent crushing of solids and aggregates the withdrawal port for mixing was relocated at the top of the reactor. This way, the liquid was taken from the clarified layer lying on top of the column. The liquid withdrawal port for partial-mix reactor was built in the same way as the decant port described earlier, so it could be easily relocated at different depths on demand.

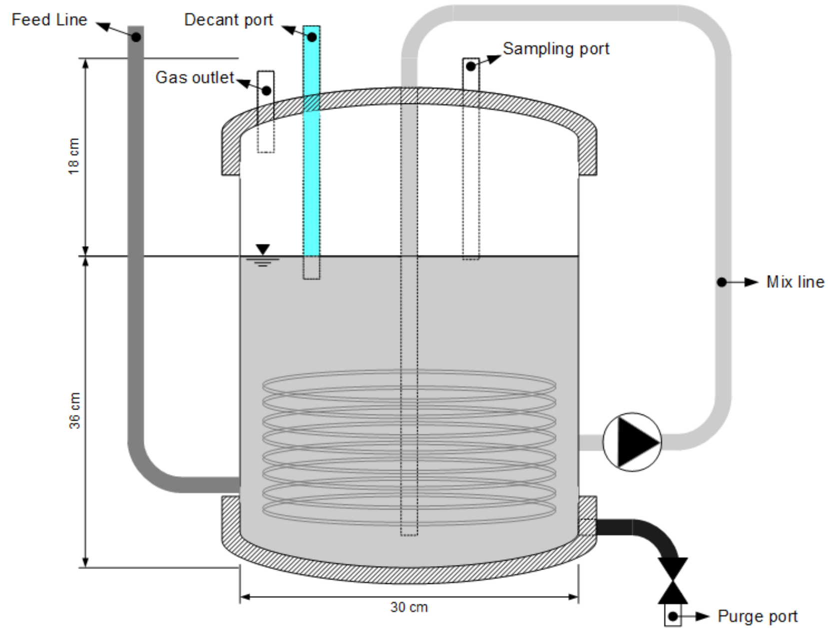



Figure 17. Experimental Scheme for a Full-Mix ASBR Reactor.

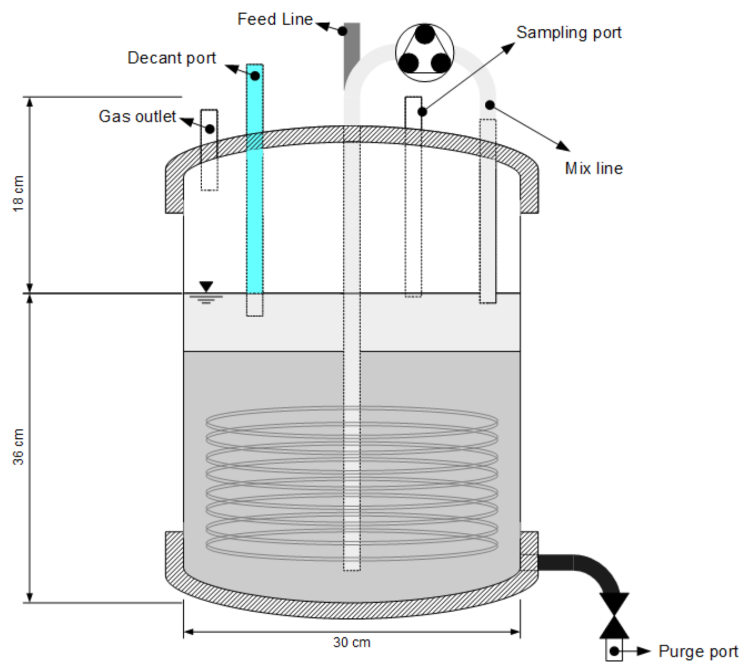



Figure 18. Experimental Scheme for a Partial-Mix ASBR Reactor.

## 4.2. **Analytical Methods**

The variables needed to assess the operation of our set of ASBRs were obtained by carefully following a set of procedures to analyze the samples taken. Most of these procedures were followed exactly as stated in Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

### 4.2.1. Total Solids and Volatile Solids

The determination of TS and VS of a sample was conducted using ceramic crucibles following Standard Methods procedures 2540B and 2540E (APHA, 2005) . The sample drying was conducted in a YAMATO Gravity Convection Oven DX600*,* while the burning of the residues was conducted using an ISOTEMP Muffle furnace. Weight measures were obtained using a precision balance (DENVER INSTRUMENT APX-200).

### 4.2.2. Total Suspended Solids and Volatile Suspended Solids

The determination of SS was carried out using Grade 934-AH™ Glass Microfiber Whatman® Filters of 47 mm in diameter, as specified in Standard Methods procedure 2540D and 2540E (APHA, 2005). Before the determination is conducted, all filters were rinsed, dried and burned to remove any possible impurities that could interfere with the measurements.

### 4.2.3. COD Determination

The samples to be tested for COD were stored to reduce the number of COD vials used for calibration curves. The preservation of the sample was done in accordance to the Standard

Methods procedure 1060C for Samples Storage and Preservation (APHA, 2005), by acidifying a 20 ml sample with 1 ml concentrated sulfuric acid. This reduced the pH below the 2.5 recommended limit. A labeled test tube was then filled with the acidified sample and stored in the freezer. The procedure followed for the determination of COD content of each sample was APHA 5220 (APHA, 2005). Once 20 to 25 samples have been accumulated, the test tubes were taken out of the freezer to thaw. Dilutions were applied to bring the sample to a readable COD range (0-1,000 mgCOD $L^{-1}$), using the dilution factor to calculate the actual sample COD value. The dilution was made based on previous experience of running COD samples. The general rule of thumb used is summarized next in Table 7.

Table 7. Regular COD Values for Different Sample Types and Dilutions Applied.

| Sample type | Regular COD range (mgCOD $L^{-1}$) | Dilution applied |
|---|---|---|
| **Manure** | 5,000 - 30,000 | 1:20 |
| **Feed** | 2,000 - 10,000 | 1:10 |
| **Retained solids** | 5,000 - 20,000 | 1:10 / 1:20 |
| **Full-mix decant** | 1,000 - 5,000 | 1:10 |
| **Partial-mix decant** | 300 - 1,000 | No dilution |

These proposed dilution values are only indicative, and were varied if a particular sample was suspected of having a higher COD value based on its turbidity, solid content or other related variable.

A calibration curve was constructed using a dilution of known COD values (prepared with Potassium Hydrogen Phthalate) for each batch of samples analyzed. The calibration consisted of 5 data points, with concentrations specified in Table 8.

Table 8. Calibration Curve for COD Determination.

| Calibration point | [COD] ($mgO_2\ L^{-1}$) |
|---|---|
| **Blank** | 0 |
| **S1** | 200 |
| **S2** | 400 |
| **S3** | 800 |
| **S4** | 1,000 |

A volume of 2 ml of each of the samples and of each of the calibration point solutions were added to a COD vial (CHEMetrics K-7365 Reagent kits) and introduced in the digestion machine (HACH DRB200) at 150 °C for 2 hours. After the test tubes had been cooled, the absorbance was read for each of the calibration points and the samples in the colorimeter (GENESYS 10vis Thermo Scientific). A calibration line was plotted for the 5 calibration points, and the COD was calculated for the samples by substituting the absorbance in the calibration equation, taking into consideration the dilution applied to the sample.

$$Calibration\ curve: \qquad [COD]_{read} = A + B \cdot Abs \qquad \text{Eq. 18}$$

$$[COD]_{sample} = \frac{[COD]_{read}}{dilution\ ratio} \qquad \text{Eq. 19}$$

With A and B being constants determined for each particular calibration curve, Abs the absorbance read in the colorimeter, $[COD]_{read}$ the value of the COD determined for the vial, $[COD]_{sample}$ the actual value of the sample's COD, and the dilution ratio expressed as ml of sample per ml of total volume. It must be remembered to include in the dilution ratio the volume of acid added to the sample in order to store it under safe conditions (i.e. 20/21).

### 4.2.4. Determination of Bicarbonates and VFAs

VFAs and bicarbonates present in the Retained Solids and Feed samples were determined through titration as described by Anderson and Yang (1992). First, a 50 ml sample was poured into a beaker and placed on top of a magnetic stirring unit. The pH is measured until no significant variation is observed (OAKTON pH meter 01X555402).Once the read pH was constant for the stirred sample, 1N HCl was added with a burette until a constant pH of 5.1 was reached, making sure to note the volume of acid consumed ($V_1$). Then, more acid was added until the final value of pH of 3.5 was achieved, writing down the amount of volume required ($V_2$). Then, the total VFAs and the bicarbonates expressed as mM $L^{-1}$ was calculated following the procedure reported in Anderson and Yang (1992).

## 4.3. **Sampling Methods**

### 4.3.1. Samples for Mass Balance Determination

Figure 19 shows a scheme of an ASBR with all the inputs and outputs necessary to establish a mass balance. Each of the streams provides valuable information to assess the operation of the reactors. Samples of Feed, Decant and Retained Solids were taken periodically by the procedures that are described below. The different tests conducted to determine the characteristics of each stream allowed establishing mass balances and relationships between different variables to improve the understanding of the process.

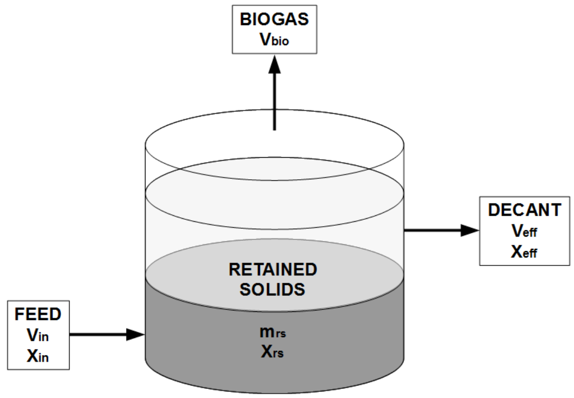



Figure 19. Mass Balance over an ASBR.

#### *4.3.1.1. Feed Sampling*

Feed sample was taken from the return line of the feed tank (Figure 14) five minutes after the circulation pump had been operating, to provide a representative sample of the feed going inside the reactors. A set of two valves was placed in the line to ease the sample collection by redirecting the return flow to the sampling port. Samples taken this way had a volume between 300 and 500 ml.

#### *4.3.1.2. Decant Sampling*

Decant samples were taken during the normal decanting operation of the reactors by redirecting the flow to our sampling bottles. In order to avoid sampling scum (low density material that floats in the liquid surface) in our sample, the initial volume decanted was discarded. After 10 seconds, the decant sample was taken until a volume between 300 and 500 ml was obtained.

#### *4.3.1.3. Average Retained Solids Sampling*

The average retained solids sample was obtained through the sampling port located on the top of the reactor. A glass tube was inserted 24 cm below the liquid surface (approximately 2/3 of the reactor depth) and connected to a vacuum flask where samples between 200 and 300 ml were extracted. The contents of the vacuum flask were then transferred to a sample bottle for further analysis. In order to generate the vacuum required to operate the vacuum flasks, a portable unit was used (BARNANT Vacuum Pressure Station 400-3910). These samples taken at the end of the react phase to ensure that the data is representative of the retained solids after feed had been digested.

### 4.3.2. Reactor Profile Determination

Profiles of retained solids were established by taking samples at different liquid depths as depicted in Figure 20. Small samples of the reactor content at different depths were withdrawn using a graduated glass probe through the sampling port. The liquid extracted from each reactor depth was assumed to be representative of a particular volume layer. Each sample taken was saved in a labeled test tube for further analysis. Given that small samples that were taken when sampling profiles (5-7 ml), determination of TSS/VSS total mass was conducted instead of TS/VS, which requires a larger sample size.

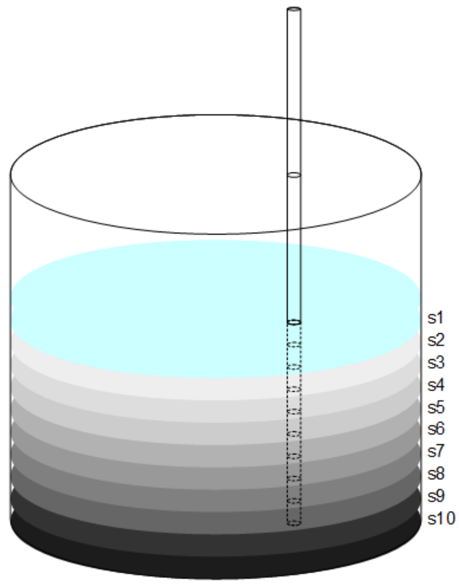



Figure 20. Profile Sampling Scheme.

*4.3.2.1. Total Retained Mass Determination Using Euler Method*

The simplest way of determining the total mass accumulated within a reactor using profile data is the discretization method, also known as Euler method. Using the calibration data available for each of the reactors that correlates reactor depth with volume (Figure 21), the reactor was divided into 10 slices that were assumed to have constant concentration of solids.

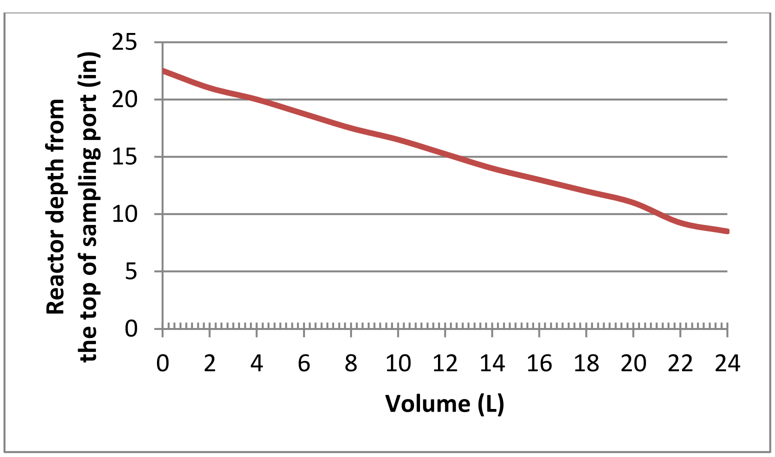



Figure 21. Example Calibration Data Relating Volume to Reactor Depth for Reactor 6.

The volume of each slice was obtained using the calibration data, and the total mass of solids was calculated using Equations 20 and 21, where $m_{TSS}^{reactor}$ and $m_{VSS}^{reactor}$ are the masses of TSS and VSS inside the reactor, $[TSS]_i$ and $[VSS]_i$ are the concentrations of TSS and VSS of the i$^{th}$ sample, and $V_i$ is the volume of the slice associated with the i$^{th}$ sample.

$$m_{TSS}^{reactor} = \sum_{i=1}^{10} [TSS]_i \cdot V_i \qquad \text{Eq. 20}$$

$$m_{VSS}^{reactor} = \sum_{i=1}^{10} [VSS]_i \cdot V_i \qquad \text{Eq. 21}$$

This method was used for both mixing and settling profiles, and in an ideal reactor, in which all solids are brought into suspension, equal results should be obtained as long as the slices had been assigned proper volumes. In reality, the presence of caking (see Appendix I) along with the problems locating the concentrated-clarified liquid interface made it harder to obtain similar mass values using mixing and settling profiles.

#### *4.3.2.2. Total Retained Mass Determination Using Polynomial Fit*

The settling profiles for VSS had a recurring shape that easily fit a polynomial function. An example of this is shown in Figure 22. Two different regions can be distinguished; the clarified region (in the example going from 2 to 14 cm depth) and the sludge region (covering from 14 cm depth to the reactor bottom in the example). The first region is assumed to be constant, and will contain a very limited amount of solids, while in the sludge area the solids concentration increases following a second order equation. A, B, C and D are constants determined for each profile, and d is the reactor depth in cm from the liquid surface.

$$[VSS]_{clarified\ area} = A \qquad \text{Eq. 22}$$

$$[VSS]_{sludge\ area} = B \cdot d^2 + C \cdot d + D \qquad \text{Eq. 23}$$

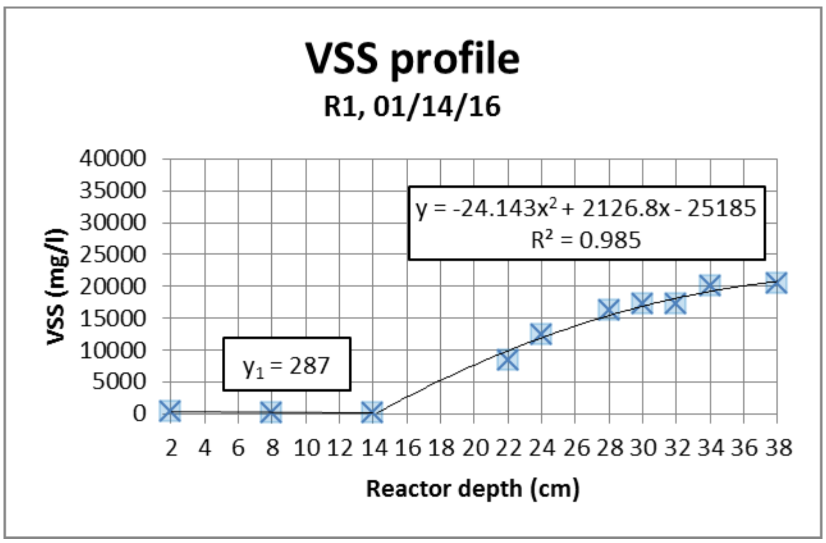



Figure 22. Example of Polynomial Calculation of Total Mass for Reactor 1, January 14, 2016.

This method allows manually adjusting the position of the interface (14cm in Figure 22), improving the correlation quality. Using the calibration data, the reactor depth was converted into volume, and the application of extremely small depth increments using a program such as Matlab provided a more accurate measurement of the total VSS accumulated in a reactor. A Matlab program was developed to automatize the calculation of profiles and is attached in Appendix II.

*4.3.2.3. Method Comparison*

As was previously stated, the Euler method can be used for both TSS and VSS data for mixing and settling profiles, whereas the polynomial fit method can only be applied to settled profiles and VSS data. On the other hand, the polynomial fit method is likely to provide more accurate data, as it can help locate the interface with a lower margin of error at the same time as the overall error is reduced by using infinitesimal increments.

Figure 23 shows the comparison between the mass calculated using a settling profile and VSS data for the Euler and the polynomial fit methods. The mass calculated through the Euler method was slightly higher (188 gVSS) than the one calculated using polynomial fit method (181 gVSS), since the effect of overestimating the concentration close to the bottom of the reactor (Euler method) was higher than the underestimation of the concentrations close to the interface. Overall, the polynomial fit method seems to provide more accurate results, as it does not depend on the slice-size selected for each interval, and the interface can be determined with a higher accuracy while keeping the impact of choosing an incorrect value low. Therefore, when the adequate data was available (settling profile, VSS concentrations data), the polynomial fit method was used, using the Matlab program developed to calculate the total mass of VSS in the reactor.

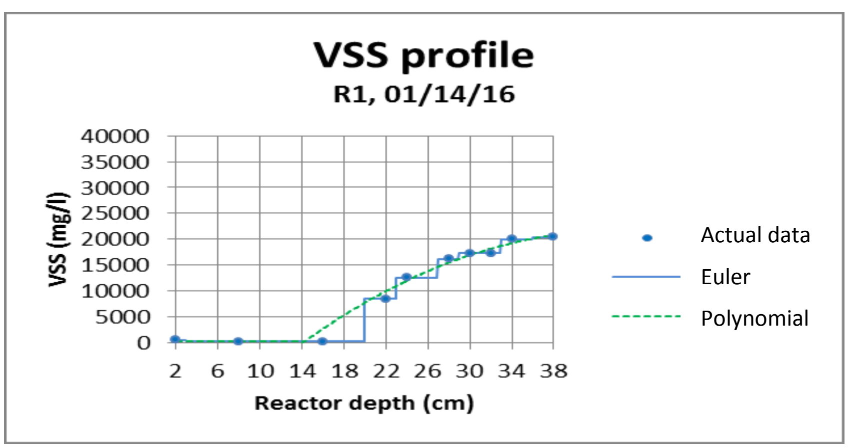



Figure 23. Comparison between Euler and Polynomial Fit Method to Determine Mass of VSS Retained in Reactor 1 on January 14, 2016.

#### 4.3.3. Concentrated Solids – Clarified Layer Interface Location

The location of the interface between the concentrated layer of retained solids and the clarified layer in partial-mix reactors was determined in a similar way as the previously discussed reactor profile determination. The glass probe was submerged at increasing depths of the reactor's liquid. When the probe was submerged within the clarified layer, a translucent liquid filled the glass probe. When a darker liquid was withdrawn it provided the location of the interface between clarified and concentrated layers. The interface depth was, therefore, located at the depth at which the sampling probe withdrew liquid that changed from clear to dark.

#### 4.3.4. Settling Rate

Settling rate was determined by determining the interface between concentrated and clarified layers throughout the settling phase. Plotting the interface data points versus the time after the settling phase began provided settling curves from which initial settling velocity ($V_0$) could be determined.

### 4.4. **Manure Collection and Feed Preparation**

Manure was collected periodically from the Oklahoma State University Swine Research and Education Center (OSU SREC). Glycerol was used to increase the OLR, and it was obtained from University of Central Oklahoma Motor Pool biodiesel facility.

### 4.4.1. Manure Collection and Transferring

The manure was collected at the pit where the manure flushed from the farm is discharged before it discharged to a covered anaerobic lagoon. Each time, a volume ranging between 100 and 180 L was obtained directly from the outlet pipe and transported to the BAE West Lab. The manure was processed to remove large solid particles that might damage or clog the hydraulic system. The transferring process can be easier to understand when following the explanation with Figure 24.

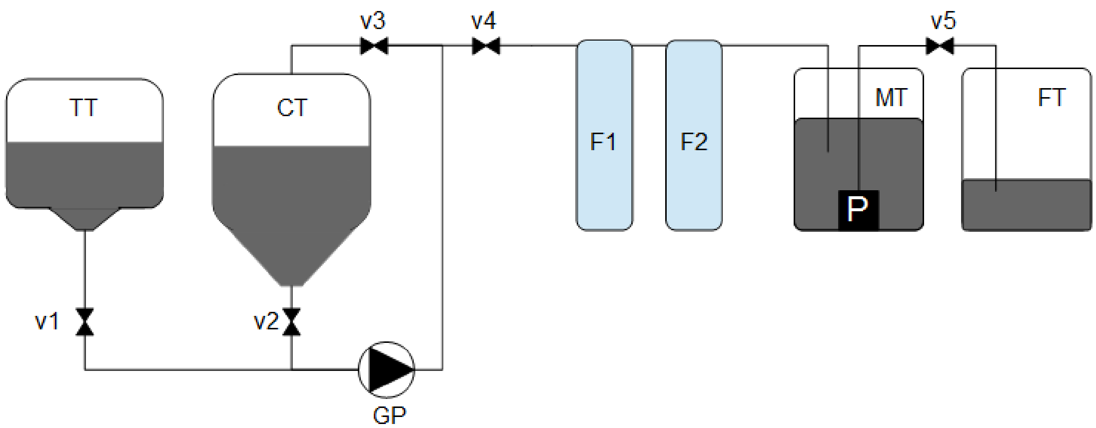



Figure 24. Schematic of Manure Transfer Process.

The manure collected in the farm was transferred from the transport tank (TT, SPRAYER 110 gal PE container) to the conical tank (CT, ACE Roto Mold 85 gal PE container) located inside the reactor room. In order to do so, the grinding pump (GP, OBERDORFER 7429, 1/3 hp) was operated with valves 1 and 3 (v1, v3) opened. Once all of the contents of the transport tank were emptied, the conical tank contents are ground for an hour to reduce manure's average particle size (closing v1 and opening v2).After this, ground manure was passed through a pair of filters (20" 142606 Rev A) arranged in series in order to remove larger particles and hairs remaining in the manure that may clog the hydraulic system (close v3 and open v4). As the manure passes through the filters, it was collected in the manure tank (MT, PVC container 50 gal).

The solids content of this manure were measured and an adequate volume was diluted with tap water to obtain the goal concentration of solids in the feed tank (FT).

### 4.4.2. Feed Preparation

The ground and filtered manure were combined with tap water to obtain the final feed that will be used in the experiments. Equation 24 was used to calculate how much manure was added to fill the feed tank, with $V_{man}^{add}$ being the volume of manure to add, $V_{tot}^{add}$ the total volume of the feed, $[VS]_{goal}$ the desired concentration of VS in the feed and $[VS]_{man}$ the calculated concentration of VS in the manure.

$$V_{man}^{add} = V_{tot}^{add} \cdot \frac{[VS]_{goal}}{[VS]_{man}} \quad \text{Eq. 24}$$

The strength of the feed was increased by adding glycerol. Small amounts of this easily biodegradable compound helped increase the COD present in the feed. The amount of COD present in the glycerol was determined to be 2 g COD $g^{-1}$ glycerol. The mass of glycerol needed to increase the OLR of the feed was calculated following equations 25 through 27, where $t_{feed}$ is the days of feed available in the feed tank, $V_{feed}^{T}$ the volume of feed in the tank, $V_{fed}^{day}$ the volume of feed used daily, $m_{COD}^{tot}$ the total mass of COD to add to the feed tank, $m_{CODadd}^{reactor}$ the goal COD addition to each reactor due to glycerol, $n_{reactor}$ the number of reactors and $m_{glycerol}^{tot}$ the total mass of glycerol to be added to the feed tank.

$$t_{feed} = \frac{V_{feed}^{T}}{V_{fed}^{day}} \quad \text{Eq. 25}$$

$$m_{COD}^{tot} = m_{CODadd}^{reactor} \cdot t_{feed} \cdot n_{reactor} \qquad \text{Eq. 26}$$

$$m_{glycerol}^{tot} = \frac{m_{COD}^{tot}}{2\,\frac{gCOD}{g\ glycerol}} \qquad \text{Eq. 27}$$

It must be pointed out that despite accurately calculating the ratio between manure and tap water added to the feed tank, and the addition of glycerol based on the previously developed formulas, certain variability in the obtained feed was always present during the experimental period. This was a natural result of the degradation of OM in the feed tank (which did after all act like an anaerobic digester to some extent) and the sedimentation of particles in the bottom of the tank that could not be brought back in suspension by mass transfer limitations. In the case of the OLR increase by adding glycerol, a low solubility of this compound was observed. This resulted into a considerably lower impact of the glycerol addition than expected, as most of the OM never got dissolved in the feed and formed solid plaques that had to be periodically removed from the cooling coils and tank walls. Nevertheless, the average operation conditions in the experimental period were maintained fairly constant.

### 4.5. **Experimental Methods**

As outlined in Objectives, testing of the partial-mix system was conducted in three trials, each of which had a particular installation setup that is discussed in this subsection. Pre-test observations were made to establish that performance of the full-mix digester matched those of the 400 m$^3$ reactors studied in Hamilton and Steele (2014). The gas handling system remained unchanged throughout the entire period of observation, while the hydraulic installation was adapted to each particular trial.

### 4.5.1. Pre-test Observations

Before the three trials were conducted, samples of retained solids and decanted effluent were taken each week, along with two to three samples of feed. Gas production was followed daily and leaks found in the gas handling system were sealed. Determination of reactor pH, VFA and alkalinity, solid content and COD of Feed, Retained Solids and Decant samples, OM removal efficiencies, and reactor profiles were conducted in a regular basis to assess the operation of the set of reactors during the pre-test.

### 4.5.2. 1st Trial: Full and Partial-Mix Schemes Operated Simultaneously in R5 and R6

Once the set of six reactors achieved fairly constant performance parameters (i.e. similar VSS mass retained, biogas production, effluent quality, SRT), trial one was started by changing reactor 6's design to the partial-mix scheme. The reactor room installation was modified as shown in Figure 25.

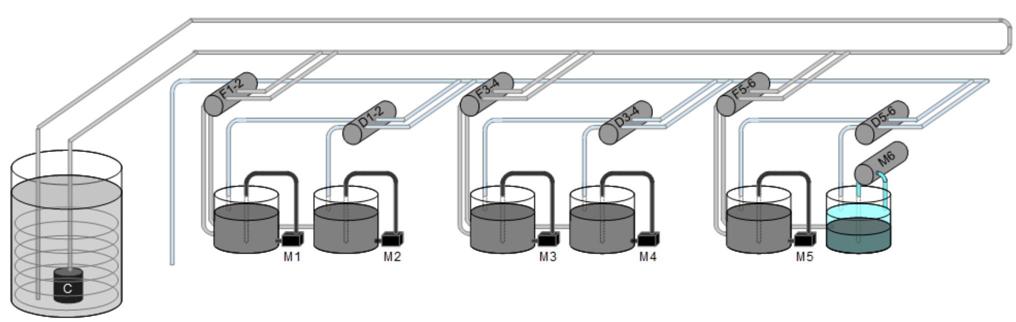



Figure 25. Reactor Scheme during Trial 1.

These two reactors were evaluated weekly in for reactor stability, retained solids mass and decant solid content, OM removal efficiencies. Feed was sampled and evaluated two to three times per week, while the biogas production of all of the reactors was followed closely every day.

#### 4.5.3. 2nd Trial: Comparison of Reactors 1-5 Operating under Full and Partial-Mix Schemes Sequentially

The rest of the installation was switched to the partial-mix scheme (Figure 26), while maintaining constant operating conditions (OLR, HRT, T) during trial 2. The obtained data for reactors 1 through 5 operating with a full-mix scheme was compared to that obtained when operating under partial-mix conditions. Weekly samples of Retained Solids and Decant in all six reactors were taken and evaluated for solids content, reactor stability biogas production, and OM removal efficiencies.

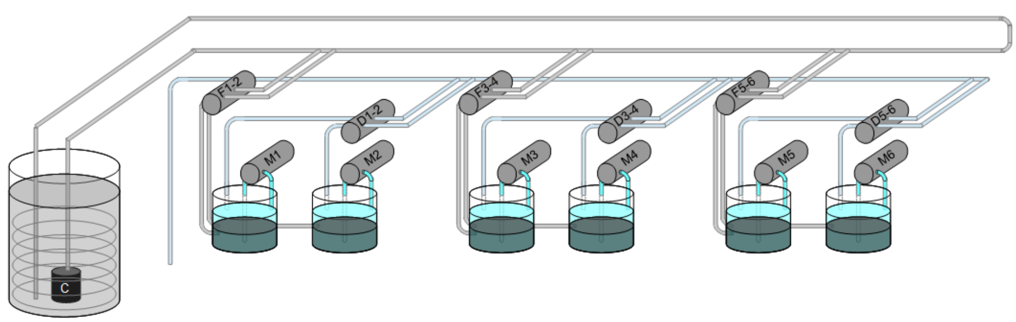



Figure 26. Reactor Scheme during Trial 2.

#### 4.5.4. 3rd Trial: Comparison of Reactors 1-6 Operating Using a Partial-Mix Scheme at 12 and 6-day HRT Sequentially

The last part of the experiment consisted of comparing the data recorded for the entire set of reactors (R1-6) operating under partial-mix conditions at a 12 day HRT with the same data obtained when halving the HRT to 6 days. Samples of Retained Solids and Decant in all six reactors were taken weekly, were evaluated for solids content. Reactor stability was tested in the Retained Solids sample (pH, VFAs and alkalinity), detailed gas production was recorded, and reactor profiles and OM removal efficiencies were calculated during this third trial.

# CHAPTER V

# RESULTS AND DISCUSSION

## 5.1. General Effect of Mixing Schemes

The operation of an ASBR reactor under full and partial-mix schemes can be better understood by observing the reactor profiles resulting from each reactor setup (Figures 27 and 28). Mixing profiles were taken after 80 minutes of continuous mixing. Settling profiles were taken after the reactors had settling for 80 minutes.

The higher mixing intensity applied to the full-mix reactors resulted in a constant concentration all along the reactor depth. In the partial-mix reactors, a considerably lower mixing intensity was used, resulting in a two-layer behavior. The liquid withdrawn for mixing from the upper layer was practically solid-free, while the solids were concentrated in the lower layer.

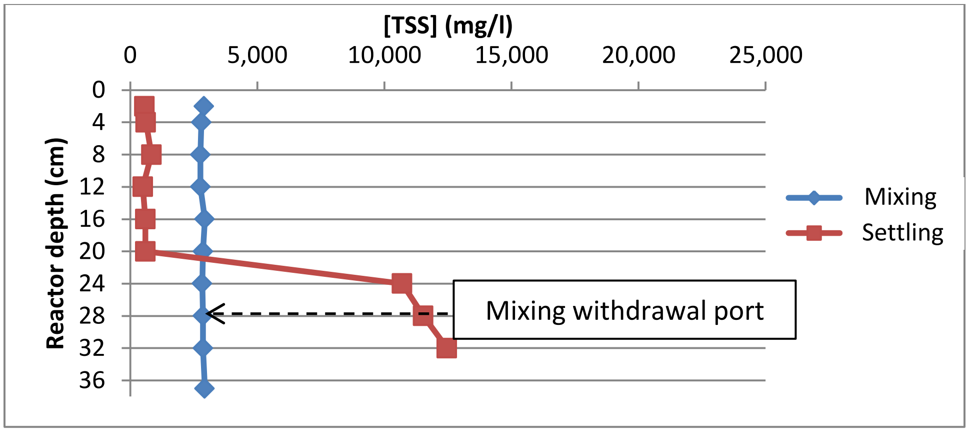



Figure 27. Mixing and Settling Reactor Profiles for Full-Mix Reactor (R5) on July 7, 2015.

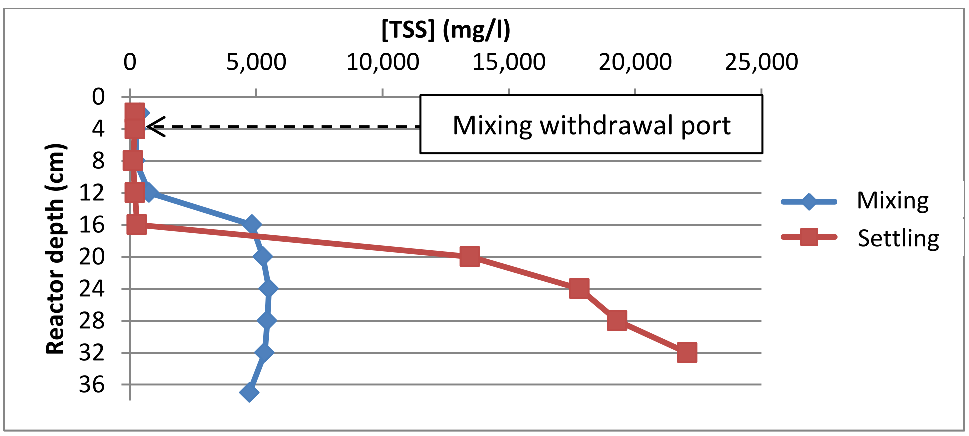



Figure 28. Mixing and Settling Reactor Profiles for Partial-Mix Reactor (R6) on July 7, 2015.

### 5.2. Description of Operational Parameters during Experimental Period

Table 9 summarizes the different parts of the study. Table 10 provides the average values of OLR, HRT and F/M ratio during the presented period of time. Figure 29 provides an overview of each single data point calculated for the OLR in terms of COD and VS. Since the amount of OM being fed to the reactor was maintained somewhat constant during each experimental period, F/M was largely dependent on the amount of mass accumulated in reactors rather than on the particular OLR at which they were being operated.

Table 9. Summary of Experiments Conducted, Dates Involved and Objectives.

| | Dates | Objective |
|---|---|---|
| **Pre-test** | June 10th 2014 – March 12th 2015 | Study of the operation of full-mix ASBRs (R1-5) |
| **1st trial** | March 12th – July 21st 2015 | Comparison of partial-mix (R6) and full-mix scheme (R5). Reactors run simultaneously |
| **2nd trial** | March 12th – July 21st 2015<br>October 5th – December 20th 2015 | Comparison of reactors 1 through 5 operating under full and partial-mix scheme with similar OLR |
| **3rd trial** | October 5th – December 20th 2015<br>January 11th – March 15th 2016 | Determination of the influence of HRT on partial-mix reactors operation (R1-6) |

Table 10. Operational Parameters at Each Experimental Period.

| Exp. period | Total Period | Dates | HRT (days) | Average OLR (gCOD $L^{-1}$ $day^{-1}$) | Average F/M Ratio (gCOD $gVSS^{-1}$ $day^{-1}$) | | Notes |
|---|---|---|---|---|---|---|---|
| **Pre-test (R1-5 Full-mix)** | June 10th 2014<br>March 11th 2015 | 6/10/14 – 10/11/14 | 24 | 0.16 | 0.05 | | 1 cycle per day. Solids loss |
| | | 11/11/14 – 1/11/15 | 12 | 0.42 | 0.15 | | 2 cycles per day introduced |
| | | 1/12/15 – 2/18/15 | 12 | 0.26 | 0.10 | | $[VS]_{feed}$ lowered |
| | | 2/19/15 – 3/11/15 | 6 | 0.37 | 0.29 | | HRT lowered |
| **1st trial (R5: Full-mix) (R6: Partial-mix)**<br>**2nd trial part I (R1-5 Full-mix)** | March 12th 2015<br>July 21st 2015 | | | | Partial-mix | Full-mix | |
| | | 3/12/15 – 3/24/15 | 12 | 0.22 | 0.13 | 0.26 | $[VS]_{feed}$ and HRT restored |
| | | 3/25/15 – 4/16/15 | 12 | 0.33 | 0.11 | 0.28 | Glycerol +1gCOD $r^{-1}$ $day^{-1}$ |
| | | 4/17/15 – 5/13/15 | 12 | 0.26 | 0.08 | 0.22 | Glycerol +1.5gCOD $r^{-1}$ $day^{-1}$ |
| | | 5/14/15 – 6/4/15 | 12 | 0.34 | 0.13 | 0.26 | Glycerol +2gCOD $r^{-1}$ $day^{-1}$ |
| | | 6/5/15 – 7/21/15 | 12 | 0.39 | 0.14 | 0.25 | Glycerol +3gCOD $r^{-1}$ $day^{-1}$ |
| **2nd trial part II (R1-5 Partial-mix)**<br>**3rd trial part I (R1-6 12 day HRT)** | October 5th 2015<br>December 20th 2015 | 10/5/15 – 12/20/15 | 12 | 0.34 | 0.06 | | Glycerol +4gCOD $r^{-1}$ $day^{-1}$ |
| **3rd trial part II (R1-6 Partial-mix)** | January 11th 2016<br>March 15th 2016 | 1/11/16 – 3/15/16 | 6 | 0.87 | 0.11 | | Glycerol +4gCOD $r^{-1}$ $day^{-1}$<br>HRT halved |

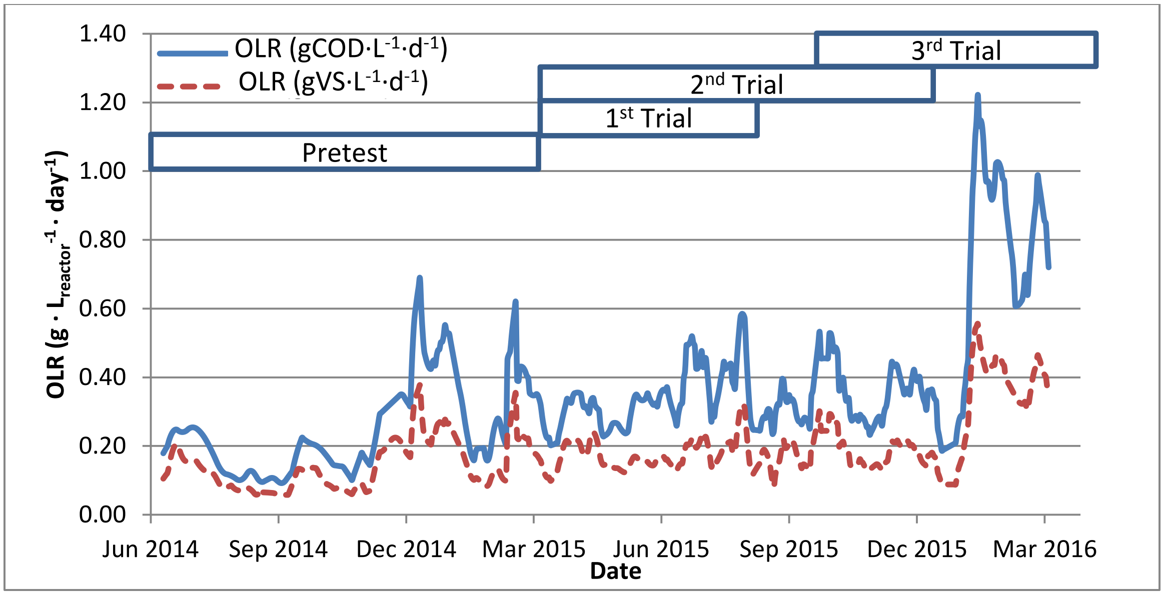



Figure 29. Evolution of OLR throughout the Different Experiments.

### 5.3. Pre-test Observations

The research project started on June 2014, and the first goal was to reproduce the basic operation of ASBRs in our set of 6 bench-scale reactors. The initial conditions were set at 24 days HRT, one cycle per day, and a low OLR (between 0.10 and 0.15 grams of VS per liter of reactor per day). Temperature was kept at 35 °C. It must be noted that prior to the beginning of these experiments, the reactors had been operating for an extensive period of time, so a community of microorganisms had already developed inside the reactor allowing the digestion of OM in anaerobic conditions. Two regions were observed during this startup period: an acclimation period to the new operating conditions, and a regular operation region which is representative of a typical ASBR reactor.

During the first five months of operation, the reactors experienced a sustained loss of OM that had been accumulated during the previous operation of the installation. The OM present in the effluent was higher than that being fed to the reactor, which caused a steady decrease in accumulated solids within the reactors. A reduction in the strength of the manure being fed to the reactors was identified as the cause for the net loss in solids inside the reactor, since not enough OM was being fed to counteract the effect of unsettleable solids being removed in the effluent. The scraping system of the SREC experienced operation problems, hence the flushed manure lowered its solids and OM content.

At the end of October 2014, the reactors reached a stabilization point, in which the net loss of solids stopped, and the typical operation of ASBRs was achieved. Since it was now possible to maintain a certain amount of solids inside the reactors, it was decided to reduce the HRT from 24 to 12 days. This was achieved by increasing the number of cycles per day to 2, while maintaining the volume fed and decanted per cycle constant (1 L).

### 5.3.1. Reactor Stability: pH, VFAs and Alkalinity

Reactors pH was maintained within the operation range described in McCarthy (1964) without addition of acids or bases. At the same time, the ratio of VFA to alkalinity was kept well below the recommended limit of 0.3. The variation of such parameters is presented in Figure 30.

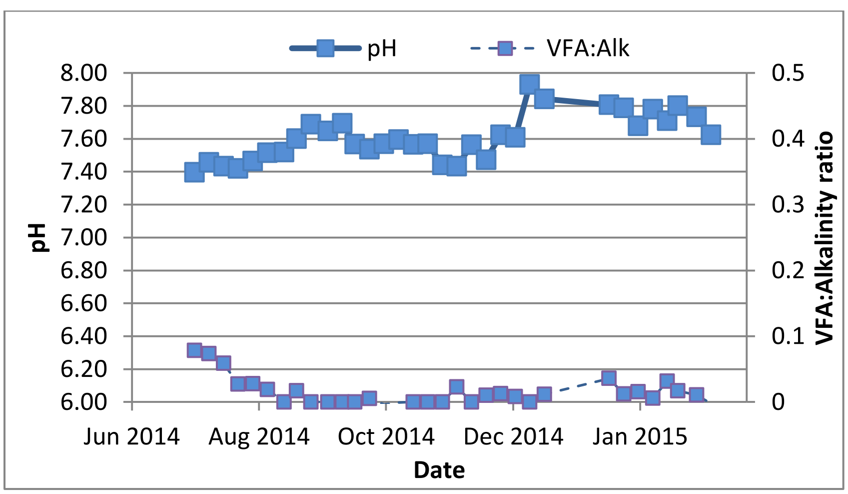



Figure 30. VFA:Alkalinity Ratio and pH for Full-Mix Reactors (R1-5) during Pre-test Observations.

5.3.2. Accumulation of VSS, Decanted Effluent Quality and SRT

A strong relationship between accumulated mass of VSS, effluent VSS concentration and SRT was observed in the operation of full-mix ASBRs. Figure 31 shows the evolution of the three mentioned variables during the whole studied period. VSS is the average mass retained in the reactors, SRTmav is the moving average of the SRT, and VSSdec is the concentration of VSS in the effluent. Four different regions have been highlighted in Figure 31.

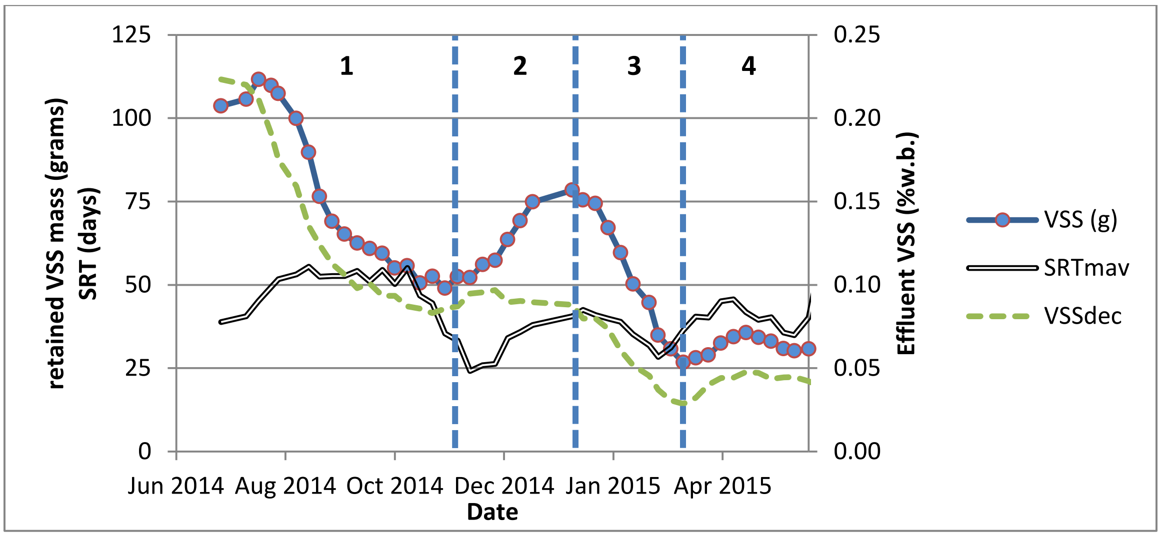



Figure 31. Average SRT, VSS Retained Mass and Decanted Effluent VSS Concentration in Full-Mix Reactors during Pre-test Observations and 1st Trial.

The first region shows the acclimation of the reactors to the set operation conditions. A high amount of accumulated VSS inside the reactors could not be maintained by the diluted feed added, therefore a sharp decrease in retained VSS was experienced (Table 11). As these solids were removed from the reactor, a decrease in decanted VSS was also observed, resulting in a slight increase in SRT.

Table 11. Accumulated Solids during the Acclimation Period (Region 1).

| Reactor | Initial VSS mass (g) | Final VSS mass (g) | VSS mass lost (%) |
|---|---|---|---|
| **1** | 104 | 44 | 58 |
| **2** | 110 | 49 | 55 |
| **3** | 121 | 55 | 55 |
| **4** | 114 | 31 | 73 |
| **5** | 135 | 65 | 52 |
| **6** | 116 | 55 | 53 |

By the end of October, a stable operation had been achieved (i.e. no more solids mass was being lost through decanting). HRT was decreased from 24 to 12 days, therefore increasing the OLR (region 2, November – December 2014). A steady increase in the retained VSS resulted from this, while the effluent's solid content remained constant. In this case, the decrease observed in SRT can be explained by the doubling of the volume of liquid decanted per day.

The operating conditions were pushed further in region 3 (January – March 2015), when a decrease in the feed strength followed by a decrease in HRT from 12 to 6 days was tested. As it is observed in the previous Figure, a constant and sharp decrease in the accumulated solids was experienced, after which it was decided to go back to the previous conditions in terms of feed strength and HRT. Region 4 already shows data for the first two months of the 1st Trial (March – May 2015), and is included to see how the relationship between VSS mass, VSS concentration in the effluent and average SRT in full-mix reactors was maintained.

### 5.3.3. Organic Matter Removal Efficiencies

The difficulties experienced in settling the finer particles resulting from the aggressiveness of the full-mix scheme had a direct impact in the OM removal efficiencies. The removal efficiencies of VS and VSS over the period in which reactors 1 through 5 operated under full-mix conditions, the same four regions mentioned in the previous subsection are observed (see Figure 32).

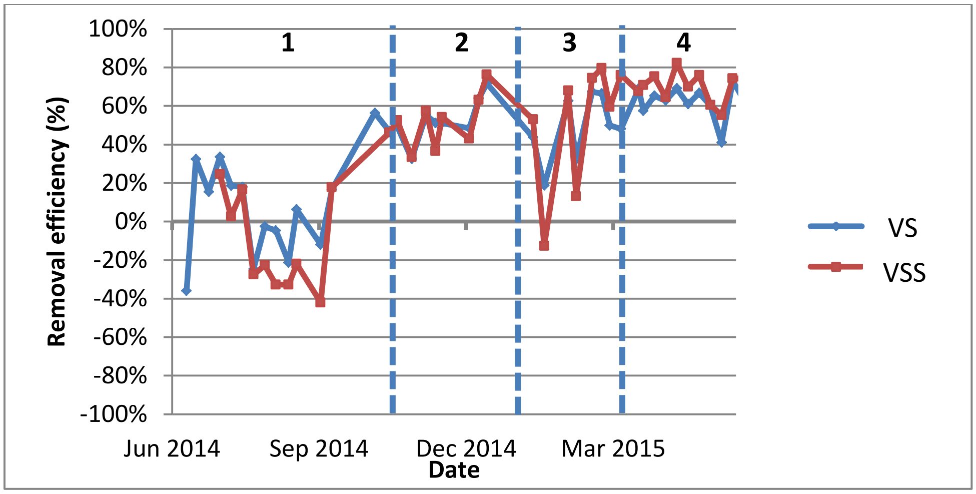



Figure 32. Average Organic Matter Removal Efficiencies for Full-Mix Reactors during Pre-test Observations and 1st Trial.

During the acclimation period (region 1), removal efficiencies often were below 0% (i.e. more solids are being decanted from the reactor than those being fed). Once enough mass had been removed from the reactor to allow stable operation, the HRT was decreased to 12 days (region 2), and removal efficiencies in the range of 40-60% were observed. The attempt to operate the reactor with a more diluted feed and a lower HRT resulted in a highly unstable operation in terms of organic removal efficiency, making it impossible to maintain the reactors' operability (region 3). When the operation conditions were restored and glycerol started to be added, a fairly constant region in terms of OM removal efficiency was achieved. Values of VS and VSS removal efficiencies lied in a range between 60 and 80%. As a result of the low settleability achieved with the full-mix scheme, the differences between VS and VSS removal efficiencies were low. This means that most of the OM removal was achieved through the destruction of readily biodegradable solids rather than the capture and accumulation of settleable particles. When the HRT was lowered to 6 days, the time available for microorganisms to digest the OM available was not enough to achieve decent removal efficiencies and stable operation could not be maintained.

### 5.3.4. Biogas Production

The gas produced by full-mix reactors can be related to the different operation regions as well (Figure 33). While acclimating to the new conditions (region 1), the biogas yield achieved very low values, in the neighborhood of 0.1 liters of biogas per gram of COD fed.

Once a more stable operation was achieved and removal efficiencies increased (region 2), gas yields twice or even three times higher than in the previous region were observed. During the period of the failed attempt of decreasing HRT and feed concentration, the biogas yield decreased slightly, showing values around 0.20 L g $COD^{-1}$. When glycerol was introduced for its co-digestion, biogas yield experienced a sharp increase, reaching values of around 0.6 L $gCOD_{fed}^{-1}$.

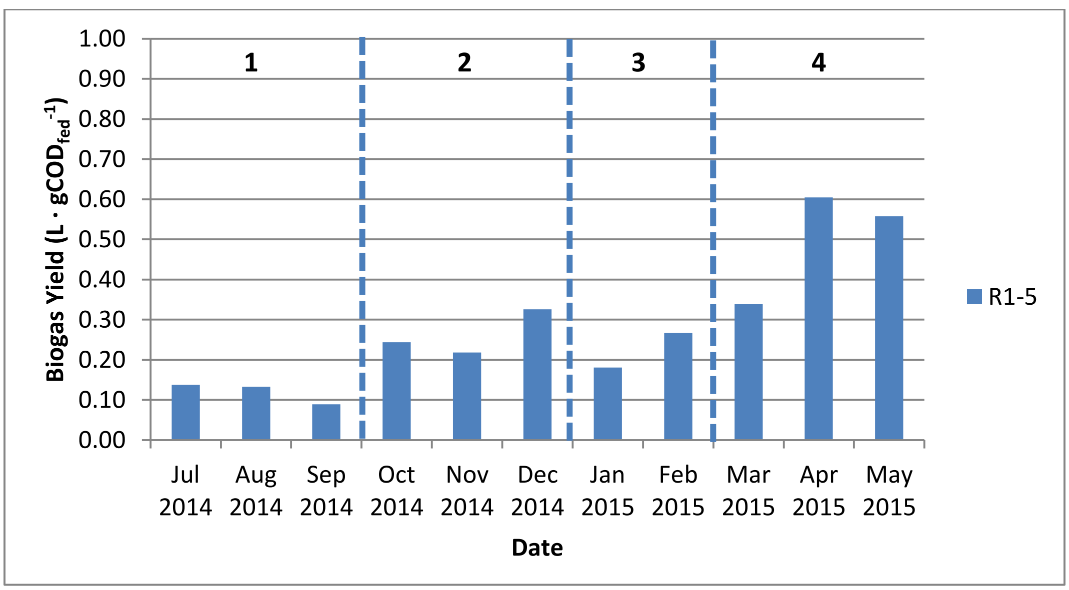



Figure 33. Average Biogas Yield in Full-Mix Reactors (R1-5) during Pre-test Observations and 1st Trial.

Average VRE during the operation of the set of full-mix reactors is given in Figure 34. The amount of biogas produced per unit of volume of reactor was very low until glycerol started being added in region 4. Also, it is worthwhile noting the peak observed in December 2014, which was caused by the combination of a peak in feed strength (Figure 29) along with the halving of HRT applied at the end of November 2014.

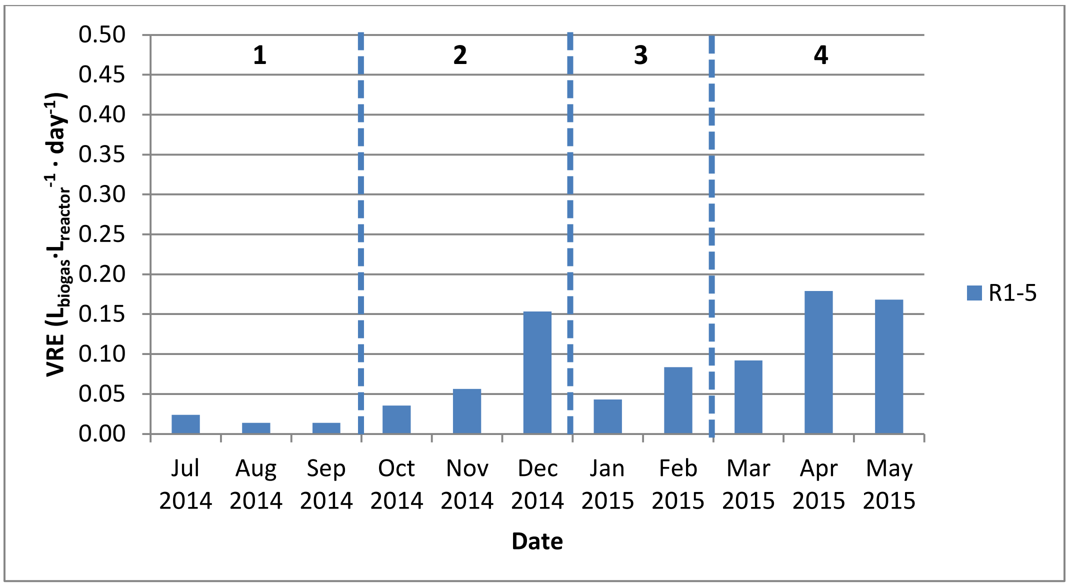



Figure 34. Average VRE for Full-Mix Reactors (R1-5) during Pre-test Observations and 1st Trial.

5.3.5. Comparison of Results in Bench-Scale and Full-Scale Full-Mix ASBRs

The results for full-mix operation discussed in this subsection were compared to the results reported by Hamilton and Steele for the 400 $m^3$ ASBR operated at Oklahoma State University's SREC (Hamilton and Steele, 2014), and are reported in Table 12.

Table 12. Comparison of Full-Mix Experimental Results and Full-Scale ASBR (Hamilton and Steele, 2014).

| | **Full-scale ASBR Hamilton and Steele, 2014** | | **Full-mix, bench-scale reactors** | | | |
|---|---|---|---|---|---|---|
| | ***Exp. 1*** | ***Exp. 2*** | ***Region1*** | ***Region2*** | ***Region3*** | ***Region4*** |
| **HRT (days)** | 20 | 5 | 24 | 12 | 6 | 12 |
| **SRT (days)** | 51 | 26 | 50 | 34 | 36 | 50 |
| **OLR (gVS $L^{-1}$ $day^{-1}$)** | 0.32 | 0.48 | 0.16 | 0.34 | 0.30 | 0.34 |
| **T (°C)** | 22-32 | 22-24 | 35 | 35 | 35 | 35 |
| **Biogas yield (L $gVS^{-1}$)** | 0.85* | 0.58* | 0.13 | 0.37 | 0.33 | 0.67 |
| **VRE ($L_{biogas}$ $L_{reactor}^{-1}$ $d^{-1}$)** | 0.28* | 0.28* | 0.02 | 0.11 | 0.06 | 0.17 |
| **COD r.e. (%)** | 73 | 57 | 11 | 69 | n.a. | 72 |
| **VS r.e. (%)** | 62 | 55 | 10 | 53 | 49 | 65 |
| **pH** | 7.3 | 7.3 | 7.6 | 7.66 | 7.7 | 7.7 |

* Values originally reported in terms of $CH_4$. They were converted to biogas by using the 65% $CH_4$ content reported by the authors.

Once the operation of bench-scale full-mix reactors was stabilized (Region 4 in Table 12), the results of Experiment 1 reported in Hamilton and Steele (2014) for a 400 $m^3$ full-scale full-mix reactor were replicated. Removal efficiencies were almost the same both in terms of COD and VS, and so were the OLR and the SRT. The main differences were observed in the pH values reported, the $CH_4$ yield (slightly higher in this thesis' results) and the VRE (slightly higher in the full-scale results). It is important to note that in Hamilton and Steele's experiment no glycerol was codigested as opposed to Region 4 in the pre-test. The cause of the limited removal efficiencies observed in the full-scale reactor and replicated in the bench-scale may be the interconnection of VSS mass retained, effluent quality and SRT (see Figure 31), which implies that under the full-mix scheme it is impossible to completely detach SRT and HRT.

### 5.4. 1st Trial: Full and Partial-Mix Schemes Operated Simultaneously in R5 and R6

In order to overcome the operation issues observed in the pre-test and the full-scale ASBR, a new mixing scheme was proposed which would reduce the stress suffered by solid particles and aggregates. If our hypothesis was accurate, a less aggressive mixing should provide enhanced solid settleability, thus leading to an increase in SRT, organic removal efficiencies and effluent quality. The operating conditions during this trial were maintained constant at 12 days HRT and an average OLR of 0.34 g COD $L_{reactor}^{-1}$ $day^{-1}$. Glycerol was added in order to increase this OLR, but the combination of OM settling in the feed tank, partial digestion occurring in the feed tank and low solubility of the glycerol used resulted in a lower impact than desired of glycerol in the overall OLR.

### 5.4.1. Reactor Stability: pH, VFAs and Alkalinity

As can be seen in Figure 35 the partial-mix reactor had slightly higher bicarbonates and VFA concentrations than the full-mix reactor. This was a natural result of maintaining a higher concentration of OM accumulated within the reactor, and a longer residence time (increased "sludge-age"). At the same time, pH was similar for both mixing schemes, with partial-mix being slightly higher in all cases. During the last period of this experiment, the pH of the reactors approached the higher limit (pH=8) for anaerobic digestion, and even surpassed that limit during two weeks in the case of the partial-mix reactor.

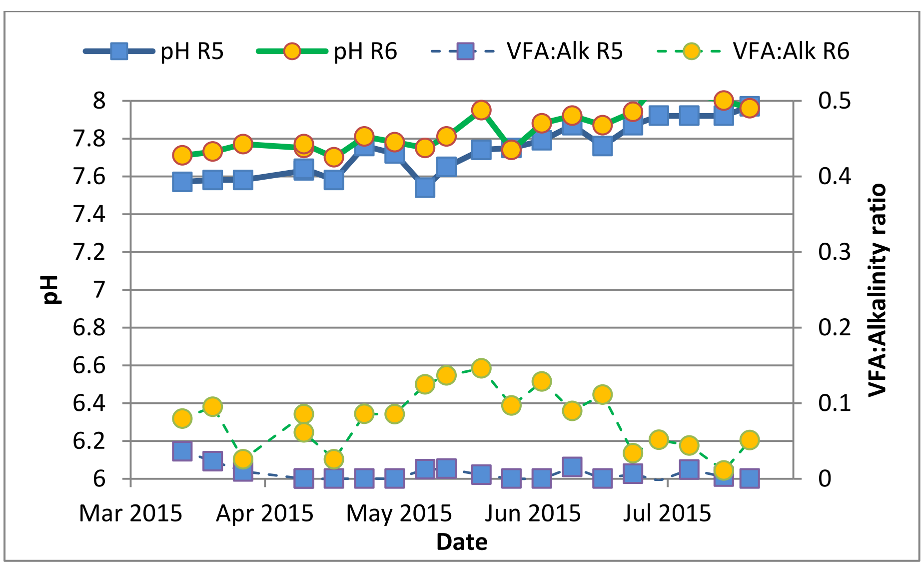



Figure 35. Reactor Stability under Full (R5) and Partial-Mix (R6) Schemes during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.4.2. VSS Mass and Accumulation Rate

The mass of VSS accumulated in the full-mix (R5) and partial-mix (R6) reactors is shown in Figure 36.

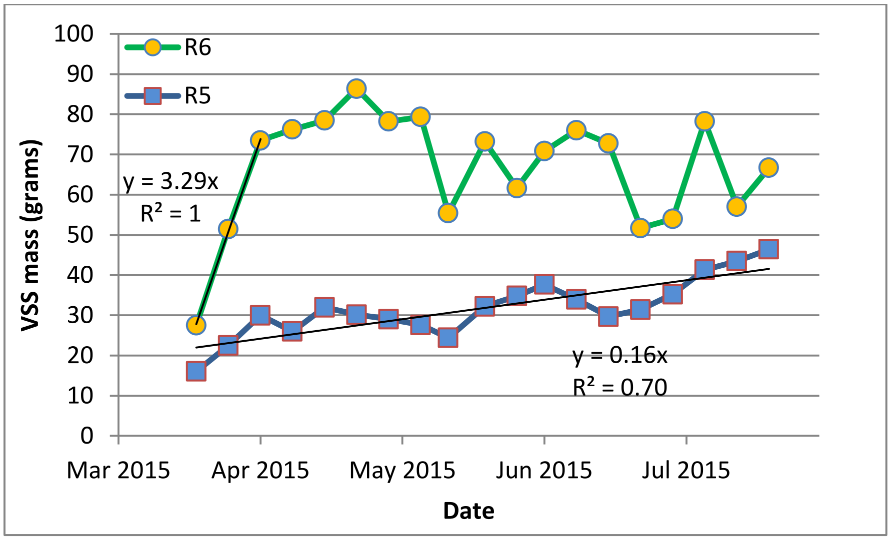



Figure 36. VSS Mass and Accumulation Rate in Full (R5) and Partial-Mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

The partial-mix reactor accumulated VSS at high rates during the first two weeks of the trial, after which the rate slowed down. A maximum VSS mass in the partial-mix reactor was reached one month after the trial started, followed by an instability region in which the total mass of VSS varied from week to week pivoting around a value of 70 gVSS. This instability has been identified later as a result of solids adhering to the reactor walls (caking effect, see Appendix I). The full-mix reactor accumulated solids at a slower rate than the partial-mix system (0.16 gVSS $day^{-1}$). There seems to be an upper limit to how many solids could be kept in suspension, which was reached at the beginning of May 2015 by the partial-mix reactor. At the end of the first experiment, the full-mix reactor was still accumulating solids at a fairly constant rate. This was explained by the lower accumulation rate of solids present in that scheme that maintained the total mass much lower than the upper limit observed for the partial-mix reactor.

### 5.4.3. Decanted Effluent Quality

Both full and partial-mix ASBR designs allowed decreasing the solids concentration in the decanted effluent when comparing it to the influent fed (Figure 37). The partial-mix reactor achieved a higher decanted effluent quality as the concentration of VSS was maintained at lower values than those for the full-mix reactor.

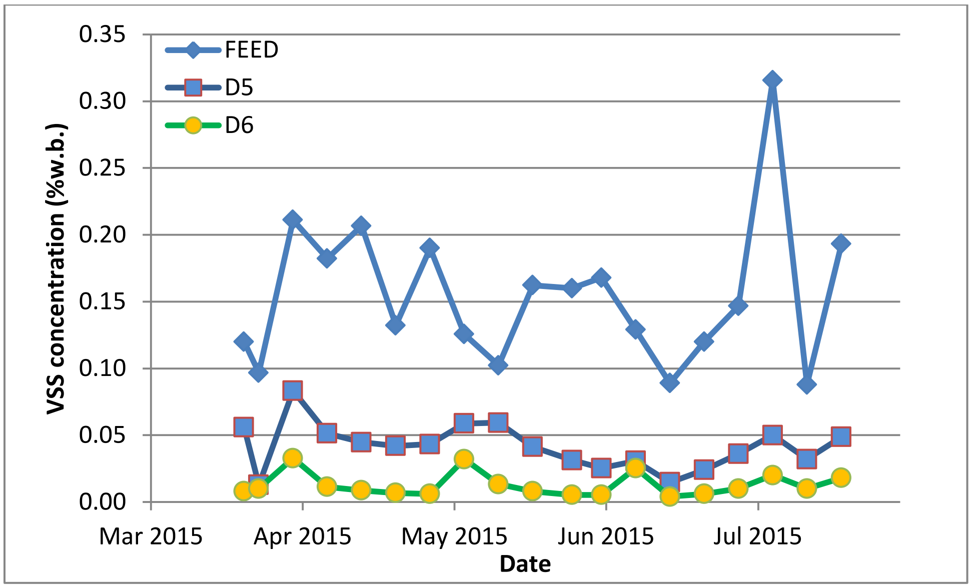



Figure 37. Concentration of VSS in Influent and Decanted Effluent in Full (D5) and Partial-Mix (D6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

An evaluation of the solids characteristics of the treated effluent of both schemes showed that there was an increase in the effluent quality in the partial-mix reactor (Figure 38). The drop in solid content in the effluent was achieved by increasing the ability to retain VSS with the implemented less aggressive mixing system. In contrast, the amount of DS was the same in the two studied reactors. In comparison to the full-mix scheme, the partial-mix scheme presented 70% less SS (in terms of TSS, VSS and fixed suspended solids, FSS), while maintaining the same amount of DS. It was then concluded that partial-mix provides an advantage in retaining solids within the reactor.

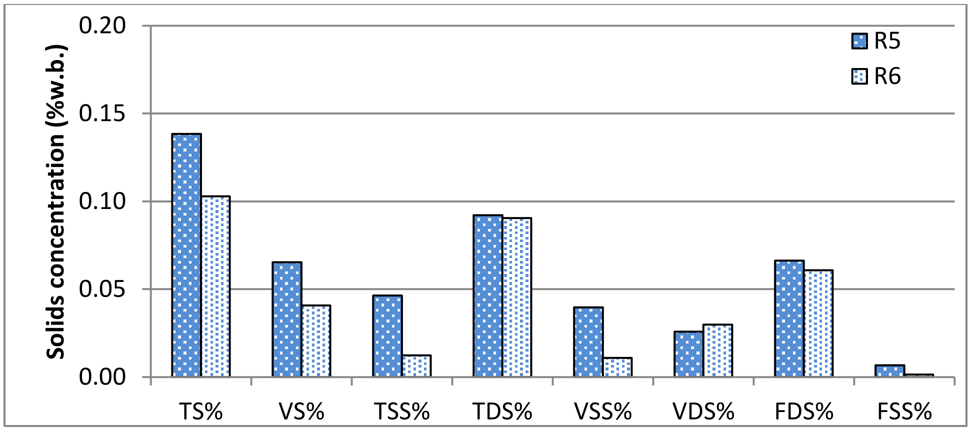



Figure 38. Average Effluent Quality of Full (R5) and Partial-mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.4.4. Organic Matter Removal Efficiencies

A clear improvement on the OM removal efficiency was observed in both VS and COD when using the proposed partial-mix scheme (Figures 39 through 41). The main reason behind this improvement lays in the ability to retain a great percentage of the VSS fed to the reactor, as described in the previous subsection. By doing so, it was possible to prevent the untreated solid particles from leaving the reactor, and enough time was provided to digest them.

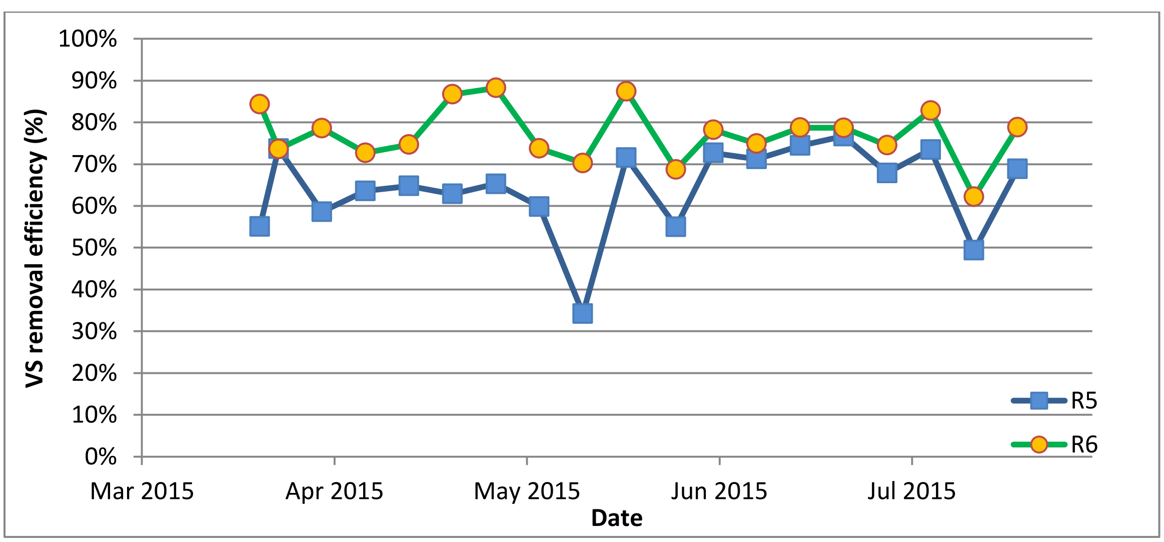



Figure 39. VS Removal Efficiency in Full (R5) and Partial-Mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

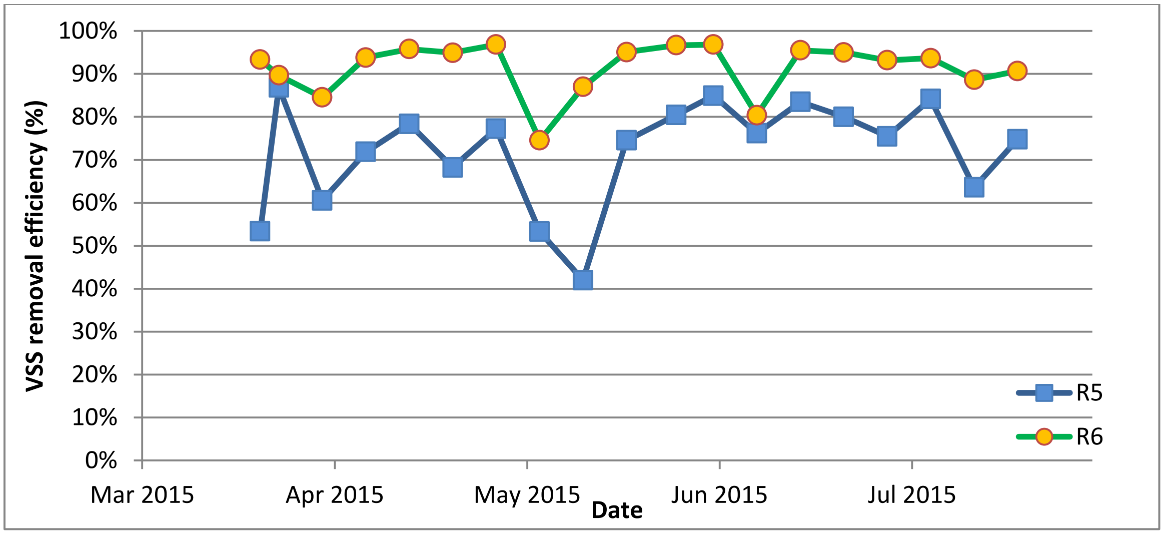



Figure 40. VSS Removal Efficiency in Full (R5) and Partial-Mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

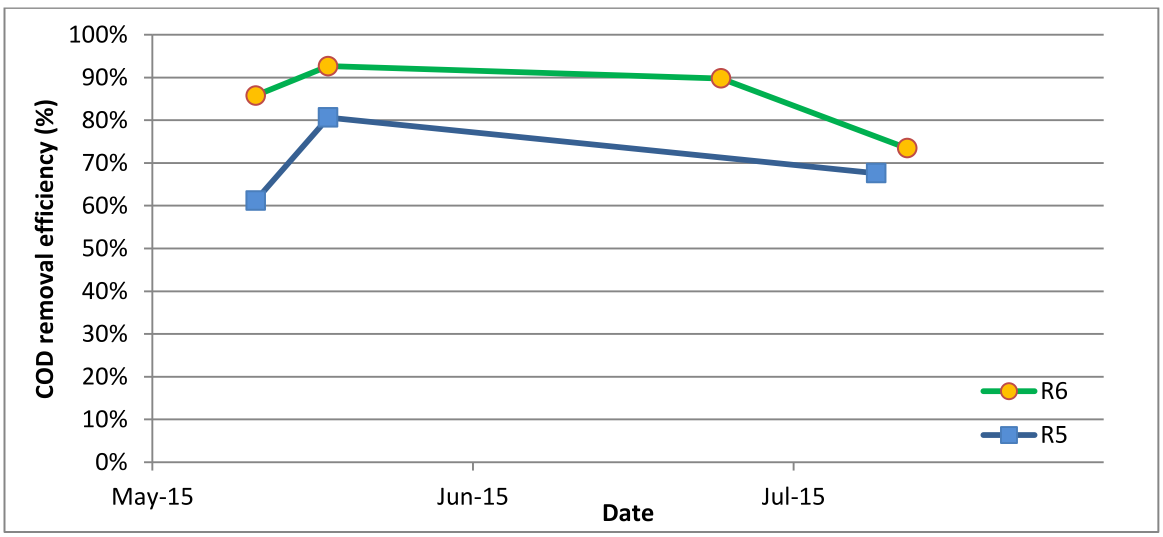



Figure 41. COD Removal Efficiency in Full and Partial-Mix Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

It must be noted that eventually some valleys in removal efficiency were observed in both full and partial-mix reactors. The most likely explanation to this behavior is that during normal operation of the reactors, scum was formed on the top of the reactor. Given that the decant port was located close to the liquid surface, the presence of scum had a great influence in the effluent quality. It is also worthwhile noting that the valley-behavior occurred in both schemes with the same periodicity, and in the case of full-mix reactor the reduction in removal efficiency seems to be more accentuated. Fewer samples were analyzed during this trial for COD removal efficiency, but they also provided evidence that supports the claim that OM removal was enhanced with the partial-mix system.

### 5.4.5. Biogas Production

As a result of the increased ability to retain solids shown by the partial-mix reactor previously discussed, a higher biogas production was observed in this reactor when compared to the full-mix reactor (Figure 42). Daily biogas production for the partial-mix reactor remained higher than that of the full-mix reactor until the end of June 2015, when a peak in biogas produced in the full-mix reactor was observed.

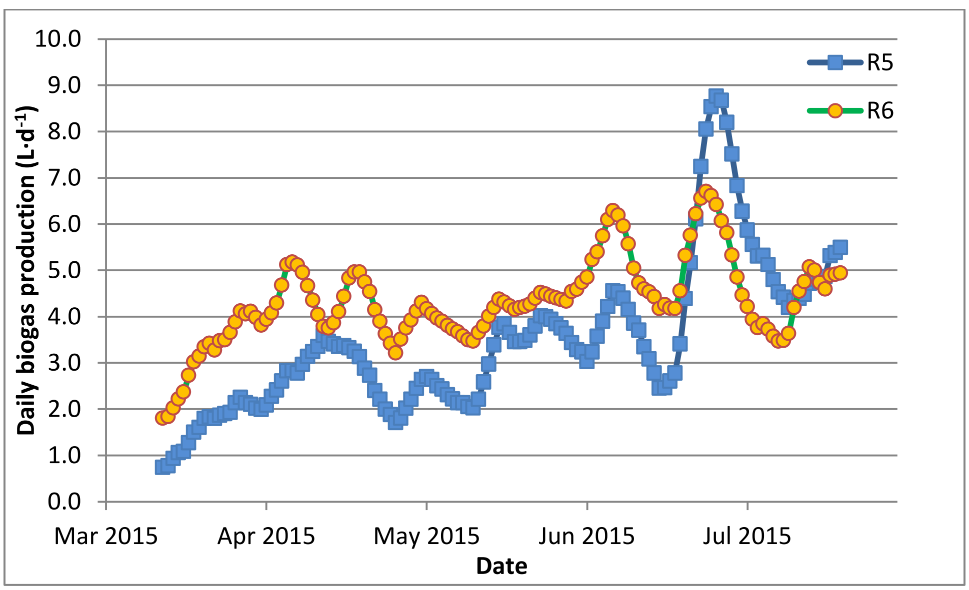



Figure 42. Daily Biogas Production in Full (R5) and Partial-Mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

Similarly, a greater biogas yield was observed in the partial-mix reactor until July 2015, when the full-mix reactor achieved a higher yield, as can be seen in Figure 43. Looking at the individual trends it could be inferred that the OM fed was consumed at a higher rate in the partial-mix reactor because of the larger mass of microorganisms retained within the reactor.

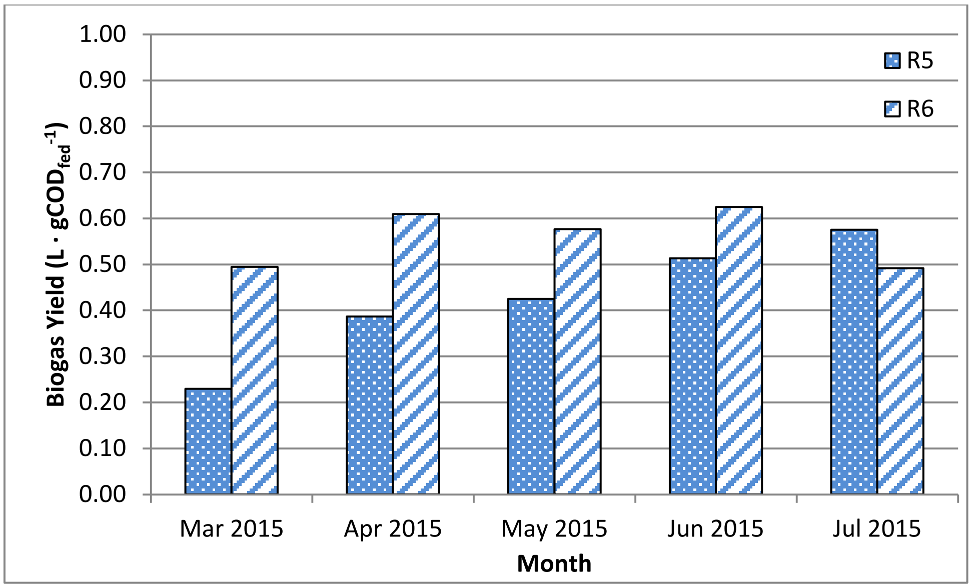



Figure 43. Average Monthly Biogas Yield in Full (R5) and Partial-Mix (R6) Reactors during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

Biogas yield in the partial-mix reactor increased until April 2015, after which the biogas yield averaged approximately 0.6 L $g^{-1}$ COD. The full-mix reactor increased its biogas yield at a slower rate, which was in accordance with the slow rate of solids accumulating in the reactor. As the mass of OM and microorganisms accumulated in the reactor increase, the yield rose to surpass the biogas production observed in the partial-mix reactor.

The average VRE was slightly higher for the partial-mix reactor than the full-mix reactor (Figure 44). Volumetric reactor efficiency of the partial-mix reactor increased faster and was kept above a value of 0.15 L $L^{-1}$ $day^{-1}$ for four months, while full-mix reactor took longer to reach its highest VRE (0.20 L $L^{-1}$ $day^{-1}$).

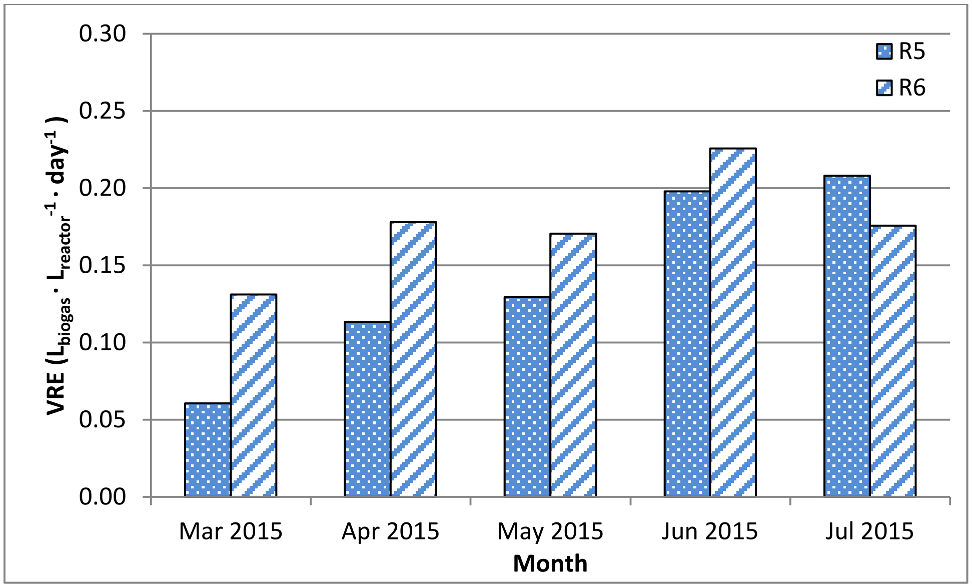



Figure 44. Average Monthly VRE for Full (R5) and Partial-Mix (R6) Reactor during 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.4.6. SRT

SRT increased using the partial-mix setup (Figure 45). The average SRT maintained during this experimental period in the full-mix reactor was 42 days. The partial-mix reactor achieved an average SRT of 359 days. The fact that the average SRT was 10 times greater with the partial-mix reactor than with the full-mix reactor is in accordance with the increased OM removal efficiency and the improved effluent quality commented in previous sections.

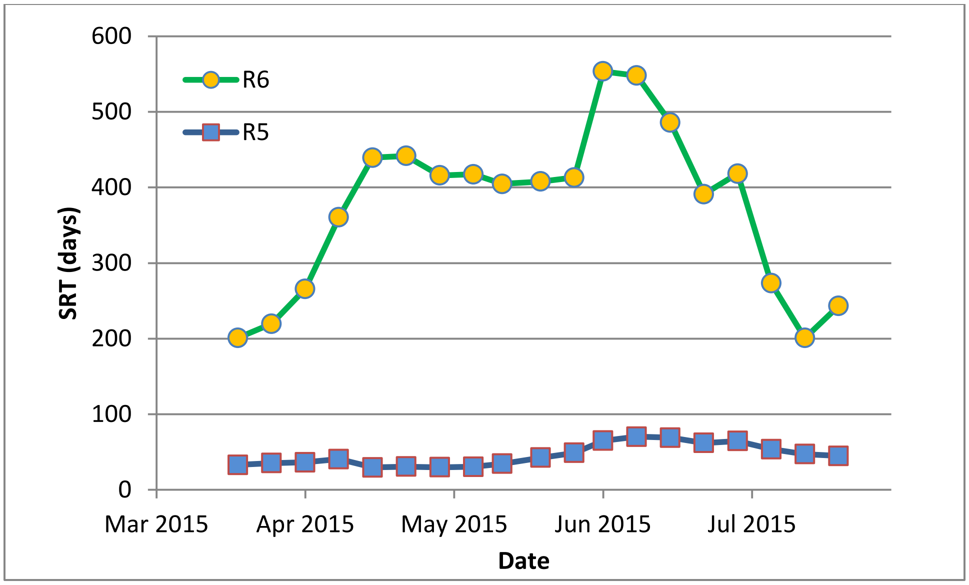



Figure 45. SRT in Full (R5) and Partial-Mix (R6) during the 1st Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

It must be pointed out that the full-mix scheme provided a more stable operation in terms of SRT. Solids retention time in the full-mix reactor had a standard deviation of 22 days while partial-mix reactor's was 228 days. This was caused by the higher retained mass and the very small solids concentration in the effluent; a small variation on the measured effluent concentration results in a very high change on SRT.

$$SRT = \frac{m_s^R}{C_s^{eff} \cdot Q^{eff}} \qquad \text{Eq. 5}$$

The drop observed in July 2015 was caused by a sharp decrease in the feed quality, and affected both full and partial-mix schemes.

### 5.4.7. Brief Evaluation of Results

While maintaining a stable operation in terms of pH and VFA:Alk ratios, improvements in retained solids accumulation rate, effluent quality, OM removal efficiencies, and SRT were observed. Biogas production reached at the end of the trial was similar for both mixing schemes, but the gas production in partial-mix reactor appeared to respond to increased organic loading more quickly that the full-mix reactor during the first months of the trial. The higher rate of OM consumption due to the higher amount of microorganisms kept within the reactor may be the cause for this behavior.

## 5.5. 2nd trial: Comparison of Reactors 1-5 Operating under Full and Partial-Mix Schemes Sequentially

Once the proposed partial-mix scheme was successfully tested in one reactor, the remaining reactors of the experimental setup were changed to the partial-mix mixing system. The data for reactors 1 through 5 was compared when operating under full-mix (February – July 2015) and partial-mix (October – December 2015) schemes. Reactors in both periods were operated at 12 days HRT. Even though OLR ranged from 0.2 to 0.6 g COD $L^{-1}$ $d^{-1}$ during the two experimental periods of Trial 2 (Figure 29), its average value was maintained at 0.34 g COD $L^{-1}$ $d^{-1}$ in both cases.

### 5.5.1. Reactor Stability: pH, VFAs and Alkalinity

As previously observed in the 1st trial, pH, bicarbonates and VFA concentration in the partial-mix reactors were slightly higher than those measured in full-mix reactors (Figure 46). These differences can be explained by the increased amount of solids present in the reactor, as well as the longer sludge-age. Figure 46 shows the values of pH and VFA to alkalinity ratio lied within safe limits for anaerobic digesters. Keeping pH values close to the upper end of the safe range for anaerobic digestion did not show any detrimental effect.

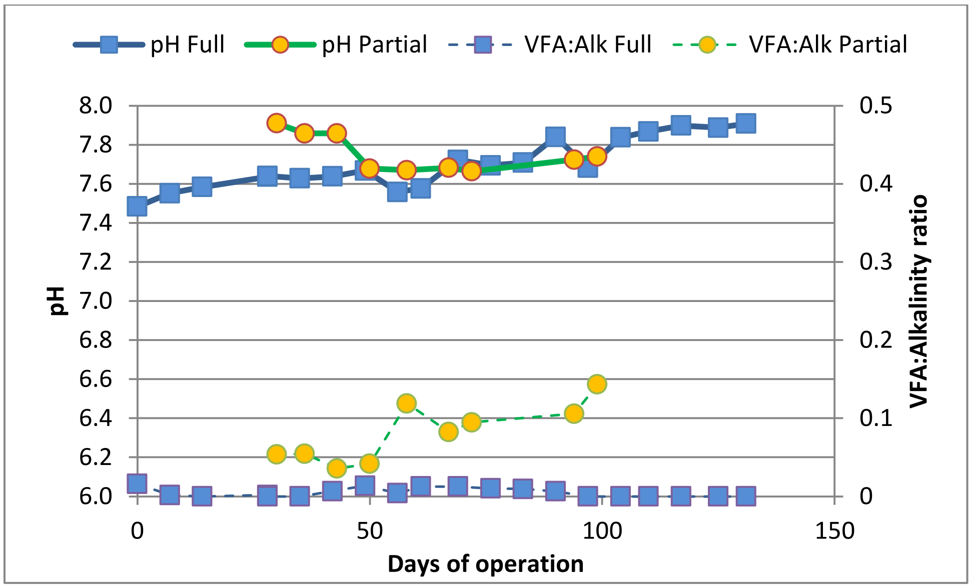



Figure 46. Reactor Stability in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.5.2. VSS Mass and Accumulation Rate

It must be noted that between the 1st and 2nd trial, the caking effect was discovered (see Appendix I), which probably led to an underestimation of the solids retained within the reactors during the full-mix part of the trial. In order to overcome this problem the sampling procedure for reactor profiles was improved to allow accounting for all the solids retained in the reactor. Reactors were shaken prior to sampling profiles to bring the solids attached to the reactor walls into suspension.

As can be seen in Figure 47, the mass of solids retained at the beginning partial-mix operation are higher the solids present at the end of the Full=mix period (105 versus 75 g). The full mix reactors accumulated solids at a considerable lower rate compared to the partial-mix scheme 0.10 gVSS $day^{-1}$ versus 0.80 gVSS $day^{-1}$. As previously stated, these results should be taken with caution, as the presence of a caking effect could result in the underestimation of accumulated solids in reactors 1 through 5 when working under full-mix conditions. Nevertheless, the caking effect could have been minimized in the case of the full-mix reactors since a higher mixing power was used, resulting in a higher liquid flow that would prevent caking from happening.

Assuming a negligible caking effect in full-mix reactors, solids were accumulated in partial-mix reactors at about two times the rate of full-mix reactors. On top of this, the plateau observed for full-mix reactors (around 50 gVSS) was further increased to the neighborhood of 130 gVSS with the partial-mix scheme.

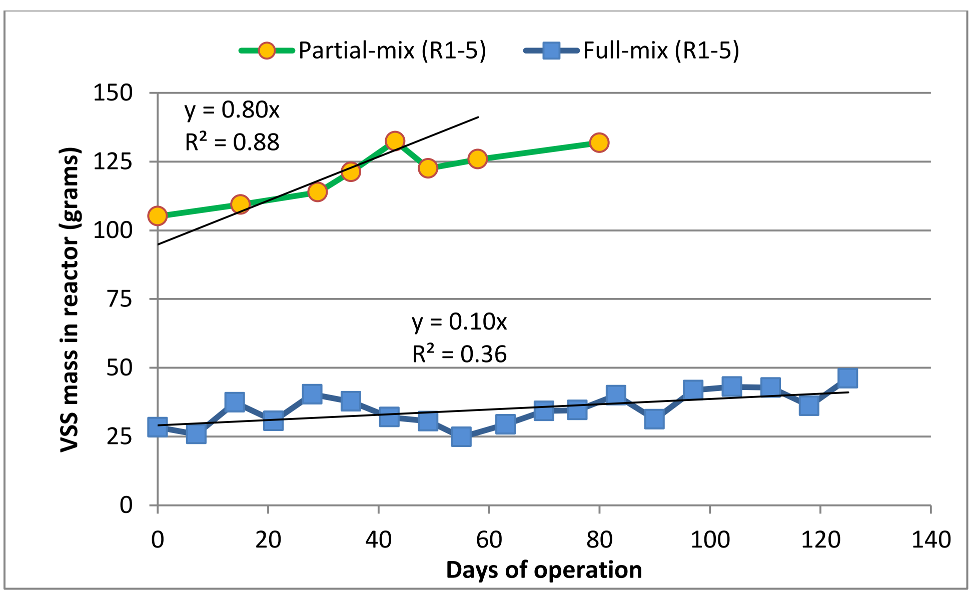



Figure 47. Average VSS Mass and Accumulation Rate in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

5.5.3. Decanted Effluent Quality

Decanted effluent concentration of solids in reactors 1 through 5 was lower than the liquid fed under both mixing systems tested in trial 2 (Figure 48).

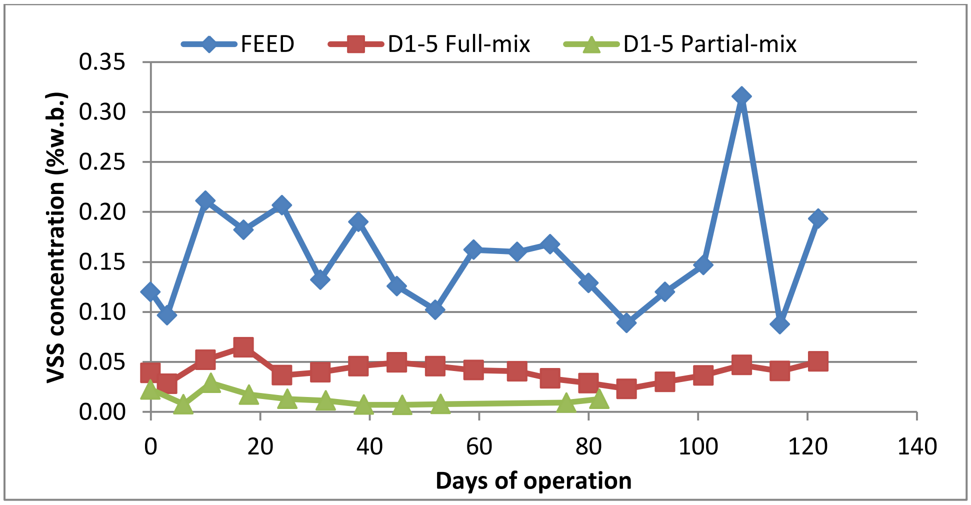



Figure 48. Concentration of VSS in Influent and Decanted Effluent in Full and Partial-Mix Reactors during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

All total, volatile and suspended solids concentrations were reduced extensively when the reactors operated under the partial-mix scheme, as can be observed in Figure 49.

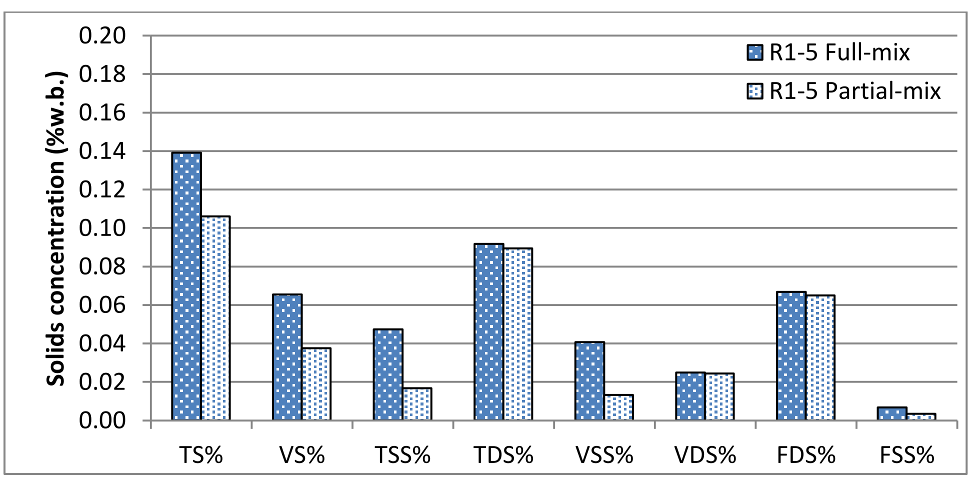



Figure 49. Average Effluent Quality in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

Total and volatile dissolved solids concentrations were similar between the two mixing schemes tested. It is worthwhile to note that these differences were achieved even when the average mass of solids retained in the partial-mix reactors (~120 gVSS) was higher than that of the full-mix reactors (~40 gVSS) during the studied period. Therefore, it was concluded that the partial-mix reactor was very efficient at retaining and/or converting solid OM. The enhanced capability of retaining VSS resulted in a longer time for hydrolysis of solid OM to take place, but this did not translate in a noticeable increase in VDS in the effluent compared to the full-mix scheme.

A relationship between total retained mass of solids within the reactor and the reactor's effluent quality was observed (Figure 50). The higher the mass of retained VSS in a full-mix reactor, the higher concentration of VSS removed from the reactor in the effluent. On the contrary, concentration of VSS in decanted effluent was not related to mas of VSS retained in the partial-mix reactors.

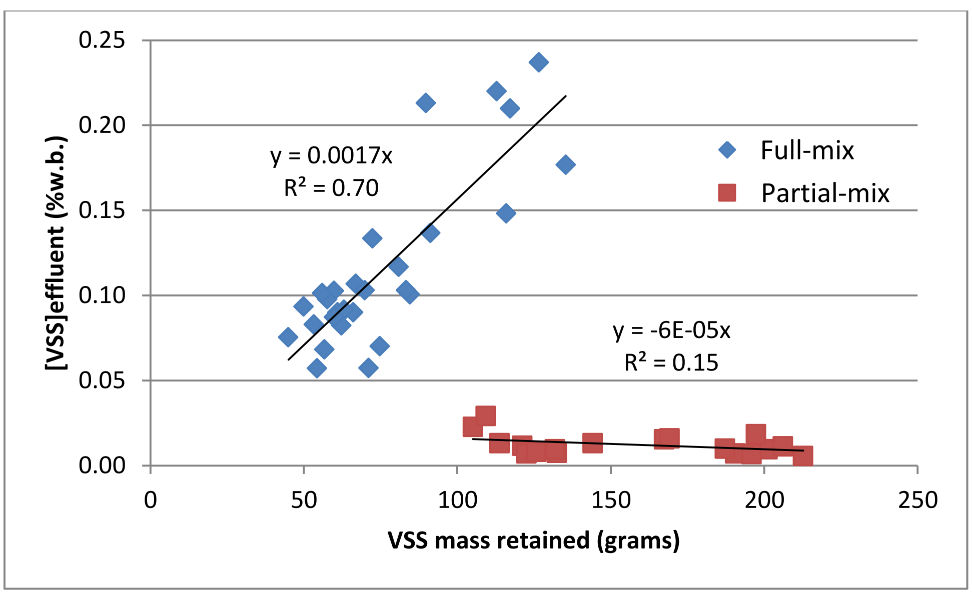



Figure 50. Dependence between VSS Mass Retained and Concentration of VSS in the Effluent for Full and Partial-Mix Schemes during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.5.4. Organic Matter Removal Efficiencies

The OM removal efficiencies increased for the 5 reactors when they operated under partial-mix conditions (Figures 51, 52, 53). High values of VSS removal efficiency were observed reaching values between 90 and 100%. An average increase of 30% in terms of VSS removal was achieved when compared to the full-mix scheme.

The first three points in Figures 51 and 52 were slightly below the average removal efficiencies in partial-mix reactors, as the reactors required some transition time to remove all the finer particles created during the last days of full-mix operation. After these particles were decanted from the reactors, higher removal efficiency was achieved for the rest of the operation period. The COD removal efficiency was also increased notably when the five reactors operated under partial-mix conditions, reaching an average reduction of 86% of the incoming feed. The average removal efficiency achieved using a full-mix scheme for the same group of reactors was 73%.

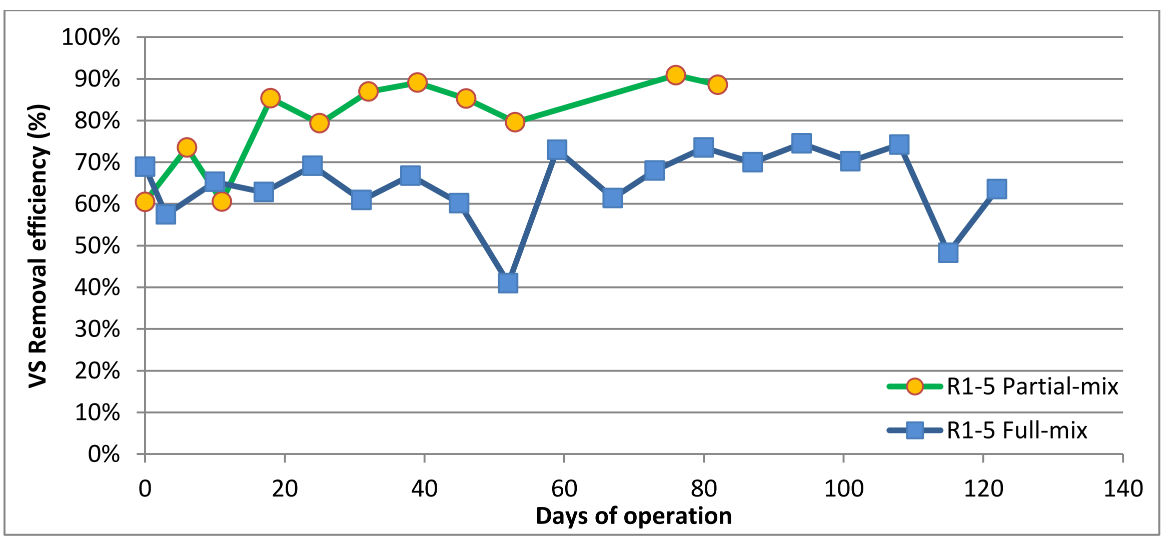



Figure 51. Average VS Removal Efficiency in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

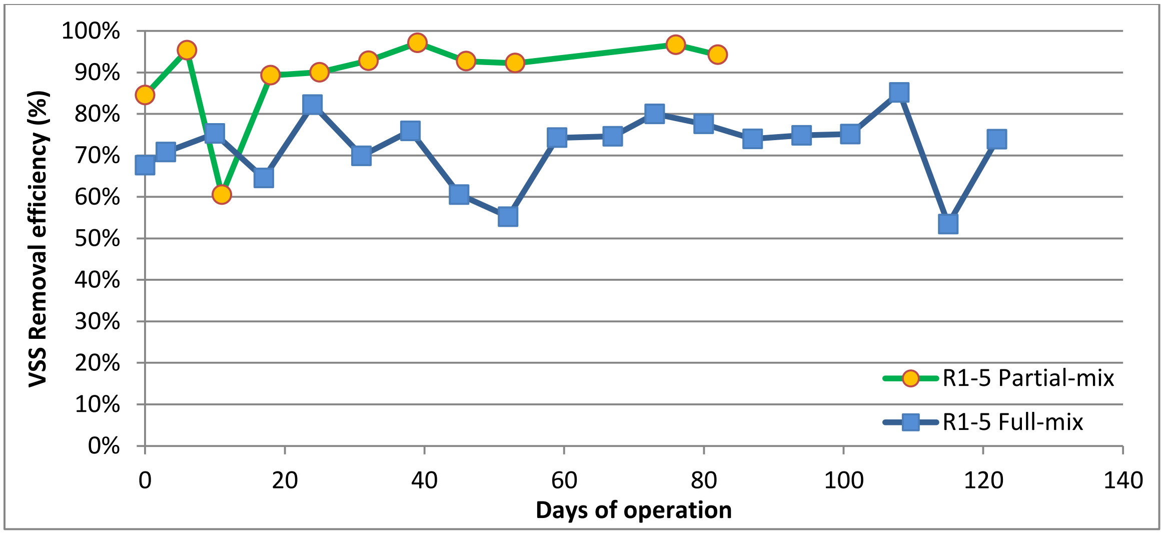



Figure 52. Average VSS Removal Efficiency in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

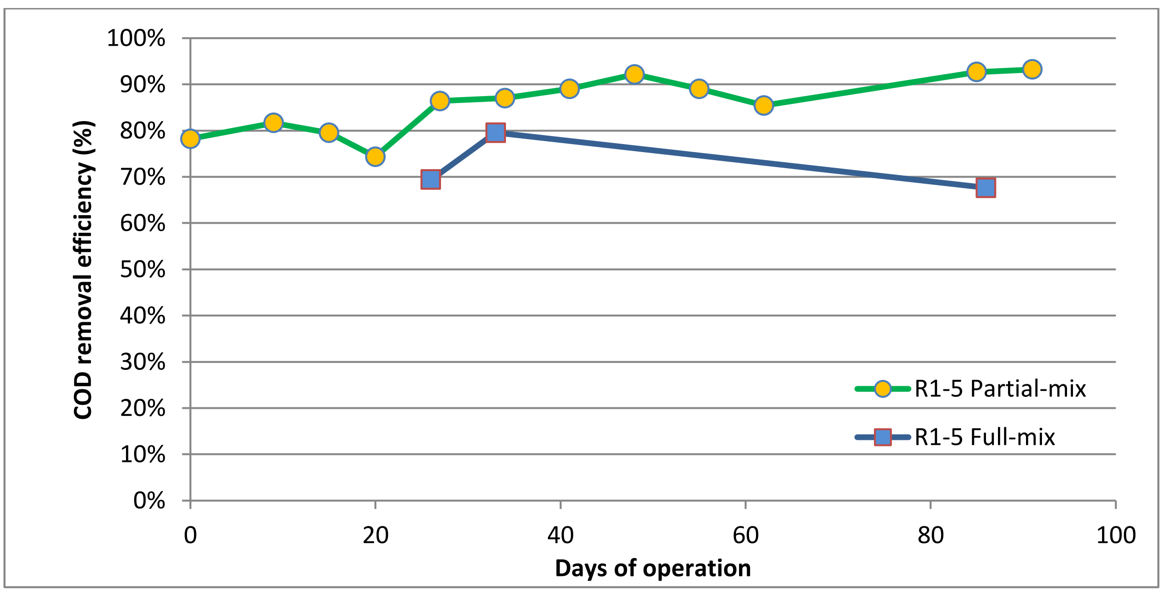



Figure 53. Average COD Removal Efficiency in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.5.5. Biogas Production

Figure 54 shows the average daily biogas production observed in reactors 1 through 5 when operating under full and partial-mix conditions. An acclimation period of about 30 days was observed when reactors 1 through 5 were switched to the partial-mix design. After this period, the average daily biogas production of the partial-mix reactors reached values between 6 and 8 liters per day, while the full-mix reactors maintained average daily biogas productions between 3 and 6 liters. A peak in average daily biogas production was observed after 100 days of operation of reactors 1 through 5 under full-mix design, reaching 9 liters of biogas per day, after which the production dropped to the previously mentioned interval of biogas between 3 and 6 liters per day.

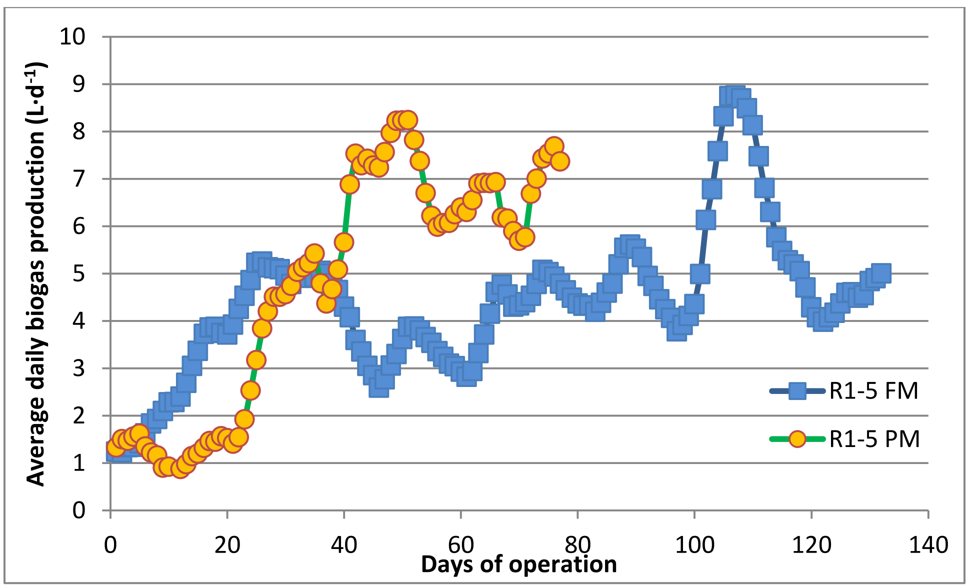



Figure 54. Average Daily Biogas Production in Full and Partial-Mix Reactors (R1-5) during 2$^{nd}$ Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

Figure 55 shows that biogas yield increased when the reactors 1 through 5 were switched to the partial-mix scheme.

The biogas yield when reactors were operated under full-mix scheme stabilized around values of 0.6 L $gCOD^{-1}$ fed, while in the case of partial-mix scheme these values reached 0.75 L $gCOD^{-1}$ fed. The observed difference in biogas yield could be a result of an increased percentage of easier to digest glycerol in the feed (even though the average OLR remained constant throughout the experiment). Another explanation is that the partial-mix reactors did not start producing biogas at a high rate right away. By looking at Figure 55, it can be seen that the first month of operation of R1-5 (October 2015), the biogas production was fairly low. OM must have accumulated during that month to provide a high peak in biogas production in November. Finally, there is a limit to how much biogas can be produced out of a given mass of OM. It is likely that under the extremely high conditions of SRT that partial-mix reactors operate, the biogas yield obtained was close to the aforementioned limit.

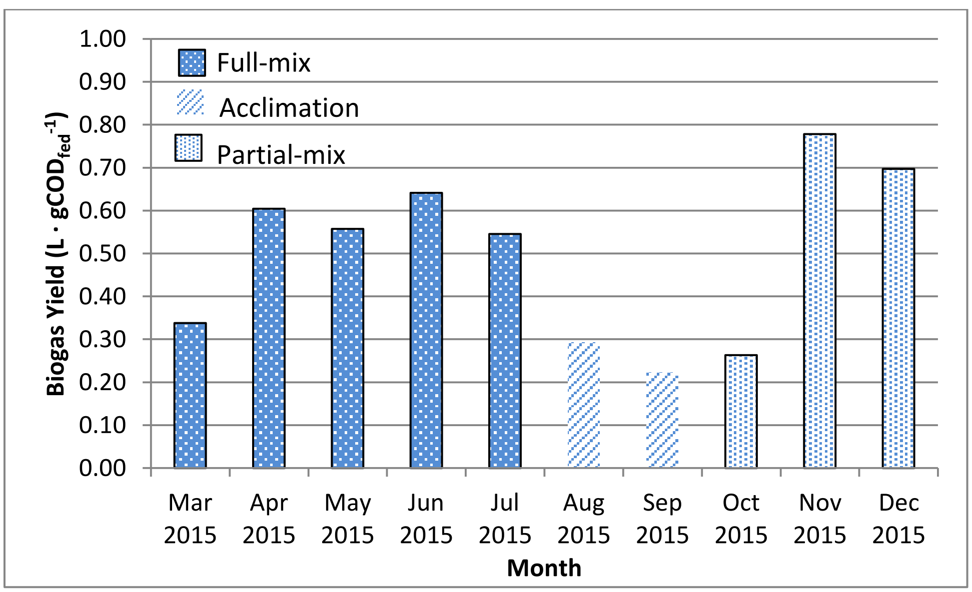



Figure 55. Average Biogas Yields in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

A similar behavior was observed when analyzing the VRE (Figure 56). Little difference, if any, was observed in terms of L of biogas produced per L of reactor per day when reactors 1 through 5 switched from full to partial-mix schemes.

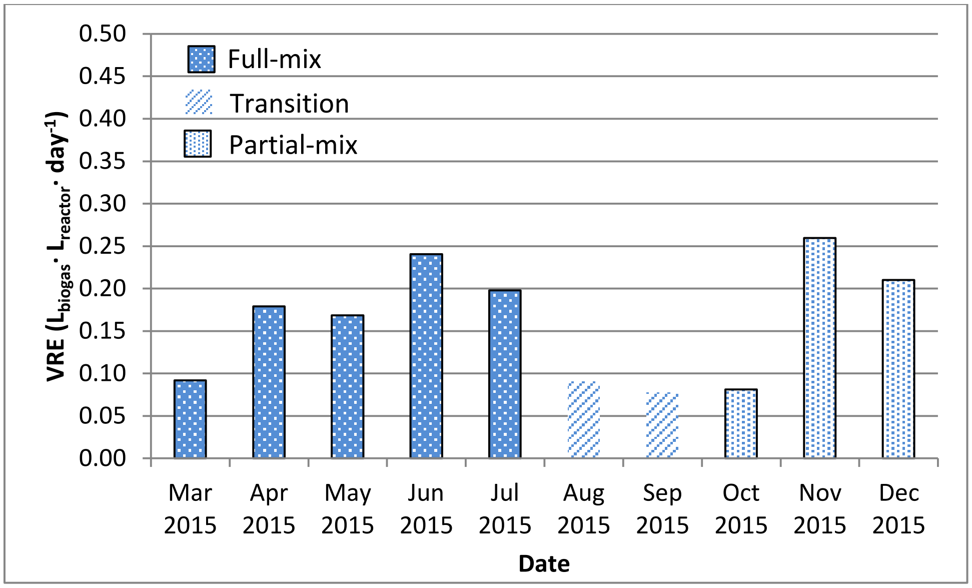



Figure 56. Average VRE in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

### 5.5.6. SRT

Solid Retention Time increased under partial-mix setup (Figure 57). The average SRT achieved by reactors 1 through 5 under full-mix conditions was 50 days, with a maximum of 70 and a minimum of 35 days. The same set of reactors achieved SRTs as high as 788 days under partial-mix, starting at a lower point of 346 days and increasing steadily until reaching a somewhat constant region of about 700 days SRT. When comparing the operation of R1-5 under partial-mix conditions with the operation of R6 also under partial-mix conditions studied in the 1st trial, it is seen that the SRTs achieved in the 2nd trial are twice as high as the 1st Trial (see Figure 58).

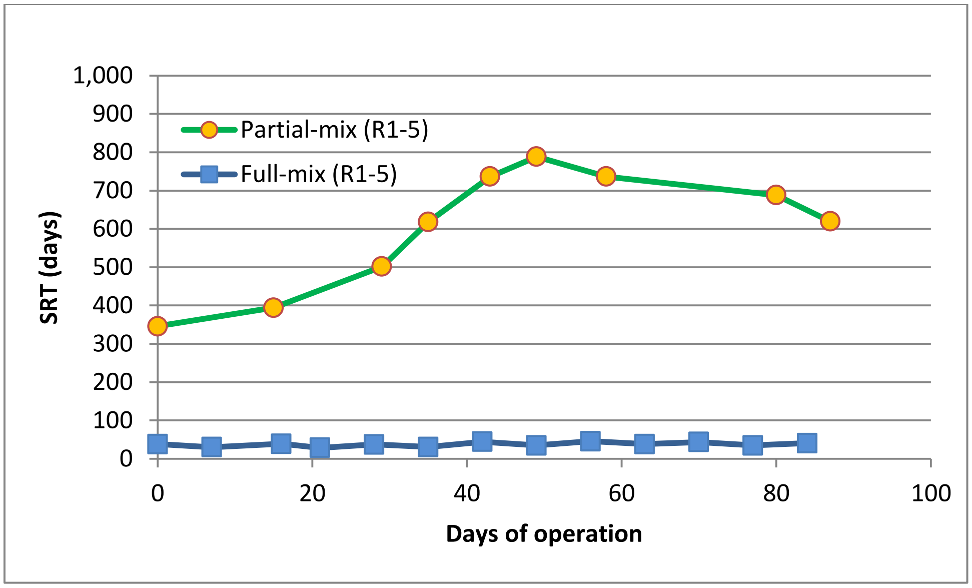



Figure 57. Average SRT in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

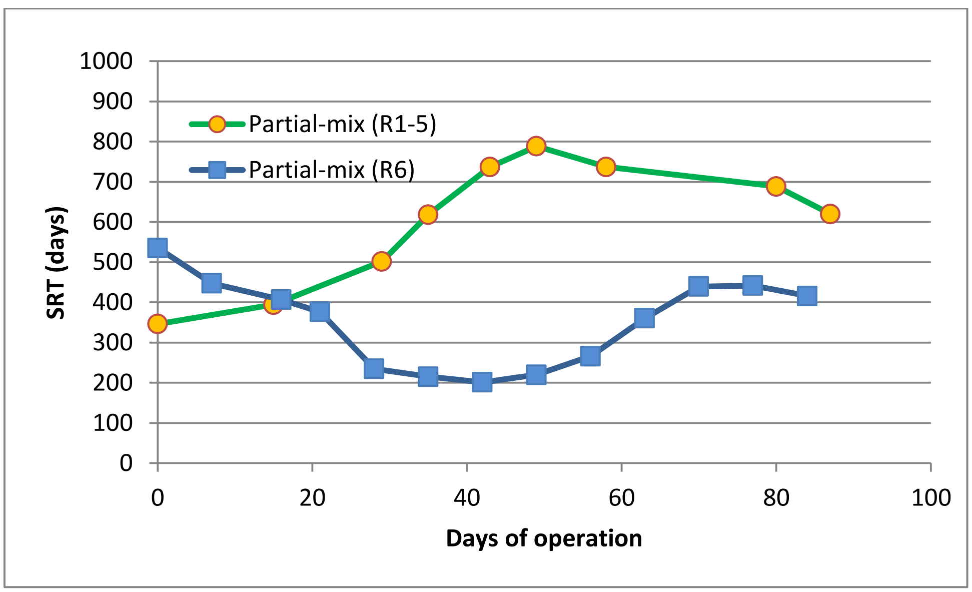



Figure 58. Average SRT in Partial-mix Reactors in 1st Trial (R6) and 2nd Trial (R1-5) (Average OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

Two possible explanations can be given for this. The first explanation is that R6 experienced caking and it was not possible to account for the extra mass attached to the walls (underestimation of SRT in the 1st trial). The second explanation is that solids built up to twice as much as the ones reported in the 1st trial, while the effluent quality remained the same. The available data suggests that the cause of the low SRTs observed in R6 operating under partial-mix conditions was due to caking (see Appendix I).

#### 5.5.7. Brief Evaluation of Results

The comparison between reactors 1 through 5 operating under full and partial-mix schemes provided evidence that supported our previous findings in the 1st trial. VFA to alkalinity ratio and pH values were in accordance with the ones obtained during 1st trial, and allowed a stable reactor operation in both full and partial-mix schemes. Solids accumulation rate doubled for partial-mix configuration, and a plateau was observed for both configurations, which seemed to be highly dependent on the OLR used.

Effluent quality was increased in terms of SS, while DS remained constant for both full and partial-mix systems. Organic removal efficiencies were increased notably when operating under partial-mix scheme, thanks to the capture of more SS. SS removal efficiency increase was in the order of 30%, while DS removal efficiencies did not vary.

It was possible to achieve SRTs 10 times higher with partial-mix as compared to the full-mix scheme. An upper limit was observed, which seemed to be highly related to the plateau identified in the VSS mass accumulation. Biogas production showed little difference between full and partial-mix schemes, even though solids were being accumulated at a higher rate using the partial-mix configuration. This was explained by the growth rate of microorganisms being considerably lower than the accumulation rate of organic material, therefore the increase in VSS did not translate in an increase in the biogas production higher than the maximum limit based on stoichiometry.

## 5.6. 3rd Trial: Comparison of Reactors 1-6 Operating Using a Partial-Mix Scheme at 12-day HRT and 0.34gCOD $L^{-1}$ $d^{-1}$ OLR, and 6-day HRT and 0.87 gCOD $L^{-1}$ $d^{-1}$ OLR Sequentially

### 5.6.1. Reactor Stability: pH, VFAs and Alkalinity

The concentration of bicarbonates and VFAs were maintained within safe limits for the operation of an anaerobic digester (Figure 59). The increased OLR resulting from the reduction of HRT while maintaining the average feed characteristics constant resulted in an increase of the mass of solids retained within the reactor, and therefore the sludge-age. As a result, VFAs increased slightly more when using short HRTs as compared to longer HRTs, which may enhance the production of biogas. The values of pH were kept constant in the range between 7.6 and 7.8 for all the duration of the experiment.

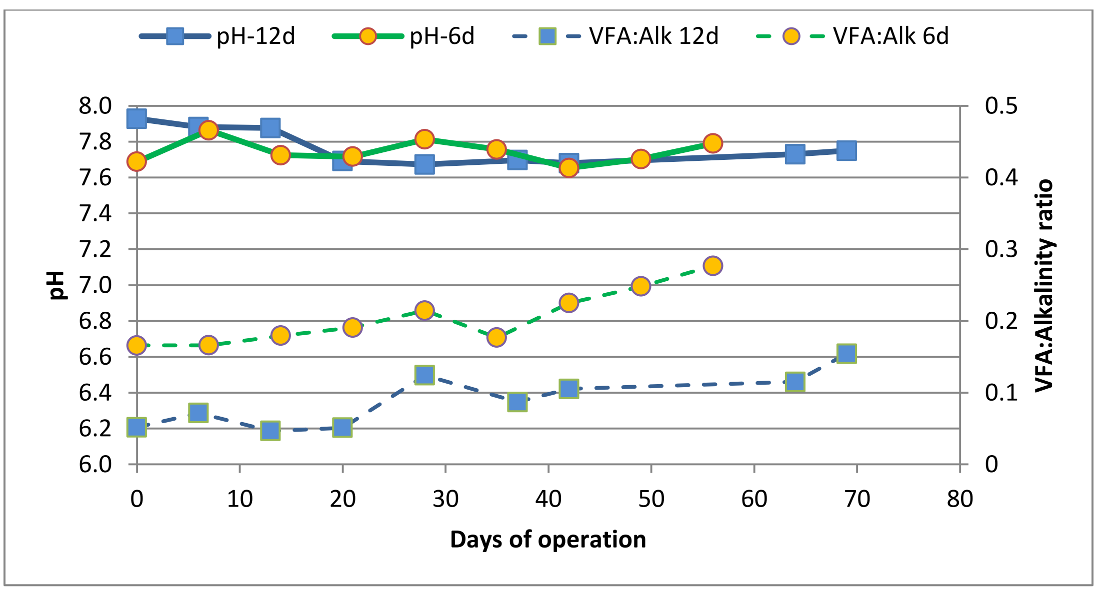



Figure 59. Reactor Stability in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

### 5.6.2. VSS Mass and Accumulation Rate

The same "plateau-effect" observed in previous experiments using partial-mix scheme was observed during 12 and 6-day HRT operation periods (Figure 60). Partial-mix reactors operating at 12 days HRT reached an upper limit of VSS mass of 130 g, after which the accumulation rate decreased sharply. By decreasing the HRT to 6 days, the location of the plateau was increased to 210 gVSS. The accumulation rate was twice as high for the 6-day HRT as opposed to the 12-day HRT, achieving values of 2.3 gVSS per reactor and day.

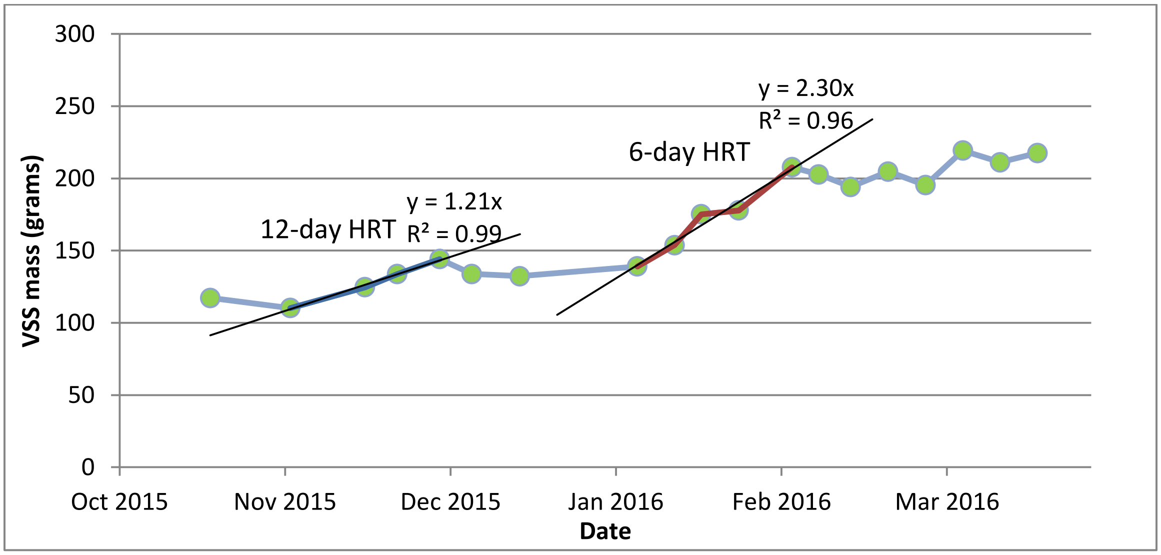



Figure 60. Average Accumulation Rates in Partial-mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

The observed ability to increase the mass of VSS at which the plateau is reached by either decreasing the HRT or increasing the OLR is a very important feature of the partial-mix reactor. Further study on plateau locations based on the combination of HRT and OLR could allow the development of equations to help ASBR design in terms of reactor size (determine the volume to allow keeping a set mass of VSS), schedule of solids wasting (remove solids to continuously operate in the accumulation-region).

### 5.6.3. Decanted Effluent Quality

The reduction in HRT and the subsequent increase in OLR did not affect the capability of the partial-mix reactors to obtain a low solid concentration in the decanted effluent quality compared to the influent liquid (Figure 61).

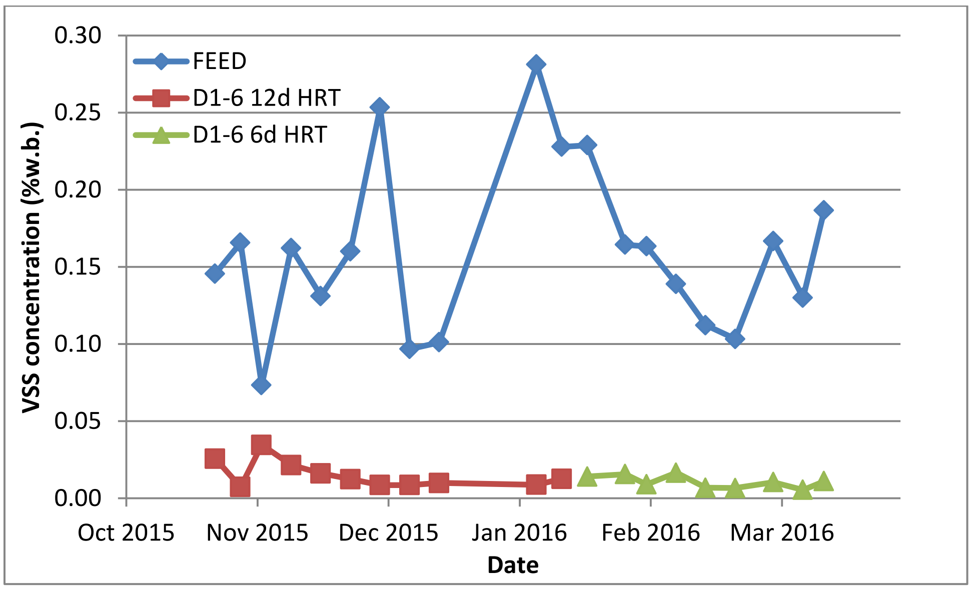



Figure 61. Concentration of VSS in Influent and Decanted Effluent in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

The effluent quality in partial-mix reactors did not vary when reducing the HRT from 12 to 6 days, as shown in Figure 62. The slight increase in solid content observed in the 6-day HRT effluent could be explained by the small increase in the TDS present, which contrasts with the slight decrease in TSS content. An improvement in the hydrolysis process could be behind this effect, but since the differences are so small it could also be explained by experimental error. The main observation is that there is no benefit in terms of effluent quality to operate a partial-mix reactor with HRTs higher than 6 days.

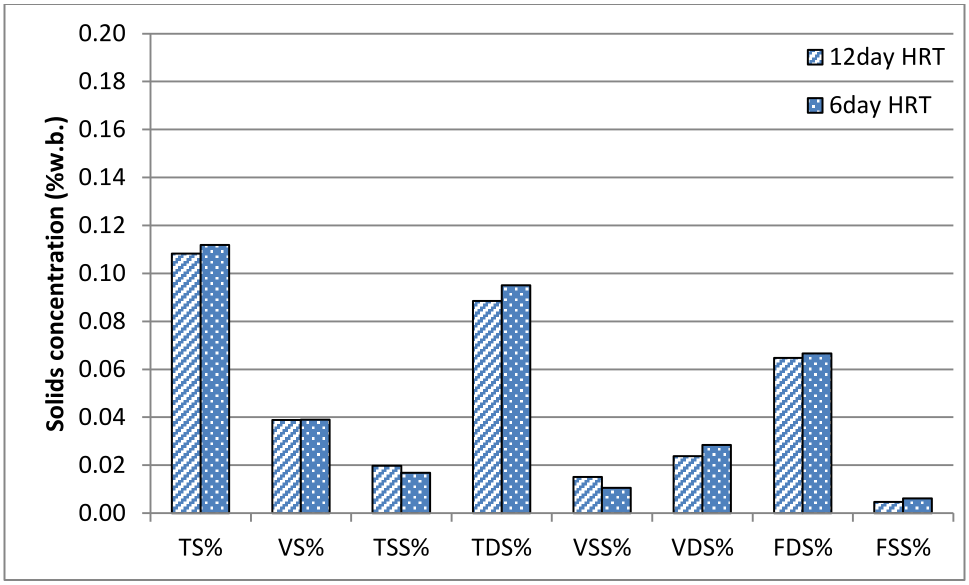



Figure 62. Average Effluent Quality in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

### 5.6.4. Organic Matter Removal Efficiencies

The high removal efficiencies for VS and COD observed in partial-mix reactors in 1st and 2nd trial were maintained at the same levels when lowering the HRT to 6 days (Figures 63, 64 and 65). It must be noted that, as opposed to the partial-mix under 12-day HRT operation period, there was not an acclimation period when we reduced HRT to 6 days, which is translated in slightly better efficiencies in the first days of operation than the 2nd trial (when the reactors were switched from a full-mix to a partial-mix scheme).

Reducing the HRT from 12 to 6 days did not reduce the OM removal efficiencies reported in previous experiments when operating partial-mix reactors.

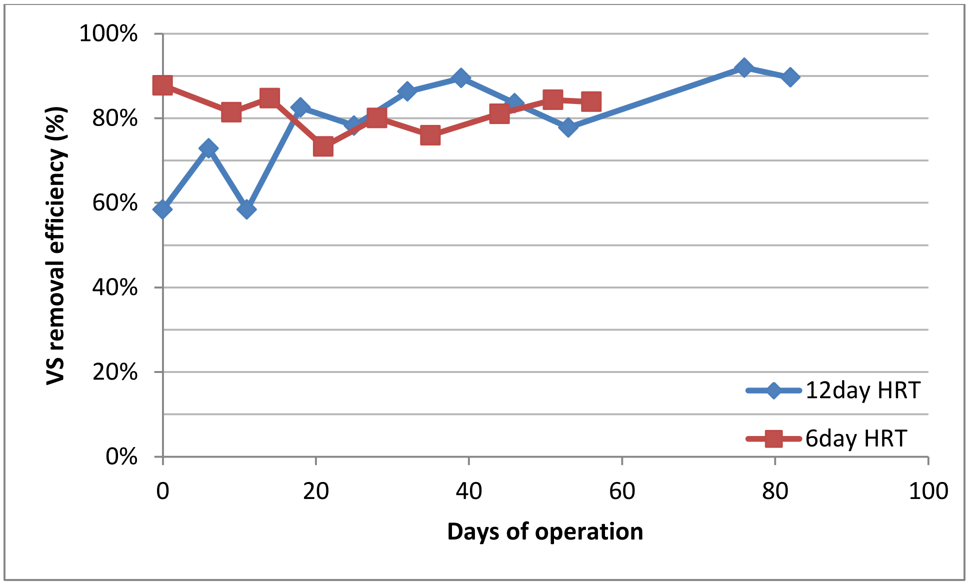



Figure 63. Average VS Removal Efficiency in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

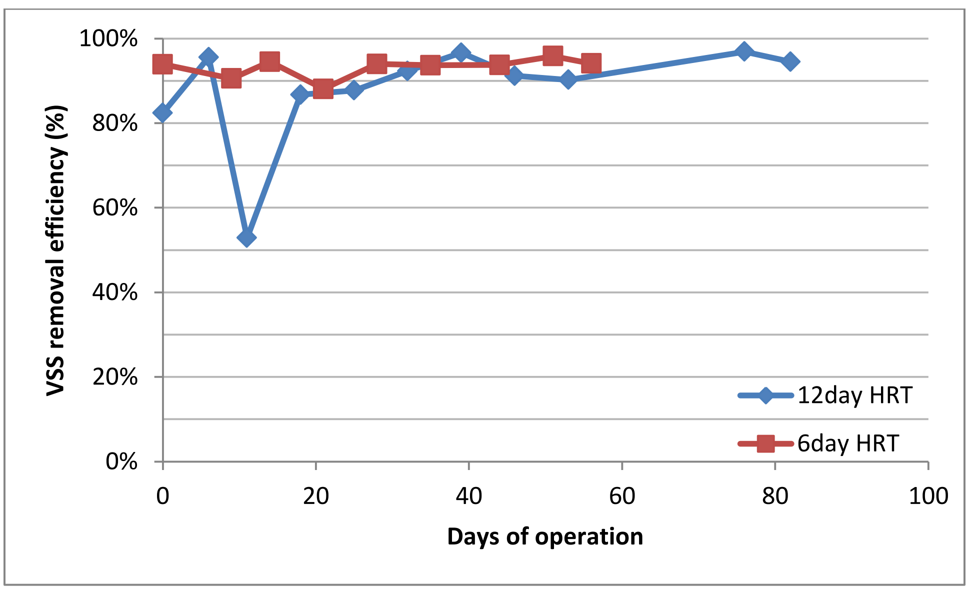



Figure 64. Average VS Removal Efficiency in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

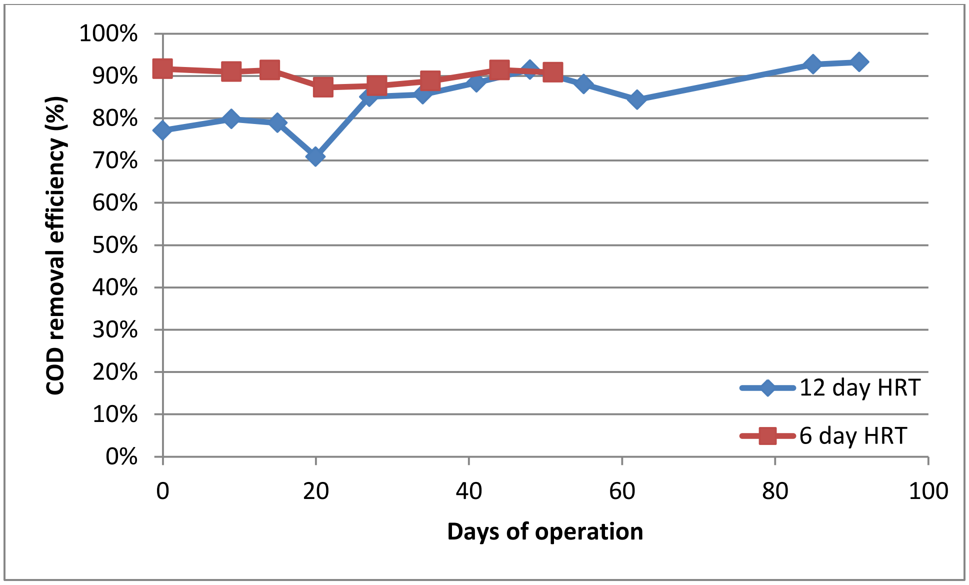



Figure 65. Average COD Removal Efficiency in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

### 5.6.5. Gas Production

Daily biogas production more than doubled when operating at 6-day HRT and 0.87 gCOD $L^{-1}$ $day^{-1}$ OLR (Figure 66). Biogas yield increased slightly when HRT was lowered and OLR increased, as is seen in Figure 67. Once the reactors acclimated to the new mixing system (November and December 2015, 12 day HRT), biogas yield reached values between 0.6 and 0.8 L $gCOD_{fed}^{-1}$. Then, when the HRT was halved, the average yields remained in the neighborhood of 0.8 L $gCOD_{fed}^{-1}$, slightly above the previous operation period. This difference may be related to the accumulation of OM in the reactors. The higher mass of microorganisms present in the reactors when operating at 6 days HRT is explained by the larger amount of time it has been provided for them to grow (i.e. the experiment at 6 days HRT was conducted later than the one at 12 days HRT), and also by the higher availability of OM present for new microorganisms to grow (i.e. decreasing the HRT is translated into an increase in OLR and therefore a surplus of OM).

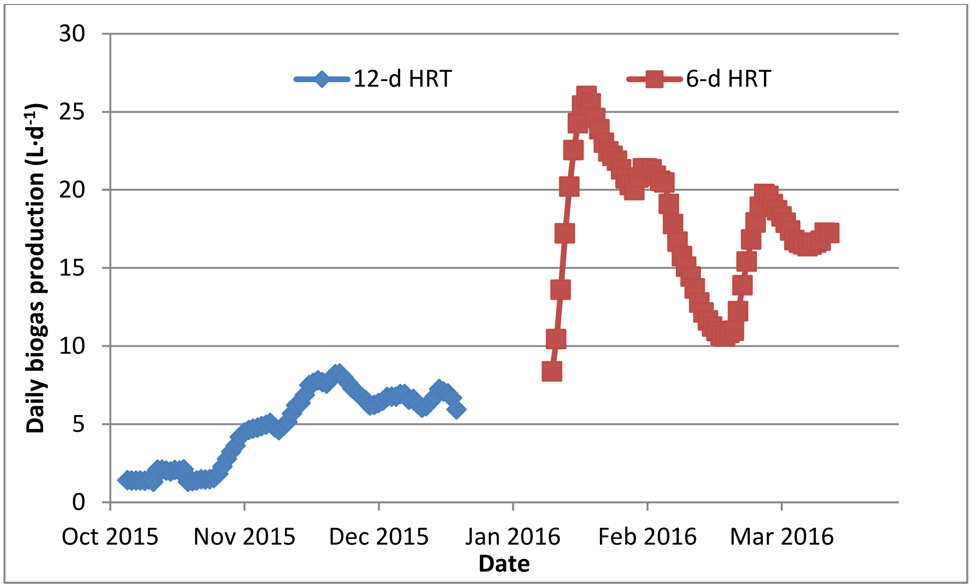



Figure 66. Average Daily Biogas Production in Individual Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

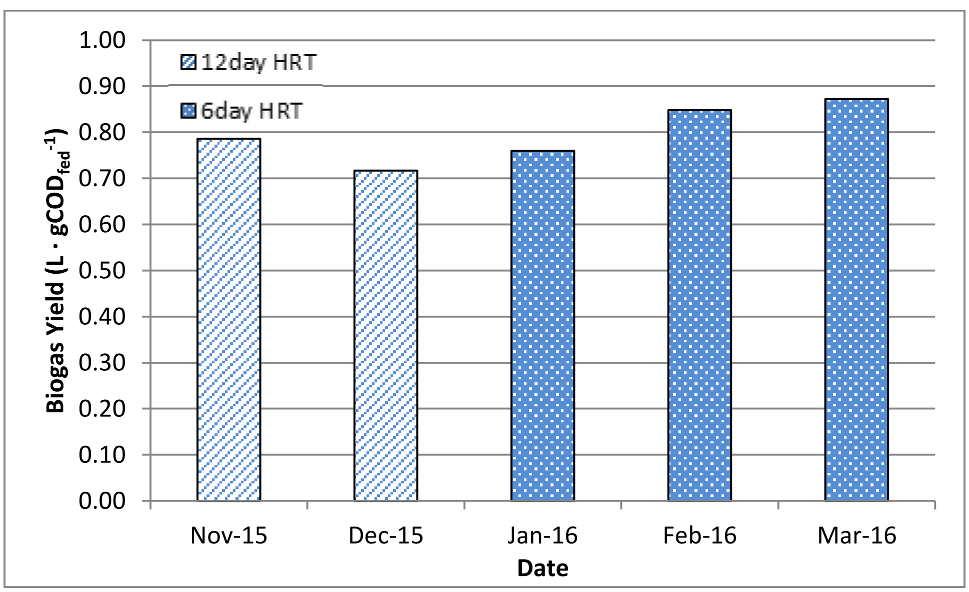



Figure 67. Average Monthly Biogas Yield in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

Eventually, an equilibrium should be reached in which no more microorganisms would grow under a set of operation conditions.

Since more than twice as much OM was fed to the same volume of reactor while maintaining the effluent quality, the volume of biogas produced per liter of reactor more than doubled when the reactors operated at 6-day HRT and 0.87 gCOD $L^{-1}$ $day^{-1}$ (Figure 68).

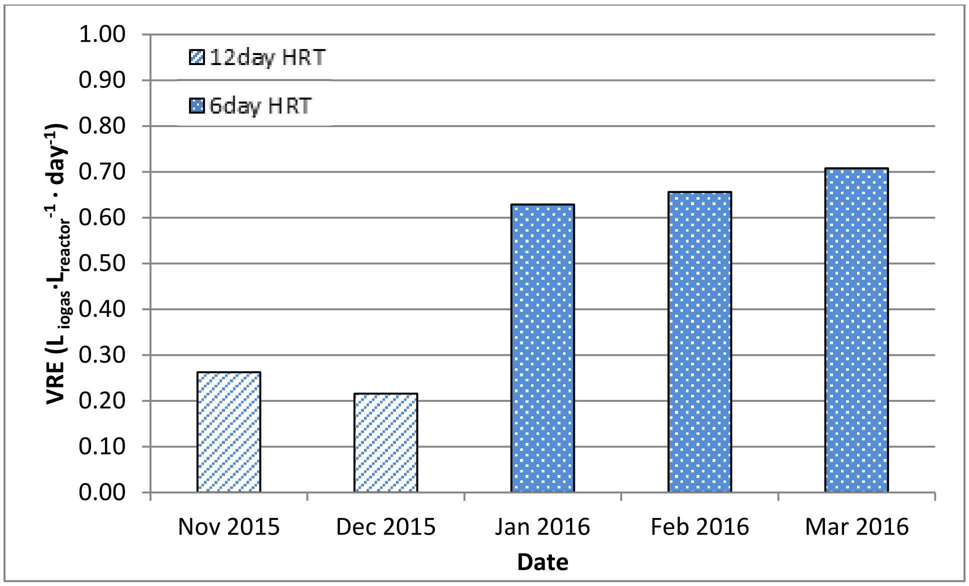



Figure 68. Average VRE in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

### 5.6.6. SRT

A very interesting behavior was observed when comparing the SRT under 12 and 6-day HRT for the set of six reactors (Figure 69). There seems to be a maximum value of achievable SRT of around 800 days. This maximum value was reached after two months operating at 12 days HRT. When the reactors operated at 6-day HRT, the maximum SRT achieved was slightly above 700 days and was achieved in about a month. As the HRT was decreased, more solids were fed to the reactor in the same period of time (i.e. the OLR is increased accordingly), therefore the plateau of retained solids observed in the previous experiments was moved higher. Even when the removal efficiency was maintained constant at higher OLR, a decrease of HRT results in an increase in the volume of solids removed in the effluent, therefore balancing the increase in solids mass that can be maintained in the reactor.

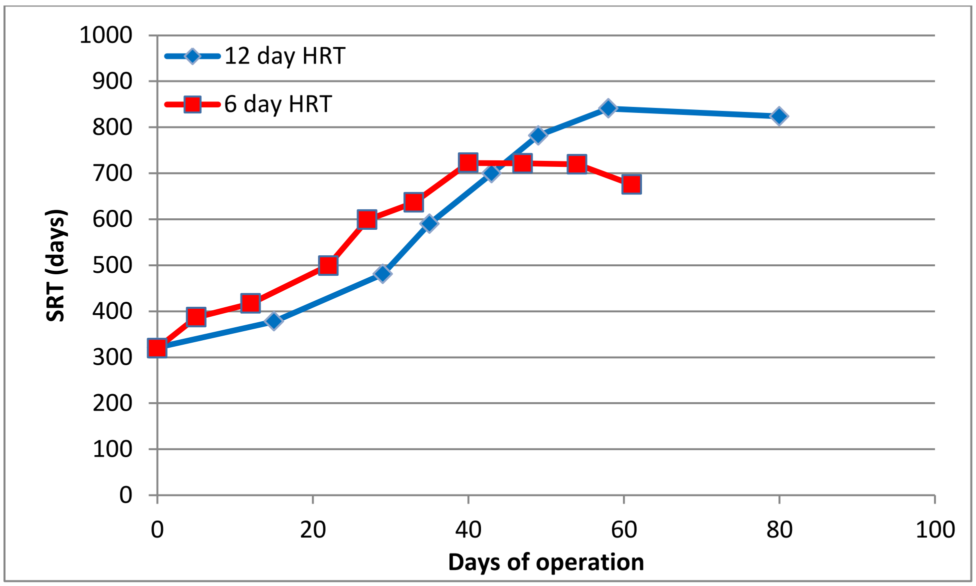



Figure 69. Average SRT in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

### 5.6.7. Brief Evaluation of Results

Most of the variables used to evaluate the operation of the ASBRs did not change when lowering the HRT of reactors operating under the partial-mix scheme; similar values of effluent quality, OM removal efficiencies, biogas yield, and SRT were achieved. On the other hand, the fact that twice as much volume of influent was treated per day resulted in a large increase of VRE. This result provides a way to further increase the process efficiency.

The accumulation rate of VSS was doubled when the HRT decreased from 12 to 6 days HRT and the OM in the feed was kept fairly constant. This lead to an increased limit for solids accumulation located at around 210 grams of VSS. Even though the reactor stayed within safe operating conditions in terms of pH and ratio of VFA to alkalinity, VFAs accumulated at a higher rate when using the lower HRT. Therefore, special care must be taken to ensure the reactor's environment does not get out of safe limits when using lower HRTs.

### 5.7. Settling Rate of Retained Solids

Settling rates were determined for partial-mix reactors at various times of the experimental period. Observed settling curves are plotted in Figures 70 and 71.

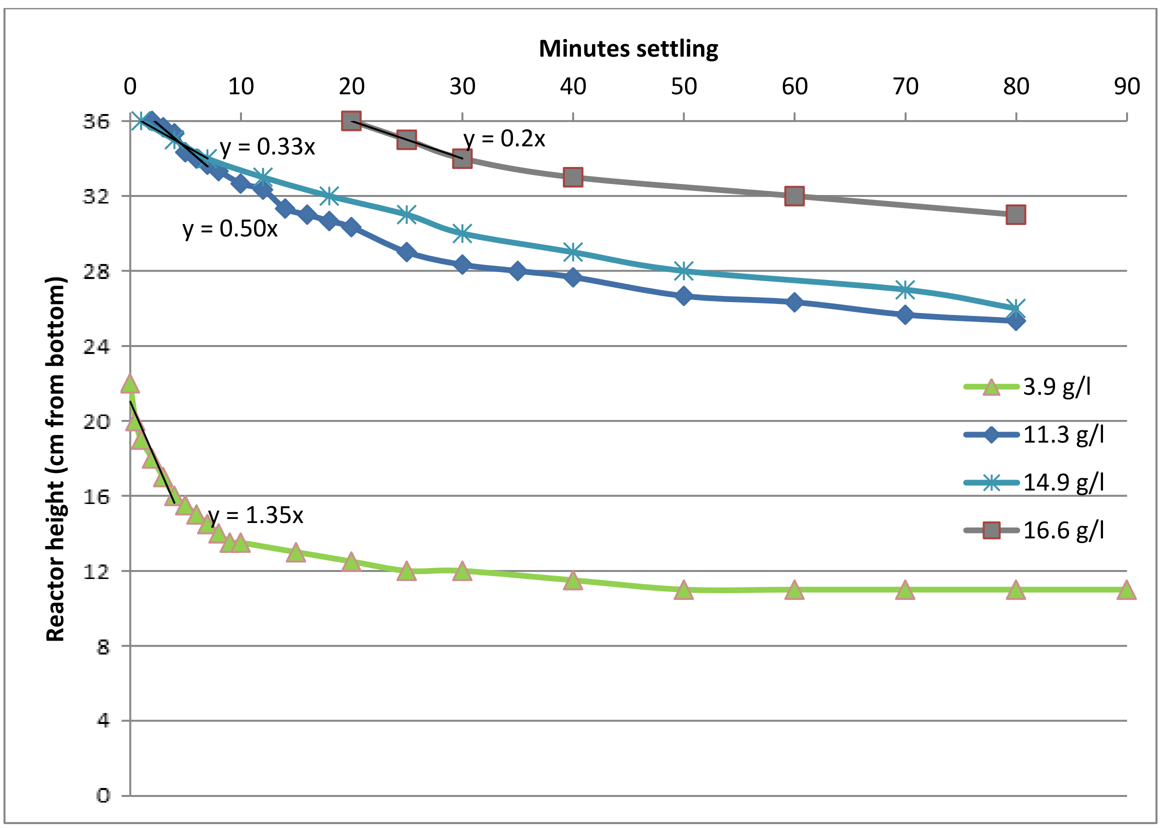



Figure 70. Settling Curves and Initial Settling Velocities in Partial-mix Reactor at Different TSS Concentrations

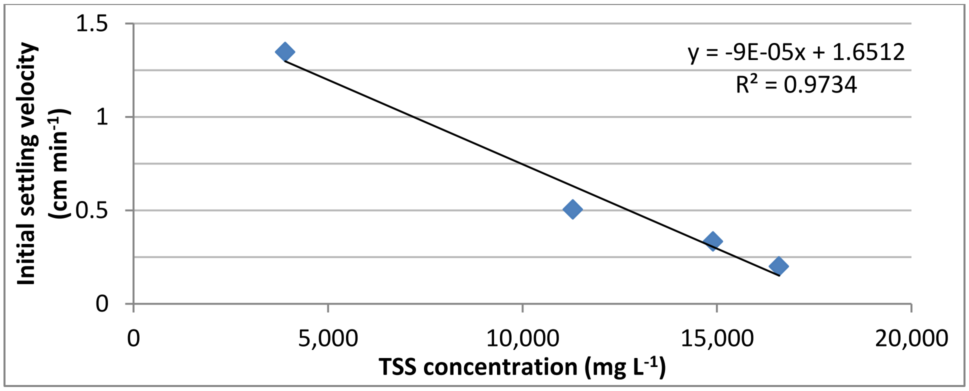



Figure 71. Initial Settling Velocity vs. TSS Concentration of Mixed Clouds in Partial-Mix Reactors.

.

Although it was not possible to determine whether or not the mixing scheme affected settling rate, the supernatant obtained after settling (i.e. the layer of clarified liquid above the concentrated solids layer) has been measured to contain much less unsettleable VSS solids when a reactor operates with a partial-mix scheme (Figures 38 and 49).

Finally, yet another benefit of using a partial-mix system is the fact that even though the settling rates may not change at similar operation conditions, the particles start their settling at a deeper point. This can be used to either reduce the settling times for the operation of partial-mix ASBRs, or obtain increased effluent quality by reducing the particle interactions between the finer, harder-to-settle particles in the clarified layer.

### 5.8. Influence of Mixing on Biogas Production Rate

As it was previously discussed in the literature review, there is not a clear consensus between researchers whether it is beneficial to mix diluted wastewaters or reduce the process energy demands by keeping reactors unmixed. Even when it has been decided to mix a reactor, there are also different opinions on how much time the mixing should be conducted to obtain similar results than with a continuously mixed reactor.

Figure 72 shows the average of several observations of gas production at mixed and unmixed periods during the react phase. During the last year of this research, biogas production rate through the whole ASBR cycle was followed closely with the purpose of determining the importance of mixing for our particular conditions. Each cycle lasted 12 hours, in which mixing and settling periods of 90 minutes each were alternative conducted (resulting in 4 different mixing and settling periods within a cycle, which will be labeled mix1, set 1, mix 2, etc.).The first observation was that the overall behavior of biogas production rate did not seem to depend on the mixing scheme used. The overall shape of biogas rate production followed the same trend for full and partial-mix reactors; a peak in biogas production rate was achieved during the second mixing period, after which it slowly decreased through the rest of the cycle. The influence of mixing was especially important during the first 9 hours of the cycle, as biogas production rate increased when the reactors were mixed compared to settling phases.

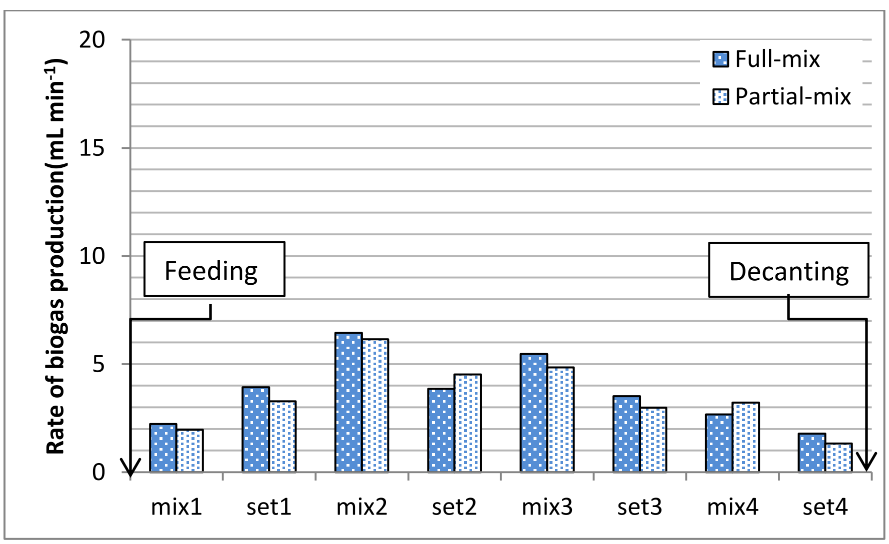



Figure 72. Average Biogas Production Rate in Full and Partial-Mix Reactors (R1-5) during 2nd Trial (OLR = 0.34 gCOD $L^{-1}$ $day^{-1}$, HRT = 12 days).

During the last three hours of the cycle the influence of mixing the reactor decreased considerably, as the reduced amount of OM available did not allow the production of gas whether or not the reactor was being mixed.

Figure 73 shows biogas production throughout the react period at 12 and 6 days HRT. The reduction in HRT translated into an important increase in the OLR, which went from an average of 0.34 to an average of 0.87 gCOD $L^{-1}$ $day^{-1}$. In this case, mixing the reactor contents when more OM is available seemed to reduce the decay of biogas rate rather than increase the biogas production rate. At the same time, the biogas production rate at the very end of the cycle (s4) was still very high, which would explain the presence of accumulation of undigested OM during the normal operation of the ASBR cycle. This suggests that under moderately high OLR and/or low HRT conditions, either the total mixing time or the total cycle period should be increased to allow the digestion of all the OM fed. Nevertheless, it is likely based on previous results reported in this thesis that the growth of extra microorganisms under high OM availability will counteract this OM surplus and reach a plateau where no more OM accumulates at a given cycle time, OLR and HRT.

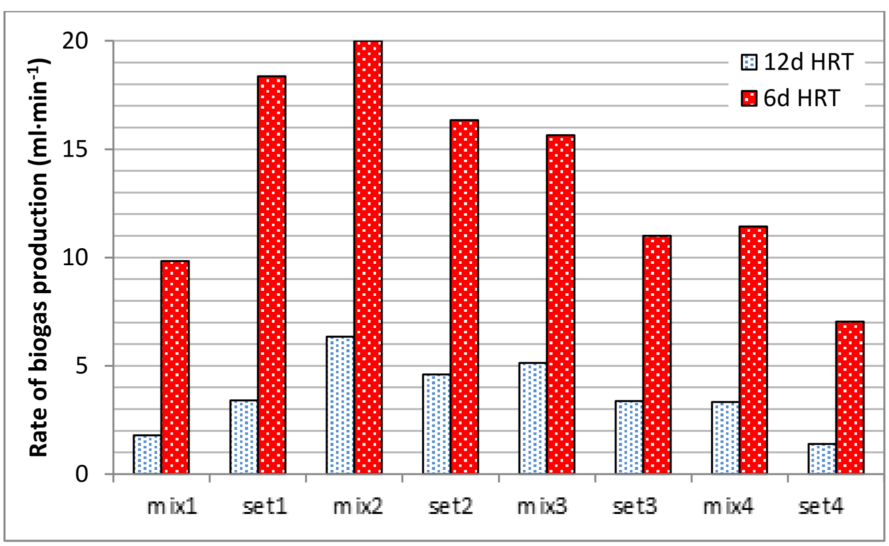



Figure 73. Average Biogas Production Rate in Partial-Mix Reactors (R1-6) at 12-day HRT (0.34 gCOD $L^{-1}$ $day^{-1}$) and 6-day HRT (0.87 gCOD $L^{-1}$ $day^{-1}$) during 3rd Trial.

In general, it was observed that mixing is beneficial for maintaining a high biogas production rate. In the case of our experiments at 12 days HRT, the production rate was slightly increased when mixing, while during the 6 days HRT operation the effect of mixing was to prevent the biogas production rate to decay rapidly. It can be concluded that intermittent mixing is suitable for the operation of dilute wastewater, and requires a more detailed study to develop the best relationship between mixing and settling times.

### 5.9. Comparison of Full-Mix, Full-Scale ASBR and Partial-Mix, Bench-Scale ASBRs

Table 13 provides a comparison of the operational and performance parameters of the bench-scale partial-mix reactors studied in this thesis and the results obtained by Hamilton and Steele (2014) when they studied the operation of a full scale ASBR.

Table 13. Comparison between Full-Scale ASBR Studied by Hamilton & Steele and Experimental Results for Bench Scale Partial-Mix ASBRs.

| | Bench-scale | | Full-scale | |
|---|---|---|---|---|
| Mixing scheme | *Partial-mix* | | *Full-mix* | |
| HRT (days) | 12 | 6 | 20 | 5 |
| SRT (days) | ~800 | ~700 | 51 | 26 |
| OLR (gVS $L_{reactor}^{-1}$ $day^{-1}$) | 0.16 | 0.41 | 0.32 | 0.48 |
| OLR (gCOD $L_{reactor}^{-1}$ $day^{-1}$) | 0.32 | 0.87 | 0.70 | 0.85 |
| T (°C) | 35 | 35 | 22-32 | 22-24 |
| Biogas yield (L $gVS_{fed}^{-1}$) | 1.18 | 1.71 | 0.85* | 0.58* |
| Biogas yield (L $gCOD_{fed}^{-1}$) | 0.58 | 0.83 | 0.38* | 0.32* |
| VRE ($L_{biogas}$ $L_{reactor}^{-1}$ $day^{-1}$) | 0.18 | 0.66 | 0.28* | 0.28* |
| Removal efficiency (%COD) | 85 | 90 | 73 | 57 |
| Removal efficiency (%VS) | 79 | 81 | 62 | 55 |
| pH | 7.8 | 7.8 | 7.3 | 7.3 |

* Values originally reported in terms of $CH_4$. They were converted to biogas by using the 65% $CH_4$ content reported by the authors.

The results for the partial-mix scheme clearly outperformed the full-scale reactor. When an HRT of 12 days was used, an SRT of above 800 days were achieved in the lab-scale experiments, which resulted in a better stabilization of OM and a higher biogas yield. VRE is still higher in the full-scale reactor, but this is a result higher OLR. Partial-mix lab-scale reactors operating under 6 days HRT allowed to almost three times the biogas yield and VRE of the full-scale, full-mix reactor.

Summarizing, the partial-mix scheme is a very promising design for ASBR digesters that could potentially increase their efficiency. The main benefit is the increased ability to capture solids, effectively decoupling HRT from SRT. This enhances OM removal efficiencies considerably, even when reducing HRT down to 6 days.

# CHAPTER VI

## CONCLUSIONS

The partial-mix system provided stable operating conditions when treating diluted swine manure in terms of pH, VFAs and alkalinity. Little differences between a full-mix design and the proposed partial-mix design were observed in the pH values (both operated in the higher end of the typical anaerobic digestion range), while a higher amount of VFAs were measured in the partial-mix design. This may be attributed to the considerably longer SRTs maintained and the higher masses of OM retained within the reactor, that increased the extent of OM conversion to VFA. The concentration of VFAs compared to the alkalinity did not reach unstable values, but a steady increase in the VFA-to- alkalinity ratio observed during the last part of the experiments (HRT of 6 days) must be studied to determine the optimum SRT to keep in the reactor.

The ability to retain OM within the reactor improved considerably when using the partial-mix design. In the full-mix scheme, a relationship between the VSS mass kept in the reactor and the concentration of VSS leaving in the effluent was observed. This behavior was not observed in the partial-mix design, which makes the concentration of OM leaving the reactor independent of the total mass accumulated. As a result of this, a partially mixed reactor was capable of retaining most of the slowly digestible OM fed. The reason behind this is that most of the VSS fed to the reactor settled in the reactor. Retaining solids allowed a much more thorough digestion of OM, increasing OM removal efficiencies in terms of VS, VSS and COD.

The absence of a considerable increase in biogas yield experienced in the partial-mix reactors indicates that the biggest effect of this mixing scheme lies in the retention of solids rather than their digestion.

The biogas yields of full and partial-mix reactors have been observed to be fairly similar to each other, with a slight improvement for the partial-mix scheme. An explanation is that the increased VSS accumulation rate observed in the partial-mix reactors was caused by the accumulation of OM. The improvement in biogas production found in the partial-mix reactor was the ability to maintain the same biogas yield while increasing OLR (and decreasing HRT), which resulted in an increase in the VRE.

Due to the more efficient retention of solids, SRT and HRT could be operated independently. While there was a 100-fold difference between SRT and HRT (>700 days SRT, 6 days HRT) at the end of this experiment, biogas production, OM removal efficiency, effluent quality, and mass accumulation remained equal or higher than operation at 12 day HRT. This SRT is considerably higher than the minimum required for carrying out the anaerobic digestion of OM (20 to 30 days); therefore, it is possible to finely adjust the operation of the reactors by setting an appropriate sludge wasting schedule. In addition, providing larger than minimum SRT will help degrade the recalcitrant fraction of the OM.

## 6.1. Future Research

The promising results described in this thesis open an interesting path to further improvement of the ASBR technology by improving VRE and applying this technology to industries with diluted wastewaters not suitable for regular treatment methods. The next step in the development of partial-mix ASBR technology will be to determine a lower limit for HRT that can be achieved to maintain stable operation.

The observed plateaus of solids retained associated with a particular OLR and HRT should be evaluated to develop a relationship able to predict maximum retainable mass for a particular set of conditions. This would allow the operation of reactors in a more efficient way, scheduling the sludge wasting to optimize the microorganism growth and biogas production.

Studying the influence of the interface location between concentrated and diluted phase should be evaluated. It is unknown what would provide better results; raising the cloud the highest possible while maintaining a clarified layer, or keeping the solids barely suspended and passing the clarified liquid through the matrix of OM and microorganisms.

Finally, the reactor efficiency can be further increased by reducing the energy input required to operate it. This can be achieved by optimizing the cycle length and mixing/settling ratios to allow the maximum production of biogas (positive energy stream) while reducing the energy input for mixing (negative energy stream).

# REFERENCES

Adekunle, K. F., and J. A. Okolie. 2015. A Review of Biochemical Process of Anaerobic Digestion. *Advances in Bioscience and Biotechnology* 06(03):205-212.

Anderson, G. K., and G. Yang. 1992. Determination of Bicarbonate and Total Volatile Acid Concentration in Anaerobic Digesters Using a Simple Titration. *Water Environment Research* 64(1):53-59.

Babaee, A., and J. Shayegan. 2011. Effects of Organic Loading Rates (OLR) on production of methane from anaerobic digestion of vegetable waste. In *Proceedings of the World Renewable Energy Congress*. Linköping, Sweden.

Bolzonella, D., P. Pavan, P. Battistoni, and F. Cecchi. 2005. Mesophilic anaerobic digestion of waste activated sludge: influence of the solid retention time in the wastewater treatment process. *Process Biochemistry* 40(3-4):1453-1460.

Borja, R., C. J. Banks, and Z. Wang. 1995. Effect of organic loading rate on anaerobic treatment of slaughterhouse wastewater in a fluidised-bed reactor. *Bioresource technology* 52(2):157-162.

Burton, F., G. Tchobanoglous, R. Tsuchihashi, H. D. Stensel, Metcalf, and I. Eddy. 2013. *Wastewater Engineering: Treatment and Resource Recovery*. McGraw-Hill Education.

Chae, K. J., A. Jang, S. K. Yim, and I. S. Kim. 2008. The effects of digestion temperature and temperature shock on the biogas yields from the mesophilic anaerobic digestion of swine manure. *Bioresour Technol* 99(1):1-6.

Dague, R. R. 1993. Anaerobic sequencing batch reactor. Google Patents.

Eaton, A. D., M. A. H. Franson, A. P. H. Association, A. W. W. Association, and W. E. Federation. 2005. *Standard Methods for the Examination of Water & Wastewater*. American Public Health Association.

Franke-Whittle, I. H., A. Walter, C. Ebner, and H. Insam. 2014. Investigation into the effect of high concentrations of volatile fatty acids in anaerobic digestion on methanogenic communities. *Waste Manag* 34(11):2080-2089.

Habben, C. E. 1991. Initial studies of the anaerobic sequencing batch reactor.

Hamilton, D. W. 2011. *Consistency of manure/water mixtures*. Stillwater, Okla. : Division of Agricultural Sciences and Natural Resources, Oklahoma State University.

Hamilton, D. W., and M. T. Steele. 2014. Operation and Performance of a Farm-Scale Anaerobic Sequencing Batch Reactor Treating Dilute Swine Manure. *Transactions of the ASABE*:1473-1482.

Hansen, K. H., I. Angelidaki, and B. K. Ahring. 1998. Anaerobic Digestion of Swine Manure: Inhibition by Ammonia. *Water Research* 32(1):5-12.

Kafle, G. K., S. Bhattarai, S. H. Kim, and L. Chen. 2014. Effect of feed to microbe ratios on anaerobic digestion of Chinese cabbage waste under mesophilic and thermophilic conditions: biogas potential and kinetic study. *J Environ Manage* 133:293-301.

Kaparaju, P., I. Buendia, L. Ellegaard, and I. Angelidakia. 2008. Effects of mixing on methane production during thermophilic anaerobic digestion of manure: lab-scale and pilot-scale studies. *Bioresource technology* 99(11):4919-4928.

Karim, K., K. T. Klasson, R. Hoffmann, S. R. Drescher, D. W. DePaoli, and M. Al-Dahhan. 2005. Anaerobic digestion of animal waste: Effect of mixing. *Bioresource technology* 96(14):1607-1612.

Kayranli, B., and A. Ugurlu. 2011. Effects of temperature and biomass concentration on the performance of anaerobic sequencing batch reactor treating low strength wastewater. *Desalination* 278(1–3):77-83.

Kim, J. K., B. R. Oh, Y. N. Chun, and S. W. Kim. 2006. Effects of temperature and hydraulic retention time on anaerobic digestion of food waste. *J Biosci Bioeng* 102(4):328-332.

Kim, M., Y.-H. Ahn, and R. Speece. 2002. Comparative process stability and efficiency of anaerobic digestion; mesophilic vs. thermophilic. *Water Research* 36(17):4369-4385.

Kinnunen, V., R. Craggs, and J. Rintala. 2014. Influence of temperature and pretreatments on the anaerobic digestion of wastewater grown microalgae in a laboratory-scale accumulating-volume reactor. *Water Res* 57:247-257.

Latif, M. A., C. M. Mehta, and D. J. Batstone. 2015. Low pH anaerobic digestion of waste activated sludge for enhanced phosphorous release. *Water Res* 81:288-293.

Lee, I. S., P. Parameswaran, and B. E. Rittmann. 2011. Effects of solids retention time on methanogenesis in anaerobic digestion of thickened mixed sludge. *Bioresour Technol* 102(22):10266-10272.

Lindmark, J., E. Thorin, R. Bel Fdhila, and E. Dahlquist. 2014. Effects of mixing on the result of anaerobic digestion: Review. *Renewable and Sustainable Energy Reviews* 40:1030-1047.

Malý, J., and H. Fadrus. 1971. Influence of Temperature on Anaerobic Digestion. *Journal (Water Pollution Control Federation)* 43(4):641-650.

Massé, D., F. Croteau, L. Masse, and S. Danesh. 2004. The effect of scale-up on the digestion of swine manure slurry in psychrophilic anaerobic sequencing batch reactors. *Transactions of the ASAE* 47(4):1367.

Massé, D. I., and L. Massé. 2000. Treatment of slaughterhouse wastewater in anaerobic sequencing batch reactors. *Canadian Agricultural Engineering* 42(3):131.

Massé, D. I., L. Massé, and F. Croteau. 2003. The effect of temperature fluctuations on psychrophilic anaerobic sequencing batch reactors treating swine manure. *Bioresource technology* 89(1):57-62.

McCarty, P. L. 1964. Anaerobic waste treatment fundamentals. *Public works* 95(9):107-112.

Mills, P. 1979. Minimisation of energy input requirements of an anaerobic digester. *Agricultural Wastes* 1(1):57-66.

Moset, V., M. Poulsen, R. Wahid, O. Hojberg, and H. B. Moller. 2015. Mesophilic versus thermophilic anaerobic digestion of cattle manure: methane productivity and microbial ecology. *Microb Biotechnol* 8(5):787-800.

Ndegwa, P., D. Hamilton, J. Lalman, and H. Cumba. 2005. Optimization of anaerobic sequencing batch reactors treating dilute swine slurries. *Transactions of the ASAE* 48(4):1575-1583.

Ndegwa, P. M., D. W. Hamilton, J. A. Lalman, and H. J. Cumba. 2008. Effects of cycle-frequency and temperature on the performance of anaerobic sequencing batch reactors (ASBRs) treating swine waste. *Bioresour Technol* 99(6):1972-1980.

Ndon, U. J., and R. R. Dague. 1997. Effects of temperature and hydraulic retention time on anaerobic sequencing batch reactor treatment of low-strength wastewater. *Water Research* 31(10):2455-2466.

Nges, I. A., and J. Liu. 2010. Effects of solid retention time on anaerobic digestion of dewatered-sewage sludge in mesophilic and thermophilic conditions. *Renewable Energy* 35(10):2200-2206.

Pérez, M., L. I. Romero, and D. Sales. 1999. Anaerobic thermophilic fluidized bed treatment of industrial wastewater: Effect of F:M relationship. *Chemosphere* 38(14):3443-3461.

Pinheiro, D. M., S. M. Ratusznei, J. A. D. Rodrigues, M. Zaiat, and E. Foresti. 2008. Fluidized ASBR treating synthetic wastewater: Effect of recirculation velocity. *Chemical Engineering and Processing: Process Intensification* 47(2):184-191.

Rincón, B., R. Borja, J. M. González, M. C. Portillo, and C. Sáiz-Jiménez. 2008. Influence of organic loading rate and hydraulic retention time on the performance, stability and microbial communities of one-stage anaerobic digestion of two-phase olive mill solid residue. *Biochemical Engineering Journal* 40(2):253-261.

Sanchez, E., R. Borja, L. Travieso, A. Martin, and M. F. Colmenarejo. 2005. Effect of organic loading rate on the stability, operational parameters and performance of a secondary upflow anaerobic sludge bed reactor treating piggery waste. *Bioresour Technol* 96(3):335-344.

Sarti, A., B. S. Fernandes, M. Zaiat, and E. Foresti. 2007. Anaerobic sequencing batch reactors in pilot-scale for domestic sewage treatment. *Desalination* 216(1):174-182.

Shizas, I., and D. M. Bagley. 2002. Improving anaerobic sequencing batch reactor performance by modifying operational parameters. *Water Research* 36(1):363-367.

Siddique, M. N. I., M. S. A. Munaim, and A. W. Zularisam. 2016. Effect of food to microbe ratio variation on anaerobic co-digestion of petrochemical wastewater with manure. *Journal of the Taiwan Institute of Chemical Engineers* 58:451-457.

Stroot, P. G., K. D. McMahon, R. I. Mackie, and L. Raskin. 2001. Anaerobic codigestion of municipal solid waste and biosolids under various mixing conditions—I. Digester performance. *Water Research* 35(7):1804-1816.

Swedish Gas Centre. 2012. Basic Data on Biogas. Svenskt Gastekniskt Center AB. SE - 212 28 Malmö, Sweden: S. G. C. AB.

van Haandel, A. C., and J. G. M. van der Lubbe. 2012. *Handbook of Biological Wastewater Treatment: Design and Optimisation of Activated Sludge Systems*. IWA Pub.

Vavilin, V., and I. Angelidaki. 2005. Anaerobic degradation of solid material: importance of initiation centers for methanogenesis, mixing intensity, and 2D distributed model. *Biotechnology and Bioengineering* 89(1):113-122.

Wang, Q., M. Kuninobu, H. I. Ogawa, and Y. Kato. 1999. Degradation of volatile fatty acids in highly efficient anaerobic digestion. *Biomass and Bioenergy* 16(6):407-416.

Wang, Q., C. K. Noguchi, M. Kuninobu, Y. Hara, K. Kakimoto, H. I. Ogawa, and Y. Kato. 1997. Influence of hydraulic retention time on anaerobic digestion of pretreated sludge. *Biotechnology Techniques* 11(2):105-108.

Water Environment Federation. 2009. *Design of Municipal Wastewater Treatment Plants MOP 8, Fifth Edition*. Mcgraw-hill.

Wijekoon, K. C., C. Visvanathan, and A. Abeynayaka. 2011. Effect of organic loading rate on VFA production, organic matter removal and microbial activity of a two-stage thermophilic anaerobic membrane bioreactor. *Bioresour Technol* 102(9):5353-5360.

Zhang, T., C. Mao, N. Zhai, X. Wang, and G. Yang. 2015. Influence of initial pH on thermophilic anaerobic co-digestion of swine manure and maize stalk. *Waste Manag* 35:119-126.

APPENDICES

# APPENDIX I: CAKING EFFECT OBSERVATION

A set of small experiments were conducted to verify that caking had indeed an important effect on the reactors' accumulated mass accounted during the first year of operation of the experimental installation.

Some of the results obtained during the operation of both partial and full-mix reactors have been pointing out the possibility of solids adhering to the reactor walls. These results include excessive fluctuation between total solid mass inside reactors that cannot be accounted by a mass balance, differences in total solid calculation using mixing and settling profiles or high variability in interface location from week to week in partial mix reactor.

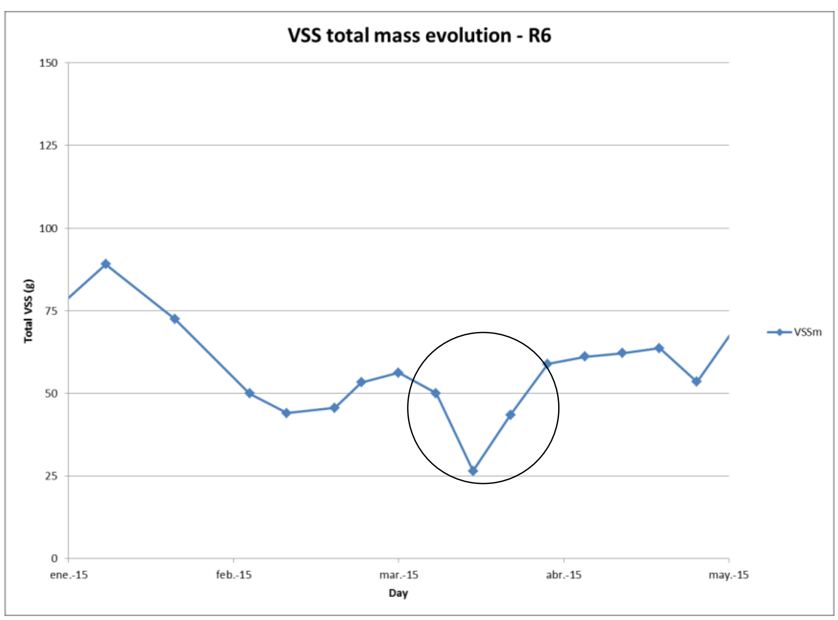



Figure 74. Observation of a Retained Mass Fluctuation Likely Caused by Caking.

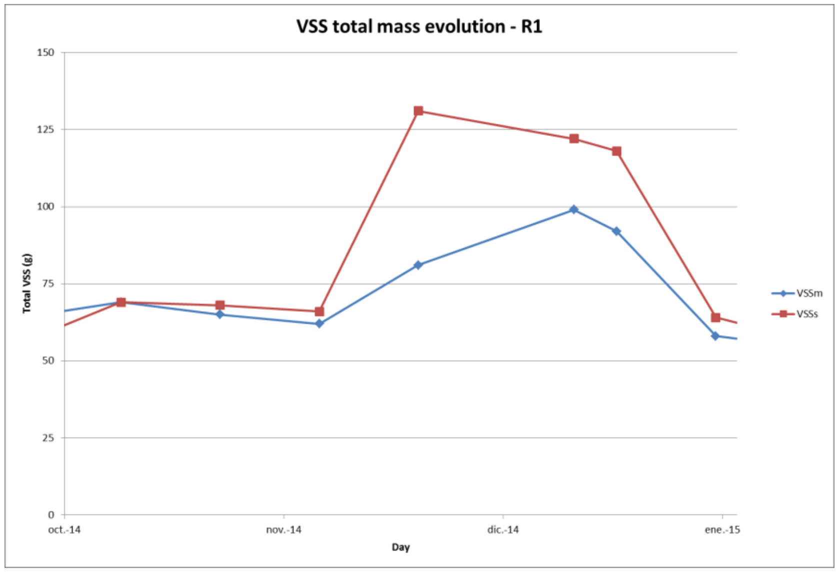



Figure 75. Caking Effect: Total Mass of VSS Underestimated by Mixing Profile.

An experiment was conducted to determine how the accounted accumulated mass calculated through mixing profiles changed with time (Figure 76). This experiment provided the proof that caking is an important effect that must be solved or at least taken into account.

We started by vigorously shaking a reactor with a full-mix setup, and taking a profile of TSS. The resulting concentration along the reactor was close to 8,000 mgTSS $L^{-1}$. The same reactor was sampled 3 hours later, after one settling step had occurred, observing that the average concentration has descended below the 6,000 mgTSS $L^{-1}$. One day later (8 settling cycles carried out since the last shake), the average concentration of SS was below 3,000 mgTSS $L^{-1}$. Finally, after 5 days without shaking the reactor, the average concentration decreased slightly to 2,000 mgTSS $L^{-1}$.

A summary of these results is presented in Table 14.

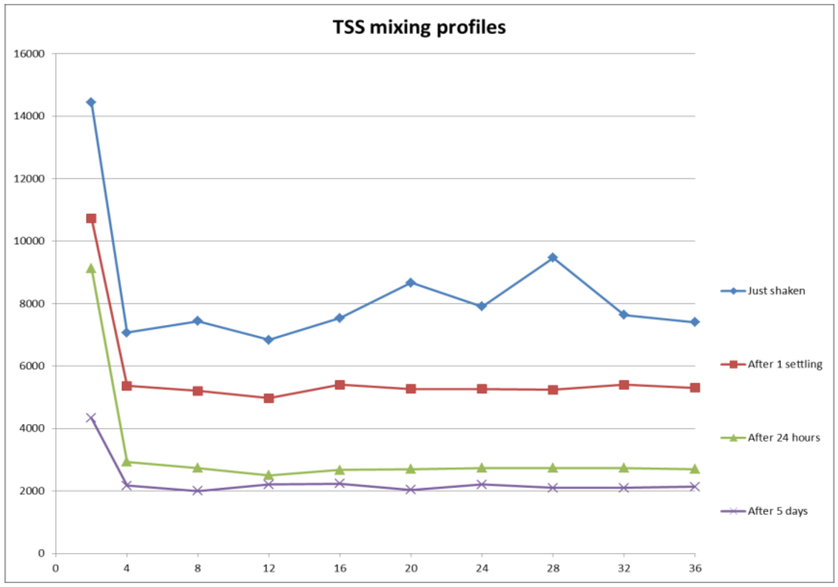



Figure 76. Caking Effect Observation over Time.

Table 14. Caking Effect Data.

| Sample | # of set cycles | $[TSS]_{average}$ (mg $L^{-1}$) | mass TSS (g) | % $TSS_{suspended}$ |
|---|---|---|---|---|
| Just shaken | - | 7770 | 197 | 100 |
| 3 hours later | 1 | 5276 | 134 | 68 |
| 1 day later | 8 | 2715 | 74 | 38 |
| 5 days later | 40 | 2130 | 54 | 27 |

Even with such a limited number of data points, we can fit the decrease in SS observed logarithmically, as shown in Figure 77.

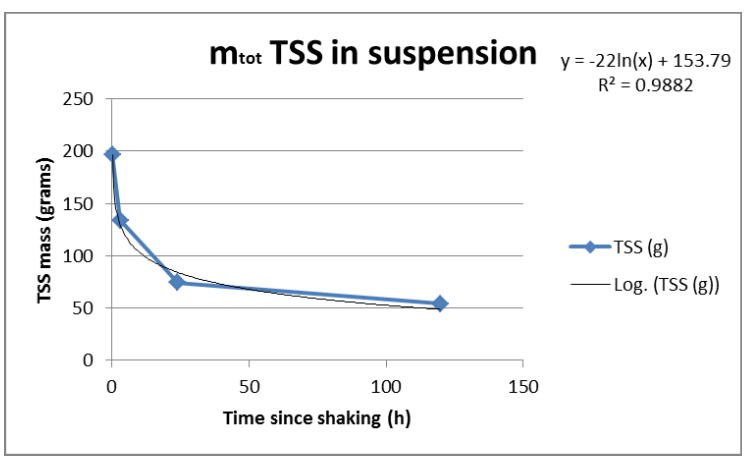
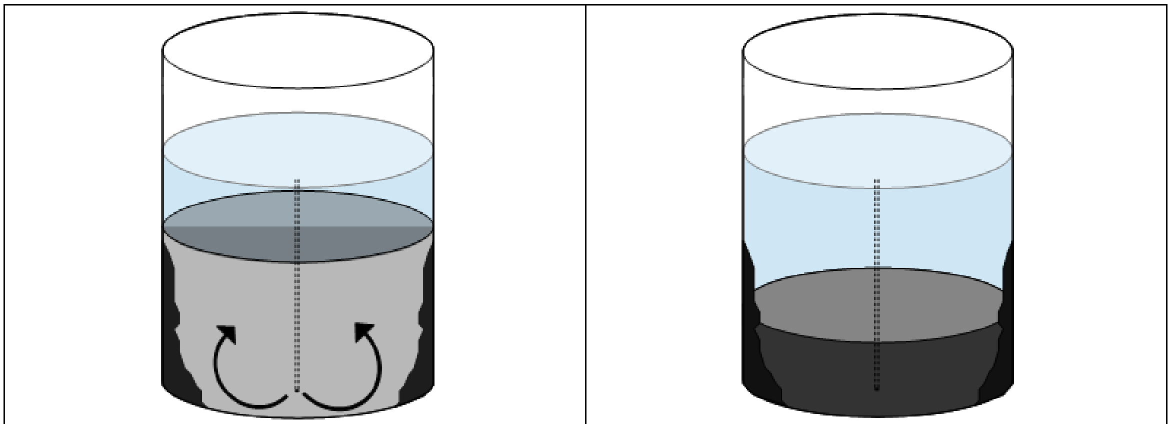



Figure 77. Logarithmic Fit for Decrease in Total Suspended Solids Mass.

The observed caking seems to take place in the first few settling cycles, forming a solid crust that effectively changes the reactor shape (Figure 78).



| a. Wall cake during mixing cycle | b. Wall cake during settling cycle |
|---|---|

Figure 78. Wall Cake in Reactor.

Profile samples are taken in the central part of the reactor. Therefore, caking results in an underestimation of the total amount of solids present. Based on data collected for the investigation of the caking effect, the height of the crust formed must be higher than the height of the settled solids. This conclusion is reached by observing the calculated mass of solids inside the reactor using a settling profile right after shaking and another settling profile taken 5 days after shaking (Figure 79). The solids adhered to the wall during those 5 days are slightly above 50% (a decrease from 171 to 77 grams was calculated).

At the same time, it is logical to expect that no solid crust will be formed above the solids cloud height. As a result, we can expect the crust of solids to reach a height somewhere in between the cloud height (upper limit) and the settled solids height (lower limit).

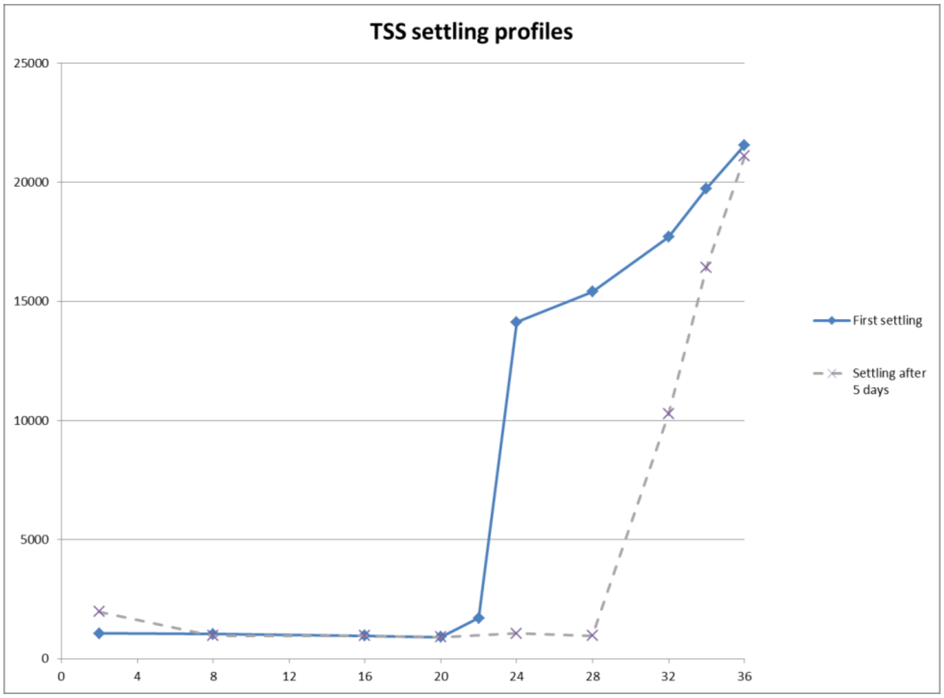



Figure 79. Settling Profile Concentration Differences Right After Shaking and 5 Days after Shaking.

## APPENDIX II: MATLAB PROGRAM FOR TOTAL MASS CALCULATION USING PROFILE DATA

The following Matlab program was developed to estimate the total mass of VSS accumulated in a reactor using data from settling profiles, as described in sub-section 4.3.2.2.

```
>>mass.m

clear all

%Reactor selection. Based on its geometric characteristics, a constant
%for volume determination is assigned (y=V·x, with x in cm). Reactors 1
%through 4 have the same calibration constant to correlate depth and
%volume, while reactor 5 and reactor 6 have different constants. Depth
%of the reactor also varies slightly from R1-4 to R5-6.

reactor=input('Reactor number (1-6): ');

if reactor<5
    V=0.6918;
    depth=34.29; %cm

elseif reactor==5
    V=0.6546;
    depth=35.56; %cm

elseif reactor==6
    V=0.6643;
    depth=35.56; %cm

else
    print('Error, reactor must be an integer number between 1 and 6')

end
```

```
%Input the polynomial constants ([TSS]=Bx^2+Cx+D), interface location
%and settled phase concentration. Increments are set as 0.01 cm (can be
%varied by changing 'i' value.

B=input('B (constant for x^2): ');
C=input('C (constant for x): ');
D=input('D (constant): ');

interface=input('interface depth (cm): ');

A=input('A (settled phase concentration (mgVSS/L)): ');

i=0.01;

%Calculate mass of VSS in settled phase (mclear), concentrated phase
%(mconc) and in the whole reactor (mtot=mclear+mconc)

mclear=interface*V*A/1000; %grams of VSS in settled phase
Vinc=V*i; %volume per increment, l.
l=interface; %location of interface
ii=1; %iteration number flag

%Loop that goes from the interface position to the bottom of the
%reactor in increments of 'i' centimeters, evaluating the total mass
%present in that increment by multiplying the VSS concentration by the
%volume of that increment (based on calibration curves for each
%reactor).

while l<=depth;

    mixconc(ii)=(B*l^2+C*l+D); %[VSS] at the given point, in mg/L
    minc(ii)=mixconc(ii)/1000*Vinc; %mass at the given point, in gVSS
    ii=ii+1; %iteration number flag updated
    l=l+i; %depth increased by 'i' cm

end

%Results shown in screen and concentrated region is plotted to verify
%proper interface location.

mclear

mconc=sum(minc)

mtot=mclear+mconc

plot(minc)
```

# APPENDIX III: DATA FOR REACTOR STABILITY. PH, VFA AND ALKALINITY

Table 15. pH Values for Feed and Retained Solids Samples.

| | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 7/1/2014 | 7.83 | 7.36 | 7.28 | 7.39 | 7.48 | 7.47 | 7.47 |
| 7/8/2014 | 7.46 | 7.39 | 7.42 | 7.52 | 7.47 | 7.48 | 7.61 |
| 7/15/2014 | 7.64 | 7.39 | 7.48 | 7.43 | 7.44 | 7.42 | 7.43 |
| 7/22/2014 | 7.76 | 7.36 | 7.45 | 7.43 | 7.41 | 7.45 | 7.49 |
| 7/29/2014 | 7.70 | 7.46 | 7.49 | 7.46 | 7.46 | 7.45 | 7.46 |
| 8/5/2014 | 8.08 | 7.46 | 7.57 | 7.46 | 7.56 | 7.52 | 7.58 |
| 8/13/2014 | 7.84 | 7.43 | 7.59 | 7.53 | 7.51 | 7.53 | 7.51 |
| 8/19/2014 | 8.03 | 7.53 | 7.51 | 7.55 | 7.71 | 7.7 | 7.57 |
| 8/26/2014 | | 7.52 | 7.74 | 7.72 | 7.69 | 7.77 | 7.77 |
| 9/3/2014 | 7.84 | 7.63 | 7.65 | 7.65 | 7.7 | 7.61 | 7.84 |
| 9/10/2014 | 7.88 | 7.67 | 7.67 | 7.72 | 7.71 | 7.7 | 7.83 |
| 9/16/2014 | 7.98 | 7.5 | 7.58 | 7.55 | 7.68 | 7.53 | 7.65 |
| 9/23/2014 | 7.93 | 7.5 | 7.56 | 7.53 | 7.53 | 7.56 | 7.65 |
| 9/30/2014 | 8.19 | 7.48 | 7.56 | 7.57 | 7.6 | 7.64 | 7.61 |
| 10/7/2014 | 7.29 | 7.61 | 7.59 | 7.59 | 7.6 | 7.58 | 7.6 |
| 10/14/2014 | | 7.43 | 7.6 | 7.69 | 7.59 | 7.52 | 7.59 |
| 10/21/2014 | | 7.66 | 7.31 | 7.68 | 7.33 | 7.87 | 7.4 |
| 10/28/2014 | | 7.28 | 7.5 | 7.34 | 7.66 | 7.42 | 7.71 |
| 11/4/2014 | | 7.26 | 7.31 | 7.37 | 7.33 | 7.89 | 7.47 |
| 11/11/2014 | | 7.42 | 7.62 | 7.34 | 7.92 | 7.52 | 7.97 |
| 11/18/2014 | | 7.5 | 7.55 | 7.38 | 7.39 | 7.54 | 7.42 |
| 11/25/2014 | | 7.47 | 7.84 | 7.51 | 7.85 | 7.45 | 7.81 |
| 12/2/2014 | | 7.46 | 7.52 | 7.78 | 7.61 | 7.67 | 7.54 |
| 12/9/2014 | | 7.66 | 8.11 | 7.79 | 8.26 | 7.83 | 8.28 |
| 12/16/2014 | | 7.68 | 7.96 | 7.77 | 7.98 | 7.82 | 8.11 |
| 1/16/2015 | | 7.68 | 7.9 | 7.77 | 7.9 | 7.78 | 7.94 |
| 1/23/2015 | | 7.53 | 8.01 | 7.7 | 8.04 | 7.66 | 7.86 |
| 1/30/2015 | | 7.64 | 7.65 | 7.7 | 7.65 | 7.75 | 7.64 |
| 2/6/2015 | | 7.77 | 7.97 | 7.63 | 7.77 | 7.76 | 7.81 |
| 2/13/2015 | | 7.63 | 7.73 | 7.75 | 7.64 | 7.8 | 7.86 |
| 2/18/2015 | | 7.62 | 7.89 | 7.64 | 8.16 | 7.69 | 7.82 |
| 2/27/2015 | | 7.64 | 7.7 | 7.78 | 7.78 | 7.76 | 7.79 |
| 3/6/2015 | | 7.55 | 7.71 | 7.51 | 7.74 | 7.61 | 7.73 |
| 3/13/2015 | | 7.52 | 7.44 | 7.51 | 7.38 | 7.57 | 7.71 |
| 3/20/2015 | 7.81 | 7.42 | 7.56 | 7.52 | 7.68 | 7.58 | 7.73 |
| 3/27/2015 | 7.86 | 7.56 | 7.61 | 7.63 | 7.54 | 7.58 | 7.77 |
| 4/10/2015 | 7.9 | 7.59 | 7.73 | 7.46 | 7.77 | 7.63 | 7.75 |
| 4/10/2015 | 7.75 | 7.62 | 7.64 | 7.65 | 7.65 | 7.64 | 7.77 |
| 4/17/2015 | 7.75 | 7.57 | 7.67 | 7.59 | 7.73 | 7.58 | 7.7 |

Table 15 (Cont.). pH Values for Feed and Retained Solids Samples.

| | pH | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 4/24/2015 | 7.8 | 7.63 | 7.63 | 7.61 | 7.56 | 7.76 | 7.81 |
| 5/1/2015 | 7.47 | 7.62 | 7.73 | 7.48 | 7.79 | 7.72 | 7.78 |
| 5/8/2015 | 7.67 | 7.63 | 7.61 | 7.66 | 7.35 | 7.54 | 7.75 |
| 5/13/2015 | | 7.49 | 7.63 | 7.43 | 7.68 | 7.65 | 7.81 |
| 5/21/2015 | 7.86 | 7.75 | 7.66 | 7.76 | 7.7 | 7.74 | 7.95 |
| 5/28/2015 | 7.6 | 7.62 | 7.7 | 7.63 | 7.77 | 7.75 | 7.74 |
| 6/4/2015 | 7.83 | 7.65 | 7.68 | 7.76 | 7.66 | 7.79 | 7.88 |
| 6/11/2015 | 7.81 | 7.78 | 7.84 | 7.8 | 7.91 | 7.87 | 7.92 |
| 6/18/2015 | 7.9 | 7.65 | 7.64 | 7.7 | 7.66 | 7.76 | 7.87 |
| 6/25/2015 | 7.95 | 7.75 | 7.85 | 7.82 | 7.9 | 7.87 | 7.94 |
| 6/25/2015 | 7.89 | | | | | | |
| 7/1/2015 | 7.97 | 7.8 | 7.81 | 7.91 | 7.9 | 7.92 | 8.1 |
| 7/8/2015 | | 7.8 | 7.89 | 7.89 | 7.99 | 7.92 | 8.04 |
| 7/16/2015 | 7.96 | 7.84 | 7.85 | 7.95 | 7.88 | 7.92 | 8.00 |
| 7/22/2015 | 7.85 | 7.84 | 7.91 | 7.87 | 7.95 | 7.97 | 7.96 |
| 8/4/2015 | 7.75 | 7.76 | 7.88 | 7.76 | 7.93 | 7.85 | 7.9 |
| 8/18/2015 | 7.81 | 7.72 | 7.7 | 7.7 | 7.67 | 7.74 | 7.81 |
| 8/26/2015 | 7.74 | 7.69 | 7.69 | 7.72 | 7.83 | 7.7 | 7.85 |
| 11/5/2015 | 7.79 | 7.83 | 7.92 | 7.82 | 7.95 | 8.03 | 8.02 |
| 11/11/2015 | 7.85 | 7.85 | 7.81 | 7.86 | 7.82 | 7.95 | 8 |
| 11/18/2015 | 7.64 | 7.86 | 7.75 | 7.85 | 7.88 | 7.95 | 7.97 |
| 11/25/2015 | 7.56 | 7.65 | 7.65 | 7.72 | 7.74 | 7.63 | 7.76 |
| 12/3/2015 | 7.66 | 7.64 | 7.68 | 7.62 | 7.71 | 7.7 | 7.69 |
| 12/12/2015 | 7.62 | 7.72 | 7.68 | 7.67 | 7.75 | 7.59 | 7.77 |
| 12/17/2015 | 7.66 | 7.68 | 7.71 | 7.63 | 7.6 | 7.7 | 7.76 |
| 1/8/2016 | 7.67 | 7.73 | 7.8 | 7.67 | 7.71 | 7.71 | 7.76 |
| 1/13/2016 | 7.67 | 7.71 | 7.74 | 7.74 | 7.78 | 7.73 | 7.8 |
| 1/18/2016 | 7.25 | 7.61 | 7.71 | 7.69 | 7.72 | 7.68 | 7.72 |
| 1/25/2016 | 7.46 | 7.81 | 7.85 | 7.85 | 7.9 | 7.86 | 7.91 |
| 2/1/2016 | 7.57 | 7.73 | 7.72 | 7.56 | 7.79 | 7.74 | 7.81 |
| 2/8/2016 | 7.53 | 7.66 | 7.69 | 7.68 | 7.76 | 7.72 | 7.79 |
| 2/15/2016 | 7.65 | 7.76 | 7.85 | 7.76 | 7.84 | 7.82 | 7.85 |
| 2/22/2016 | 7.67 | 7.66 | 7.69 | 7.71 | 7.82 | 7.8 | 7.86 |
| 2/29/2016 | 7.58 | 7.68 | 7.63 | 7.64 | 7.69 | 7.62 | 7.66 |
| 3/7/2016 | 7.66 | 7.69 | 7.66 | 7.7 | 7.78 | 7.64 | 7.75 |
| 3/14/2016 | | 7.73 | 7.72 | 7.83 | 7.79 | 7.82 | 7.85 |

Table 16. Bicarbonates in Feed and Retained Solids Samples.

| | Bicarbonates (mmol/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 7/1/2014 | | 79.3 | 85.8 | 78.2 | 71.7 | 78.3 | 97.6 |
| 7/8/2014 | | 78.25 | 85.77 | 77.11 | 77.03 | 74.93 | 87.83 |
| 7/15/2014 | | 68.43 | 79.26 | 76.06 | 81.53 | 81.55 | 83.61 |
| 7/22/2014 | | 76.21 | 82.59 | 78.3 | 81.59 | 77.19 | 84.68 |
| 7/29/2014 | | 79.91 | 81.55 | 78.3 | 80.4 | 80.43 | 80.43 |
| 8/5/2014 | | 76.12 | 79.31 | 77.21 | 80.35 | 74.99 | 90.03 |
| 8/13/2014 | | 76.26 | 74.94 | 74.98 | 78.32 | 69.64 | 83.63 |
| 8/19/2014 | | 69.56 | 77.2 | 73.91 | 71.59 | 84.62 | 77.08 |
| 8/26/2014 | | 67.42 | 71.63 | 71.67 | 76.04 | 70.59 | 75.95 |
| 9/3/2014 | | 64.12 | 66.26 | 67.35 | 67.35 | 71.75 | 74.89 |
| 9/10/2014 | | 59.75 | 61.92 | 62.99 | 65.2 | 65.15 | 69.4 |
| 9/16/2014 | | 59.83 | 61.96 | 61.98 | 61.92 | 60.84 | 68.41 |
| 9/23/2014 | | 58.71 | 59.77 | 59.78 | 60.87 | 63.03 | 65.17 |
| 9/30/2014 | | 59.78 | 60.86 | 60.85 | 63.04 | 65.23 | 64.10 |
| 10/7/2014 | | 59.74 | 58.66 | 59.78 | 60.84 | 59.79 | 65.19 |
| 10/14/2014 | | 57.72 | 57.63 | 58.71 | 57.63 | 56.58 | 58.72 |
| 10/21/2014 | | 46.72 | 49.10 | 50.01 | 46.87 | 47.75 | 50.10 |
| 10/28/2014 | | 44.75 | 45.69 | 45.77 | 44.51 | 46.82 | 46.70 |
| 11/4/2014 | | 49.05 | 49.04 | 45.70 | 46.90 | 49.79 | 53.19 |
| 11/11/2014 | | 47.88 | 47.82 | 46.86 | 47.77 | 45.62 | 47.71 |
| 11/18/2014 | | 58.65 | 49.97 | 47.90 | 47.92 | 46.76 | 47.88 |
| 11/25/2014 | | 55.46 | 54.23 | 50.01 | 50.99 | 47.84 | 50.97 |
| 12/2/2014 | | 58.70 | 63.06 | 53.18 | 54.33 | 53.19 | 56.51 |
| 12/9/2014 | | 65.19 | 70.42 | 61.91 | 62.91 | 62.96 | 63.97 |
| 12/16/2014 | | 78.16 | 74.83 | 72.71 | 70.42 | 71.63 | 76.94 |
| 1/16/2015 | | 53.19 | 55.28 | 48.81 | 53.13 | 46.57 | 54.21 |
| 1/23/2015 | | 45.62 | 48.79 | 43.47 | 47.67 | 42.34 | 43.38 |
| 1/30/2015 | | 43.46 | 43.40 | 40.18 | 43.43 | 37.96 | 40.17 |
| 2/6/2015 | | 43.43 | 43.36 | 40.20 | 43.40 | 37.99 | 39.04 |
| 2/13/2015 | | 42.37 | 41.20 | 40.14 | 42.34 | 42.25 | 39.06 |
| 2/18/2015 | | 38.02 | 41.20 | 39.10 | 40.08 | 36.89 | 41.21 |
| 2/27/2015 | | 29.34 | 30.38 | 31.46 | 29.28 | 30.40 | 36.81 |
| 3/6/2015 | | 26.09 | 27.15 | 27.19 | 26.05 | 26.08 | 33.59 |
| 3/13/2015 | | 30.42 | 30.48 | 26.07 | 26.13 | 27.14 | 33.59 |
| 3/20/2015 | 25.93 | 30.46 | 30.47 | 30.45 | 29.30 | 30.41 | 36.82 |
| 3/27/2015 | 35.63 | 33.71 | 34.79 | 32.58 | 32.60 | 34.77 | 40.13 |
| 4/10/2015 | 34.62 | 34.73 | 39.08 | 38.10 | 37.99 | 40.20 | 45.49 |
| 4/10/2015 | 35.65 | 41.29 | 42.37 | 40.22 | 38.01 | 41.28 | 45.52 |
| 4/17/2015 | 37.77 | 43.51 | 42.36 | 41.32 | 43.43 | 42.39 | 49.92 |

Table 16 (Cont.). Bicarbonates in Feed and Retained Solids Samples.

| | Bicarbonates (mmol/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 4/24/2015 | 24.85 | 39.11 | 39.11 | 38.02 | 36.92 | 39.08 | 45.48 |
| 5/1/2015 | 18.34 | 30.40 | 31.47 | 31.55 | 30.34 | 32.58 | 38.99 |
| 5/8/2015 | 22.66 | 34.78 | 35.85 | 33.66 | 33.76 | 33.69 | 42.20 |
| 5/13/2015 | | 34.79 | 33.66 | 32.63 | 33.65 | 33.66 | 40.01 |
| 5/21/2015 | 29.16 | 36.90 | 35.81 | 35.81 | 35.83 | 36.90 | 43.23 |
| 5/28/2015 | 32.39 | 40.20 | 39.06 | 39.14 | 39.02 | 40.17 | 48.73 |
| 6/4/2015 | 32.34 | 42.34 | 42.33 | 41.22 | 42.36 | 42.33 | 51.91 |
| 6/11/2015 | 31.20 | 44.48 | 43.38 | 42.33 | 44.49 | 44.47 | 50.87 |
| 6/18/2015 | 34.62 | 43.46 | 44.52 | 42.35 | 44.54 | 44.52 | 50.85 |
| 6/25/2015 | 47.46 | 48.87 | 48.82 | 47.76 | 49.92 | 48.81 | 56.35 |
| 6/25/2015 | 48.31 | | | | | | |
| 7/1/2015 | 48.63 | 55.38 | 55.38 | 54.27 | 54.24 | 54.24 | 57.39 |
| 7/8/2015 | | 54.27 | 57.54 | 58.62 | 56.43 | 57.47 | 60.66 |
| 7/16/2015 | 42.25 | 49.91 | 51.02 | 51.00 | 53.19 | 50.98 | 58.54 |
| 7/22/2015 | 42.24 | 51.02 | 49.92 | 51.02 | 52.03 | 51.00 | 57.41 |
| 8/4/2015 | 26.94 | 52.10 | 52.07 | 50.99 | 53.07 | 52.08 | 56.28 |
| 8/18/2015 | 47.60 | 43.41 | 44.50 | 42.30 | 45.60 | 44.46 | 47.60 |
| 8/26/2015 | 18.10 | 40.15 | 42.30 | 40.12 | 39.04 | 42.30 | 46.50 |
| 11/5/2015 | 38.99 | 37.89 | 34.70 | 36.89 | 44.40 | 38.95 | 43.33 |
| 11/11/2015 | 31.39 | 39.03 | 34.74 | 44.38 | 47.63 | 41.16 | 48.62 |
| 11/18/2015 | 30.12 | 45.55 | 46.67 | 49.82 | 47.70 | 49.83 | 56.26 |
| 11/25/2015 | 31.22 | 47.75 | 46.72 | 49.83 | 50.94 | 48.85 | 56.31 |
| 12/3/2015 | 33.49 | 47.67 | 49.81 | 48.74 | 55.10 | 47.71 | 51.93 |
| 12/12/2015 | 31.27 | 45.53 | 48.78 | 45.49 | 52.02 | 45.51 | 51.96 |
| 12/17/2015 | 29.05 | 47.69 | 47.62 | 48.79 | 47.69 | 47.65 | 50.82 |
| 1/8/2016 | 31.34 | 44.38 | 44.42 | 42.25 | 41.12 | 42.21 | 45.41 |
| 1/13/2016 | 32.37 | 44.39 | 44.32 | 43.32 | 46.43 | 44.35 | 45.34 |
| 1/18/2016 | 21.31 | 48.69 | 47.62 | 47.63 | 57.19 | 48.67 | 49.74 |
| 1/25/2016 | 23.54 | 51.81 | 56.15 | 50.85 | 54.02 | 49.74 | 50.76 |
| 2/1/2016 | 16.70 | 52.95 | 51.89 | 49.80 | 54.02 | 51.86 | 52.93 |
| 2/8/2016 | 29.02 | 55.12 | 55.11 | 52.99 | 55.00 | 54.07 | 56.19 |
| 2/15/2016 | 23.42 | 42.00 | 49.68 | 48.61 | 53.89 | 50.78 | 50.77 |
| 2/22/2016 | 48.61 | 45.41 | 47.55 | 46.54 | 47.51 | 49.72 | 46.42 |
| 2/29/2016 | 27.90 | 50.70 | 51.92 | 48.65 | 50.75 | 48.57 | 48.56 |
| 3/7/2016 | 25.76 | 49.69 | 52.94 | 50.84 | 57.92 | 52.98 | 50.71 |
| 3/14/2016 | | 50.69 | 54.04 | 50.77 | 60.01 | 51.75 | 50.69 |

Table 17. VFAs in Feed and Retained Solids Samples.

| | Volatile Fatty Acids (mmol/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 7/1/2014 | | 6.29 | 12.26 | 8.63 | 1.52 | 2.05 | 12.54 |
| 7/8/2014 | | 5.31 | 7.99 | 3.29 | 7.69 | 4.56 | 6.85 |
| 7/15/2014 | | 6.17 | 6.40 | 4.43 | 2.85 | 2.83 | 7.08 |
| 7/22/2014 | | 1.04 | 3.87 | 2.02 | 1.72 | 2.13 | 5.94 |
| 7/29/2014 | | 2.42 | 0.68 | 0.94 | 4.07 | 2.96 | 2.96 |
| 8/5/2014 | | 1.13 | 0.93 | 1.03 | 3.04 | 1.27 | 6.54 |
| 8/13/2014 | | -2.22 | 1.31 | 1.28 | -1.24 | -2.69 | 3.83 |
| 8/19/2014 | | 0.64 | -0.03 | 0.27 | 2.76 | 2.75 | 3.33 |
| 8/26/2014 | | -0.29 | 0.56 | -0.56 | -0.94 | -1.55 | 1.31 |
| 9/3/2014 | | -1.06 | -0.12 | -0.22 | -1.3 | -1.72 | -0.79 |
| 9/10/2014 | | -0.67 | -0.85 | -0.92 | -2.22 | -0.01 | 1.88 |
| 9/16/2014 | | -0.75 | -0.89 | -0.91 | -0.85 | 1.39 | 0.80 |
| 9/23/2014 | | 0.45 | 0.39 | 0.37 | 0.28 | 0.11 | -0.03 |
| 9/30/2014 | | 1.45 | 0.30 | 0.30 | -0.98 | -2.25 | 0.04 |
| 10/7/2014 | | 0.41 | 0.50 | -0.70 | 0.32 | -0.71 | -0.06 |
| 10/14/2014 | | -1.71 | -1.62 | -2.78 | -1.62 | -1.56 | -1.72 |
| 10/21/2014 | | -0.67 | -2.14 | -2.04 | -0.82 | -0.70 | -1.07 |
| 10/28/2014 | | -1.78 | -0.63 | -0.72 | 0.63 | -0.77 | -0.65 |
| 11/4/2014 | | 1.14 | 0.08 | 1.51 | -1.93 | 4.65 | 4.23 |
| 11/11/2014 | | 0.24 | -0.77 | -0.82 | -1.80 | 1.59 | 0.42 |
| 11/18/2014 | | 2.67 | 1.23 | 0.22 | -0.88 | -0.71 | 0.24 |
| 11/25/2014 | | 0.72 | 0.95 | 0.10 | 0.12 | 1.37 | 1.22 |
| 12/2/2014 | | 1.53 | 0.09 | -0.08 | -0.23 | 1.00 | 0.66 |
| 12/9/2014 | | -1.13 | 1.86 | -1.92 | -1.91 | -0.89 | -0.90 |
| 12/16/2014 | | 1.08 | 0.36 | 0.48 | 2.94 | -0.52 | 1.31 |
| 1/16/2015 | | 1.00 | 1.98 | 1.40 | 1.06 | 3.80 | 0.98 |
| 1/23/2015 | | 1.59 | 0.34 | -1.48 | 1.54 | 0.81 | 0.77 |
| 1/30/2015 | | -0.39 | 1.82 | -0.10 | 0.72 | 1.20 | 0.99 |
| 2/6/2015 | | -0.36 | 0.79 | -0.12 | 0.75 | 0.10 | 1.12 |
| 2/13/2015 | | -0.30 | 2.03 | 1.02 | 0.81 | 3.06 | 0.03 |
| 2/18/2015 | | 0.07 | 0.96 | -0.02 | 1.08 | 1.28 | 0.94 |
| 2/27/2015 | | -0.29 | 0.73 | 0.66 | 0.84 | -0.36 | 3.52 |
| 3/6/2015 | | -0.03 | -0.09 | -0.14 | 0.00 | -0.02 | 2.68 |
| 3/13/2015 | | 0.69 | -0.44 | 1.06 | -0.08 | 0.99 | 2.67 |
| 3/20/2015 | 4.44 | 0.66 | -1.51 | -0.42 | 0.82 | 0.71 | 3.51 |
| 3/27/2015 | 6.94 | -0.69 | -0.77 | 0.53 | 0.51 | 0.33 | 1.02 |
| 4/10/2015 | 3.72 | 1.44 | 0.00 | -1.10 | 0.10 | -0.12 | 3.88 |
| 4/10/2015 | 6.92 | -0.21 | -0.30 | -1.22 | 0.07 | -0.21 | 2.78 |
| 4/17/2015 | 8.95 | -1.52 | -0.29 | -1.33 | -0.37 | -0.32 | 1.28 |

Table 17 (Cont.). VFAs in Feed and Retained Solids Samples.

| | Volatile Fatty Acids (mmol/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| date | Feed | R1 | R2 | R3 | R4 | R5 | R6 |
| 4/24/2015 | 4.53 | -0.02 | -0.02 | 0.06 | 1.25 | 0.01 | 3.89 |
| 5/1/2015 | 6.15 | 0.72 | 0.65 | -0.52 | 1.86 | -0.55 | 3.33 |
| 5/8/2015 | 5.80 | -0.76 | 0.25 | 0.45 | 0.34 | 0.42 | 5.26 |
| 5/13/2015 | | 0.31 | 0.44 | 0.47 | 0.45 | 0.44 | 5.46 |
| 5/21/2015 | 5.28 | 0.19 | 1.37 | 0.28 | 0.27 | 0.19 | 6.31 |
| 5/28/2015 | 8.28 | -0.12 | 1.10 | -1.13 | 2.22 | -0.09 | 4.71 |
| 6/4/2015 | 8.32 | 0.81 | 0.82 | 0.93 | -0.29 | -0.26 | 6.68 |
| 6/11/2015 | 10.62 | 0.66 | 0.76 | -0.26 | -0.42 | 0.68 | 4.57 |
| 6/18/2015 | 3.72 | -0.39 | 0.62 | -0.28 | -0.48 | -0.45 | 5.66 |
| 6/25/2015 | 10.38 | -0.82 | 0.31 | -0.71 | -0.88 | 0.31 | 1.90 |
| 6/25/2015 | 20.23 | | | | | | |
| 7/1/2015 | 6.97 | -1.36 | -1.36 | -1.24 | -0.14 | -0.13 | 2.94 |
| 7/8/2015 | | -0.16 | -1.52 | -1.61 | -1.41 | 0.70 | 2.66 |
| 7/16/2015 | 1.98 | 0.21 | -0.98 | -0.96 | -1.16 | 0.14 | 0.62 |
| 7/22/2015 | 3.07 | -0.98 | -0.88 | -0.98 | 1.16 | -0.96 | 2.92 |
| 8/4/2015 | 7.66 | 0.01 | 0.04 | 1.21 | 3.28 | 0.03 | 5.21 |
| 8/18/2015 | 5.92 | 0.74 | 0.64 | 1.93 | 0.54 | 1.76 | 5.92 |
| 8/26/2015 | 13.93 | 1.01 | 1.93 | 2.12 | 1.13 | 1.93 | 6.02 |
| 11/5/2015 | 3.33 | 3.43 | 0.40 | 0.20 | 2.90 | 3.37 | 1.90 |
| 11/11/2015 | 2.88 | 1.13 | -0.72 | 4.00 | 4.82 | 2.07 | 6.97 |
| 11/18/2015 | 11.79 | 0.58 | 0.47 | 3.54 | 1.51 | 2.45 | 5.23 |
| 11/25/2015 | 11.68 | 1.45 | -0.67 | 4.61 | 3.42 | 1.35 | 5.18 |
| 12/3/2015 | 7.09 | 4.77 | 5.71 | 5.78 | 10.79 | 2.58 | 7.74 |
| 12/12/2015 | 9.48 | 2.77 | 3.58 | 4.97 | 3.33 | 4.94 | 5.55 |
| 12/17/2015 | 10.78 | 3.68 | 5.90 | 3.57 | 4.76 | 4.79 | 7.85 |
| 1/8/2016 | 6.17 | 5.07 | 2.88 | 4.14 | 5.35 | 5.25 | 7.20 |
| 1/13/2016 | 8.29 | 5.07 | 7.29 | 4.06 | 9.33 | 6.18 | 9.43 |
| 1/18/2016 | 20.22 | 7.99 | 5.90 | 5.89 | 13.93 | 8.01 | 7.93 |
| 1/25/2016 | 15.64 | 11.09 | 10.73 | 5.66 | 8.71 | 6.86 | 8.99 |
| 2/1/2016 | 27.29 | 9.87 | 8.85 | 7.88 | 9.80 | 9.97 | 9.89 |
| 2/8/2016 | 12.97 | 10.77 | 10.78 | 8.75 | 14.12 | 8.67 | 9.61 |
| 2/15/2016 | 18.99 | 13.01 | 9.07 | 9.14 | 14.23 | 8.97 | 8.98 |
| 2/22/2016 | 10.22 | 8.28 | 9.21 | 5.99 | 9.25 | 7.95 | 9.35 |
| 2/29/2016 | 14.18 | 13.36 | 8.82 | 9.11 | 11.15 | 12.42 | 12.43 |
| 3/7/2016 | 12.17 | 10.14 | 10.96 | 7.83 | 27.13 | 9.84 | 12.27 |
| 3/14/2016 | | 13.38 | 9.78 | 8.97 | 30.27 | 13.31 | 12.30 |

# APPENDIX IV: DATA FOR REACTORS MASS BALANCE: FEED, DECANT AND RETAINED SOLIDS

Table 18. Solid Content of Streams in R1.

| **R1** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 0.42 | 0.25 | | | 0.43 | 0.25 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.31 | 0.15 | | | 0.45 | 0.26 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.51 | 0.31 | | | 0.52 | 0.33 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 1.03 | 0.66 | 0.89 | 0.64 | 0.47 | 0.27 | 0.29 | 0.24 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 0.99 | 0.66 | 0.88 | 0.66 | 0.42 | 0.23 | 0.25 | 0.20 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 0.92 | 0.62 | 0.80 | 0.60 | 0.41 | 0.23 | 0.24 | 0.20 |
| 7/15/2014 | 0.5 | 0.29 | | | | | | | | | | |
| 7/17/2014 | | | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 0.76 | 0.49 | 0.62 | 0.49 | 0.37 | 0.20 | 0.18 | 0.17 |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/28/2014 | | | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | 0.67 | 0.44 | 0.55 | 0.46 | 0.38 | 0.21 | 0.24 | 0.18 |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 0.63 | 0.41 | 0.52 | 0.41 | 0.32 | 0.16 | 0.16 | 0.11 |
| 8/11/2014 | 0.4 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.56 | 0.37 | 0.41 | 0.33 | 0.31 | 0.18 | 0.14 | 0.12 |
| 8/14/2014 | | | | | | | | | | | | |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.1 | | | | | | | | |
| 8/19/2014 | | | | | 0.49 | 0.30 | 0.36 | 0.29 | 0.29 | 0.14 | 0.13 | 0.12 |
| 8/20/2014 | 0.3 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.57 | 0.38 | 0.61 | 0.49 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.42 | 0.25 | 0.33 | 0.28 | 0.27 | 0.14 | 0.10 | 0.08 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.39 | 0.24 | 0.28 | 0.20 | 0.24 | 0.13 | 0.11 | 0.09 |
| 9/12/2014 | 0.5 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/22/2014 | 0.5 | 0.28 | 0.40 | 0.28 | | | | | | | | |
| 9/24/2014 | | | | | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| **R1** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.21 | 0.08 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.51 | 0.32 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | | | | |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/21/2014 | | | | | 0.43 | 0.27 | 0.31 | 0.25 | | | | |
| 10/22/2014 | | | | | | | | | 0.22 | 0.10 | 0.10 | 0.07 |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | | | | | | | | |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/5/2014 | | | | | 0.59 | 0.40 | 0.56 | 0.42 | 0.20 | 0.11 | 0.09 | 0.09 |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/18/2014 | | | | | 0.78 | 0.48 | 0.70 | 0.50 | | | | |
| 11/19/2014 | | | | | | | | | 0.27 | 0.15 | 0.15 | 0.12 |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/2/2014 | | | | | 0.56 | 0.34 | 0.48 | 0.38 | | | | |
| 12/3/2014 | | | | | | | | | 0.26 | 0.11 | 0.13 | 0.09 |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.93 | 0.57 | 0.84 | 0.56 | 0.23 | 0.09 | 0.09 | 0.07 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| **R1** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.10 | 0.07 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/14/2015 | | | | | | | | | 0.25 | 0.13 | 0.14 | 0.11 |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.67 | 0.42 | 0.57 | 0.42 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/28/2015 | | | | | | | | | 0.18 | 0.10 | 0.07 | 0.07 |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | 0.46 | 0.30 | 0.39 | 0.28 | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | | | | |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/11/2015 | | | | | | | | | 0.18 | 0.08 | 0.09 | 0.08 |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | 0.40 | 0.27 | 0.33 | 0.24 | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | 0.13 | 0.06 | 0.05 | 0.04 |
| 2/27/2015 | | | | | 0.22 | 0.13 | 0.15 | 0.14 | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | 0.09 | 0.03 | 0.02 | 0.01 |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | | | | |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/11/2015 | | | | | | | | | 0.10 | 0.05 | 0.02 | 0.02 |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | 0.33 | 0.21 | 0.26 | 0.18 | | | | |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| R1 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/18/2015 | 0.20 | 0.12 | | | | | | | | | | |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | | | | | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | 0.13 | 0.08 | 0.04 | 0.04 |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | 0.21 | 0.11 | 0.15 | 0.12 | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | | | | | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | 0.16 | 0.08 | 0.06 | 0.06 |
| 4/8/2015 | | | | | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | 0.29 | 0.17 | 0.18 | 0.15 | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | | | | | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | 0.15 | 0.07 | 0.05 | 0.04 |
| 4/22/2015 | | | | | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | 0.31 | 0.20 | 0.21 | 0.18 | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | | | | |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | | | | |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | 0.14 | 0.07 | 0.05 | 0.04 |
| 5/6/2015 | | | | | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | 0.23 | 0.13 | 0.14 | 0.10 | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | | | | |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |
| 5/19/2015 | | | | | | | | | 0.13 | 0.05 | 0.05 | 0.05 |
| 5/20/2015 | | | | | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | 0.23 | 0.14 | 0.13 | 0.10 | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.3 | 0.18 | 0.18 | 0.16 | | | | | | | | |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | | | | | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | 0.15 | 0.08 | 0.06 | 0.06 |

Table 18 (Cont.). Solid Content of Streams in R1

| R1 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/2/2015 | | | | | | | | | | | | |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | 0.26 | 0.14 | 0.17 | 0.13 | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | | | | | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | 0.14 | 0.06 | 0.03 | 0.03 |
| 6/16/2015 | | | | | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | 0.25 | 0.14 | 0.17 | 0.14 | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | | | | |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | | | | | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | 0.17 | 0.08 | 0.05 | 0.04 |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 6/30/2015 | | | | | | | | | | | | |
| 7/1/2015 | 0.3 | 0.18 | 0.14 | 0.11 | 0.40 | 0.25 | 0.28 | 0.20 | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | | | | |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | 0.17 | 0.07 | 0.06 | 0.05 |
| 7/13/2015 | 0.5 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/14/2015 | | | | | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | 0.29 | 0.17 | 0.18 | 0.15 | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | | | | |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | | | | | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |
| 7/31/2015 | 0.9 | 0.58 | 0.84 | 0.57 | | | | | | | | |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| R1 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | | | | | | | | |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | 0.18 | 0.10 | 0.07 | 0.06 |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | 0.43 | 0.28 | 0.32 | 0.27 | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | | | | | | | | |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | | | | |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.11 | 0.05 | 0.01 | 0.01 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| R1 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.09 | 0.04 | 0.01 | 0.01 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.1 | 0.05 | 0.02 | 0.02 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.40 | 0.24 | 0.33 | 0.23 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.09 | 0.03 | 0.02 | 0.02 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.32 | 0.19 | 0.20 | 0.17 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.12 | 0.05 | 0.02 | 0.02 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.36 | 0.21 | 0.26 | 0.18 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.10 | 0.03 | 0.02 | 0.01 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.40 | 0.23 | 0.31 | 0.26 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.12 | 0.03 | 0.02 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.52 | 0.31 | 0.44 | 0.30 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | 0.12 | 0.05 | 0.01 | 0.01 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.41 | 0.26 | 0.31 | 0.22 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.12 | 0.05 | 0.01 | 0.01 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.59 | 0.37 | 0.48 | 0.37 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 1/7/2016 | | | | | | | | | | | | |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.53 | 0.35 | 0.46 | 0.33 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.11 | 0.05 | 0.01 | 0.01 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.62 | 0.42 | 0.55 | 0.39 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 0.73 | 0.47 | 0.65 | 0.49 | 0.13 | 0.04 | 0.02 | 0.02 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 0.98 | 0.65 | 0.90 | 0.62 | | | | |
| 1/26/2016 | | | | | | | | | | | | |

Table 18 (Cont.). Solid Content of Streams in R1

| **R1** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.12 | 0.04 | 0.02 | 0.02 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.92 | 0.60 | 0.82 | 0.57 | 0.14 | 0.05 | 0.02 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 0.96 | 0.63 | 0.88 | 0.62 | 0.13 | 0.05 | 0.01 | 0.01 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 1.03 | 0.68 | 0.96 | 0.66 | 0.11 | 0.04 | 0.01 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.80 | 0.52 | 0.74 | 0.51 | 0.09 | 0.03 | 0.01 | 0.00 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 1.02 | 0.68 | 0.98 | 0.66 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.12 | 0.05 | 0.02 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 0.85 | 0.55 | 0.80 | 0.55 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.11 | 0.04 | 0.01 | 0.00 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 1.01 | 0.67 | 0.98 | 0.66 | 0.11 | 0.05 | 0.02 | 0.01 |
| 3/15/2016 | | | | | | | | | | | | |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.03 | 0.69 | 0.99 | 0.68 | 0.10 | 0.03 | 0.03 | 0.02 |

Table 19. Solid Content of Streams in R2.

| **R2** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 0.3 | 0.16 | | | 0.35 | 0.19 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.33 | 0.17 | | | 0.4 | 0.22 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.37 | 0.20 | | | 0.52 | 0.33 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 1.24 | 0.79 | 1.11 | 0.78 | 0.49 | 0.27 | 0.32 | 0.26 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 1.23 | 0.80 | 1.16 | 0.84 | 0.49 | 0.28 | 0.36 | 0.27 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 0.87 | 0.55 | 0.74 | 0.54 | 0.51 | 0.30 | 0.34 | 0.27 |
| 7/15/2014 | 0.5 | 0.29 | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 0.98 | 0.64 | 0.88 | 0.67 | 0.42 | 0.23 | 0.22 | 0.18 |
| 7/24/2014 | | | | | | | | | | | | |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | 0.80 | 0.51 | 0.73 | 0.55 | 0.39 | 0.21 | 0.24 | 0.19 |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 0.72 | 0.46 | 0.63 | 0.49 | 0.38 | 0.20 | 0.21 | 0.16 |
| 8/7/2014 | | | | | | | | | | | | |
| 8/11/2014 | 0.4 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.66 | 0.43 | 0.54 | 0.41 | 0.40 | 0.23 | 0.25 | 0.20 |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.1 | | | | | | | | |
| 8/19/2014 | | | | | 0.69 | 0.43 | 0.60 | 0.45 | 0.28 | 0.12 | 0.12 | 0.11 |
| 8/20/2014 | 0.3 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.54 | 0.33 | 0.52 | 0.39 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.50 | 0.30 | 0.42 | 0.33 | 0.31 | 0.16 | 0.14 | 0.11 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.41 | 0.24 | 0.29 | 0.20 | 0.25 | 0.13 | 0.13 | 0.11 |
| 9/12/2014 | 0.5 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/17/2014 | | | | | | | | | | | | |
| 9/22/2014 | 0.5 | 0.28 | 0.40 | 0.28 | | | | | | | | |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.25 | 0.11 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.46 | 0.27 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | 0.26 | 0.12 | 0.12 | 0.09 |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | 0.41 | 0.24 | 0.30 | 0.23 | | | | |
| 10/29/2014 | | | | | | | | | 0.21 | 0.09 | 0.11 | 0.08 |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/11/2014 | | | | | 0.39 | 0.24 | 0.26 | 0.18 | 0.22 | 0.10 | 0.09 | 0.09 |
| 11/12/2014 | | | | | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 11/25/2014 | | | | | 0.57 | 0.36 | 0.46 | 0.33 | | | | |
| 11/26/2014 | | | | | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/2/2014 | | | | | 0.56 | 0.34 | 0.48 | 0.38 | | | | |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/9/2014 | | | | | 0.87 | 0.56 | 0.78 | 0.55 | | | | |
| 12/10/2014 | | | | | | | | | 0.21 | 0.09 | 0.07 | 0.07 |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.77 | 0.46 | 0.67 | 0.45 | 0.21 | 0.07 | 0.08 | 0.06 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.16 | 0.11 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/14/2015 | | | | | | | | | 0.25 | 0.13 | 0.14 | 0.11 |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.71 | 0.43 | 0.62 | 0.45 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/21/2015 | | | | | | | | | 0.22 | 0.11 | 0.12 | 0.09 |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | 0.58 | 0.35 | 0.52 | 0.37 | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | | | | | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | 0.17 | 0.09 | 0.08 | 0.07 |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/6/2015 | | | | | 0.53 | 0.33 | 0.48 | 0.33 | | | | |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | | | | | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/18/2015 | | | | | 0.47 | 0.30 | 0.39 | 0.31 | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/20/2015 | | | | | | | | | 0.14 | 0.07 | 0.05 | 0.04 |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | | | | |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | 0.11 | 0.05 | 0.03 | 0.03 |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/6/2015 | | | | | 0.21 | 0.12 | 0.17 | 0.15 | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |
| 3/18/2015 | 0.20 | 0.13 | | | | | | | | | | |
| 3/19/2015 | | | | | | | | | 0.11 | 0.05 | 0.05 | 0.04 |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | 0.27 | 0.18 | 0.20 | 0.17 | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | | | | | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | 0.14 | 0.08 | 0.04 | 0.04 |
| 4/1/2015 | | | | | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | 0.31 | 0.17 | 0.23 | 0.18 | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | | | | | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | 0.14 | 0.06 | 0.03 | 0.03 |
| 4/15/2015 | | | | | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | 0.32 | 0.18 | 0.23 | 0.19 | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | | | | | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | 0.14 | 0.07 | 0.07 | 0.06 |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | | | | |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | 0.22 | 0.12 | 0.14 | 0.10 | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | | | | | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | 0.14 | 0.08 | 0.04 | 0.04 |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/12/2015 | | | | | | | | | | | | |
| 5/13/2015 | | | | | 0.25 | 0.14 | 0.17 | 0.14 | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | | | | | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.3 | 0.18 | 0.18 | 0.16 | | | | | 0.15 | 0.07 | 0.06 | 0.05 |
| 5/27/2015 | | | | | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | 0.27 | 0.15 | 0.18 | 0.16 | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | | | | |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | 0.14 | 0.06 | 0.05 | 0.05 |
| 6/9/2015 | | | | | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | 0.31 | 0.19 | 0.23 | 0.18 | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | | | | | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | 0.12 | 0.04 | 0.04 | 0.04 |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/23/2015 | | | | | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | 0.33 | 0.18 | 0.23 | 0.18 | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 7/1/2015 | 0.3 | 0.18 | 0.14 | 0.11 | | | | | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | 0.2 | 0.10 | 0.07 | 0.06 |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/8/2015 | | | | | 0.38 | 0.22 | 0.26 | 0.20 | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | | | | |
| 7/13/2015 | 0.5 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | | | | | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | 0.17 | 0.08 | 0.07 | 0.06 |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | 0.33 | 0.19 | 0.21 | 0.16 | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |
| 7/31/2015 | 0.9 | 0.58 | 0.84 | 0.57 | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | 0.23 | 0.12 | 0.13 | 0.10 |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | 0.40 | 0.25 | 0.30 | 0.23 | | | | |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | | | | |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | | | | | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | 0.39 | 0.23 | 0.33 | 0.28 | | | | |
| 8/27/2015 | | | | | | | | | 0.16 | 0.07 | 0.08 | 0.07 |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | | | | |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.09 | 0.03 | 0.01 | 0.01 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.08 | 0.02 | 0.01 | 0.01 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.16 | 0.09 | 0.09 | 0.07 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.14 | 0.07 | 0.07 | 0.05 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.08 | 0.02 | 0.02 | 0.02 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.12 | 0.04 | 0.03 | 0.03 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.11 | 0.03 | 0.02 | 0.02 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.26 | 0.14 | 0.16 | 0.11 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.11 | 0.02 | 0.02 | 0.01 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.28 | 0.15 | 0.19 | 0.17 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.11 | 0.04 | 0.01 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.60 | 0.36 | 0.53 | 0.36 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | 0.11 | 0.03 | 0.01 | 0.01 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.54 | 0.34 | 0.42 | 0.30 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.57 | 0.36 | 0.46 | 0.36 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.09 | 0.02 | 0.02 | 0.01 |
| 1/7/2016 | | | | | | | | | | | | |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.45 | 0.28 | 0.39 | 0.28 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.11 | 0.04 | 0.02 | 0.02 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.64 | 0.42 | 0.55 | 0.39 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 0.67 | 0.43 | 0.58 | 0.42 | 0.12 | 0.03 | 0.03 | 0.02 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |

Table 19 (Cont.). Solid Content of Streams in R2.

| R2 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 1.08 | 0.72 | 1.00 | 0.69 | | | | |
| 1/26/2016 | | | | | | | | | | | | |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.12 | 0.04 | 0.02 | 0.02 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.82 | 0.53 | 0.75 | 0.54 | 0.13 | 0.04 | 0.02 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 1.03 | 0.68 | 0.91 | 0.64 | 0.13 | 0.04 | 0.01 | 0.01 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 0.87 | 0.57 | 0.82 | 0.57 | 0.10 | 0.04 | 0.01 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.64 | 0.42 | 0.58 | 0.41 | 0.10 | 0.03 | 0.01 | 0.01 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 0.86 | 0.56 | 0.82 | 0.55 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.11 | 0.04 | 0.02 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 0.97 | 0.64 | 0.92 | 0.64 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.10 | 0.03 | 0.01 | 0.00 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 0.96 | 0.63 | 0.90 | 0.61 | 0.09 | 0.02 | 0.01 | 0.01 |
| 3/15/2016 | | | | | | | | | | | | |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.13 | 0.77 | 1.09 | 0.75 | 0.10 | 0.04 | 0.03 | 0.02 |

Table 20. Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 0.40 | 0.23 | | | 0.53 | 0.33 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.45 | 0.25 | | | 0.47 | 0.27 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.41 | 0.23 | | | 0.54 | 0.34 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 1.04 | 0.68 | 0.91 | 0.67 | 0.45 | 0.25 | 0.30 | 0.25 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 0.90 | 0.60 | 0.80 | 0.62 | 0.40 | 0.21 | 0.23 | 0.19 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 0.79 | 0.52 | 0.69 | 0.53 | 0.46 | 0.27 | 0.29 | 0.23 |
| 7/15/2014 | 0.50 | 0.29 | | | | | | | | | | |
| 7/17/2014 | | | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 0.71 | 0.44 | 0.55 | 0.44 | 0.39 | 0.21 | 0.21 | 0.19 |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/28/2014 | | | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | 0.78 | 0.50 | 0.66 | 0.53 | 0.37 | 0.20 | 0.21 | 0.18 |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 0.70 | 0.45 | 0.57 | 0.45 | 0.32 | 0.15 | 0.17 | 0.12 |
| 8/11/2014 | 0.40 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.72 | 0.47 | 0.59 | 0.47 | 0.31 | 0.16 | 0.15 | 0.14 |
| 8/14/2014 | | | | | | | | | | | | |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.10 | | | | | | | | |
| 8/19/2014 | | | | | 0.62 | 0.37 | 0.43 | 0.34 | 0.28 | 0.12 | 0.13 | 0.13 |
| 8/20/2014 | 0.30 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.56 | 0.35 | 0.52 | 0.40 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.54 | 0.33 | 0.48 | 0.38 | 0.29 | 0.15 | 0.12 | 0.09 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.50 | 0.32 | 0.40 | 0.31 | 0.22 | 0.11 | 0.12 | 0.09 |
| 9/12/2014 | 0.50 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/17/2014 | | | | | | | | | | | | |
| 9/22/2014 | 0.50 | 0.28 | 0.40 | 0.28 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/24/2014 | | | | | | | | | | | | |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.23 | 0.10 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.46 | 0.30 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | | | | |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/21/2014 | | | | | 0.44 | 0.28 | 0.33 | 0.25 | | | | |
| 10/22/2014 | | | | | | | | | 0.20 | 0.08 | 0.09 | 0.07 |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | | | | | | | | |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/4/2014 | | | | | 0.53 | 0.35 | 0.46 | 0.35 | | | | |
| 11/5/2014 | | | | | | | | | 0.24 | 0.13 | 0.12 | 0.11 |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/18/2014 | | | | | 0.41 | 0.25 | 0.34 | 0.27 | | | | |
| 11/19/2014 | | | | | | | | | 0.25 | 0.13 | 0.13 | 0.11 |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/2/2014 | | | | | 0.49 | 0.30 | 0.38 | 0.28 | | | | |
| 12/3/2014 | | | | | | | | | 0.25 | 0.11 | 0.12 | 0.10 |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.73 | 0.43 | 0.66 | 0.46 | 0.19 | 0.07 | 0.04 | 0.03 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.17 | 0.11 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/14/2015 | | | | | | | | | 0.24 | 0.12 | 0.12 | 0.09 |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.50 | 0.31 | 0.42 | 0.30 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/28/2015 | | | | | | | | | 0.17 | 0.09 | 0.08 | 0.06 |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | 0.33 | 0.20 | 0.26 | 0.20 | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | | | | |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/11/2015 | | | | | | | | | 0.18 | 0.08 | 0.10 | 0.09 |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | 0.36 | 0.24 | 0.28 | 0.22 | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | 0.13 | 0.06 | 0.05 | 0.03 |
| 2/27/2015 | | | | | 0.27 | 0.16 | 0.19 | 0.17 | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | | | | |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | | | | |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/11/2015 | | | | | | | | | 0.10 | 0.05 | 0.02 | 0.02 |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | 0.21 | 0.13 | 0.13 | 0.10 | | | | |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |
| 3/18/2015 | 0.20 | 0.12 | | | | | | | | | | |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | | | | | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | 0.13 | 0.07 | 0.04 | 0.04 |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | 0.19 | 0.10 | 0.13 | 0.10 | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | | | | | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | 0.19 | 0.11 | 0.10 | 0.09 |
| 4/8/2015 | | | | | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | 0.27 | 0.16 | 0.17 | 0.13 | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | | | | | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | 0.14 | 0.07 | 0.04 | 0.04 |
| 4/22/2015 | | | | | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | 0.29 | 0.19 | 0.21 | 0.18 | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | | | | |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | | | | |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | 0.14 | 0.06 | 0.06 | 0.05 |
| 5/6/2015 | | | | | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | 0.22 | 0.13 | 0.13 | 0.10 | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | | | | |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |
| 5/19/2015 | | | | | | | | | 0.12 | 0.05 | 0.05 | 0.04 |
| 5/20/2015 | | | | | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | 0.22 | 0.12 | 0.12 | 0.10 | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.30 | 0.18 | 0.18 | 0.16 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| **R3** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | | | | | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | 0.12 | 0.05 | 0.02 | 0.02 |
| 6/2/2015 | | | | | | | | | | | | |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | 0.25 | 0.14 | 0.17 | 0.14 | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | | | | | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | 0.11 | 0.04 | 0.03 | 0.02 |
| 6/16/2015 | | | | | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | 0.25 | 0.15 | 0.16 | 0.14 | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | | | | |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | | | | | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | 0.15 | 0.06 | 0.03 | 0.03 |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 6/30/2015 | | | | | | | | | | | | |
| 7/1/2015 | 0.30 | 0.18 | 0.14 | 0.11 | 0.36 | 0.23 | 0.25 | 0.18 | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | | | | |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | 0.15 | 0.07 | 0.05 | 0.04 |
| 7/13/2015 | 0.50 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/14/2015 | | | | | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | 0.31 | 0.18 | 0.20 | 0.17 | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | | | | |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | | | | | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 7/31/2015 | 0.90 | 0.58 | 0.84 | 0.57 | | | | | | | | |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | | | | |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | | | | | | | | |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | 0.15 | 0.07 | 0.05 | 0.04 |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | 0.40 | 0.26 | 0.29 | 0.24 | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | | | | | | | | |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | 0.12 | 0.04 | 0.01 | 0.01 |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.14 | 0.07 | 0.03 | 0.02 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.1 | 0.03 | 0.01 | 0.01 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.11 | 0.05 | 0.03 | 0.03 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.16 | 0.07 | 0.06 | 0.04 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.10 | 0.03 | 0.03 | 0.03 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.59 | 0.38 | 0.51 | 0.36 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.11 | 0.05 | 0.01 | 0.01 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.53 | 0.33 | 0.43 | 0.30 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.1 | 0.03 | 0.01 | 0.01 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.54 | 0.33 | 0.44 | 0.34 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.1 | 0.02 | 0.01 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.54 | 0.34 | 0.45 | 0.31 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | 0.1 | 0.02 | 0.01 | 0.01 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.45 | 0.28 | 0.37 | 0.26 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.09 | 0.02 | 0.01 | 0.01 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.51 | 0.31 | 0.43 | 0.33 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.08 | 0.01 | 0.01 | 0.01 |
| 1/7/2016 | | | | | | | | | | | | |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.42 | 0.25 | 0.37 | 0.27 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.09 | 0.02 | 0.01 | 0.01 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.51 | 0.33 | 0.42 | 0.30 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 0.67 | 0.44 | 0.58 | 0.45 | 0.11 | 0.02 | 0.02 | 0.01 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |

Table 20 (Cont.). Solid Content of Streams in R3.

| R3 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 0.77 | 0.50 | 0.69 | 0.49 | | | | |
| 1/26/2016 | | | | | | | | | | | | |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.12 | 0.04 | 0.01 | 0.01 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.74 | 0.48 | 0.64 | 0.47 | 0.12 | 0.03 | 0.01 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 0.84 | 0.55 | 0.75 | 0.54 | 0.18 | 0.09 | 0.08 | 0.06 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 0.81 | 0.53 | 0.78 | 0.53 | 0.09 | 0.03 | 0.01 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.85 | 0.57 | 0.76 | 0.53 | 0.11 | 0.05 | 0.01 | 0.01 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 0.85 | 0.57 | 0.75 | 0.50 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.10 | 0.04 | 0.02 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 0.85 | 0.57 | 0.77 | 0.54 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.09 | 0.02 | 0.01 | 0.00 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 0.85 | 0.57 | 0.79 | 0.54 | 0.09 | 0.04 | 0.01 | 0.01 |
| 3/15/2016 | | | | | | | | | | | | |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.09 | 0.74 | 1.04 | 0.72 | 0.10 | 0.04 | 0.02 | 0.02 |

Table 21. Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 0.37 | 0.20 | | | 0.53 | 0.33 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.42 | 0.23 | | | 0.47 | 0.27 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.42 | 0.23 | | | 0.48 | 0.29 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 0.57 | 0.33 | 0.37 | 0.27 | 0.42 | 0.23 | 0.26 | 0.21 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 0.93 | 0.60 | 0.83 | 0.62 | 0.42 | 0.23 | 0.27 | 0.21 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 0.94 | 0.61 | 0.82 | 0.61 | 0.47 | 0.27 | 0.32 | 0.25 |
| 7/15/2014 | 0.50 | 0.29 | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 0.85 | 0.54 | 0.76 | 0.59 | 0.45 | 0.26 | 0.27 | 0.24 |
| 7/24/2014 | | | | | | | | | | | | |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | 0.86 | 0.56 | 0.74 | 0.57 | 0.38 | 0.20 | 0.22 | 0.20 |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 0.91 | 0.61 | 0.78 | 0.62 | 0.33 | 0.16 | 0.17 | 0.14 |
| 8/7/2014 | | | | | | | | | | | | |
| 8/11/2014 | 0.40 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.86 | 0.58 | 0.76 | 0.60 | 0.33 | 0.17 | 0.19 | 0.17 |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.10 | | | | | | | | |
| 8/19/2014 | | | | | 0.55 | 0.33 | 0.43 | 0.34 | 0.30 | 0.13 | 0.18 | 0.15 |
| 8/20/2014 | 0.30 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.65 | 0.42 | 0.61 | 0.48 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.46 | 0.26 | 0.36 | 0.30 | 0.33 | 0.18 | 0.16 | 0.13 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.44 | 0.26 | 0.33 | 0.24 | 0.24 | 0.12 | 0.12 | 0.10 |
| 9/12/2014 | 0.50 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/17/2014 | | | | | | | | | | | | |
| 9/22/2014 | 0.50 | 0.28 | 0.40 | 0.28 | | | | | | | | |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.26 | 0.13 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.47 | 0.30 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | 0.24 | 0.10 | 0.11 | 0.09 |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | 0.31 | 0.17 | 0.19 | 0.15 | | | | |
| 10/29/2014 | | | | | | | | | 0.21 | 0.09 | 0.11 | 0.08 |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/11/2014 | | | | | 0.36 | 0.21 | 0.27 | 0.23 | 0.23 | 0.10 | 0.11 | 0.10 |
| 11/12/2014 | | | | | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 11/25/2014 | | | | | 0.45 | 0.28 | 0.34 | 0.25 | | | | |
| 11/26/2014 | | | | | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/9/2014 | | | | | 0.54 | 0.33 | 0.44 | 0.32 | | | | |
| 12/10/2014 | | | | | | | | | 0.28 | 0.13 | 0.16 | 0.13 |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.73 | 0.44 | 0.66 | 0.46 | 0.23 | 0.08 | 0.11 | 0.08 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.15 | 0.10 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.73 | 0.47 | 0.65 | 0.48 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/21/2015 | | | | | | | | | 0.18 | 0.08 | 0.07 | 0.06 |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | 0.62 | 0.40 | 0.55 | 0.42 | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | | | | | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | 0.15 | 0.07 | 0.06 | 0.06 |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/6/2015 | | | | | 0.54 | 0.35 | 0.49 | 0.35 | | | | |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | | | | | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/18/2015 | | | | | 0.49 | 0.31 | 0.44 | 0.34 | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/20/2015 | | | | | | | | | 0.12 | 0.06 | 0.04 | 0.04 |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | 0.11 | 0.06 | 0.03 | 0.02 |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | | | | |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/6/2015 | | | | | 0.21 | 0.12 | 0.16 | 0.14 | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | | | | | | | | |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |
| 3/18/2015 | 0.20 | 0.13 | | | | | | | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/19/2015 | | | | | | | | | 0.09 | 0.03 | 0.03 | 0.02 |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | 0.22 | 0.14 | 0.14 | 0.13 | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | | | | | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | 0.13 | 0.07 | 0.04 | 0.04 |
| 4/1/2015 | | | | | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | 0.28 | 0.16 | 0.20 | 0.16 | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | | | | | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | 0.14 | 0.07 | 0.04 | 0.04 |
| 4/15/2015 | | | | | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | 0.34 | 0.20 | 0.25 | 0.20 | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | | | | | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | 0.12 | 0.05 | 0.04 | 0.03 |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | | | | |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | 0.21 | 0.11 | 0.13 | 0.10 | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | | | | | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | 0.14 | 0.08 | 0.04 | 0.04 |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/12/2015 | | | | | | | | | | | | |
| 5/13/2015 | | | | | 0.19 | 0.09 | 0.13 | 0.10 | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | | | | | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.30 | 0.18 | 0.18 | 0.16 | | | | | 0.14 | 0.06 | 0.05 | 0.04 |
| 5/27/2015 | | | | | | | | | | | | |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | 0.24 | 0.13 | 0.16 | 0.14 | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 6/9/2015 | | | | | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | 0.30 | 0.17 | 0.24 | 0.18 | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | | | | | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | 0.12 | 0.04 | 0.03 | 0.03 |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/23/2015 | | | | | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | 0.34 | 0.19 | 0.24 | 0.19 | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 7/1/2015 | 0.30 | 0.18 | 0.14 | 0.11 | | | | | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | 0.18 | 0.08 | 0.04 | 0.03 |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/8/2015 | | | | | 0.32 | 0.17 | 0.22 | 0.17 | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | | | | |
| 7/13/2015 | 0.50 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | | | | | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | 0.17 | 0.08 | 0.06 | 0.05 |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | 0.44 | 0.27 | 0.34 | 0.25 | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |
| 7/31/2015 | 0.90 | 0.58 | 0.84 | 0.57 | | | | | | | | |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | 0.18 | 0.07 | 0.06 | 0.05 |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | 0.48 | 0.29 | 0.40 | 0.30 | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | | | | |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | | | | | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | 0.30 | 0.17 | 0.23 | 0.18 | | | | |
| 8/27/2015 | | | | | | | | | 0.15 | 0.06 | 0.06 | 0.05 |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | 0.12 | 0.04 | 0.02 | 0.01 |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.13 | 0.06 | 0.02 | 0.02 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.11 | 0.04 | 0.01 | 0.01 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.11 | 0.06 | 0.02 | 0.01 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.53 | 0.32 | 0.48 | 0.33 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.09 | 0.03 | 0.01 | 0.01 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.68 | 0.44 | 0.59 | 0.42 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.11 | 0.05 | 0.01 | 0.01 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.32 | 0.18 | 0.22 | 0.16 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.12 | 0.04 | 0.01 | 0.01 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.55 | 0.35 | 0.45 | 0.33 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.11 | 0.04 | 0.01 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.98 | 0.64 | 0.89 | 0.61 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | | | | |
| 12/9/2015 | | | | | | | | | 0.1 | 0.01 | 0.01 | 0.01 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.64 | 0.40 | 0.56 | 0.39 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.11 | 0.04 | 0.01 | 0.01 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.62 | 0.39 | 0.51 | 0.38 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.10 | 0.05 | 0.02 | 0.01 |
| 1/7/2016 | | | | | | | | | | | | |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.48 | 0.32 | 0.39 | 0.27 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.11 | 0.03 | 0.02 | 0.01 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.80 | 0.53 | 0.72 | 0.50 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 1.30 | 0.88 | 1.20 | 0.88 | 0.13 | 0.06 | 0.03 | 0.02 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 0.87 | 0.57 | 0.79 | 0.55 | | | | |

Table 21 (Cont.). Solid Content of Streams in R4.

| R4 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/26/2016 | | | | | | | | | | | | |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.13 | 0.05 | 0.02 | 0.02 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.91 | 0.59 | 0.83 | 0.60 | 0.13 | 0.04 | 0.02 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 1.10 | 0.72 | 1.01 | 0.70 | 0.12 | 0.03 | 0.02 | 0.01 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 1.13 | 0.75 | 1.12 | 0.76 | 0.11 | 0.04 | 0.02 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.83 | 0.54 | 0.76 | 0.52 | 0.10 | 0.04 | 0.02 | 0.01 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 0.90 | 0.61 | 0.84 | 0.57 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.12 | 0.06 | 0.03 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 1.78 | 1.22 | 1.69 | 1.17 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.11 | 0.05 | 0.01 | 0.01 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 1.95 | 1.32 | 1.90 | 1.29 | 0.10 | 0.04 | 0.02 | 0.02 |
| 3/15/2016 | | | | | | | | | | | | |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.86 | 1.27 | 1.81 | 1.23 | 0.09 | 0.03 | 0.02 | 0.02 |

Table 22. Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 1.08 | 0.73 | | | 0.55 | 0.35 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.41 | 0.23 | | | 0.40 | 0.25 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.52 | 0.32 | | | 0.43 | 0.25 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 0.74 | 0.44 | 0.61 | 0.43 | 0.50 | 0.28 | 0.33 | 0.27 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 0.78 | 0.49 | 0.70 | 0.52 | 0.41 | 0.22 | 0.25 | 0.20 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 0.82 | 0.51 | 0.70 | 0.51 | 0.41 | 0.23 | 0.26 | 0.20 |
| 7/15/2014 | 0.50 | 0.29 | | | | | | | | | | |
| 7/17/2014 | | | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 0.69 | 0.42 | 0.57 | 0.44 | 0.45 | 0.26 | 0.27 | 0.24 |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/28/2014 | | | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | 0.79 | 0.49 | 0.71 | 0.54 | 0.34 | 0.17 | 0.19 | 0.17 |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 0.64 | 0.39 | 0.49 | 0.38 | 0.32 | 0.16 | 0.19 | 0.15 |
| 8/11/2014 | 0.40 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.42 | 0.23 | 0.29 | 0.23 | 0.29 | 0.14 | 0.16 | 0.14 |
| 8/14/2014 | | | | | | | | | | | | |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.10 | 1.11 | 0.75 | 1.03 | 0.78 | 0.25 | 0.10 | 0.11 | 0.10 |
| 8/20/2014 | 0.30 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.39 | 0.21 | 0.31 | 0.23 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.55 | 0.32 | 0.46 | 0.35 | 0.27 | 0.13 | 0.11 | 0.08 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.49 | 0.29 | 0.41 | 0.29 | 0.22 | 0.10 | 0.13 | 0.09 |
| 9/12/2014 | 0.50 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/22/2014 | 0.50 | 0.28 | 0.40 | 0.28 | | | | | | | | |
| 9/24/2014 | | | | | | | | | | | | |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.21 | 0.08 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.41 | 0.25 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | | | | |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/21/2014 | | | | | 0.39 | 0.21 | 0.31 | 0.22 | | | | |
| 10/22/2014 | | | | | | | | | 0.18 | 0.06 | 0.08 | 0.07 |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | | | | | | | | |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/5/2014 | | | | | 0.70 | 0.43 | 0.67 | 0.47 | 0.21 | 0.12 | 0.10 | 0.07 |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/18/2014 | | | | | 0.39 | 0.23 | 0.29 | 0.24 | | | | |
| 11/19/2014 | | | | | | | | | 0.17 | 0.06 | 0.07 | 0.06 |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/2/2014 | | | | | 0.43 | 0.25 | 0.34 | 0.22 | | | | |
| 12/3/2014 | | | | | | | | | 0.20 | 0.07 | 0.09 | 0.08 |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.67 | 0.39 | 0.59 | 0.40 | 0.21 | 0.09 | 0.07 | 0.06 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.15 | 0.10 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/14/2015 | | | | | | | | | 0.23 | 0.11 | 0.12 | 0.11 |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.46 | 0.27 | 0.37 | 0.26 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | | | | | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/28/2015 | | | | | | | | | 0.13 | 0.05 | 0.06 | 0.04 |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | 0.30 | 0.17 | 0.23 | 0.20 | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | | | | |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/6/2015 | | | | | 0.33 | 0.21 | 0.26 | 0.18 | 0.15 | 0.07 | 0.07 | 0.05 |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/11/2015 | | | | | | | | | 0.14 | 0.07 | 0.05 | 0.04 |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | 0.29 | 0.17 | 0.25 | 0.18 | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/18/2015 | | | | | 0.29 | 0.17 | 0.22 | 0.18 | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/20/2015 | | | | | | | | | 0.11 | 0.05 | 0.04 | 0.04 |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | 0.11 | 0.06 | 0.04 | 0.03 |
| 2/27/2015 | | | | | 0.21 | 0.12 | 0.16 | 0.13 | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | 0.10 | 0.06 | 0.02 | 0.02 |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | | | | |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/6/2015 | | | | | 0.19 | 0.11 | 0.14 | 0.12 | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/11/2015 | | | | | | | | | 0.09 | 0.03 | 0.02 | 0.02 |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | 0.24 | 0.15 | 0.20 | 0.14 | | | | |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |
| 3/18/2015 | 0.20 | 0.13 | | | | | | | | | | |
| 3/19/2015 | | | | | | | | | 0.13 | 0.07 | 0.06 | 0.06 |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | 0.23 | 0.14 | 0.17 | 0.14 | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | 0.09 | 0.04 | 0.01 | 0.01 |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | 0.23 | 0.13 | 0.16 | 0.12 | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | 0.18 | 0.09 | 0.10 | 0.08 |
| 4/1/2015 | | | | | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | 0.27 | 0.15 | 0.18 | 0.14 | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | 0.16 | 0.09 | 0.06 | 0.05 |
| 4/8/2015 | | | | | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | 0.27 | 0.15 | 0.18 | 0.15 | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | 0.15 | 0.08 | 0.05 | 0.04 |
| 4/15/2015 | | | | | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | 0.29 | 0.16 | 0.20 | 0.16 | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | 0.14 | 0.07 | 0.05 | 0.04 |
| 4/22/2015 | | | | | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | 0.29 | 0.18 | 0.20 | 0.17 | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | | | | |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | 0.15 | 0.06 | 0.05 | 0.04 |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | 0.22 | 0.12 | 0.16 | 0.11 | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | 0.14 | 0.07 | 0.07 | 0.06 |
| 5/6/2015 | | | | | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | 0.24 | 0.14 | 0.16 | 0.12 | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | 0.17 | 0.10 | 0.07 | 0.06 |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/12/2015 | | | | | | | | | | | | |
| 5/13/2015 | | | | | 0.25 | 0.14 | 0.19 | 0.15 | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |
| 5/19/2015 | | | | | | | | | 0.13 | 0.06 | 0.05 | 0.04 |
| 5/20/2015 | | | | | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | 0.26 | 0.17 | 0.17 | 0.14 | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.30 | 0.18 | 0.18 | 0.16 | | | | | 0.15 | 0.08 | 0.04 | 0.03 |
| 5/27/2015 | | | | | | | | | | | | |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | 0.29 | 0.16 | 0.19 | 0.16 | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | 0.12 | 0.05 | 0.03 | 0.03 |
| 6/2/2015 | | | | | | | | | | | | |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | 0.30 | 0.18 | 0.21 | 0.17 | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | 0.13 | 0.05 | 0.04 | 0.03 |
| 6/9/2015 | | | | | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | 0.33 | 0.20 | 0.23 | 0.18 | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | 0.12 | 0.04 | 0.02 | 0.01 |
| 6/16/2015 | | | | | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | 0.29 | 0.16 | 0.20 | 0.16 | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | 0.12 | 0.04 | 0.03 | 0.02 |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/23/2015 | | | | | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | 0.32 | 0.18 | 0.22 | 0.17 | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | 0.17 | 0.08 | 0.04 | 0.04 |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 6/30/2015 | | | | | | | | | | | | |
| 7/1/2015 | 0.30 | 0.18 | 0.14 | 0.11 | 0.39 | 0.25 | 0.27 | 0.20 | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | 0.19 | 0.10 | 0.07 | 0.05 |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/8/2015 | | | | | 0.39 | 0.22 | 0.31 | 0.24 | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | 0.16 | 0.07 | 0.04 | 0.03 |
| 7/13/2015 | 0.50 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/14/2015 | | | | | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | 0.35 | 0.20 | 0.25 | 0.19 | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | 0.16 | 0.06 | 0.06 | 0.05 |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | 0.35 | 0.21 | 0.23 | 0.18 | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |
| 7/31/2015 | 0.90 | 0.58 | 0.84 | 0.57 | | | | | | | | |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | | | | |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | 0.44 | 0.27 | 0.36 | 0.27 | 0.24 | 0.14 | 0.12 | 0.09 |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | 0.18 | 0.09 | 0.08 | 0.07 |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | 0.45 | 0.29 | 0.36 | 0.29 | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | 0.44 | 0.27 | 0.35 | 0.28 | | | | |
| 8/27/2015 | | | | | | | | | 0.15 | 0.07 | 0.07 | 0.07 |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | 0.12 | 0.06 | 0.01 | 0.01 |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.16 | 0.09 | 0.06 | 0.05 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.11 | 0.06 | 0.01 | 0.00 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.12 | 0.06 | 0.03 | 0.02 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.37 | 0.24 | 0.28 | 0.23 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.09 | 0.03 | 0.01 | 0.01 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.40 | 0.25 | 0.30 | 0.24 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.10 | 0.04 | 0.01 | 0.01 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.46 | 0.28 | 0.37 | 0.27 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.46 | 0.29 | 0.37 | 0.29 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.11 | 0.04 | 0.01 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.44 | 0.27 | 0.36 | 0.25 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | 0.1 | 0.02 | 0.01 | 0.01 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.40 | 0.26 | 0.31 | 0.22 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.56 | 0.37 | 0.47 | 0.36 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.09 | 0.03 | 0.01 | 0.00 |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/7/2016 | | | | | | | | | | | | |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.70 | 0.42 | 0.36 | 0.27 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.10 | 0.03 | 0.02 | 0.01 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.64 | 0.43 | 0.54 | 0.38 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 0.77 | 0.50 | 0.69 | 0.52 | 0.11 | 0.04 | 0.02 | 0.01 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 0.76 | 0.49 | 0.68 | 0.47 | | | | |
| 1/26/2016 | | | | | | | | | | | | |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.12 | 0.04 | 0.02 | 0.02 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.86 | 0.56 | 0.77 | 0.55 | 0.12 | 0.03 | 0.02 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 0.84 | 0.54 | 0.75 | 0.54 | 0.13 | 0.06 | 0.02 | 0.01 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 0.85 | 0.56 | 0.80 | 0.55 | 0.10 | 0.03 | 0.02 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.86 | 0.57 | 0.79 | 0.54 | 0.09 | 0.04 | 0.02 | 0.01 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 0.93 | 0.62 | 0.87 | 0.59 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.10 | 0.04 | 0.02 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 0.96 | 0.64 | 0.86 | 0.58 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.09 | 0.03 | 0.01 | 0.01 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 1.02 | 0.67 | 0.98 | 0.67 | 0.09 | 0.03 | 0.01 | 0.01 |

Table 22 (Cont.). Solid Content of Streams in R5.

| R5 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/15/2016 | | | | | | | | | | | | |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.05 | 0.71 | 1.01 | 0.70 | 0.10 | 0.04 | 0.02 | 0.01 |

Table 23. Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 6/4/2014 | 0.59 | 0.36 | | | | | | | | | | |
| 6/10/2014 | 0.37 | 0.21 | | | 1.05 | 0.69 | | | 0.34 | 0.19 | | |
| 6/16/2014 | 0.61 | 0.37 | | | | | | | | | | |
| 6/17/2014 | | | | | 0.41 | 0.23 | | | 0.31 | 0.20 | | |
| 6/18/2014 | 0.83 | 0.59 | | | | | | | | | | |
| 6/19/2014 | | | | | | | | | | | | |
| 6/24/2014 | 0.59 | 0.36 | | | 0.36 | 0.21 | | | 0.36 | 0.19 | | |
| 6/26/2014 | | | | | | | | | | | | |
| 7/1/2014 | 0.65 | 0.39 | 0.46 | 0.33 | 1.40 | 0.86 | 1.35 | 0.91 | 0.39 | 0.20 | 0.22 | 0.18 |
| 7/7/2014 | 0.57 | 0.36 | | | | | | | | | | |
| 7/8/2014 | 0.48 | 0.29 | 0.29 | 0.22 | 1.25 | 0.81 | 1.14 | 0.81 | 0.45 | 0.24 | 0.30 | 0.22 |
| 7/10/2014 | | | | | | | | | | | | |
| 7/15/2014 | 0.51 | 0.32 | 0.36 | 0.28 | 1.08 | 0.70 | 1.07 | 0.73 | 0.50 | 0.29 | 0.34 | 0.27 |
| 7/15/2014 | 0.50 | 0.29 | | | | | | | | | | |
| 7/22/2014 | 0.36 | 0.19 | 0.19 | 0.16 | 1.06 | 0.67 | 1.01 | 0.75 | 0.46 | 0.25 | 0.28 | 0.24 |
| 7/24/2014 | | | | | | | | | | | | |
| 7/25/2014 | 0.29 | 0.15 | | | | | | | | | | |
| 7/26/2014 | 0.43 | 0.25 | | | | | | | | | | |
| 7/29/2014 | 0.36 | 0.19 | 0.17 | 0.15 | | | | | 0.49 | 0.27 | 0.40 | 0.31 |
| 7/31/2014 | | | | | 1.09 | 0.70 | 1.03 | 0.79 | | | | |
| 8/5/2014 | 0.31 | 0.16 | 0.12 | 0.10 | 1.23 | 0.81 | 1.12 | 0.81 | 0.34 | 0.16 | 0.20 | 0.15 |
| 8/7/2014 | | | | | | | | | | | | |
| 8/11/2014 | 0.40 | 0.22 | | | | | | | | | | |
| 8/13/2014 | 0.28 | 0.15 | 0.14 | 0.12 | 0.82 | 0.50 | 0.67 | 0.49 | 0.36 | 0.18 | 0.23 | 0.17 |
| 8/18/2014 | 0.26 | 0.13 | 0.12 | 0.10 | 0.76 | 0.48 | 0.69 | 0.52 | 0.34 | 0.16 | 0.20 | 0.15 |
| 8/20/2014 | 0.30 | 0.16 | | | | | | | | | | |
| 8/20/2014 | 0.33 | 0.18 | | | | | | | | | | |
| 8/27/2014 | | | | | 0.67 | 0.42 | 0.67 | 0.50 | | | | |
| 8/28/2014 | 0.25 | 0.16 | | | | | | | | | | |
| 9/2/2014 | 0.24 | 0.14 | 0.07 | 0.07 | | | | | | | | |
| 9/3/2014 | | | | | 0.74 | 0.47 | 0.64 | 0.49 | 0.33 | 0.17 | 0.17 | 0.12 |
| 9/9/2014 | 0.27 | 0.14 | 0.15 | 0.12 | | | | | | | | |
| 9/10/2014 | | | | | 0.65 | 0.40 | 0.64 | 0.45 | 0.24 | 0.11 | 0.16 | 0.11 |
| 9/12/2014 | 0.50 | 0.30 | | | | | | | | | | |
| 9/15/2014 | 0.54 | 0.34 | 0.46 | 0.33 | | | | | | | | |
| 9/17/2014 | | | | | | | | | | | | |
| 9/22/2014 | 0.50 | 0.28 | 0.40 | 0.28 | | | | | | | | |
| 9/25/2014 | 0.56 | 0.36 | | | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 9/30/2014 | 0.48 | 0.29 | 0.38 | 0.28 | | | | | | | | |
| 10/1/2014 | 0.56 | 0.33 | | | | | | | | | | |
| 10/1/2014 | 0.46 | 0.29 | | | | | | | | | | |
| 10/2/2014 | 0.42 | 0.27 | | | | | | | | | | |
| 10/3/2014 | 0.35 | 0.20 | | | | | | | | | | |
| 10/6/2014 | 0.38 | 0.23 | | | | | | | 0.28 | 0.13 | | |
| 10/7/2014 | 0.38 | 0.26 | | | 0.53 | 0.33 | | | | | | |
| 10/8/2014 | 0.35 | 0.19 | 0.24 | 0.17 | | | | | | | | |
| 10/9/2014 | 0.31 | 0.18 | | | | | | | | | | |
| 10/13/2014 | 0.30 | 0.18 | | | | | | | | | | |
| 10/15/2014 | 0.35 | 0.21 | 0.22 | 0.17 | | | | | 0.23 | 0.09 | 0.10 | 0.07 |
| 10/20/2014 | 0.29 | 0.16 | 0.19 | 0.14 | | | | | | | | |
| 10/27/2014 | 0.24 | 0.13 | 0.14 | 0.11 | | | | | | | | |
| 10/28/2014 | 0.43 | 0.28 | | | 0.37 | 0.20 | 0.30 | 0.23 | | | | |
| 10/29/2014 | | | | | | | | | 0.18 | 0.06 | 0.08 | 0.06 |
| 11/3/2014 | 0.30 | 0.16 | 0.18 | 0.13 | | | | | | | | |
| 11/7/2014 | 0.38 | 0.23 | 0.25 | 0.20 | | | | | | | | |
| 11/11/2014 | | | | | 0.41 | 0.23 | 0.36 | 0.27 | 0.20 | 0.08 | 0.10 | 0.09 |
| 11/12/2014 | | | | | | | | | | | | |
| 11/13/2014 | 0.35 | 0.21 | 0.21 | 0.16 | | | | | | | | |
| 11/17/2014 | 0.39 | 0.23 | 0.27 | 0.21 | | | | | | | | |
| 11/24/2014 | 0.48 | 0.28 | 0.33 | 0.24 | | | | | | | | |
| 11/25/2014 | | | | | 0.46 | 0.27 | 0.36 | 0.27 | | | | |
| 11/26/2014 | | | | | | | | | | | | |
| 12/1/2014 | 0.39 | 0.24 | 0.22 | 0.17 | | | | | | | | |
| 12/4/2014 | 0.35 | 0.19 | 0.18 | 0.15 | | | | | | | | |
| 12/8/2014 | 0.37 | 0.21 | 0.15 | 0.11 | | | | | | | | |
| 12/8/2014 | 1.25 | 0.81 | 1.17 | 0.87 | | | | | | | | |
| 12/9/2014 | | | | | 0.56 | 0.33 | 0.49 | 0.34 | | | | |
| 12/10/2014 | | | | | | | | | 0.24 | 0.10 | 0.14 | 0.11 |
| 12/12/2014 | 0.55 | 0.32 | 0.38 | 0.27 | | | | | | | | |
| 12/15/2014 | 0.50 | 0.29 | 0.31 | 0.25 | | | | | | | | |
| 12/16/2014 | | | | | 0.85 | 0.51 | 0.81 | 0.54 | 0.20 | 0.07 | 0.07 | 0.05 |
| 12/17/2014 | | | | | | | | | | | | |
| 12/18/2014 | 0.39 | 0.22 | 0.17 | 0.15 | | | | | | | | |
| 12/18/2014 | 0.44 | 0.25 | 0.27 | 0.21 | | | | | | | | |
| 12/23/2014 | 0.45 | 0.25 | | | | | | | | | | |
| 12/23/2014 | 0.85 | 0.48 | | | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 12/26/2014 | 0.35 | 0.19 | | | | | | | | | | |
| 12/26/2014 | 0.68 | 0.39 | | | | | | | | | | |
| 12/29/2014 | 0.46 | 0.27 | | | | | | | | | | |
| 12/29/2014 | 0.61 | 0.35 | | | | | | | | | | |
| 1/8/2015 | | | | | | | | | | | | |
| 1/9/2015 | | | | | | | | | | | 0.14 | 0.10 |
| 1/12/2015 | 0.34 | 0.22 | 0.27 | 0.18 | | | | | | | | |
| 1/13/2015 | 0.34 | 0.22 | 0.28 | 0.22 | | | | | | | | |
| 1/16/2015 | 0.21 | 0.14 | 0.10 | 0.09 | 0.75 | 0.49 | 0.70 | 0.50 | | | | |
| 1/20/2015 | 0.16 | 0.12 | 0.08 | 0.07 | | | | | | | | |
| 1/21/2015 | | | | | | | | | 0.14 | 0.04 | 0.05 | 0.05 |
| 1/23/2015 | 0.18 | 0.12 | 0.09 | 0.07 | 0.52 | 0.34 | 0.46 | 0.35 | | | | |
| 1/23/2015 | 0.25 | 0.17 | 0.13 | 0.11 | | | | | | | | |
| 1/26/2015 | 0.16 | 0.09 | 0.06 | 0.05 | | | | | | | | |
| 1/29/2015 | 0.17 | 0.10 | 0.06 | 0.05 | | | | | | | | |
| 1/30/2015 | | | | | | | | | | | | |
| 2/2/2015 | 0.18 | 0.11 | 0.10 | 0.08 | | | | | | | | |
| 2/4/2015 | 0.33 | 0.20 | 0.25 | 0.18 | | | | | 0.09 | 0.02 | 0.01 | 0.01 |
| 2/4/2015 | 0.32 | 0.19 | 0.21 | 0.17 | | | | | | | | |
| 2/6/2015 | | | | | 0.38 | 0.25 | 0.33 | 0.22 | | | | |
| 2/9/2015 | 0.20 | 0.11 | 0.09 | 0.08 | | | | | | | | |
| 2/11/2015 | | | | | | | | | 0.10 | 0.04 | 0.00 | 0.00 |
| 2/13/2015 | 0.20 | 0.12 | 0.11 | 0.09 | 0.49 | 0.31 | 0.43 | 0.31 | | | | |
| 2/16/2015 | 2.07 | 1.30 | 2.00 | 1.30 | | | | | | | | |
| 2/16/2015 | 0.34 | 0.22 | 0.29 | 0.21 | | | | | | | | |
| 2/18/2015 | | | | | 0.48 | 0.29 | 0.41 | 0.30 | | | | |
| 2/19/2015 | 0.26 | 0.19 | 0.17 | 0.15 | | | | | | | | |
| 2/20/2015 | | | | | | | | | 0.06 | 0.02 | 0.01 | 0.00 |
| 2/24/2015 | 0.16 | 0.09 | 0.08 | 0.08 | | | | | | | | |
| 2/25/2015 | 0.27 | 0.18 | 0.20 | 0.17 | | | | | 0.08 | 0.04 | 0.01 | 0.01 |
| 2/27/2015 | | | | | 0.54 | 0.33 | 0.51 | 0.35 | | | | |
| 3/2/2015 | 0.15 | 0.10 | 0.07 | 0.05 | | | | | 0.09 | 0.06 | 0.01 | 0.01 |
| 3/4/2015 | 0.14 | 0.09 | 0.06 | 0.04 | | | | | | | | |
| 3/4/2015 | 0.22 | 0.14 | 0.16 | 0.14 | | | | | | | | |
| 3/6/2015 | | | | | 0.55 | 0.34 | 0.51 | 0.35 | | | | |
| 3/9/2015 | 0.14 | 0.08 | 0.07 | 0.07 | | | | | | | | |
| 3/11/2015 | | | | | | | | | 0.06 | 0.01 | 0.01 | 0.01 |
| 3/12/2015 | 0.35 | 0.22 | 0.27 | 0.21 | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/13/2015 | 0.20 | 0.12 | 0.13 | 0.10 | 0.54 | 0.34 | 0.51 | 0.35 | | | | |
| 3/16/2015 | 0.18 | 0.10 | 0.09 | 0.09 | | | | | | | | |
| 3/18/2015 | 0.20 | 0.13 | | | | | | | | | | |
| 3/19/2015 | | | | | | | | | 0.07 | 0.02 | 0.01 | 0.01 |
| 3/20/2015 | 0.23 | 0.15 | 0.14 | 0.12 | 0.58 | 0.37 | 0.54 | 0.39 | | | | |
| 3/23/2015 | 0.23 | 0.15 | 0.12 | 0.10 | | | | | 0.09 | 0.04 | 0.01 | 0.01 |
| 3/25/2015 | 0.41 | 0.28 | 0.30 | 0.27 | | | | | | | | |
| 3/25/2015 | 0.36 | 0.25 | 0.25 | 0.21 | | | | | | | | |
| 3/27/2015 | 0.42 | 0.30 | 0.28 | 0.22 | 0.52 | 0.34 | 0.46 | 0.32 | | | | |
| 3/30/2015 | 0.35 | 0.23 | 0.25 | 0.21 | | | | | 0.11 | 0.05 | 0.03 | 0.03 |
| 4/1/2015 | | | | | | | | | | | | |
| 4/2/2015 | 0.36 | 0.24 | 0.25 | 0.20 | | | | | | | | |
| 4/3/2015 | 0.38 | 0.27 | 0.25 | 0.21 | 0.67 | 0.43 | 0.60 | 0.42 | | | | |
| 4/3/2015 | 0.42 | 0.31 | 0.26 | 0.22 | | | | | | | | |
| 4/6/2015 | 0.35 | 0.26 | 0.22 | 0.18 | | | | | 0.12 | 0.07 | 0.01 | 0.01 |
| 4/8/2015 | | | | | | | | | | | | |
| 4/10/2015 | 0.27 | 0.17 | 0.16 | 0.14 | 0.58 | 0.36 | 0.52 | 0.38 | | | | |
| 4/13/2015 | 0.34 | 0.22 | 0.23 | 0.21 | | | | | 0.11 | 0.06 | 0.01 | 0.01 |
| 4/15/2015 | | | | | | | | | | | | |
| 4/17/2015 | 0.56 | 0.40 | 0.45 | 0.38 | 0.65 | 0.41 | 0.57 | 0.41 | | | | |
| 4/17/2015 | 0.34 | 0.25 | 0.23 | 0.20 | | | | | | | | |
| 4/20/2015 | 0.26 | 0.18 | 0.15 | 0.13 | | | | | 0.09 | 0.02 | 0.01 | 0.01 |
| 4/22/2015 | | | | | | | | | | | | |
| 4/24/2015 | 0.28 | 0.19 | 0.16 | 0.15 | 0.63 | 0.40 | 0.57 | 0.42 | | | | |
| 4/24/2015 | 0.20 | 0.14 | 0.16 | 0.15 | | | | | | | | |
| 4/27/2015 | 0.27 | 0.18 | 0.22 | 0.19 | | | | | | | | |
| 4/29/2015 | 0.24 | 0.15 | 0.14 | 0.13 | | | | | 0.09 | 0.02 | 0.01 | 0.01 |
| 5/1/2015 | 0.27 | 0.17 | 0.19 | 0.15 | 0.55 | 0.34 | 0.51 | 0.35 | | | | |
| 5/4/2015 | 0.24 | 0.17 | 0.15 | 0.13 | | | | | 0.11 | 0.04 | 0.04 | 0.03 |
| 5/6/2015 | | | | | | | | | | | | |
| 5/8/2015 | 0.23 | 0.14 | 0.15 | 0.13 | 0.65 | 0.41 | 0.59 | 0.42 | | | | |
| 5/11/2015 | 0.22 | 0.15 | 0.11 | 0.10 | | | | | 0.10 | 0.04 | 0.02 | 0.01 |
| 5/11/2015 | 0.25 | 0.17 | 0.16 | 0.13 | | | | | | | | |
| 5/12/2015 | | | | | | | | | | | | |
| 5/13/2015 | | | | | 0.59 | 0.37 | 0.55 | 0.40 | | | | |
| 5/14/2015 | 0.29 | 0.19 | 0.22 | 0.19 | | | | | | | | |
| 5/14/2015 | 0.36 | 0.23 | 0.23 | 0.20 | | | | | | | | |
| 5/18/2015 | 0.30 | 0.20 | 0.19 | 0.16 | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 5/19/2015 | | | | | | | | | 0.09 | 0.03 | 0.01 | 0.01 |
| 5/20/2015 | | | | | | | | | | | | |
| 5/21/2015 | 0.23 | 0.14 | 0.14 | 0.13 | 0.63 | 0.41 | 0.58 | 0.41 | | | | |
| 5/22/2015 | 0.32 | 0.21 | 0.17 | 0.15 | | | | | | | | |
| 5/26/2015 | 0.30 | 0.18 | 0.18 | 0.16 | | | | | 0.12 | 0.06 | 0.01 | 0.01 |
| 5/27/2015 | | | | | | | | | | | | |
| 5/28/2015 | 0.26 | 0.16 | 0.14 | 0.13 | 0.65 | 0.41 | 0.57 | 0.41 | | | | |
| 6/1/2015 | 0.28 | 0.19 | 0.18 | 0.17 | | | | | 0.10 | 0.04 | 0.01 | 0.01 |
| 6/2/2015 | | | | | | | | | | | | |
| 6/3/2015 | 0.37 | 0.24 | 0.25 | 0.22 | | | | | | | | |
| 6/4/2015 | 0.25 | 0.16 | 0.15 | 0.13 | 0.74 | 0.48 | 0.69 | 0.48 | | | | |
| 6/5/2015 | 0.34 | 0.22 | 0.19 | 0.17 | | | | | | | | |
| 6/8/2015 | 0.29 | 0.19 | 0.14 | 0.13 | | | | | 0.12 | 0.05 | 0.03 | 0.03 |
| 6/9/2015 | | | | | | | | | | | | |
| 6/11/2015 | 0.28 | 0.17 | 0.16 | 0.15 | 0.69 | 0.44 | 0.59 | 0.43 | | | | |
| 6/15/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | | | | |
| 6/16/2015 | | | | | | | | | | | | |
| 6/17/2015 | 0.24 | 0.15 | 0.09 | 0.09 | | | | | 0.10 | 0.03 | 0.00 | 0.00 |
| 6/18/2015 | 0.22 | 0.13 | 0.08 | 0.08 | 0.63 | 0.39 | 0.56 | 0.40 | | | | |
| 6/19/2015 | 0.39 | 0.26 | 0.23 | 0.21 | | | | | | | | |
| 6/22/2015 | 0.26 | 0.16 | 0.13 | 0.12 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 6/22/2015 | 0.53 | 0.35 | 0.33 | 0.27 | | | | | | | | |
| 6/23/2015 | | | | | | | | | | | | |
| 6/25/2015 | 0.37 | 0.24 | 0.17 | 0.15 | 0.61 | 0.38 | 0.51 | 0.37 | | | | |
| 6/25/2015 | 0.56 | 0.37 | 0.37 | 0.29 | | | | | | | | |
| 6/26/2015 | 0.39 | 0.24 | 0.18 | 0.15 | | | | | | | | |
| 6/29/2015 | 0.37 | 0.24 | 0.18 | 0.15 | | | | | 0.15 | 0.06 | 0.01 | 0.01 |
| 6/29/2015 | 0.48 | 0.31 | 0.27 | 0.23 | | | | | | | | |
| 6/30/2015 | | | | | | | | | | | | |
| 7/1/2015 | 0.30 | 0.18 | 0.14 | 0.11 | 0.51 | 0.31 | 0.41 | 0.30 | | | | |
| 7/2/2015 | 0.29 | 0.17 | 0.14 | 0.13 | | | | | | | | |
| 7/2/2015 | 0.41 | 0.27 | 0.25 | 0.22 | | | | | | | | |
| 7/6/2015 | 0.56 | 0.37 | 0.42 | 0.32 | | | | | 0.15 | 0.06 | 0.02 | 0.02 |
| 7/7/2015 | 0.33 | 0.19 | 0.16 | 0.14 | | | | | | | | |
| 7/7/2015 | 0.37 | 0.24 | 0.23 | 0.19 | | | | | | | | |
| 7/8/2015 | | | | | 0.58 | 0.35 | 0.49 | 0.36 | | | | |
| 7/10/2015 | 0.25 | 0.14 | 0.12 | 0.10 | | | | | | | | |
| 7/13/2015 | 0.23 | 0.13 | 0.11 | 0.09 | | | | | 0.14 | 0.05 | 0.01 | 0.01 |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 7/13/2015 | 0.50 | 0.33 | 0.34 | 0.27 | | | | | | | | |
| 7/14/2015 | | | | | | | | | | | | |
| 7/16/2015 | 0.25 | 0.14 | 0.10 | 0.08 | 0.60 | 0.36 | 0.51 | 0.37 | | | | |
| 7/16/2015 | 0.47 | 0.31 | 0.32 | 0.25 | | | | | | | | |
| 7/17/2015 | 0.32 | 0.19 | 0.18 | 0.16 | | | | | | | | |
| 7/20/2015 | 0.34 | 0.21 | 0.25 | 0.19 | | | | | 0.13 | 0.04 | 0.02 | 0.02 |
| 7/21/2015 | 0.63 | 0.42 | 0.52 | 0.39 | | | | | | | | |
| 7/22/2015 | 0.37 | 0.24 | 0.25 | 0.21 | 0.61 | 0.38 | 0.52 | 0.38 | | | | |
| 7/30/2015 | 0.36 | 0.20 | 0.24 | 0.19 | | | | | | | | |
| 7/31/2015 | 0.90 | 0.58 | 0.84 | 0.57 | | | | | | | | |
| 8/3/2015 | 0.68 | 0.43 | 0.59 | 0.44 | | | | | | | | |
| 8/4/2015 | 0.41 | 0.28 | 0.34 | 0.25 | 0.65 | 0.42 | 0.58 | 0.42 | 0.19 | 0.10 | 0.06 | 0.05 |
| 8/6/2015 | 0.21 | 0.12 | 0.10 | 0.09 | | | | | | | | |
| 8/17/2015 | 0.33 | 0.21 | 0.24 | 0.18 | | | | | 0.12 | 0.05 | 0.01 | 0.01 |
| 8/18/2015 | 0.48 | 0.34 | 0.36 | 0.30 | 0.66 | 0.42 | 0.56 | 0.41 | | | | |
| 8/21/2015 | 0.25 | 0.14 | 0.17 | 0.14 | | | | | | | | |
| 8/21/2015 | | | 0.32 | 0.24 | | | | | | | | |
| 8/25/2015 | 0.17 | 0.07 | 0.09 | 0.07 | | | | | | | | |
| 8/26/2015 | 0.17 | 0.08 | 0.07 | 0.05 | 0.65 | 0.41 | 0.58 | 0.40 | | | | |
| 8/27/2015 | | | | | | | | | 0.12 | 0.04 | 0.02 | 0.02 |
| 8/28/2015 | 0.65 | 0.41 | 0.57 | 0.41 | | | | | | | | |
| 8/28/2015 | 0.5 | 0.31 | 0.37 | 0.27 | | | | | | | | |
| 8/31/2015 | 0.27 | 0.15 | 0.15 | 0.13 | | | | | | | | |
| 8/31/2015 | 0.43 | 0.27 | 0.29 | 0.23 | | | | | | | | |
| 9/4/2015 | 0.36 | 0.21 | 0.21 | 0.19 | | | | | | | | |
| 9/4/2015 | 0.46 | 0.30 | 0.32 | 0.26 | | | | | | | | |
| 9/8/2015 | 0.4 | 0.24 | 0.30 | 0.27 | | | | | | | | |
| 9/8/2015 | 0.45 | 0.28 | 0.35 | 0.28 | | | | | | | | |
| 9/11/2015 | 0.25 | 0.13 | 0.12 | 0.11 | | | | | | | | |
| 9/11/2015 | 0.27 | 0.16 | 0.13 | 0.11 | | | | | | | | |
| 9/17/2015 | 0.48 | 0.29 | 0.41 | 0.32 | | | | | | | | |
| 9/17/2015 | 0.19 | 0.13 | 0.16 | 0.13 | | | | | | | | |
| 9/23/2015 | 1.14 | 0.76 | 0.95 | 0.71 | | | | | | | | |
| 10/6/2015 | 1.05 | 0.70 | 0.95 | 0.70 | | | | | | | | |
| 10/6/2015 | 0.44 | 0.29 | 0.35 | 0.31 | | | | | | | | |
| 10/9/2015 | 0.25 | 0.14 | 0.15 | 0.14 | | | | | 0.13 | 0.06 | 0.03 | 0.02 |
| 10/9/2015 | 0.53 | 0.34 | 0.42 | 0.33 | | | | | | | | |
| 10/13/2015 | 0.3 | 0.17 | 0.19 | 0.15 | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 10/13/2015 | 0.55 | 0.35 | 0.46 | 0.35 | | | | | | | | |
| 10/16/2015 | 0.3 | 0.16 | 0.15 | 0.13 | | | | | | | | |
| 10/19/2015 | 0.33 | 0.20 | 0.20 | 0.16 | | | | | | | | |
| 10/19/2015 | 0.93 | 0.61 | 0.84 | 0.61 | | | | | | | | |
| 10/19/2015 | 0.35 | 0.23 | 0.28 | 0.20 | | | | | | | | |
| 10/20/2015 | 0.26 | 0.17 | 0.19 | 0.16 | | | | | | | | |
| 10/21/2015 | 0.17 | 0.09 | 0.11 | 0.10 | | | | | | | | |
| 10/22/2015 | 0.24 | 0.15 | 0.17 | 0.15 | | | | | 0.15 | 0.08 | 0.06 | 0.04 |
| 10/22/2015 | 0.32 | 0.21 | 0.26 | 0.22 | | | | | | | | |
| 10/23/2015 | 0.28 | 0.17 | 0.21 | 0.18 | | | | | | | | |
| 10/23/2015 | 0.34 | 0.22 | 0.29 | 0.22 | | | | | | | | |
| 10/26/2015 | 0.36 | 0.22 | 0.30 | 0.22 | | | | | | | | |
| 10/28/2015 | 0.22 | 0.15 | 0.21 | 0.17 | | | | | 0.1 | 0.04 | 0.01 | 0.01 |
| 10/28/2015 | 0.27 | 0.18 | 0.15 | 0.14 | | | | | | | | |
| 10/29/2015 | 0.22 | 0.15 | 0.12 | 0.10 | | | | | | | | |
| 11/2/2015 | 0.21 | 0.16 | 0.09 | 0.07 | | | | | 0.17 | 0.08 | 0.09 | 0.06 |
| 11/3/2015 | | | | | | | | | | | | |
| 11/5/2015 | 0.28 | 0.18 | 0.18 | 0.17 | 0.45 | 0.29 | 0.37 | 0.29 | | | | |
| 11/9/2015 | 0.28 | 0.18 | 0.17 | 0.16 | | | | | 0.13 | 0.06 | 0.05 | 0.04 |
| 11/11/2015 | 0.22 | 0.13 | 0.11 | 0.09 | 0.76 | 0.49 | 0.69 | 0.50 | | | | |
| 11/13/2015 | 0.22 | 0.14 | 0.12 | 0.12 | | | | | | | | |
| 11/13/2015 | 0.42 | 0.27 | 0.23 | 0.20 | | | | | | | | |
| 11/16/2015 | 0.34 | 0.22 | 0.16 | 0.13 | | | | | 0.13 | 0.06 | 0.04 | 0.03 |
| 11/17/2015 | | | | | | | | | | | | |
| 11/18/2015 | 0.43 | 0.31 | 0.29 | 0.24 | 0.77 | 0.49 | 0.68 | 0.48 | | | | |
| 11/23/2015 | 0.33 | 0.22 | 0.20 | 0.16 | | | | | 0.12 | 0.04 | 0.03 | 0.02 |
| 11/25/2015 | 0.35 | 0.24 | 0.21 | 0.19 | 0.75 | 0.47 | 0.65 | 0.47 | | | | |
| 11/30/2015 | 0.44 | 0.30 | 0.33 | 0.25 | | | | | 0.11 | 0.03 | 0.03 | 0.01 |
| 12/1/2015 | | | | | | | | | | | | |
| 12/3/2015 | 0.24 | 0.16 | 0.10 | 0.10 | 0.70 | 0.46 | 0.63 | 0.43 | | | | |
| 12/4/2015 | 0.38 | 0.27 | 0.27 | 0.22 | | | | | | | | |
| 12/7/2015 | 0.25 | 0.18 | 0.12 | 0.10 | | | | | 0.12 | 0.04 | 0.03 | 0.02 |
| 12/12/2015 | 0.28 | 0.18 | 0.16 | 0.13 | 0.66 | 0.43 | 0.60 | 0.42 | | | | |
| 12/14/2015 | 0.25 | 0.16 | 0.11 | 0.10 | | | | | 0.12 | 0.05 | 0.02 | 0.02 |
| 12/16/2015 | 0.59 | 0.42 | 0.46 | 0.38 | | | | | | | | |
| 12/17/2015 | 0.29 | 0.21 | 0.14 | 0.12 | 0.73 | 0.48 | 0.62 | 0.44 | | | | |
| 1/6/2016 | 0.45 | 0.33 | 0.35 | 0.28 | | | | | 0.07 | 0.01 | 0.01 | 0.01 |
| 1/7/2016 | | | | | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| R6 | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 1/8/2016 | 0.30 | 0.21 | 0.20 | 0.17 | 0.70 | 0.44 | 0.62 | 0.45 | | | | |
| 1/11/2016 | 0.48 | 0.34 | 0.36 | 0.31 | | | | | | | | |
| 1/12/2016 | 0.41 | 0.30 | 0.29 | 0.23 | | | | | 0.09 | 0.02 | 0.02 | 0.01 |
| 1/13/2016 | 0.35 | 0.24 | 0.27 | 0.20 | 0.74 | 0.49 | 0.65 | 0.45 | | | | |
| 1/14/2016 | | | | | | | | | | | | |
| 1/15/2016 | 0.62 | 0.45 | 0.46 | 0.41 | | | | | | | | |
| 1/18/2016 | 0.43 | 0.30 | 0.28 | 0.23 | 0.78 | 0.50 | 0.72 | 0.52 | 0.11 | 0.02 | 0.02 | 0.01 |
| 1/19/2016 | | | | | | | | | | | | |
| 1/22/2016 | 0.39 | 0.26 | 0.24 | 0.22 | | | | | | | | |
| 1/22/2016 | 0.43 | 0.30 | 0.26 | 0.23 | | | | | | | | |
| 1/25/2016 | 0.32 | 0.22 | 0.14 | 0.12 | 0.82 | 0.52 | 0.71 | 0.49 | | | | |
| 1/26/2016 | | | | | | | | | | | | |
| 1/27/2016 | 0.32 | 0.23 | 0.18 | 0.16 | | | | | 0.12 | 0.04 | 0.02 | 0.01 |
| 1/27/2016 | 0.43 | 0.32 | 0.27 | 0.24 | | | | | | | | |
| 2/1/2016 | 0.36 | 0.24 | 0.20 | 0.16 | 0.91 | 0.60 | 0.80 | 0.57 | 0.11 | 0.02 | 0.01 | 0.01 |
| 2/3/2016 | 0.50 | 0.35 | 0.36 | 0.33 | | | | | | | | |
| 2/5/2016 | | | | | | | | | | | | |
| 2/8/2016 | 0.3 | 0.19 | 0.18 | 0.14 | 0.95 | 0.63 | 0.88 | 0.64 | 0.12 | 0.04 | 0.01 | 0.01 |
| 2/10/2016 | | | | | | | | | | | | |
| 2/11/2016 | 0.40 | 0.29 | 0.29 | 0.26 | | | | | | | | |
| 2/15/2016 | 0.24 | 0.16 | 0.14 | 0.11 | 0.87 | 0.58 | 0.80 | 0.54 | 0.09 | 0.02 | 0.01 | 0.01 |
| 2/16/2016 | | | | | | | | | | | | |
| 2/18/2016 | 0.38 | 0.26 | 0.28 | 0.23 | | | | | | | | |
| 2/22/2016 | 0.24 | 0.16 | 0.13 | 0.10 | 0.90 | 0.60 | 0.83 | 0.56 | 0.11 | 0.04 | 0.02 | 0.01 |
| 2/23/2016 | | | | | | | | | | | | |
| 2/26/2016 | 0.29 | 0.20 | 0.19 | 0.18 | | | | | | | | |
| 2/26/2016 | 0.45 | 0.32 | 0.33 | 0.28 | | | | | | | | |
| 2/29/2016 | 0.40 | 0.27 | 0.28 | 0.20 | 0.90 | 0.60 | 0.83 | 0.57 | | | | |
| 3/1/2016 | | | | | | | | | | | | |
| 3/2/2016 | 0.36 | 0.25 | 0.21 | 0.17 | | | | | 0.11 | 0.05 | 0.03 | 0.01 |
| 3/4/2016 | 0.47 | 0.33 | 0.36 | 0.31 | | | | | | | | |
| 3/7/2016 | 0.30 | 0.20 | 0.18 | 0.15 | 0.95 | 0.63 | 0.87 | 0.59 | | | | |
| 3/8/2016 | | | | | | | | | | | | |
| 3/9/2016 | 0.29 | 0.21 | 0.16 | 0.13 | | | | | 0.10 | 0.03 | 0.01 | 0.01 |
| 3/12/2016 | 0.37 | 0.25 | 0.27 | 0.25 | | | | | | | | |
| 3/12/2016 | 0.37 | 0.26 | 0.26 | 0.23 | | | | | | | | |
| 3/14/2016 | 0.31 | 0.22 | 0.21 | 0.19 | 0.94 | 0.62 | 0.88 | 0.59 | 0.10 | 0.04 | 0.01 | 0.01 |
| 3/15/2016 | | | | | | | | | | | | |

Table 23 (Cont.). Solid Content of Streams in R6.

| **R6** | Solid content (% wet basis) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feed | | | | Retained Solids | | | | Decant | | | |
| date | TS | VS | TSS | VSS | TS | VS | TSS | VSS | TS | VS | TSS | VSS |
| 3/19/2016 | 0.29 | 0.20 | 0.17 | 0.15 | | | | | | | | |
| 3/19/2016 | 0.39 | 0.28 | 0.28 | 0.21 | | | | | | | | |
| 3/22/2016 | | | | | | | | | | | | |
| 3/24/2016 | 0.40 | 0.29 | 0.33 | 0.27 | | | | | | | | |
| 3/25/2016 | 0.28 | 0.20 | 0.22 | 0.20 | 1.15 | 0.78 | 1.08 | 0.73 | 0.12 | 0.05 | 0.03 | 0.02 |

# APPENDIX V: DATA FOR BIOGAS PRODUCTION

Table 24. Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 7/1/2014 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8/9/2014 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 7/2/2014 | 0.0 | 1.0 | 0.8 | 0.3 | 0.2 | 0.0 | 8/10/2014 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 7/3/2014 | 0.0 | 1.0 | 0.6 | 0.3 | 0.1 | 0.3 | 8/11/2014 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7/4/2014 | 0.0 | 1.0 | 0.6 | 0.3 | 0.0 | 0.3 | 8/12/2014 | 0.1 | 0.2 | 0.1 | 0.0 | 0.1 | 0.1 |
| 7/5/2014 | 0.0 | 1.0 | 0.6 | 0.3 | 0.0 | 0.3 | 8/13/2014 | 0.4 | 0.6 | 0.4 | 0.0 | 0.3 | 0.2 |
| 7/6/2014 | 0.0 | 1.0 | 0.6 | 0.3 | 0.0 | 0.3 | 8/14/2014 | 0.4 | 0.8 | 0.4 | 0.0 | 0.3 | 0.4 |
| 7/7/2014 | 0.0 | 1.0 | 0.5 | 0.3 | 0.2 | 0.3 | 8/15/2014 | 0.6 | 0.7 | 0.4 | 0.2 | 0.1 | 0.2 |
| 7/8/2014 | 0.0 | 2.4 | 1.6 | 1.3 | 0.8 | 1.2 | 8/16/2014 | 0.6 | 0.7 | 0.4 | 0.2 | 0.1 | 0.2 |
| 7/9/2014 | 0.0 | 2.5 | 1.9 | 1.5 | 1.7 | 1.8 | 8/17/2014 | 0.6 | 0.7 | 0.4 | 0.2 | 0.1 | 0.2 |
| 7/10/2014 | 0.0 | 4.2 | 1.5 | 1.2 | 0.8 | 1.4 | 8/18/2014 | 0.2 | 0.7 | 0.3 | 0.1 | 0.2 | 0.4 |
| 7/11/2014 | 0.0 | 1.8 | 1.0 | 1.0 | 1.3 | 1.3 | 8/19/2014 | 0.4 | 0.5 | 0.4 | 0.1 | 0.1 | 0.2 |
| 7/12/2014 | 0.0 | 1.8 | 1.0 | 1.0 | 1.3 | 1.3 | 8/20/2014 | 0.3 | 0.2 | 0.2 | 0.0 | 0.0 | 0.2 |
| 7/13/2014 | 0.0 | 1.8 | 1.0 | 1.0 | 1.3 | 1.3 | 8/21/2014 | 0.4 | 0.5 | 0.3 | 0.0 | 0.0 | 0.1 |
| 7/14/2014 | 0.0 | 0.6 | 0.4 | 0.6 | 0.5 | 0.7 | 8/22/2014 | 0.5 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| 7/15/2014 | 0.6 | 1.3 | 0.7 | 0.5 | 0.2 | 0.6 | 8/23/2014 | 0.5 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| 7/16/2014 | 0.6 | 0.0 | 0.0 | 0.9 | 0.6 | 1.1 | 8/24/2014 | 0.5 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| 7/17/2014 | 0.5 | 0.0 | 0.0 | 1.2 | 0.0 | 0.9 | 8/25/2014 | 0.6 | 0.4 | 0.2 | 0.5 | 0.0 | 0.0 |
| 7/18/2014 | 0.3 | 1.1 | 0.7 | 0.7 | 0.3 | 0.6 | 8/26/2014 | 0.4 | 0.6 | 0.4 | 0.6 | 0.1 | 0.1 |
| 7/19/2014 | 0.3 | 1.1 | 0.7 | 0.7 | 0.3 | 0.6 | 8/27/2014 | 0.1 | 0.2 | 0.1 | 0.2 | 0.0 | 0.0 |
| 7/20/2014 | 0.3 | 1.1 | 0.7 | 0.7 | 0.3 | 0.6 | 8/28/2014 | 0.4 | 0.4 | 0.1 | 0.3 | 0.0 | 0.0 |
| 7/21/2014 | 0.2 | 1.0 | 0.6 | 0.2 | 0.1 | 0.4 | 8/29/2014 | 1.0 | 0.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| 7/22/2014 | 0.3 | 0.9 | 0.6 | 0.2 | 0.2 | 0.4 | 8/30/2014 | 1.0 | 0.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| 7/23/2014 | 0.4 | 0.6 | 0.5 | 0.0 | 0.0 | 0.3 | 8/31/2014 | 1.0 | 0.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| 7/24/2014 | 0.5 | 0.7 | 0.7 | 0.1 | 0.0 | 0.2 | 9/1/2014 | 1.0 | 0.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| 7/25/2014 | 0.3 | 0.7 | 0.4 | 0.0 | 0.0 | 0.3 | 9/2/2014 | 0.7 | 0.4 | 0.1 | 0.0 | 0.0 | 0.2 |
| 7/26/2014 | 0.4 | 0.7 | 0.4 | 0.0 | 0.1 | 0.3 | 9/3/2014 | 0.7 | 0.5 | 0.2 | 0.0 | 0.0 | 0.2 |
| 7/27/2014 | 0.5 | 0.6 | 0.4 | 0.0 | 0.0 | 0.2 | 9/4/2014 | 0.4 | 0.3 | 0.1 | 0.0 | 0.0 | 0.1 |
| 7/28/2014 | 0.7 | 0.8 | 0.5 | 0.1 | 0.1 | 0.4 | 9/5/2014 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.1 |
| 7/29/2014 | 0.9 | 1.0 | 0.7 | 0.2 | 0.5 | 0.5 | 9/6/2014 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.1 |
| 7/30/2014 | 0.6 | 0.6 | 0.5 | 0.1 | 0.2 | 0.2 | 9/7/2014 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 0.1 |
| 7/31/2014 | 0.4 | 0.7 | 0.4 | 0.0 | 0.2 | 0.1 | 9/8/2014 | 0.6 | 0.4 | 0.1 | 0.1 | 0.0 | 0.3 |
| 8/1/2014 | 0.4 | 0.6 | 1.0 | 1.8 | 0.1 | 0.2 | 9/9/2014 | 1.2 | 0.9 | 1.0 | 1.6 | 0.0 | 1.8 |
| 8/2/2014 | 0.4 | 0.6 | 1.0 | 1.8 | 0.1 | 0.2 | 9/10/2014 | 0.6 | 0.6 | 0.0 | 0.1 | 0.0 | 0.3 |
| 8/3/2014 | 0.4 | 0.6 | 1.0 | 1.8 | 0.1 | 0.2 | 9/11/2014 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.1 |
| 8/4/2014 | 0.3 | 0.5 | 1.1 | 2.1 | 0.1 | 0.1 | 9/12/2014 | 0.4 | 0.4 | 0.0 | 0.0 | 0.0 | 0.1 |
| 8/5/2014 | 0.2 | 0.4 | 0.3 | 0.1 | 0.0 | 0.2 | 9/13/2014 | 0.7 | 0.8 | 0.2 | 0.0 | 0.0 | 0.4 |
| 8/6/2014 | 0.3 | 0.5 | 0.4 | 0.0 | 0.1 | 0.0 | 9/14/2014 | 0.9 | 0.8 | 0.1 | 0.0 | 0.0 | 0.3 |
| 8/7/2014 | 0.2 | 0.4 | 0.3 | 0.0 | 0.0 | 0.1 | 9/15/2014 | 0.8 | 0.6 | 3.4 | 0.0 | 0.2 | 0.2 |
| 8/8/2014 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 9/16/2014 | 1.1 | 0.8 | 2.6 | 0.5 | 0.0 | 0.0 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 |
| 9/17/2014 | 0.8 | 0.6 | 0.6 | 0.2 | 0.0 | 0.0 |
| 9/18/2014 | 0.6 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| 9/19/2014 | 0.6 | 0.7 | 0.1 | 0.3 | 0.3 | 0.1 |
| 9/20/2014 | 0.3 | 0.4 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/21/2014 | 0.3 | 0.4 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/22/2014 | 0.4 | 0.5 | 0.0 | 0.1 | 0.2 | 0.0 |
| 9/23/2014 | 0.4 | 0.4 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/24/2014 | 0.3 | 0.4 | 0.0 | 0.1 | 0.0 | 0.0 |
| 9/25/2014 | 0.4 | 0.5 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/26/2014 | 0.4 | 0.5 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/27/2014 | 0.4 | 0.5 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/28/2014 | 0.4 | 0.5 | 0.0 | 0.1 | 0.1 | 0.0 |
| 9/29/2014 | 0.4 | 0.5 | 0.0 | 0.2 | 0.2 | 0.0 |
| 9/30/2014 | 0.5 | 0.6 | 0.0 | 0.2 | 0.1 | 0.1 |
| 10/1/2014 | 0.4 | 0.4 | 0.0 | 0.0 | 0.1 | 0.0 |
| 10/2/2014 | 1.1 | 1.2 | 0.1 | 0.0 | 0.7 | 0.3 |
| 10/3/2014 | 2.0 | 2.1 | 0.4 | 0.4 | 1.5 | 1.1 |
| 10/4/2014 | 2.5 | 2.3 | 0.6 | 0.9 | 1.5 | 1.2 |
| 10/5/2014 | 2.6 | 2.3 | 0.7 | 1.0 | 1.5 | 1.3 |
| 10/6/2014 | 3.1 | 2.5 | 1.0 | 1.1 | 1.7 | 1.4 |
| 10/7/2014 | 1.4 | 1.6 | 0.4 | 0.3 | 1.1 | 0.9 |
| 10/8/2014 | 1.4 | 1.7 | 0.3 | 0.6 | 1.1 | 0.9 |
| 10/9/2014 | 1.5 | 1.4 | 0.2 | 0.4 | 1.0 | 0.7 |
| 10/10/2014 | 1.6 | 1.2 | 0.3 | 0.2 | 1.1 | 0.8 |
| 10/11/2014 | 1.6 | 1.2 | 0.3 | 0.2 | 1.1 | 0.8 |
| 10/12/2014 | 1.6 | 1.2 | 0.3 | 0.2 | 1.1 | 0.8 |
| 10/13/2014 | 0.9 | 0.7 | 0.0 | 0.0 | 0.7 | 0.4 |
| 10/14/2014 | 0.9 | 0.8 | 0.0 | 0.2 | 0.8 | 0.5 |
| 10/15/2014 | 1.9 | 1.4 | 0.4 | 1.3 | 1.2 | 0.9 |
| 10/16/2014 | 1.7 | 1.5 | 0.3 | 0.4 | 1.2 | 0.8 |
| 10/17/2014 | 1.6 | 1.3 | 0.2 | 0.3 | 1.1 | 0.8 |
| 10/18/2014 | 1.6 | 1.2 | 0.2 | 0.3 | 1.1 | 0.8 |
| 10/19/2014 | 1.6 | 1.2 | 0.2 | 0.3 | 1.1 | 0.8 |
| 10/20/2014 | 1.5 | 1.1 | 0.1 | 0.3 | 1.1 | 0.8 |
| 10/21/2014 | 1.0 | 1.0 | 0.4 | 1.6 | 0.9 | 0.6 |
| 10/22/2014 | 1.3 | 0.8 | 0.1 | 0.1 | 0.8 | 0.4 |
| 10/23/2014 | 1.2 | 1.0 | 0.1 | 0.4 | 0.8 | 0.6 |
| 10/24/2014 | 0.9 | 0.8 | 0.0 | 0.5 | 0.9 | 0.5 |
| 10/25/2014 | 0.9 | 0.8 | 0.0 | 0.5 | 0.9 | 0.5 |

| | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 |
| 10/26/2014 | 0.9 | 0.8 | 0.0 | 0.5 | 0.9 | 0.5 |
| 10/27/2014 | 0.2 | 0.2 | 0.0 | 0.0 | 0.6 | 0.1 |
| 10/28/2014 | 0.3 | 0.3 | 0.0 | 0.4 | 0.6 | 0.1 |
| 10/29/2014 | 1.5 | 1.1 | 0.1 | 0.8 | 1.1 | 0.6 |
| 10/30/2014 | 1.2 | 1.0 | 0.2 | 1.6 | 1.1 | 1.1 |
| 10/31/2014 | 0.9 | 0.7 | 0.0 | 0.8 | 0.3 | 0.3 |
| 11/1/2014 | 0.9 | 0.7 | 0.0 | 0.8 | 0.3 | 0.2 |
| 11/2/2014 | 0.9 | 0.7 | 0.0 | 0.8 | 0.3 | 0.2 |
| 11/3/2014 | 0.6 | 0.3 | 0.3 | 2.5 | 1.0 | 1.3 |
| 11/4/2014 | 0.8 | 0.9 | 0.0 | 0.7 | 0.2 | 0.2 |
| 11/5/2014 | 1.9 | 1.8 | 0.0 | 1.8 | 0.7 | 0.7 |
| 11/6/2014 | 0.9 | 1.0 | 0.0 | 0.4 | 0.7 | 0.7 |
| 11/7/2014 | 2.0 | 1.9 | 0.1 | 1.5 | 1.0 | 0.8 |
| 11/8/2014 | 2.0 | 1.9 | 0.1 | 1.5 | 1.0 | 0.8 |
| 11/9/2014 | 2.0 | 1.9 | 0.1 | 1.5 | 1.0 | 0.8 |
| 11/10/2014 | 2.9 | 2.8 | 0.1 | 2.1 | 0.5 | 0.5 |
| 11/11/2014 | 0.3 | 1.8 | 0.0 | 0.2 | 0.8 | 0.6 |
| 11/12/2014 | 0.3 | 2.5 | 0.0 | 1.3 | 0.8 | 0.7 |
| 11/13/2014 | 0.6 | 3.1 | 0.0 | 0.5 | 1.0 | 0.9 |
| 11/14/2014 | 2.7 | 3.2 | 0.0 | 1.0 | 0.9 | 0.7 |
| 11/15/2014 | 2.7 | 3.2 | 0.0 | 1.0 | 0.9 | 0.7 |
| 11/16/2014 | 2.7 | 3.2 | 0.0 | 1.0 | 0.9 | 0.7 |
| 11/17/2014 | 0.3 | 2.3 | 0.0 | 1.8 | 1.5 | 1.0 |
| 11/18/2014 | 3.6 | 2.7 | 0.0 | 1.4 | 1.6 | 1.2 |
| 11/19/2014 | 0.5 | 2.9 | 0.4 | 2.0 | 1.1 | 0.0 |
| 11/20/2014 | 0.0 | 3.9 | 0.0 | 1.7 | 1.4 | 0.5 |
| 11/21/2014 | 0.6 | 3.5 | 0.1 | 1.9 | 1.4 | 0.2 |
| 11/22/2014 | 0.7 | 3.5 | 0.1 | 1.9 | 1.3 | 0.2 |
| 11/23/2014 | 0.7 | 3.5 | 0.1 | 1.9 | 1.3 | 0.2 |
| 11/24/2014 | 1.6 | 3.5 | 0.0 | 3.1 | 1.3 | 2.5 |
| 11/25/2014 | 2.9 | 4.5 | 0.1 | 1.1 | 1.8 | 1.8 |
| 11/26/2014 | 2.3 | 3.7 | 0.0 | 1.7 | 1.3 | 0.9 |
| 11/27/2014 | 2.3 | 3.7 | 0.0 | 1.7 | 1.3 | 0.9 |
| 11/28/2014 | 2.3 | 3.7 | 0.0 | 1.7 | 1.3 | 0.9 |
| 11/29/2014 | 2.3 | 3.7 | 0.0 | 1.7 | 1.3 | 0.9 |
| 11/30/2014 | 2.3 | 3.7 | 0.0 | 1.7 | 1.3 | 0.9 |
| 12/1/2014 | 2.4 | 4.0 | 0.6 | 2.9 | 1.9 | 1.6 |
| 12/2/2014 | 4.0 | 4.3 | 0.1 | 0.8 | 2.1 | 2.0 |
| 12/3/2014 | 0.8 | 1.9 | 0.6 | 3.8 | 1.9 | 0.7 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 12/4/2014 | 2.0 | 3.0 | 0.0 | 1.0 | 2.3 | 1.5 | 1/12/2015 | 0.6 | 0.2 | 0.0 | 0.0 | 1.0 | 1.1 |
| 12/5/2014 | 1.8 | 3.4 | 0.5 | 2.6 | 2.1 | 1.8 | 1/13/2015 | 1.2 | 0.8 | 0.0 | 2.0 | 1.4 | 1.5 |
| 12/6/2014 | 1.8 | 3.4 | 0.5 | 2.6 | 2.1 | 1.8 | 1/14/2015 | 2.4 | 1.3 | 0.1 | 2.8 | 1.3 | 1.4 |
| 12/7/2014 | 1.8 | 3.4 | 0.5 | 2.6 | 2.1 | 1.8 | 1/15/2015 | 1.3 | 0.7 | 0.1 | 2.8 | 1.3 | 1.5 |
| 12/8/2014 | 2.9 | 5.1 | 1.8 | 4.8 | 2.8 | 2.6 | 1/16/2015 | 0.8 | 0.4 | 0.0 | 2.6 | 1.1 | 1.1 |
| 12/9/2014 | 6.2 | 7.4 | 2.9 | 4.8 | 4.5 | 4.6 | 1/17/2015 | 0.8 | 0.4 | 0.0 | 2.6 | 1.1 | 1.1 |
| 12/10/2014 | 8.9 | 8.9 | 5.8 | 9.2 | 4.5 | 5.6 | 1/18/2015 | 0.8 | 0.4 | 0.0 | 2.6 | 1.1 | 1.1 |
| 12/11/2014 | 7.7 | 8.2 | 4.2 | 6.6 | 5.4 | 5.1 | 1/19/2015 | 0.8 | 0.4 | 0.0 | 2.6 | 1.1 | 1.1 |
| 12/12/2014 | 7.3 | 7.7 | 5.0 | 8.2 | 5.3 | 4.8 | 1/20/2015 | 0.6 | 0.1 | 0.0 | 2.3 | 0.8 | 1.0 |
| 12/13/2014 | 7.2 | 7.7 | 5.0 | 8.3 | 5.3 | 4.8 | 1/21/2015 | 0.6 | 0.2 | 0.0 | 1.8 | 1.0 | 0.7 |
| 12/14/2014 | 7.2 | 7.7 | 5.0 | 8.3 | 5.3 | 4.8 | 1/22/2015 | 0.5 | 0.2 | 0.0 | 2.2 | 0.9 | 0.9 |
| 12/15/2014 | 5.1 | 5.9 | 4.3 | 7.1 | 4.5 | 3.7 | 1/23/2015 | 0.1 | 0.4 | 0.0 | 2.6 | 1.2 | 0.7 |
| 12/16/2014 | 5.6 | 6.2 | 2.8 | 4.2 | 4.3 | 3.8 | 1/24/2015 | 0.1 | 0.4 | 0.0 | 2.6 | 1.2 | 0.7 |
| 12/17/2014 | 5.3 | 5.7 | 3.7 | 6.5 | 3.8 | 3.3 | 1/25/2015 | 0.1 | 0.4 | 0.0 | 2.6 | 1.2 | 0.7 |
| 12/18/2014 | 4.5 | 5.3 | 2.8 | 4.3 | 4.0 | 3.1 | 1/26/2015 | 0.2 | 0.3 | 0.0 | 2.4 | 1.1 | 0.9 |
| 12/19/2014 | 3.5 | 4.2 | 2.4 | 4.4 | 3.2 | 2.9 | 1/27/2015 | 0.3 | 0.4 | 0.2 | 2.7 | 1.2 | 1.2 |
| 12/20/2014 | 3.3 | 4.0 | 2.3 | 4.4 | 3.1 | 2.8 | 1/28/2015 | 0.7 | 1.4 | 0.1 | 2.1 | 0.9 | 0.9 |
| 12/21/2014 | 3.3 | 4.0 | 2.3 | 4.4 | 3.1 | 2.8 | 1/29/2015 | 0.8 | 1.6 | 0.0 | 2.3 | 1.3 | 1.2 |
| 12/22/2014 | 3.8 | 4.8 | 3.2 | 5.8 | 3.1 | 2.4 | 1/30/2015 | 0.9 | 1.4 | 0.0 | 2.2 | 1.4 | 1.0 |
| 12/23/2014 | 3.4 | 4.6 | 1.2 | 2.5 | 2.9 | 2.3 | 1/31/2015 | 0.9 | 1.4 | 0.0 | 2.2 | 1.4 | 1.0 |
| 12/24/2014 | 3.4 | 3.0 | 1.9 | 4.1 | 2.2 | 1.7 | 2/1/2015 | 0.9 | 1.4 | 0.0 | 2.2 | 1.4 | 1.0 |
| 12/25/2014 | 3.4 | 2.9 | 2.0 | 4.2 | 2.1 | 1.6 | 2/2/2015 | 1.0 | 1.6 | 0.3 | 2.2 | 1.1 | 0.0 |
| 12/26/2014 | 2.5 | 3.7 | 1.8 | 3.9 | 1.9 | 1.3 | 2/3/2015 | 0.8 | 1.5 | 0.2 | 2.2 | 1.1 | 0.7 |
| 12/27/2014 | 2.5 | 3.7 | 1.8 | 3.9 | 1.9 | 1.3 | 2/4/2015 | 0.9 | 1.2 | 0.6 | 2.5 | 1.1 | 0.9 |
| 12/28/2014 | 2.5 | 3.7 | 1.8 | 3.9 | 1.9 | 1.3 | 2/5/2015 | 1.9 | 2.6 | 2.0 | 3.9 | 1.9 | 1.8 |
| 12/29/2014 | 2.5 | 3.6 | 1.1 | 3.1 | 1.6 | 1.2 | 2/6/2015 | 2.1 | 2.5 | 1.6 | 3.6 | 1.8 | 1.8 |
| 12/30/2014 | 2.4 | 3.6 | 1.0 | 3.0 | 1.6 | 1.2 | 2/7/2015 | 2.1 | 2.5 | 1.6 | 3.6 | 1.8 | 1.8 |
| 12/31/2014 | 3.3 | 3.4 | 0.3 | 0.5 | 1.4 | 1.5 | 2/8/2015 | 2.1 | 2.5 | 1.6 | 3.6 | 1.8 | 1.8 |
| 1/1/2015 | 3.4 | 3.4 | 0.3 | 0.4 | 1.4 | 1.5 | 2/9/2015 | 0.6 | 2.4 | 1.3 | 3.3 | 1.6 | 1.0 |
| 1/2/2015 | 3.4 | 3.4 | 0.3 | 0.4 | 1.4 | 1.5 | 2/10/2015 | 1.0 | 2.1 | 1.3 | 3.4 | 1.6 | 1.6 |
| 1/3/2015 | 3.4 | 3.4 | 0.3 | 0.4 | 1.4 | 1.5 | 2/11/2015 | 0.6 | 1.6 | 0.6 | 2.7 | 1.2 | 1.6 |
| 1/4/2015 | 3.4 | 3.4 | 0.3 | 0.4 | 1.4 | 1.5 | 2/12/2015 | 1.1 | 2.1 | 1.2 | 3.3 | 1.6 | 1.9 |
| 1/5/2015 | 2.5 | 2.7 | 0.1 | 0.2 | 1.1 | 1.3 | 2/13/2015 | 1.0 | 2.7 | 0.8 | 3.0 | 1.3 | 1.7 |
| 1/6/2015 | 1.0 | 2.0 | 0.0 | 0.0 | 1.1 | 0.8 | 2/14/2015 | 0.9 | 2.7 | 0.7 | 2.9 | 1.3 | 1.7 |
| 1/7/2015 | 1.1 | 2.5 | 0.0 | 0.0 | 1.0 | 1.3 | 2/15/2015 | 0.9 | 2.7 | 0.7 | 2.9 | 1.3 | 1.7 |
| 1/8/2015 | 1.0 | 2.0 | 0.0 | 0.0 | 0.7 | 0.8 | 2/16/2015 | 0.7 | 2.3 | 0.4 | 2.6 | 1.1 | 1.5 |
| 1/9/2015 | 1.5 | 0.7 | 0.0 | 0.0 | 1.1 | 1.2 | 2/17/2015 | 0.4 | 1.5 | 0.2 | 2.0 | 0.8 | 1.0 |
| 1/10/2015 | 1.5 | 0.7 | 0.0 | 0.0 | 1.1 | 1.2 | 2/18/2015 | 0.3 | 1.8 | 0.1 | 1.6 | 0.6 | 0.9 |
| 1/11/2015 | 1.5 | 0.7 | 0.0 | 0.0 | 1.1 | 1.2 | 2/19/2015 | 1.3 | 3.4 | 1.0 | 3.2 | 1.7 | 1.6 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 2/20/2015 | 2.3 | 5.3 | 2.0 | 4.5 | 3.0 | 2.6 | 3/31/2015 | 2.0 | 5.6 | 2.4 | 6.7 | 2.0 | 3.8 |
| 2/21/2015 | 2.3 | 5.3 | 2.0 | 4.5 | 3.0 | 2.6 | 4/1/2015 | 2.0 | 5.4 | 2.2 | 5.8 | 1.8 | 3.6 |
| 2/22/2015 | 2.3 | 5.3 | 2.0 | 4.5 | 3.0 | 2.6 | 4/2/2015 | 2.3 | 5.6 | 2.3 | 6.9 | 2.1 | 3.4 |
| 2/23/2015 | 1.9 | 3.3 | 0.4 | 4.4 | 4.0 | 3.0 | 4/3/2015 | 3.9 | 7.9 | 3.1 | 7.9 | 2.7 | 4.8 |
| 2/24/2015 | 1.1 | 2.1 | 0.1 | 4.3 | 2.9 | 2.4 | 4/4/2015 | 3.9 | 7.9 | 3.1 | 7.9 | 2.7 | 4.8 |
| 2/25/2015 | 0.8 | 3.3 | 0.3 | 5.2 | 2.6 | 1.9 | 4/5/2015 | 3.9 | 7.9 | 3.1 | 7.9 | 2.7 | 4.8 |
| 2/26/2015 | 1.1 | 1.8 | 0.1 | 4.3 | 1.7 | 1.3 | 4/6/2015 | 3.3 | 7.2 | 3.3 | 8.8 | 2.8 | 5.5 |
| 2/27/2015 | 1.1 | 2.3 | 0.1 | 4.2 | 1.2 | 0.4 | 4/7/2015 | 4.0 | 8.4 | 3.5 | 9.3 | 3.2 | 5.6 |
| 2/28/2015 | 1.1 | 2.3 | 0.1 | 4.2 | 1.2 | 0.4 | 4/8/2015 | 3.6 | 7.6 | 3.3 | 8.9 | 2.8 | 5.1 |
| 3/1/2015 | 1.1 | 2.3 | 0.1 | 4.2 | 1.2 | 0.4 | 4/9/2015 | 3.1 | 6.5 | 2.8 | 7.7 | 2.4 | 4.5 |
| 3/2/2015 | 0.8 | 1.9 | 0.1 | 4.1 | 1.2 | 4.9 | 4/10/2015 | 3.5 | 7.1 | 3.0 | 7.7 | 3.7 | 4.0 |
| 3/3/2015 | 0.9 | 2.3 | 0.9 | 4.0 | 1.2 | 3.9 | 4/11/2015 | 3.5 | 7.1 | 3.0 | 7.7 | 3.7 | 4.0 |
| 3/4/2015 | 0.4 | 1.4 | 0.6 | 2.8 | 0.8 | 2.2 | 4/12/2015 | 3.5 | 7.1 | 3.0 | 7.7 | 3.7 | 4.0 |
| 3/5/2015 | 1.0 | 2.2 | 1.0 | 3.7 | 1.2 | 2.6 | 4/13/2015 | 2.6 | 5.8 | 2.6 | 7.5 | 3.3 | 3.6 |
| 3/6/2015 | 0.9 | 2.3 | 1.1 | 4.2 | 1.2 | 3.0 | 4/14/2015 | 4.1 | 7.8 | 3.2 | 8.0 | 3.6 | 3.3 |
| 3/7/2015 | 1.0 | 2.4 | 1.2 | 4.3 | 1.3 | 3.7 | 4/15/2015 | 3.6 | 7.7 | 2.8 | 7.4 | 3.0 | 3.8 |
| 3/8/2015 | 1.0 | 2.4 | 1.2 | 4.3 | 1.3 | 3.8 | 4/16/2015 | 3.5 | 7.2 | 2.7 | 7.6 | 3.4 | 4.6 |
| 3/9/2015 | 0.7 | 2.0 | 1.1 | 3.5 | 1.1 | 3.5 | 4/17/2015 | 3.8 | 7.6 | 2.9 | 7.5 | 3.4 | 5.2 |
| 3/10/2015 | 0.7 | 1.8 | 1.1 | 4.0 | 1.0 | 2.8 | 4/18/2015 | 3.8 | 7.6 | 2.9 | 7.5 | 3.4 | 5.2 |
| 3/11/2015 | 0.8 | 1.9 | 1.2 | 4.0 | 1.0 | 2.8 | 4/19/2015 | 3.8 | 7.6 | 2.9 | 7.5 | 3.4 | 5.2 |
| 3/12/2015 | 0.8 | 1.6 | 0.9 | 3.0 | 0.5 | 1.5 | 4/20/2015 | 2.1 | 5.8 | 2.4 | 6.5 | 2.7 | 4.5 |
| 3/13/2015 | 0.4 | 1.7 | 0.8 | 2.1 | 0.9 | 2.0 | 4/21/2015 | 2.9 | 6.0 | 2.5 | 6.7 | 2.8 | 4.6 |
| 3/14/2015 | 0.3 | 1.7 | 0.8 | 2.1 | 0.9 | 2.0 | 4/22/2015 | 2.2 | 4.7 | 2.0 | 5.4 | 2.1 | 4.2 |
| 3/15/2015 | 0.3 | 1.7 | 0.8 | 2.1 | 0.9 | 2.0 | 4/23/2015 | 2.9 | 5.6 | 2.4 | 6.1 | 2.6 | 4.2 |
| 3/16/2015 | 0.5 | 2.6 | 1.5 | 2.7 | 1.5 | 2.8 | 4/24/2015 | 1.7 | 3.8 | 1.7 | 4.4 | 1.7 | 3.3 |
| 3/17/2015 | 0.6 | 2.1 | 0.9 | 2.3 | 1.1 | 2.4 | 4/25/2015 | 1.7 | 3.8 | 1.7 | 4.4 | 1.7 | 3.3 |
| 3/18/2015 | 1.9 | 1.9 | 1.0 | 2.0 | 1.0 | 2.7 | 4/26/2015 | 1.7 | 3.8 | 1.7 | 4.4 | 1.7 | 3.3 |
| 3/19/2015 | 1.4 | 3.6 | 0.9 | 3.3 | 1.8 | 3.7 | 4/27/2015 | 1.6 | 3.4 | 1.3 | 3.7 | 1.5 | 3.1 |
| 3/20/2015 | 1.4 | 3.2 | 0.9 | 3.6 | 2.0 | 3.4 | 4/28/2015 | 1.9 | 3.6 | 1.5 | 4.3 | 1.8 | 3.1 |
| 3/21/2015 | 1.4 | 3.2 | 0.9 | 3.6 | 2.0 | 3.4 | 4/29/2015 | 3.0 | 5.6 | 2.0 | 5.0 | 2.2 | 4.7 |
| 3/22/2015 | 1.4 | 3.2 | 1.0 | 3.6 | 2.1 | 3.5 | 4/30/2015 | 3.4 | 5.7 | 2.5 | 6.1 | 2.8 | 4.5 |
| 3/23/2015 | 2.5 | 3.9 | 1.0 | 3.7 | 1.2 | 3.1 | 5/1/2015 | 2.7 | 5.4 | 2.4 | 6.2 | 2.7 | 4.1 |
| 3/24/2015 | 1.5 | 3.4 | 1.0 | 3.7 | 1.6 | 3.0 | 5/2/2015 | 2.7 | 5.4 | 2.4 | 6.2 | 2.7 | 4.1 |
| 3/25/2015 | 1.6 | 4.3 | 1.2 | 4.5 | 2.4 | 4.4 | 5/3/2015 | 2.7 | 5.4 | 2.4 | 6.2 | 2.7 | 4.1 |
| 3/26/2015 | 2.7 | 5.0 | 2.1 | 6.5 | 2.2 | 3.5 | 5/4/2015 | 2.2 | 5.2 | 2.2 | 5.8 | 2.6 | 4.0 |
| 3/27/2015 | 3.0 | 6.1 | 2.2 | 6.7 | 2.2 | 4.2 | 5/5/2015 | 2.1 | 5.5 | 2.4 | 6.0 | 2.5 | 4.0 |
| 3/28/2015 | 3.0 | 6.1 | 2.2 | 6.7 | 2.2 | 4.2 | 5/6/2015 | 1.6 | 5.0 | 2.0 | 5.3 | 2.0 | 3.6 |
| 3/29/2015 | 3.1 | 6.1 | 2.2 | 6.7 | 2.2 | 4.2 | 5/7/2015 | 1.8 | 4.7 | 2.1 | 5.5 | 2.3 | 3.8 |
| 3/30/2015 | 1.5 | 5.2 | 2.3 | 6.5 | 1.8 | 4.1 | 5/8/2015 | 1.7 | 4.6 | 2.0 | 4.6 | 2.1 | 3.6 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 5/9/2015 | 1.7 | 4.6 | 2.0 | 4.6 | 2.1 | 3.6 | 6/17/2015 | 3.4 | 4.0 | 2.3 | 5.9 | 1.9 | 3.8 |
| 5/10/2015 | 1.7 | 4.6 | 2.0 | 4.6 | 2.1 | 3.6 | 6/18/2015 | 2.8 | 3.5 | 2.1 | 4.8 | 1.8 | 3.0 |
| 5/11/2015 | 1.3 | 5.1 | 1.7 | 4.5 | 2.0 | 3.2 | 6/19/2015 | 5.3 | 5.1 | 3.3 | 8.2 | 3.4 | 4.7 |
| 5/12/2015 | 1.5 | 4.0 | 1.8 | 4.4 | 1.9 | 3.4 | 6/20/2015 | 5.4 | 5.1 | 3.3 | 8.3 | 3.4 | 4.7 |
| 5/13/2015 | 1.4 | 3.3 | 1.8 | 3.7 | 2.0 | 3.5 | 6/21/2015 | 5.4 | 5.1 | 3.3 | 8.3 | 3.4 | 4.7 |
| 5/14/2015 | 2.7 | 3.8 | 2.6 | 5.8 | 3.0 | 4.6 | 6/22/2015 | 7.2 | 6.5 | 4.2 | 10.3 | 5.0 | 5.6 |
| 5/15/2015 | 3.8 | 4.5 | 3.7 | 8.3 | 3.9 | 4.3 | 6/23/2015 | 9.4 | 8.9 | 5.2 | 13.4 | 6.7 | 6.9 |
| 5/16/2015 | 3.9 | 4.6 | 3.7 | 8.4 | 4.0 | 4.3 | 6/24/2015 | 9.2 | 7.9 | 4.9 | 12.3 | 7.2 | 6.9 |
| 5/17/2015 | 3.9 | 4.6 | 3.7 | 8.4 | 4.0 | 4.3 | 6/25/2015 | 9.9 | 8.7 | 5.5 | 13.5 | 8.1 | 7.0 |
| 5/18/2015 | 3.6 | 4.5 | 3.5 | 8.3 | 3.9 | 4.4 | 6/26/2015 | 8.3 | 9.2 | 5.2 | 12.0 | 9.1 | 6.4 |
| 5/19/2015 | 3.2 | 4.4 | 3.2 | 7.6 | 3.4 | 4.3 | 6/27/2015 | 8.3 | 9.2 | 5.2 | 12.0 | 9.1 | 6.4 |
| 5/20/2015 | 2.8 | 3.9 | 2.9 | 6.6 | 3.0 | 3.9 | 6/28/2015 | 8.3 | 9.2 | 5.2 | 12.0 | 9.1 | 6.4 |
| 5/21/2015 | 2.5 | 3.7 | 2.7 | 6.2 | 3.0 | 3.9 | 6/29/2015 | 7.5 | 8.8 | 4.7 | 10.6 | 8.4 | 5.9 |
| 5/22/2015 | 3.8 | 5.1 | 3.7 | 8.6 | 4.0 | 4.5 | 6/30/2015 | 7.7 | 10.0 | 4.6 | 10.6 | 7.7 | 5.3 |
| 5/23/2015 | 3.9 | 5.1 | 3.8 | 8.6 | 4.0 | 4.5 | 7/1/2015 | 6.2 | 9.0 | 4.0 | 9.1 | 6.7 | 5.1 |
| 5/24/2015 | 3.9 | 5.1 | 3.8 | 8.6 | 4.0 | 4.5 | 7/2/2015 | 5.0 | 6.3 | 3.2 | 7.2 | 5.7 | 4.0 |
| 5/25/2015 | 3.9 | 5.1 | 3.8 | 8.6 | 4.0 | 4.5 | 7/3/2015 | 4.9 | 6.3 | 3.2 | 7.2 | 5.6 | 4.0 |
| 5/26/2015 | 4.0 | 4.7 | 4.0 | 8.9 | 4.1 | 4.5 | 7/4/2015 | 4.9 | 6.3 | 3.2 | 7.2 | 5.6 | 4.0 |
| 5/27/2015 | 3.5 | 4.4 | 3.8 | 8.5 | 3.9 | 4.4 | 7/5/2015 | 4.9 | 6.3 | 3.2 | 7.2 | 5.6 | 4.0 |
| 5/28/2015 | 3.5 | 4.3 | 3.5 | 7.9 | 3.7 | 4.3 | 7/6/2015 | 4.8 | 6.7 | 3.4 | 7.8 | 5.2 | 3.7 |
| 5/29/2015 | 3.1 | 4.1 | 3.3 | 7.7 | 3.5 | 4.3 | 7/7/2015 | 3.6 | 5.9 | 2.7 | 5.9 | 4.4 | 3.1 |
| 5/30/2015 | 3.1 | 4.0 | 3.3 | 7.7 | 3.5 | 4.3 | 7/8/2015 | 3.9 | 5.6 | 3.0 | 6.8 | 5.7 | 4.4 |
| 5/31/2015 | 3.1 | 4.0 | 3.3 | 7.7 | 3.5 | 4.3 | 7/9/2015 | 3.8 | 5.9 | 2.9 | 6.5 | 4.6 | 3.4 |
| 6/1/2015 | 2.7 | 4.4 | 3.0 | 8.1 | 2.9 | 5.4 | 7/10/2015 | 2.9 | 3.9 | 2.3 | 5.5 | 4.0 | 3.2 |
| 6/2/2015 | 2.7 | 5.5 | 2.8 | 7.7 | 3.0 | 4.5 | 7/11/2015 | 2.7 | 3.3 | 2.1 | 5.2 | 3.9 | 3.2 |
| 6/3/2015 | 2.7 | 5.6 | 2.9 | 7.5 | 3.3 | 5.1 | 7/12/2015 | 2.7 | 3.3 | 2.1 | 5.2 | 3.9 | 3.2 |
| 6/4/2015 | 2.3 | 5.0 | 2.4 | 6.3 | 2.5 | 4.9 | 7/13/2015 | 3.9 | 5.0 | 2.6 | 6.5 | 4.6 | 5.2 |
| 6/5/2015 | 4.2 | 6.1 | 3.7 | 7.9 | 4.6 | 6.2 | 7/14/2015 | 4.8 | 5.8 | 2.8 | 7.1 | 5.4 | 6.2 |
| 6/6/2015 | 4.2 | 6.1 | 3.7 | 7.9 | 4.6 | 6.2 | 7/15/2015 | 3.7 | 4.8 | 2.3 | 6.0 | 4.2 | 5.0 |
| 6/7/2015 | 4.2 | 6.1 | 3.7 | 7.9 | 4.6 | 6.2 | 7/16/2015 | 3.9 | 5.3 | 2.6 | 6.1 | 4.3 | 4.2 |
| 6/8/2015 | 4.2 | 5.3 | 3.9 | 13.7 | 4.9 | 6.9 | 7/17/2015 | 4.0 | 5.0 | 2.7 | 6.2 | 5.0 | 4.8 |
| 6/9/2015 | 4.0 | 5.2 | 3.7 | 10.3 | 4.2 | 5.9 | 7/18/2015 | 4.0 | 5.0 | 2.7 | 6.2 | 5.0 | 4.8 |
| 6/10/2015 | 3.9 | 5.9 | 3.7 | 10.1 | 4.5 | 5.7 | 7/19/2015 | 4.0 | 5.0 | 2.7 | 6.2 | 5.0 | 4.8 |
| 6/11/2015 | 2.8 | 5.2 | 3.4 | 9.0 | 3.9 | 5.1 | 7/20/2015 | 4.1 | 5.0 | 2.6 | 5.8 | 4.9 | 4.3 |
| 6/12/2015 | 3.5 | 4.6 | 3.0 | 7.5 | 3.4 | 4.3 | 7/21/2015 | 5.8 | 6.2 | 3.5 | 7.6 | 6.6 | 5.7 |
| 6/13/2015 | 3.5 | 4.6 | 3.0 | 7.5 | 3.4 | 4.3 | 7/22/2015 | 5.7 | 5.7 | 3.6 | 7.7 | 6.4 | 6.0 |
| 6/14/2015 | 3.5 | 4.6 | 3.0 | 7.5 | 3.4 | 4.3 | 7/23/2015 | 5.0 | 5.5 | 2.8 | 7.1 | 5.7 | 5.3 |
| 6/15/2015 | 3.8 | 5.2 | 2.7 | 6.5 | 2.7 | 5.1 | 7/24/2015 | 4.1 | 5.6 | 2.7 | 6.1 | 5.1 | 4.1 |
| 6/16/2015 | 4.0 | 4.2 | 2.3 | 6.1 | 2.5 | 4.7 | 7/25/2015 | 4.1 | 5.5 | 2.7 | 6.1 | 5.1 | 4.0 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 7/26/2015 | 4.1 | 5.5 | 2.7 | 6.1 | 5.1 | 4.0 | 9/3/2015 | 2.2 | 2.9 | 1.5 | 3.0 | 1.9 | 1.5 |
| 7/27/2015 | 3.7 | 4.6 | 2.5 | 5.6 | 4.6 | 3.7 | 9/4/2015 | 2.8 | 3.4 | 1.8 | 3.6 | 2.4 | 2.1 |
| 7/28/2015 | 3.7 | 4.5 | 2.5 | 5.6 | 4.6 | 3.7 | 9/5/2015 | 2.5 | 3.1 | 1.6 | 3.3 | 2.1 | 2.4 |
| 7/29/2015 | 3.5 | 4.5 | 2.6 | 5.6 | 4.4 | 3.5 | 9/6/2015 | 2.3 | 2.9 | 1.5 | 3.2 | 1.9 | 2.1 |
| 7/30/2015 | 3.4 | 4.0 | 2.5 | 5.4 | 3.8 | 2.9 | 9/7/2015 | 1.8 | 2.5 | 1.2 | 2.8 | 1.5 | 1.6 |
| 7/31/2015 | 3.4 | 4.1 | 2.5 | 5.3 | 3.8 | 3.0 | 9/8/2015 | 1.5 | 2.1 | 0.8 | 2.5 | 0.9 | 0.9 |
| 8/1/2015 | 3.4 | 4.3 | 2.6 | 5.2 | 3.9 | 3.2 | 9/9/2015 | 2.0 | 2.6 | 1.2 | 2.8 | 2.2 | 2.0 |
| 8/2/2015 | 3.4 | 4.3 | 2.6 | 5.2 | 3.9 | 3.2 | 9/10/2015 | 1.5 | 1.8 | 0.9 | 2.2 | 1.2 | 1.1 |
| 8/3/2015 | 3.4 | 4.0 | 2.4 | 4.8 | 3.7 | 2.8 | 9/11/2015 | 1.5 | 2.0 | 1.0 | 2.2 | 1.4 | 1.3 |
| 8/4/2015 | 6.1 | 6.6 | 2.9 | 6.1 | 4.7 | 4.9 | 9/12/2015 | 1.5 | 2.0 | 1.0 | 2.2 | 1.4 | 1.3 |
| 8/5/2015 | 6.8 | 7.1 | 3.5 | 7.7 | 5.7 | 5.9 | 9/13/2015 | 1.5 | 2.0 | 1.0 | 2.2 | 1.4 | 1.3 |
| 8/6/2015 | 5.4 | 5.8 | 3.1 | 6.4 | 4.9 | 4.8 | 9/14/2015 | 1.0 | 1.4 | 0.8 | 1.3 | 1.0 | 0.6 |
| 8/7/2015 | 4.1 | 4.6 | 2.4 | 0.6 | 3.9 | 3.9 | 9/15/2015 | 1.1 | 1.3 | 0.6 | 1.8 | 1.2 | 0.4 |
| 8/8/2015 | 4.0 | 4.5 | 2.3 | 0.3 | 3.9 | 3.9 | 9/16/2015 | 0.7 | 1.1 | 0.5 | 1.5 | 0.8 | 0.3 |
| 8/9/2015 | 4.0 | 4.5 | 2.3 | 0.3 | 3.9 | 3.9 | 9/17/2015 | 0.5 | 0.9 | 0.4 | 1.4 | 0.6 | 0.2 |
| 8/10/2015 | 3.4 | 4.0 | 2.0 | 0.0 | 2.7 | 3.5 | 9/18/2015 | 0.1 | 0.3 | 0.1 | 0.4 | 0.1 | 0.4 |
| 8/11/2015 | 2.5 | 3.0 | 1.6 | 0.0 | 1.7 | 2.7 | 9/19/2015 | 0.1 | 0.3 | 0.1 | 0.3 | 0.1 | 0.4 |
| 8/12/2015 | 2.0 | 2.3 | 1.3 | 0.0 | 1.1 | 2.2 | 9/20/2015 | 0.1 | 0.3 | 0.1 | 0.3 | 0.1 | 0.4 |
| 8/13/2015 | 1.3 | 1.8 | 1.0 | 0.0 | 0.7 | 2.0 | 9/21/2015 | 0.9 | 0.9 | 0.5 | 1.5 | 0.6 | 0.5 |
| 8/14/2015 | 1.3 | 1.8 | 1.0 | 0.0 | 0.7 | 2.0 | 9/22/2015 | 0.8 | 1.1 | 0.0 | 0.5 | 0.1 | 0.0 |
| 8/15/2015 | 1.3 | 1.8 | 1.0 | 0.0 | 0.7 | 2.0 | 9/23/2015 | 0.8 | 2.2 | 0.6 | 2.6 | 1.9 | 1.4 |
| 8/16/2015 | 1.3 | 1.8 | 1.0 | 0.0 | 0.7 | 2.0 | 9/24/2015 | 2.3 | 4.4 | 2.2 | 5.7 | 2.9 | 2.4 |
| 8/17/2015 | 0.7 | 1.2 | 0.6 | 0.0 | 0.5 | 1.4 | 9/25/2015 | 3.1 | 5.5 | 2.5 | 6.0 | 3.2 | 2.4 |
| 8/18/2015 | 0.8 | 2.7 | 0.7 | 0.0 | 0.0 | 1.2 | 9/26/2015 | 2.3 | 4.7 | 2.1 | 4.7 | 2.5 | 1.7 |
| 8/19/2015 | 1.8 | 2.6 | 0.7 | 2.6 | 1.5 | 1.5 | 9/27/2015 | 2.0 | 4.3 | 1.9 | 4.2 | 2.2 | 1.3 |
| 8/20/2015 | 1.6 | 2.3 | 0.5 | 2.6 | 1.9 | 1.8 | 9/28/2015 | 1.7 | 3.6 | 1.4 | 3.7 | 1.8 | 0.9 |
| 8/21/2015 | 1.2 | 1.8 | 0.4 | 2.1 | 0.8 | 0.7 | 9/29/2015 | 1.8 | 4.0 | 1.4 | 3.9 | 1.6 | 0.9 |
| 8/22/2015 | 1.2 | 1.8 | 0.4 | 2.1 | 0.7 | 0.6 | 9/30/2015 | 1.2 | 3.5 | 1.2 | 3.2 | 1.3 | 0.6 |
| 8/23/2015 | 1.2 | 1.8 | 0.4 | 2.1 | 0.7 | 0.6 | 10/1/2015 | 0.8 | 3.1 | 1.0 | 2.8 | 1.1 | 0.4 |
| 8/24/2015 | 0.6 | 1.1 | 0.7 | 1.4 | 0.8 | 0.3 | 10/2/2015 | 0.6 | 2.7 | 0.8 | 2.2 | 0.9 | 0.2 |
| 8/25/2015 | 0.7 | 1.2 | 0.6 | 1.2 | 0.9 | 0.7 | 10/3/2015 | 0.4 | 2.4 | 0.7 | 1.8 | 0.7 | 0.1 |
| 8/26/2015 | 0.7 | 1.2 | 0.6 | 1.2 | 1.0 | 0.8 | 10/4/2015 | 0.4 | 2.2 | 0.7 | 1.9 | 0.7 | 0.4 |
| 8/27/2015 | 0.5 | 0.8 | 0.4 | 1.1 | 0.8 | 0.3 | 10/5/2015 | 0.3 | 0.6 | 0.5 | 1.4 | 1.5 | 0.3 |
| 8/28/2015 | 1.7 | 2.5 | 1.2 | 2.5 | 2.3 | 1.5 | 10/6/2015 | 0.2 | 0.1 | 1.6 | 2.6 | 0.5 | 0.3 |
| 8/29/2015 | 1.8 | 2.6 | 1.3 | 2.6 | 2.3 | 1.5 | 10/7/2015 | 1.5 | 1.9 | 2.1 | 3.0 | 2.1 | 1.6 |
| 8/30/2015 | 1.6 | 2.3 | 1.0 | 2.4 | 2.0 | 1.5 | 10/8/2015 | 2.0 | 2.7 | 1.6 | 2.4 | 1.6 | 1.2 |
| 8/31/2015 | 2.1 | 3.1 | 1.3 | 3.1 | 2.2 | 1.4 | 10/9/2015 | 0.5 | 1.2 | 0.8 | 2.5 | 1.6 | 1.5 |
| 9/1/2015 | 2.8 | 3.7 | 1.8 | 3.6 | 2.5 | 2.1 | 10/10/2015 | 0.5 | 1.2 | 0.8 | 2.5 | 1.6 | 1.5 |
| 9/2/2015 | 2.6 | 3.6 | 1.6 | 3.3 | 2.1 | 2.0 | 10/11/2015 | 0.5 | 1.2 | 0.8 | 2.5 | 1.6 | 1.5 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | | | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 10/12/2015 | 0.2 | 0.7 | 0.7 | 1.4 | 0.9 | 0.5 | 11/20/2015 | 7.1 | 8.8 | 7.3 | 10.9 | 6.8 | 8.2 |
| 10/13/2015 | 0.7 | 1.4 | 0.6 | 2.7 | 1.5 | 1.5 | 11/21/2015 | 7.1 | 8.8 | 7.3 | 10.9 | 6.7 | 8.2 |
| 10/14/2015 | 0.3 | 0.8 | 0.6 | 2.0 | 1.5 | 1.3 | 11/22/2015 | 7.1 | 8.8 | 7.3 | 10.9 | 6.7 | 8.2 |
| 10/15/2015 | 0.4 | 0.9 | 1.9 | 38.6 | 1.1 | 1.1 | 11/23/2015 | 6.8 | 7.7 | 5.5 | 11.8 | 6.9 | 8.1 |
| 10/16/2015 | 0.0 | 0.4 | 1.0 | 4.6 | 1.0 | 0.6 | 11/24/2015 | 7.9 | 9.1 | 7.1 | 13.0 | 7.4 | 9.1 |
| 10/17/2015 | 0.0 | 0.4 | 0.9 | 3.3 | 1.0 | 0.5 | 11/25/2015 | 7.7 | 8.0 | 6.3 | 12.3 | 6.7 | 8.1 |
| 10/18/2015 | 0.1 | 0.6 | 0.8 | 1.6 | 1.0 | 0.7 | 11/26/2015 | 7.7 | 8.0 | 6.3 | 12.2 | 6.7 | 8.1 |
| 10/19/2015 | 0.2 | 1.4 | 1.6 | 2.8 | 1.7 | 1.6 | 11/27/2015 | 5.4 | 6.5 | 5.2 | 7.3 | 6.1 | 7.2 |
| 10/20/2015 | 0.0 | 1.1 | 2.2 | 0.6 | 0.3 | 2.0 | 11/28/2015 | 4.8 | 6.1 | 4.9 | 6.0 | 5.9 | 6.9 |
| 10/21/2015 | 0.5 | 1.2 | 1.3 | 3.8 | 1.7 | 1.7 | 11/29/2015 | 4.8 | 6.1 | 4.9 | 6.0 | 5.9 | 6.9 |
| 10/22/2015 | 0.0 | 1.0 | 1.7 | 3.7 | 2.2 | 1.9 | 11/30/2015 | 4.4 | 5.1 | 4.6 | 9.0 | 5.9 | 7.2 |
| 10/23/2015 | 0.0 | 1.6 | 1.4 | 3.0 | 1.5 | 1.1 | 12/1/2015 | 5.0 | 7.4 | 5.7 | 10.4 | 6.6 | 7.9 |
| 10/24/2015 | 0.0 | 1.8 | 1.7 | 2.5 | 1.3 | 0.9 | 12/2/2015 | 4.9 | 6.3 | 5.0 | 9.8 | 6.2 | 7.3 |
| 10/25/2015 | 0.0 | 1.8 | 1.8 | 2.5 | 1.2 | 0.8 | 12/3/2015 | 4.7 | 6.0 | 4.5 | 7.3 | 5.4 | 5.8 |
| 10/26/2015 | 0.6 | 0.2 | 0.9 | 4.3 | 1.4 | 1.3 | 12/4/2015 | 6.0 | 7.6 | 5.5 | 6.7 | 6.4 | 7.5 |
| 10/27/2015 | 1.9 | 0.7 | 0.6 | 1.6 | 1.1 | 1.0 | 12/5/2015 | 6.1 | 7.7 | 5.6 | 6.6 | 6.5 | 7.6 |
| 10/28/2015 | 0.5 | 0.6 | 2.2 | 5.3 | 2.2 | 2.8 | 12/6/2015 | 6.1 | 7.7 | 5.6 | 6.6 | 6.5 | 7.6 |
| 10/29/2015 | 1.3 | 2.1 | 3.6 | 5.2 | 4.6 | 5.5 | 12/7/2015 | 6.1 | 9.1 | 4.8 | 11.7 | 6.9 | 7.7 |
| 10/30/2015 | 2.9 | 3.1 | 3.9 | 7.5 | 4.8 | 5.4 | 12/8/2015 | 5.7 | 7.6 | 5.1 | 11.7 | 6.6 | 7.4 |
| 10/31/2015 | 3.5 | 3.0 | 4.6 | 7.5 | 4.9 | 5.5 | 12/9/2015 | 5.3 | 6.8 | 2.9 | 11.0 | 6.5 | 7.4 |
| 11/1/2015 | 3.4 | 2.6 | 4.7 | 7.3 | 4.5 | 5.1 | 12/10/2015 | 5.3 | 6.8 | 2.9 | 11.0 | 6.5 | 7.4 |
| 11/2/2015 | 3.6 | 2.4 | 2.9 | 6.4 | 4.4 | 4.9 | 12/11/2015 | 5.1 | 6.4 | 5.1 | 10.2 | 6.0 | 7.0 |
| 11/3/2015 | 3.6 | 3.0 | 3.5 | 9.4 | 5.2 | 5.2 | 12/12/2015 | 2.9 | 3.9 | 3.3 | 6.4 | 3.6 | 4.2 |
| 11/4/2015 | 3.8 | 3.2 | 3.1 | 7.4 | 4.7 | 4.0 | 12/13/2015 | 5.2 | 7.0 | 5.9 | 11.4 | 6.5 | 7.5 |
| 11/5/2015 | 5.1 | 4.6 | 2.1 | 7.7 | 5.3 | 4.0 | 12/14/2015 | 3.9 | 5.3 | 3.7 | 8.0 | 5.0 | 5.9 |
| 11/6/2015 | 5.1 | 6.6 | 3.8 | 6.7 | 4.9 | 4.4 | 12/15/2015 | 4.0 | 5.4 | 4.0 | 8.4 | 5.6 | 6.5 |
| 11/7/2015 | 5.1 | 6.6 | 3.8 | 6.7 | 4.9 | 4.4 | 12/16/2015 | 5.6 | 6.5 | 4.0 | 10.3 | 8.5 | 9.5 |
| 11/8/2015 | 5.1 | 6.6 | 3.8 | 6.7 | 4.9 | 4.4 | 12/17/2015 | 7.5 | 8.9 | 5.0 | 12.9 | 8.9 | 9.8 |
| 11/9/2015 | 4.0 | 6.3 | 3.2 | 6.7 | 4.3 | 4.2 | 12/18/2015 | 6.8 | 8.5 | 6.4 | 13.8 | 8.3 | 9.5 |
| 11/10/2015 | 4.3 | 6.3 | 5.7 | 7.5 | 5.9 | 5.4 | 12/19/2015 | 5.5 | 7.3 | 5.5 | 11.5 | 6.8 | 8.0 |
| 11/11/2015 | 1.1 | 1.6 | 2.6 | 4.6 | 1.4 | 2.5 | 12/20/2015 | 4.4 | 6.7 | 3.9 | 9.7 | 5.4 | 6.5 |
| 11/12/2015 | 2.4 | 2.8 | 2.3 | 5.5 | 3.5 | 4.6 | 12/21/2015 | 2.8 | 4.2 | 2.4 | 7.6 | 4.3 | 5.2 |
| 11/13/2015 | 5.6 | 7.1 | 5.3 | 10.2 | 6.4 | 7.7 | 12/22/2015 | 1.6 | 2.8 | 3.9 | 6.3 | 3.4 | 4.4 |
| 11/14/2015 | 5.7 | 7.2 | 5.3 | 10.2 | 6.4 | 7.8 | 12/23/2015 | 0.7 | 1.1 | 2.4 | 3.9 | 1.9 | 3.0 |
| 11/15/2015 | 7.5 | 9.5 | 6.8 | 12.3 | 8.2 | 9.8 | 12/24/2015 | 0.5 | 0.8 | 2.1 | 3.4 | 1.6 | 2.7 |
| 11/16/2015 | 7.5 | 8.9 | 6.1 | 11.5 | 7.8 | 9.6 | 12/25/2015 | 0.5 | 0.8 | 2.1 | 3.4 | 1.6 | 2.7 |
| 11/17/2015 | 6.5 | 7.4 | 5.0 | 7.6 | 6.2 | 7.9 | 12/26/2015 | 0.5 | 0.8 | 2.1 | 3.4 | 1.6 | 2.7 |
| 11/18/2015 | 4.7 | 6.0 | 4.4 | 7.2 | 6.2 | 7.1 | 12/27/2015 | 0.5 | 0.8 | 2.1 | 3.4 | 1.6 | 2.7 |
| 11/19/2015 | 6.8 | 9.2 | 6.5 | 8.1 | 7.5 | 9.4 | 12/28/2015 | 0.5 | 0.8 | 2.1 | 3.4 | 1.6 | 2.7 |

Table 24 (Cont.). Daily Biogas Production during the Whole Experimental Period.

| | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 |
| 12/29/2015 | 1.0 | 1.2 | 2.0 | 3.2 | 1.4 | 2.3 |
| 12/30/2015 | 1.3 | 1.5 | 1.9 | 3.1 | 1.2 | 2.1 |
| 12/31/2015 | 1.3 | 1.5 | 1.9 | 3.1 | 1.2 | 2.1 |
| 1/1/2016 | 1.3 | 1.5 | 1.9 | 3.1 | 1.2 | 2.1 |
| 1/2/2016 | 1.3 | 1.5 | 1.9 | 3.1 | 1.2 | 2.1 |
| 1/3/2016 | 1.3 | 1.5 | 1.9 | 3.1 | 1.2 | 2.1 |
| 1/4/2016 | 0.0 | 0.1 | 1.8 | 1.3 | 0.3 | 1.1 |
| 1/5/2016 | 0.0 | 0.1 | 1.8 | 1.3 | 0.3 | 1.1 |
| 1/6/2016 | 1.4 | 1.3 | 2.4 | 2.9 | 1.7 | 2.8 |
| 1/7/2016 | 3.8 | 4.2 | 3.3 | 4.6 | 4.1 | 4.7 |
| 1/8/2016 | 4.7 | 5.0 | 4.0 | 7.1 | 4.9 | 6.0 |
| 1/9/2016 | 4.4 | 5.3 | 3.5 | 8.2 | 5.2 | 6.2 |
| 1/10/2016 | 4.3 | 5.4 | 3.4 | 8.5 | 5.3 | 6.3 |
| 1/11/2016 | 4.3 | 4.6 | 3.5 | 8.8 | 5.7 | 7.2 |
| 1/12/2016 | 6.5 | 8.5 | 6.4 | 10.7 | 8.2 | 9.9 |
| 1/13/2016 | 10.1 | 13.2 | 10.2 | 15.3 | 12.7 | 14.7 |
| 1/14/2016 | 13.6 | 17.5 | 12.3 | 18.9 | 14.5 | 16.8 |
| 1/15/2016 | 18.9 | 21.8 | 15.0 | 24.4 | 17.5 | 20.9 |
| 1/16/2016 | 26.5 | 30.5 | 21.5 | 33.5 | 24.3 | 29.1 |
| 1/17/2016 | 32.6 | 34.0 | 22.2 | 38.7 | 27.8 | 29.8 |
| 1/18/2016 | 29.3 | 28.0 | 11.9 | 36.8 | 26.2 | 26.9 |
| 1/19/2016 | 25.9 | 27.1 | 10.7 | 34.4 | 24.7 | 26.2 |
| 1/20/2016 | 26.1 | 25.4 | 9.4 | 35.1 | 26.1 | 26.3 |
| 1/21/2016 | 23.6 | 23.6 | 10.8 | 32.2 | 24.9 | 25.4 |
| 1/22/2016 | 26.0 | 26.0 | 9.8 | 32.4 | 25.9 | 25.0 |
| 1/23/2016 | 26.1 | 26.1 | 9.7 | 32.5 | 25.9 | 25.0 |
| 1/24/2016 | 26.1 | 26.1 | 9.7 | 32.5 | 25.9 | 25.0 |
| 1/25/2016 | 23.1 | 23.4 | 8.4 | 28.7 | 23.1 | 22.8 |
| 1/26/2016 | 18.9 | 20.0 | 8.0 | 26.3 | 18.7 | 20.5 |
| 1/27/2016 | 21.4 | 22.7 | 8.7 | 28.2 | 21.9 | 22.5 |
| 1/28/2016 | 21.3 | 23.6 | 8.3 | 28.4 | 22.4 | 24.3 |
| 1/29/2016 | 23.7 | 25.5 | 7.2 | 30.1 | 22.0 | 23.5 |
| 1/30/2016 | 22.2 | 23.1 | 6.6 | 27.3 | 19.9 | 22.9 |
| 1/31/2016 | 20.1 | 21.8 | 6.6 | 27.2 | 21.5 | 24.0 |
| 2/1/2016 | 19.0 | 19.3 | 5.9 | 26.5 | 19.9 | 20.7 |
| 2/2/2016 | 15.5 | 17.2 | 5.2 | 22.8 | 17.4 | 20.4 |
| 2/3/2016 | 28.2 | 29.6 | 6.8 | 33.8 | 30.6 | 30.4 |
| 2/4/2016 | 27.3 | 28.3 | 7.1 | 32.7 | 29.3 | 28.4 |
| 2/5/2016 | 22.5 | 24.0 | 8.4 | 27.6 | 24.3 | 25.1 |

| | Biogas production (l/day) | | | | | |
|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 |
| 2/6/2016 | 19.2 | 20.9 | 9.4 | 25.8 | 21.9 | 22.5 |
| 2/7/2016 | 15.8 | 17.6 | 7.5 | 22.9 | 19.3 | 20.8 |
| 2/8/2016 | 15.1 | 16.4 | 6.6 | 23.1 | 18.6 | 17.5 |
| 2/9/2016 | 14.1 | 15.9 | 6.9 | 22.1 | 17.5 | 18.4 |
| 2/10/2016 | 15.9 | 16.3 | 9.3 | 23.2 | 19.3 | 17.7 |
| 2/11/2016 | 14.3 | 15.4 | 8.4 | 21.4 | 19.3 | 19.5 |
| 2/12/2016 | 13.1 | 14.0 | 6.9 | 18.5 | 16.0 | 16.5 |
| 2/13/2016 | 12.8 | 13.5 | 6.3 | 18.2 | 14.4 | 15.4 |
| 2/14/2016 | 12.0 | 12.7 | 6.1 | 17.4 | 13.2 | 14.1 |
| 2/15/2016 | 11.3 | 11.8 | 6.7 | 16.3 | 12.1 | 12.1 |
| 2/16/2016 | 9.7 | 10.3 | 7.2 | 14.9 | 10.8 | 11.0 |
| 2/17/2016 | 11.5 | 11.8 | 4.4 | 14.6 | 10.0 | 11.1 |
| 2/18/2016 | 13.1 | 13.1 | 6.1 | 16.4 | 11.6 | 11.2 |
| 2/19/2016 | 5.3 | 5.7 | 9.3 | 17.1 | 13.5 | 13.0 |
| 2/20/2016 | 5.1 | 5.6 | 9.3 | 17.0 | 13.5 | 13.1 |
| 2/21/2016 | 5.1 | 5.6 | 9.3 | 17.0 | 13.5 | 13.1 |
| 2/22/2016 | 6.2 | 7.1 | 10.0 | 14.6 | 11.3 | 10.1 |
| 2/23/2016 | 8.0 | 8.8 | 9.3 | 13.3 | 10.2 | 10.6 |
| 2/24/2016 | 11.3 | 11.7 | 10.3 | 15.9 | 12.6 | 11.3 |
| 2/25/2016 | 11.6 | 12.6 | 10.5 | 15.8 | 13.2 | 13.1 |
| 2/26/2016 | 20.8 | 21.1 | 14.3 | 23.4 | 19.8 | 17.1 |
| 2/27/2016 | 24.9 | 24.8 | 15.3 | 27.0 | 21.7 | 19.6 |
| 2/28/2016 | 22.6 | 23.7 | 14.3 | 25.5 | 21.1 | 20.8 |
| 2/29/2016 | 21.7 | 21.6 | 13.2 | 23.4 | 20.9 | 17.8 |
| 3/1/2016 | 18.5 | 18.3 | 12.4 | 21.7 | 18.7 | 16.4 |
| 3/2/2016 | 20.8 | 19.8 | 13.3 | 23.1 | 20.7 | 17.7 |
| 3/3/2016 | 18.7 | 18.0 | 12.7 | 22.4 | 19.9 | 19.0 |
| 3/4/2016 | 16.3 | 17.8 | 14.1 | 23.2 | 21.4 | 18.5 |
| 3/5/2016 | 16.7 | 19.0 | 14.3 | 23.4 | 20.2 | 17.9 |
| 3/6/2016 | 17.1 | 19.7 | 14.4 | 23.4 | 19.4 | 17.6 |
| 3/7/2016 | 16.1 | 18.9 | 11.3 | 21.1 | 17.7 | 16.9 |
| 3/8/2016 | 14.4 | 16.5 | 9.4 | 18.3 | 15.7 | 14.3 |
| 3/9/2016 | 15.6 | 17.1 | 9.9 | 20.1 | 16.8 | 15.3 |
| 3/10/2016 | 13.2 | 14.8 | 9.6 | 18.3 | 14.8 | 14.0 |
| 3/11/2016 | 16.4 | 19.3 | 10.9 | 21.6 | 18.6 | 17.2 |
| 3/12/2016 | 17.4 | 20.5 | 11.5 | 22.0 | 19.0 | 17.3 |
| 3/13/2016 | 17.6 | 20.5 | 11.5 | 21.2 | 18.6 | 16.7 |
| 3/14/2016 | 19.5 | 21.7 | 11.4 | 21.6 | 17.0 | 15.8 |
| 3/15/2016 | 15.1 | 17.0 | 9.7 | 18.7 | 16.6 | 15.9 |

# APPENDIX VI: DATA FOR RETAINED MASS IN REACTORS

Table 25. VSS Accumulated in R1-6 Calculated with Matlab Program.

| | VSS (matlab) grams | | | | | | | VSS (matlab) grams | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| date | R1 | R2 | R3 | R4 | R5 | R6 | date | R1 | R2 | R3 | R4 | R5 | R6 |
| 6/26/2014 | 104 | 110 | 82 | 114 | 135 | 214 | 4/8/2015 | *31* | | *35* | | 26 | 76 |
| 7/10/2014 | 97 | 93 | 33 | 87 | 113 | 116 | 4/15/2015 | | *46* | | *43* | 32 | 78 |
| 7/17/2014 | 94 | | 121 | | 136 | | 4/22/2015 | *40* | | *43* | | 30 | 86 |
| 7/24/2014 | | 116 | | 107 | | 115 | 4/29/2015 | | *40* | | *27* | 29 | 78 |
| 7/28/2014 | 156 | | 120 | | 130 | | 5/6/2015 | *31* | | *33* | | 28 | 79 |
| 8/7/2014 | | 105 | | 95 | | 148 | 5/12/2015 | | *28* | | *22* | 24 | 55 |
| 8/14/2014 | 66 | | 90 | | 61 | | 5/20/2015 | *29* | | *27* | | 32 | 73 |
| 8/20/2014 | | 93 | | 67 | | 114 | 5/27/2015 | | *36* | | *32* | 35 | 62 |
| 8/27/2014 | 61 | | 75 | | 46 | | 6/2/2015 | *35* | | *31* | | 38 | 71 |
| 9/3/2014 | | 75 | | 64 | | 104 | 6/9/2015 | | *39* | | *47* | 34 | 76 |
| 9/10/2014 | 68 | | 30 | | 89 | | 6/16/2015 | *31* | | *33* | | 30 | 73 |
| 9/17/2014 | | 40 | 66 | 54 | | 79 | 6/23/2015 | | *42* | | *52* | 31 | 52 |
| 9/24/2014 | 45 | | 74 | | 79 | | 6/30/2015 | *47* | | *47* | | 35 | 54 |
| 10/1/2014 | | 67 | | 39 | | 95 | 7/7/2015 | | *46* | | *41* | 41 | 78 |
| 10/8/2014 | 47 | | 62 | | 78 | | 7/14/2015 | *33* | | *32* | | 43 | 57 |
| 10/15/2014 | | 46 | | 35 | | 79 | 7/21/2015 | | *45* | | *47* | 46 | 67 |
| 10/22/2014 | 44 | | 61 | | 65 | | 8/4/2015 | | *53* | | *51* | 57 | 71 |
| 10/29/2014 | | 49 | | 31 | | 55 | 8/18/2015 | *50* | | *56* | | 51 | 77 |
| 11/5/2014 | 60 | | 55 | | 74 | | 9/11/2015 | | | | | 51 | 70 |
| 11/12/2014 | | 51 | | 38 | | 60 | 10/19/2015 | 103 | 96 | 91 | 145 | 91 | 178 |
| 11/19/2014 | 58 | | 57 | | 58 | | 11/3/2015 | 127 | 111 | 91 | 125 | 93 | 115 |
| 11/26/2014 | | 69 | | 40 | | 58 | 11/17/2015 | 110 | 103 | 104 | 157 | 95 | 179 |
| 12/3/2014 | 57 | | 66 | | 57 | | 11/23/2015 | 124 | 116 | 99 | 154 | 112 | 196 |
| 12/10/2014 | | 71 | | 67 | | 71 | 12/1/2015 | 142 | 116 | 121 | 170 | 113 | 203 |
| 12/17/2014 | 94 | 73 | 78 | 70 | 67 | 45 | 12/7/2015 | 131 | 113 | 124 | 125 | 119 | 191 |
| 1/8/2015 | 95 | 85 | 85 | 92 | 72 | 79 | 12/16/2015 | 151 | 103 | 111 | 149 | 114 | 165 |
| 1/14/2015 | 101 | | 72 | | 77 | | 1/7/2016 | 131 | 127 | 108 | 146 | 148 | 176 |
| 1/21/2015 | | 86 | | 69 | | 69 | 1/14/2016 | 181 | 131 | 117 | 141 | 151 | 202 |
| 1/28/2015 | 57 | | 50 | | 57 | | 1/19/2016 | 193 | 138 | 144 | 178 | 184 | 214 |
| 2/4/2015 | | 82 | | 63 | 69 | 60 | 1/26/2016 | 207 | 141 | 148 | 193 | 156 | 221 |
| 2/11/2015 | 49 | | 51 | | 47 | 57 | 2/5/2016 | 230 | 176 | 162 | 222 | 216 | 240 |
| 2/20/2015 | | 64 | | 45 | 29 | 57 | 2/10/2016 | 230 | 147 | 161 | 231 | 219 | 229 |
| 2/25/2015 | 30 | | 34 | | 27 | 53 | 2/16/2016 | 228 | 156 | 171 | 204 | 194 | 212 |
| 3/4/2015 | | *36* | | *31* | 12 | 58 | 2/23/2016 | 229 | 153 | 166 | 218 | 214 | 249 |
| 3/11/2015 | *25* | | *20* | | 22 | 47 | 3/1/2016 | 217 | 139 | 162 | 230 | 188 | 236 |
| 3/18/2015 | | *42* | | *27* | 16 | 27 | 3/8/2016 | 210 | 169 | 186 | 271 | 227 | 252 |
| 3/25/2015 | *28* | | *27* | | 22 | 51 | 3/15/2016 | 207 | 165 | 173 | 246 | 239 | 237 |
| 4/1/2015 | | *44* | | *38* | 30 | 74 | 3/22/2016 | 208 | 158 | 185 | 274 | 225 | 256 |

# APPENDIX VII: DATA FOR COD IN FEED AND DECANTS

Table 26. COD of Feed and Effluent Streams during the Whole Experimental Period.

| | COD (mg O2/l) | | | | | | |
|---|---|---|---|---|---|---|---|
| date | FEED | D1 | D2 | D3 | D4 | D5 | D6 |
| 6/10/2014 | 3784 | 3972 | 2653 | 4412 | 4255 | 4443 | 2684 |
| 6/17/2014 | 6166 | 3263 | 3477 | 3935 | 3783 | 3385 | 2835 |
| 6/24/2014 | 5638 | 4621 | 4052 | 4770 | 4351 | 3364 | 2736 |
| 7/1/2014 | 6244 | 4147 | 4476 | 3776 | 3489 | 4599 | 3242 |
| 7/8/2014 | 5712 | 3600 | 4473 | 3434 | 3725 | 3434 | 3850 |
| 7/15/2014 | 4467 | 3188 | 4320 | 3775 | 3901 | 3230 | 4027 |
| 7/22/2014 | 2917 | 2854 | 3450 | 2948 | 3607 | 3764 | 3984 |
| 7/29/2014 | 2754 | 3138 | 3361 | 3138 | 3329 | 2754 | 4672 |
| 8/5/2014 | 2255 | 2504 | 3253 | 2442 | 2629 | 2660 | 2878 |
| 8/13/2014 | 3379 | 2796 | 4071 | 2869 | 3379 | 2796 | 3853 |
| 8/18/2014 | 2146 | 2276 | 2405 | 2372 | 2631 | 1888 | 2921 |
| 9/3/2014 | 1967 | 1777 | 2251 | 1903 | 2409 | 1808 | 2441 |
| 9/10/2014 | 2914 | 1695 | 1855 | 1663 | 1855 | 1631 | 2080 |
| 10/28/2014 | 4807 | 1407 | 1571 | 1472 | 1636 | 1146 | 1244 |
| 11/7/2014 | 3238 | 1430 | | 1856 | | 1588 | |
| 12/18/2014 | 4922 | 678 | 755 | 709 | 786 | 555 | 601 |
| 5/11/2015 | 2596 | | 675 | | 701 | 1007 | 370 |
| 5/18/2015 | 4156 | 909 | | 838 | | 805 | 305 |
| 6/25/2015 | 4771 | | | | | | 489 |
| 7/10/2015 | 2867 | | | | | 928 | |
| 7/13/2015 | 2125 | | | | | | 564 |
| 10/13/2015 | 2787 | | | 629 | 606 | 586 | 735 |
| 10/22/2015 | 3593 | 497 | 431 | 759 | 647 | 962 | 1066 |
| 10/28/2015 | 2382 | 471 | 366 | 516 | 487 | 602 | 579 |
| 11/2/2015 | 2655 | 536 | 1148 | 689 | 428 | 604 | 1230 |
| 11/9/2015 | 3535 | 474 | 503 | 621 | 321 | 487 | 767 |
| 11/16/2015 | 4297 | 603 | 545 | 535 | 498 | 603 | 928 |
| 11/23/2015 | 4786 | 544 | 537 | 469 | 501 | 570 | 703 |
| 11/30/2015 | 5894 | 573 | 466 | 378 | 368 | 531 | 703 |
| 12/7/2015 | 4036 | 533 | 421 | 332 | 411 | 513 | 690 |
| 12/14/2015 | 3124 | 530 | 414 | 414 | 414 | 503 | 655 |
| 1/6/2016 | 5231 | 398 | 411 | 299 | 434 | 378 | 365 |
| 1/12/2016 | 5494 | 434 | 434 | 302 | 296 | 395 | 362 |
| 1/18/2016 | 6794 | 599 | 652 | 524 | 590 | 534 | 498 |
| 1/27/2016 | 5079 | 472 | 459 | 417 | 508 | 469 | 430 |
| 2/1/2016 | 5275 | 488 | 475 | 413 | 433 | 505 | 420 |
| 2/8/2016 | 4308 | 418 | 434 | 1117 | 444 | 526 | 352 |
| 2/15/2016 | 3033 | 359 | 313 | 395 | 372 | 424 | 385 |
| 2/22/2016 | 3360 | 300 | 251 | 431 | 545 | 316 | 414 |
| 3/2/2016 | 5320 | 486 | 408 | 363 | 493 | 392 | 610 |
| 3/9/2016 | 4180 | 431 | 317 | 301 | 457 | 317 | 477 |

VITA

Hernan Fernandez-Barriales Lopez

Candidate for the Degree of

Master of Science

Thesis: USING A PARTIAL-MIX, SINGLE-JET MIXING SYSTEM TO IMPROVE SOLIDS RETENTION IN ANAEROBIC SEQUENCING BATCH REACTORS

Major Field: Biosystems Engineering

Biographical:

Education:

Completed the requirements for the Master of Science in Biosystems Engineering at Oklahoma State University, Stillwater, Oklahoma in July, 2016.

Completed the requirements for the Superior Engineer in Chemical Engineering at Universidade de Santiago de Compostela, Santiago de Compostela, Spain in 2012.

Experience:

Project Engineer
Oklahoma Water Resources Board, Oklahoma City, OK 2016 – present

Graduate Research Assistant
Oklahoma State University, Stillwater, OK 2014 – 2016

Engineer
Ingema S.L., Cañamero, Spain 2012 – 2014