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ESCUELA DE INGENIERÍAS INDUSTRIALES

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ANAEROBIC DIGESTION OF OFMSW

Autor:
Olagunju Olusegun Ayodeji

Tutores:
Fernando Fdz-Polanco and
Natalia Alfaro

Departamento Ingenieria Quimica

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ABSTRACT

In this study, design of the anaerobic digestion plant to treat the organic fraction of municipal solid waste was described, using the experimental data under laboratory scale using conventional biochemical methane potential (BMP) assay, to quantify biogas productivity. Biochemical methane potential (BMP) tests were used as a tool to evaluate the methane production of OFMSW and the analyses of the fraction indicated that organic substrates obtained major productivity (420 mlCH4/gVS). The loading rate ratio 1:1 had optimum biodegradability rate than ratio 2:1, which was also investigated. The loading rate ratio of 1:1 had optimum biogas and methane yield after 20 days hydraulic retention time. It was concluded that the organic waste generated from the municipal landfills has great potential to produce methane, which can be used as a source of environmentally friendly and clean energy for the transport sector, industries and residential homes.

Keywords: OFMSW, Anaerobic digestion, Biochemical methane potential, biomethane, biogas.

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ABBREVATION

OFMSW	Organic fraction municipal solid waste
CO_2	Carbon dioxide
H_2	Hydrogen
HRT	Hydraulic retention time
TS	Total solids
VS	Volatile solids
OLR	Optimum Organic Loading Rates
SWM	Solid Waste Management
BMP	Biochemical Methane Potential
UMP	Ultimate Methane Production
S/I	Substrate/Inoculum
VFA	Volatile fatty acid
AD	Anaerobic digestion
SS	Sewage sludge

INTRODUCTION

Organic Fraction Municipal Solid Waste removal has become an ecological problem, brought to light because of the increase in public health concerns and environmental awareness. The average solid waste generation rate in 23 developing countries is 0.77 kg/person/day (Troschinetz and Mihelcic, 2009) and its still on the increase. At present, worldwide municipal solid waste generation is about two billion tons per year, which is predicted to increase to 3 billion tons by 2025 (Charles *et al*., 2009). The production of fruit and vegetable waste is also very high and becoming a source of concern in municipal landfills because of its high biodegradability (Bouallagui *et al*., 2005).

Recently, the organic fraction of solid waste has been recognized as a valuable resource that can be converted into useful products via microbial mediated transformations (Yu and Huang, 2009; Lesteur *et al.*, 2010). There are various methods available for the treatment of organic waste but anaerobic digestion appears to be a promising approach (Lee *et al.,* 2009c). Anaerobic digestion involves a series of metabolic reactions such as hydrolysis, acidogensis and methanogensis (Themelis and Ulloa, 2007). Anaerobic digestion of organic waste in landfills releases the gases methane and carbon dioxide that escape into the atmosphere and pollute the environment (Zhu *et al*., 2009). Under controlled conditions, the same process has the potential to provide useful products such as biofuel and organic amendment (soil conditioner) and the treatment system does not require an oxygen supply (Chanakya *et al*., 2007; Guermoud *et al*., 2009). Further, methane and hydrogen as potential fuels are considered comparatively cleaner than fossil fuel. In addition, this has the benefit of not depending on fossil fuel for energy consumption (Jingura and Matengaifa, 2009). Thus, anaerobic digestion represents an opportunity to decrease environmental pollution and at the same time, providing biogas and organic fertilizer or carrier material for bio-fertilizers.

The anaerobic treatment of solid organic waste is not as widespread as the aerobic process, mainly due to the longer time required to achieve bio-stabilization (Fernandez *et al*., 2010). The process is also sensitive to high levels of free ammonia resulting from anaerobic degradation of the nitrogen rich protein components (Fountoulakis *et al.*, 2008). The specific activity of methanogenic bacteria has been found to decrease with increasing concentrations of ammonia (Chen *et al*., 2008).

Recent advancements in bioreactor designs have increased the use of anaerobic digestion for the treatment of solid organic waste. To date, a number of novel bioreactor designs have been developed where anaerobic digestion can be performed at a much higher rate than the conventional methods. Many factors, including the type and concentration of substrate, temperature, moisture, pH, and other factors may affect the performance of the anaerobic digestion process in the bioreactor (Behera *et al*., 2010; Jeong *et al*., 2010). The objective of this research is focused on the application of anaerobic digestion on organic fraction municipal solid waste for the purpose of reducing the waste and quantify the amount of biogas that can be produced using substrate/inoculum ratio of 1:1 and 2:1. In addition, to design anaerobic digester that can produce biogas for a community of 40 000 people using OFMSW.

Purpose of Anaerobic digestion for organic fraction municipal solid waste

Due to its simplicity and financial reason, solid waste disposal on sanitary landfill has been the common practice for many decades. However, a study of Eriksson *et al.*, (2005) shows that reducing landfilling in favour of increasing recycle of energy and materials lead to a lower environmental impact, a lower consumption of energy resources, and lower economic costs. Landfilling of energy-rich waste should be avoided as much as possible, partly because of the negative environmental impacts from landfilling, and mainly because of its low recovery of resources. Furthermore, burying organic fraction of municipal solid waste together with other fractions implied extra cost for leachate treatment, low biogas quality and quantity, and high post closure care. In Europe the introduction of the European Landfill Directive (EC, 2009) has stimulated European Union Member States to develop sustainable solid waste management strategies, including collection, pre-treatment and final treatment methods. According to the Directive, it is compulsory for the Member States to reduce the amount of biodegradable solid waste that is deposited on sanitary landfills. Thus by the year 2020 there will be only less than 35 % of the total biodegradable solid wastes that were produced in 1995 being deposited on sanitary landfills.

Separation of municipal waste into a recyclable fraction, residual waste and a source sorted organic fraction is a common practice option of waste management adopted by the European Union Member States in order to meet the obligations of the Landfill Directive. In Germany, for instance, in 2006 around 8.45 million tons of OFMSW were collected. It consisted of 4.15 million tons of source sorted organic household residues and 4.3 million tons of compostable solid waste from gardens and parks (Statistisches Bundesamt, 2008a). Due to the high moisture content and low caloric value of organic waste, incineration will not be an economical option. Thus, the treatment of OFMSW can be realized alternatively by anaerobic digestion.

Compared to composting, anaerobic digestion of OFMSW has several advantages, such as better handling of wet waste, the possibility of energy recovery in the form of methane, less area requirement and less emission of bad odour and greenhouse gasses (Baldasano and Soriano, 2000; Hartmann and Ahring, 2006). Furthermore, if the digestate of an anaerobic digester has to be disposed in a landfill, anaerobic digestion of OFMSW has advantages such as: minimization of masses and volume, inactivation of biological and biochemical processes in order to avoid landfill gas and odour emissions, reduction of landfill settlements, and immobilization of pollutants in order to reduce leachate contamination (Fricke *et al*., 2005).

Microbial processes in anaerobic digestion

Anaerobic digestion is described as a series of processes involving microorganisms to break down biodegradable material in the absence of oxygen. The overall result of anaerobic digestion is a nearly complete conversion of the biodegradable organic material into methane, carbon dioxide, hydrogen sulphide, ammonia and new bacterial biomass (Gallert and Winter, 2005). Buswell (1952 as cited in Gallert and Winter, 2005) proposed a generic formula describing the overall chemical reaction of the anaerobic fermentation process of organic compounds which can be used for the prediction of biogas production:

In the anaerobic digestion process different types of bacteria degrade the organic matter successively in a multistep process and parallel reactions. The anaerobic digestion process of complex organic polymers is commonly divided into three inter-related steps: hydrolysis, fermentation (also known as acidogenesis), ß_oxidation (acetogenesis) and methanogenesis, which are schematically illustrated in Figure 1 (modified from Stronach *et al*., 1986; Pavlosthatis and Giraldo-Gomez, 1991).

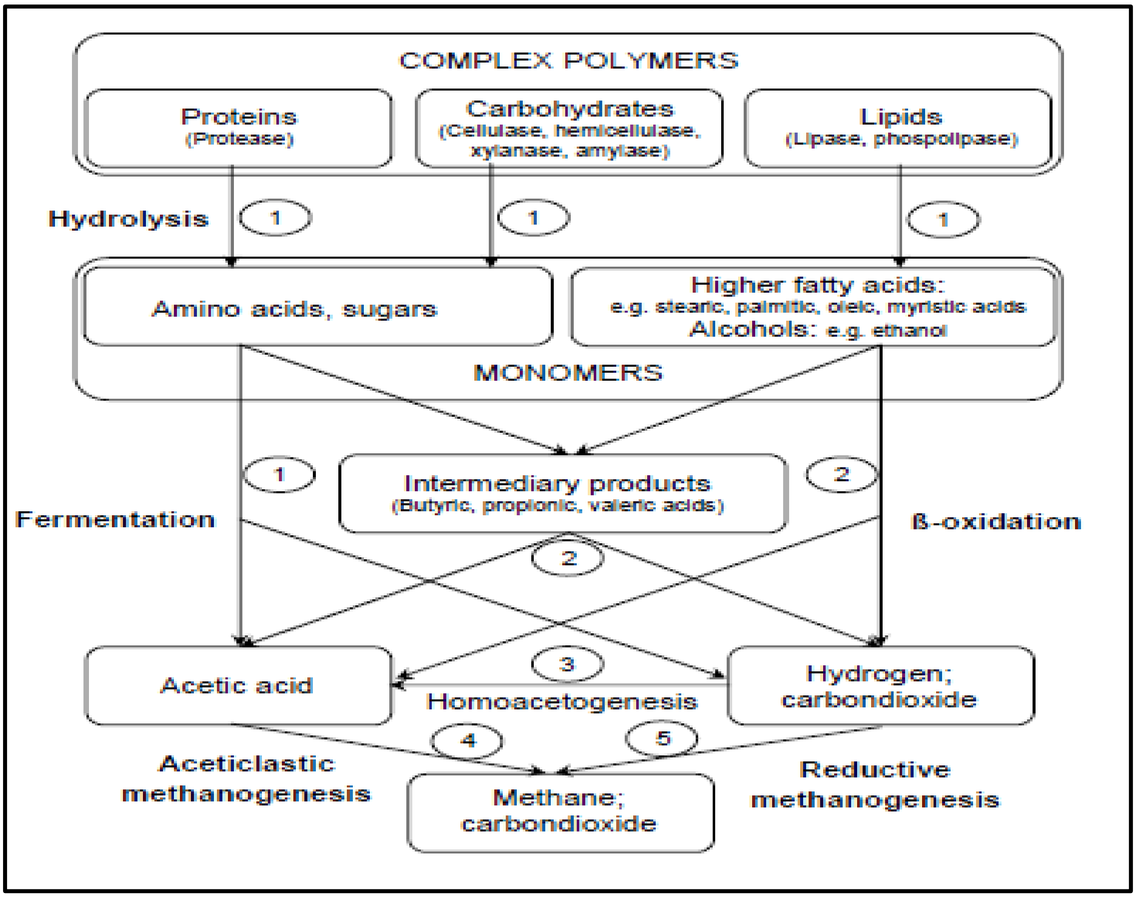

Figure 1: Schematic diagram of complete anaerobic digestion of complex polymers. Names in brackets indicate the enzymes excreted by hydrolytic bacteria. Numbers indicate the bacterial groups involved: 1. Fermentative bacteria, 2. Hydrogen producing acetogenic bacteria, 3. Hydrogen consuming acetogenic bacteria, 4. Aceticlastic methanogenic bacteria, 5. Carbon dioxide reducing methanogenic bacteria.

Hydrolysis: in the first step, extra-cellular enzymes into soluble products hydrolyze complex organic polymers such as polysaccharides, proteins, and lipids (fat and grease). The size of these soluble products must be small enough to allow their transport across the cell membrane of bacteria. Hydrolysis is a rather slow and energy consuming process and is normally considered as the overall rate limiting step for the complete anaerobic digestion of complex polymers (Gallert and Winter, 2005).

Fermentation (acidogenesis): The monomers produced from the hydrolysis process are then degraded by a large diversity of facultative anaerobes and anaerobes through many fermentative pathways. The degradation of these compounds results in the production of carbon dioxide, hydrogen gas, alcohols, organic acids, some organic nitrogen compounds, and some organic sulphur compounds. The most important of the organic acids is acetate since it can be used directly as a substrate by methanogenic bacteria (Gallert and Winter, 2008).

Acetogenesis: Acetate can be produced not only through the fermentation of soluble organic compounds but also through acetogenesis. In this step low molecular weight volatile fatty acids are converted into acetate, hydrogen gas and carbon dioxide by acetogenic bacteria. This conversion process can only be thermodynamically favoured if the partial hydrogen pressure is kept low. Thus, efficient removal of the produced hydrogen gas is necessary (Gerardi, 2003).

Methanogenesis*:* Finally, methane gas is produced by methane producing bacteria. Methane is formed around 66 % from acetate by means acetate decarboxylation proceeded by acetoclastic methanogenic bacteria (eg *Methanosaeta* spp. and *Methsnosarcina* spp.) and 34 % from carbon dioxide reduction by hydrogen, catalysed by hydrogen utilizing (hydrogenophilic) methanogenic bacteria. In particular, hydrogen utilizing methanogenic bacteria maybe responsible for the low partial pressure of hydrogen gas in anaerobic reactors, thus they create optimal conditions for acetogenic bacteria to breakdown the hydrolyzed organic compounds other than CO_2, H_2 and acetate into substrates for methanogenic bacteria (Veenstra, 2000; Metcalf and Eddy Inc., 2003). Alternatively, sulphate reducing bacteria or autotrophic acetogenic bacteria may also use hydrogen for sulphate reduction or acetate production from $CO_2 + H_2$ and thus decrease the hydrogen partial pressure.

CONDITIONS FOR ANAEROBIC DIGESTION

Digester Temperature

Temperature inside the digester has a major effect on the biogas production process. There are various temperature ranges during which anaerobic fermentation can take place (Choorit and Wisarnwan, 2007);

a) Psychrophilic (< 30 ^{o}C)

b) Mesophilic (30 – 40 ^{o}C)

c) Thermophilic (50 – 60 ^{o}C)

However, anaerobes are most active in the mesophilic and thermophilic temperature ranges (Kumar, 2012). The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35 °C. When the ambient temperature goes down to below 10 ^{o}C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25 ºC to 30 °C. Proper insulation of digester helps to increase gas production in cold climates or high altitudes (FAO, 1996; Ward *et al.*, 2008).

Concentration of feedstock

The solids concentration in the influent to the reactor affects the rate of fermentation. The amount of fermentable material of the feed in a unit volume of slurry is defined as solids concentration. The mobility of the methanogens within the substrate is gradually impaired by increasing solids content, and the biogas yield may suffer as a result. Ordinarily 6-9% solids concentration is best suited. In an experiment reportedly conducted in China, the optimum concentration of solids was considered to be 6 % in summer but between 10 and 20 % in winter and spring. When temperatures are low and materials take longer to decompose; it is better to have a higher total solids concentration, although this might result into impeded flows through the reactor (Kumar, 2012).

Loading rate

Loading rate is the amount of raw materials fed per unit volume of digester capacity per Day. Gas production is also highly dependent on the loading rate. Studies have shown that methane yield increased with a reduction in the loading rate. If the loading rate is too high, there will be more substrate than the bacteria can decompose. If the digester is being overloaded, the gas production will rise up initially and then fall after a while when inhibition occurs. Inhibition is caused because methanogens multiply slowly than the acid forming bacteria and the gas inhibits the methanogens from producing methane and thus the gas production will be inhibited (Ward *et al.*, 2008).

Feed materials composition and nutrients

Anaerobic digestion processes are able to utilize a large number of organic materials as feedstock, including animal manure, human waste, crop residues and other wastes. Although, in order to grow, bacteria need more than a supply of organic substances as a source of carbon and nutrients, they also require certain mineral nutrients. In addition to carbon, oxygen and hydrogen, the generation of biomass requires an adequate supply of nitrogen, sulphur, phosphorus, potassium, calcium, magnesium etc. Agricultural residues and wastes usually contain adequate amounts of these elements (Kumar, 2012).

Hydraulic retention time (HRT)

Retention time (also known as hydraulic detention time) is the average time spent by the substrate inside the digester before it comes out. In countries with colder climates, the HRT may go up to 100 days as compared to warmer climates where the values lie between 30-50 days. Shorter retention time is likely to face the risk of washout of bacterial population while longer retention time requires large volume of the digester and hence more capital. There is a linear relationship between retention time and the digester temperature up to 35° C, the higher the temperature, the lower the retention time and the reverse is true (Ward *et al.*, 2008).

pH value

The methane-producing bacteria live best under neutral to slightly alkaline conditions. The pH in a biogas digester is directly dependent on the retention time. In the initial stages of fermentation, large amounts of organic acids are produced by acid forming bacteria; this in turn leads to the pH inside the digester falling to values below 5. This inhibits or even stops the digestion process. Methanogenic bacteria are very sensitive to pH and do not thrive below pH 6.5. Later on, as the digestion process continues, concentration of ammonium increases due to digestion of nitrogen which can increase the pH value to above 8.Once the process of fermentation has stabilized under anaerobic conditions, the pH will normally take on a value of between 7 and 8.5 (Ward *et al.*, 2008).

Moisture content

The microorganisms' excretive and other essential metabolic processes require water to take place hence the feedstock should have optimum moisture content for performance of the bacteria. The optimum value of moisture content should be about 90% of the total volume of feedstock.

Excess water in the feedstock leads to a fall in the rate of production per unit volume of feedstock and on the other hand, inadequate water leads to an accumulation of acetic acids which inhibit the digestion process and hence production. Furthermore, a thick scum will form on the surface of the substrate. This scum may prevent effective mixing of the charge in the digester (Kumar, 2012).

Substrate Pre-treatment

This refers to all the processes that the feedstock undergoes prior to use in anaerobic digestion. These processes range from physical ones like sorting and particle size reduction to chemical processes like alkali treatment and metal addition among others (Igoni *et al*., 2008). The pre-treatment of feedstock can yield higher biogas production rates and volatile solids reduction (Tiehm *et al.*, 2001). The main effects that pre-treatments have on various substrates are particle-size reduction, biodegradability enhancement, formation of refractory compounds and loss of organic material (Carlsson *et al*., 2012).

QUALITIES OF OFMSW AS A SUBSTRATE FOR ANAEROBIC DIGESTION

For efficient biogas production, a clear understanding of the nature of the input substrate has to be made because the properties of the substrate have a direct bearing on the resultant volume of the biodigester, the quantity/quality of output biogas and hence the production cost. Among the substrate parameters that should be ascertained are: Total Solids (TS), Volatile Solids (VS), Substrate and organic loading rate. These have been summarised as below:

Total Solids

OFSMW is a predominantly solid substrate with a TS content of 30% as well as relatively large particle sizes (East Bay Municipal Utility District, 2008). It is of heterogeneous nature with a complex composition, which usually makes estimates or measurements for its composition quite difficult (Curry and Pillay, 2012).

Volatile Solids

OFMSW has a high range of volatile solids ranging between 90-95% of TS and 28-29% of wet weight (Cho and Park, 1995).

Optimum Organic Loading Rates (OLR)

OFMSW gives optimum anaerobic biodigester performance at organic loading rates between 5-10kgVS/m^3 (Davidsson *et al*., 2007; Zhang *et al*., 2007).

Biogas yield

Values from literature indicate that depending on the source of the OFMSW, the substrate can yield approximately anywhere between 300 to 500m^3 of biogas per tonne of volatile solids of 65% methane (Curry and Pillay, 2012). The average biogas production from OFMSW is 367m^3/ VS (EBMUD, 2008). Table 1 below shows the various biogas yields as quoted from different sources. The average methane content of biogas obtained from OFMSW as primary feedstock is 65% (Davidsson *et al*., 2007).

Table 1: Experimental biogas yield from OFMSW

Sources	Biogas yield m^3/VS
Discharged Food	355 (Curry and Pillay, 2012)
Food waste	367 (EBMUD, 2008)
OFMSW	310-490 (Curry and Pillay, 2012)
OFMSW	300-400 (Davidsson *et al*., 2007)
OFMSW	390 (Karnchanawong and Uparawanna, 2006)

Benefits of Using OFMSW as a Substrate for Biogas Production

Availability at low or no cost

Compared to energy crops that require extra costs to be cultivated, OFMSW is readily available in abundance and is an inexhaustible substrate, which requires minimal input to be ready as a raw material for biogas production. In most cases, it is available at no extra cost since the anaerobic digestion can be incorporated into the existing waste management systems in which OFMSW is normally discarded to landfills as a useless component (Pognani et al., 2009).

Resource for environmental conservation

The use of OFMSW for biogas production is a great opportunity that helps to solve the current growing problems of solid waste management (SWM) in urban settings that are relying majorly on landfilling of the OFMSW that leads to methane gas emissions to the atmosphere. In addition, the anaerobic digestion process produces useful energy in the form of biogas heat that can be use as a substitute to the traditional fossil fuels for heating, cooking as well as electricity generation. Fossil fuels are rich in carbon emissions and any clean energy alternative is of absolute value to environmental conservation ((EBMUD, 2008; Chen et al., 2010).

MATERIALS AND METHODS

The aim of the study is to evaluate the performance of OFMSW in anaerobic digestion with inoculum constituted by effluent from the wastewater plant. Samples of OFMSW were collected from Alfonso VIII residential cafeteria.

The experimental work was carried out at the chemical engineering laboratory, University of Valladolid, Spain. Several tests were carried out on the considered substrates: chemical and physical analysis, in order to characterize the substrate; BMP and anaerobic digestion tests in a lab scale, in order to evaluate the biogas production and the methane yield and results were compared to data from the literature.

Substrate and inoculum

All the fractions that compounded the final mixture of OFMSW were evaluated by BMP tests. The final mixtures (OFMSW) were composed only of food (fruit/vegetable; meat/fish; cereal, plastic, paper). For all the assays, OFMSW were obtained and tested, in order to establish a distinctive substrate for all the experiments, the same waste was used. Given the amount of substrate that should be used for these tests and the heterogeneity that the OFMSW could provide, the mixture offers the perfect conditions for evaluating the parameters that could have an influence on the biodegradability process. The characterization of the substrates is presented in Table 2.

Table 2: Substrates and inoculum characterization (TS, VS: total and volatile solids)

Parameters	**Units**	**OFMSW**	**Inoculum**
TS	g/kg	340.9	19.23
VS	g/kg	298.9	11.95
VS/TS	%	89	62

Mechanical pre-treatment

Mechanical pre-treatment is the reduction of the particle size resulting to increased specific surface area (Wang *et al.*, 2012). Anaerobic digestion process efficiency increase due to a large area being exposed to the bacteria. When the specific surface area is not exposed, the chemical oxygen demand degradation is lowered as well as the methane production. The studies show that the relationship that exists between particle size and production rate of biogas is inversely proportional (Wang *et al*., 2012). The size reduction in the mechanical pre-treatment process was achieved by using the homogeniser blender to reduce the size of the substrate in order to make it easier for bacteria to break down the substrate easily.

Biochemical methane potential tests

Biochemical methane potential (BMP) tests allow determining kinetics and methane potentials of the substrates. The BMP tests follow an internal protocol based on standardized assays for research purposes (Angelidaki et al., 2009). The assays were performed in triplicates. Glass bottles of 2 L capacity were used to carry out the tests. A substrate-inoculum ratio of 1:1 and 2:1 in terms of VS were applied. The inoculum is WWTP mesophilic digested sludge and was pre-incubated for 2 days at 35ºC. A buffer solution (5 g$NaHCO_3$/L) and micro and macro-nutrients (1mL/L) are added to assure inoculum activity. Also some Na_2S assures oxygen depletion. Inoculum alone is also tested by triplicates to determine its methane production so that it can be subtracted in the other reactors and calculate the net methane productions. An extra reactor with cellulose as substrate is always prepared as a control test. The gas chamber is washed with helium to displace air before closing the reactors with a septum. The incubation temperature is for all the tests 35ºC (mesophilic conditions). Reactors are stirred in a rotary shaker (5 rpm). Periodical monitoring analyses (every day and later every 2 days) of biogas production by pressure meter (*IFM Electronics*, PI-1696) and biogas composition by gas chromatography (*Varian 3800*, sample uptake with a 100µL *Hamilton* syringe) are performed during the tests. Methane potentials are always expressed as average values of the net volume of methane per gram of initial substrate VS content. The BMP test was terminated when a daily production of less than 1% of the whole production occurred as it is indicated in Equation. 1.

$$V\_CH_4neto / gSV\_added = \frac{(V_{accumulated}(ml) - V_{accumolated}\_blank(ml))}{VS_{added}(g)} \qquad \text{Equation 1}$$

The results provided by the BMP assays were obtained from the triplicate average for each bottle and were expressed as the net volume of methane per g of VS added (mlCH4 / gVS_{added}).

Analytical methods

Substrates characterization was partially performed in the University of Valladolid, following an internal protocol based on Standard methods (Apha, 2005) to determine the next parameters: TS, VS (total and volatile solids);

Figure 2: Gas chromatograph, pressure meter, BMP reactor and rotary shaker.

RESULTS AND DISCUSSION

Methane cumulative production for all the mixtures was continuously monitored. As mentioned above, the experiment finished when no significant methane production was detected. As a result, the ultimate methane production (UMP), which means the maximum methane potential, was obtained for all the mixtures and expressed as ($mlCH_4/gVS_{added}$). The results of methane production from OFMSW in batch experiments are presented in Figure 3. The maximum methane yield was achieved during the first 14 days of the digestion (400 mlCH4 / g VS_{added}). About 90% of the maximum methane production was released in the first six days. After 14 days digestion there was no longer a significant methane production observed and it was decided that after 20 days of digestion, the potential methane production of OFMSW has already reached its maximum. However, in the case of substrate/inoculum ratio of 2:1, methane production was slower in the first 10 days and this could be due to the amount of substrate that might be more than what the bacteria can decompose initially.

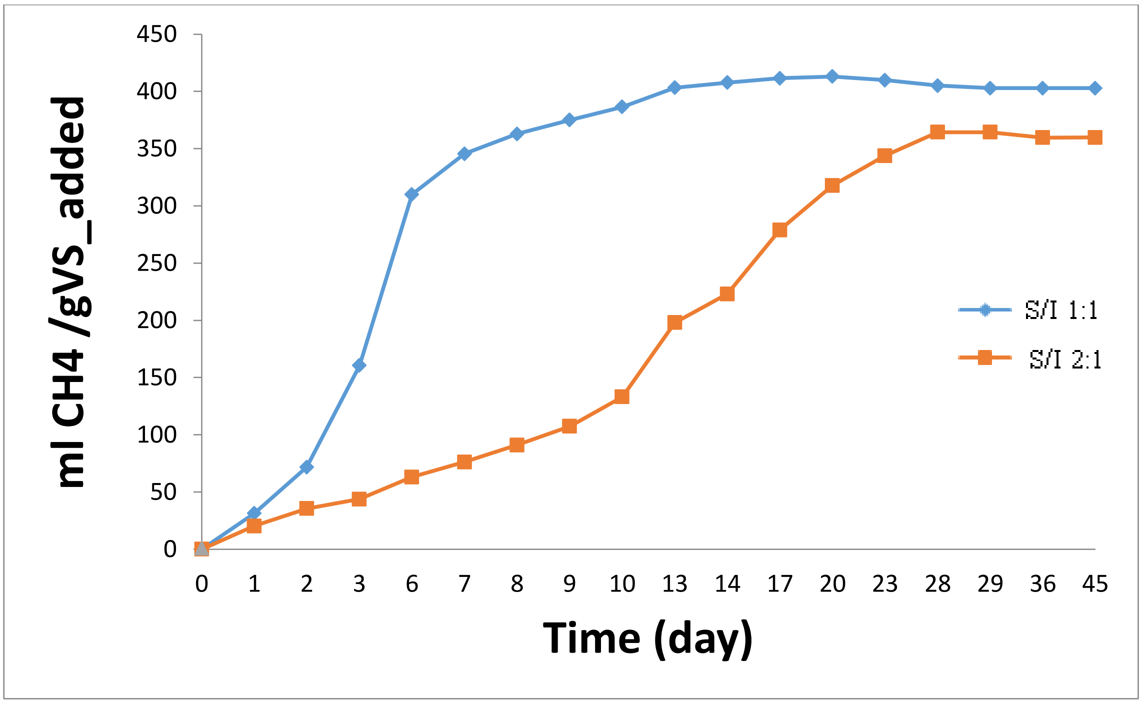

Figure 3: Methane production potential of OFMSW.

Removal efficiency

The removal percentages of each substrate were obtained at the end of the experiment. All the parameters (TS, VS) were analysed and compared to the initial data in order to evaluate the removal percentages. For the estimation of the equivalent removal of substrate, the efficiency produced by the inoculum in the blanks assays was considered in order to obtain the results (table 3). Removal percentages of over 30% for TS and 40% for VS were obtained for the substrates. This removal results obtained for the OFMSW due to its composition showed high biodegradability and productivity.

Table 3: Substrates and inoculum characterization at the end of the process

Parameters	Units	OFMSW	Inoculum
TS	g/kg	20.94	19.59
VS	g/kg	10.38	9.7
VS/TS	%	50	50

Volatile fatty acids

After the termination of the experiment, the effluent was analysed for volatile fatty acid. The dominant volatile fatty acids in the effluent were acetic and butyric acid. The concentrations of acetic and butyric acid reached their maximum values of 11.94 mg /L and 61.98 mg/L at the end of the experiment. This indicated that the acetogenic and methanogenic population in the reactor was intact. Other volatile fatty acids such as propanoic, valeric and hexanoic acid were not present in the effluent

Conclusion

The maximum methane productivity, biodegradability, and the higher rate of methane productivity were reached at S/I ratio of 1:1 (Fig. 3). At this ratio, the final methane productivity was 420 mLCH4/g VS for OFMSW, which ranged between the values obtained by Curry and Pillay (2012) during the anaerobic digestion of OFMSW (310–

490 mLCH4/g VS). By day 6, the CH_4 productivity for OFMSW accounted for about 80% of the final productivity.

However, At S/I ratio of 2:1 the final methane productivity and biodegradability was slightly lower (20%) than those obtained at a S/I of 1:1 (Fig. 1). At this S/I ratio of 2:1, the occurrence of a lag phase (6 days) together with the lower rate and final CH_4 productivity suggest the potential inhibition of the methanogenic activity (Fig. 3). In this context, González-Fernández and García-Encina (2009), Zhou *et al.* (2011) reported an accumulation of VFAs (mainly acetic acid and byturic acid) at a high S/I ratio. The accumulation of these organic acids can cause a drop in pH and therefore an adverse impact on bacteria (Speece, 2006). The accumulation of VFAs observed by the above mentioned authors was likely due to the higher availability of easily hydrolysable substrate at high S/I ratios, however, in any case the likely accumulation never resulted in the complete stop of the biodegradation process. The final CH_4 content in the biogas was approximately constant for the different ratio.

PLANT DESIGN

The basic requirements of an anaerobic digester design are to allow for a continuously high and sustainable organic load rate, a short hydraulic retention time (to minimise reactor volume) and to produce the maximum volume of methane.

Apata Ibadan is a small community in Nigeria with inhabitants of about 40 000 people. The total amount of organic fraction municipal solid waste produce per person/day is estimated to be 0.5 kg OFMSW/p.d that comprises of natural food such as fruit/vegetable and fish. Table 4 shows the main components of the integrated waste.

Table 4: OFMSW data from an experimental study.

Overall waste composition	
Perishable fraction	90%
Paper/cardboard	6.7%
Recyclable plastics	3.3%
OFMSW data (analytical result)	
Overall waste production kg/d	20,000
Total solids (TS, g/kg)	340.9
Volatile solids (VS, g/kg)	298.9
Experimental study result	
(m^3 methane/ kgVS $_{added}$)	0.42

At present, all the wastes are transported to a landfill (around 30 km from the residential area). Because of the increasing costs of this disposal technique and the limited amount of space in landfills, several approaches to solve the waste problem have been considered. Among them, the anaerobic digestion (AD) of the organic fraction municipal solid waste was regarded as very appropriate, after the results reported recently in the literature. The analysis carried out on the organic fraction of these wastes showed that they were very similar to the separately collected organic fraction of municipal solid waste (SC-OFMSW). A study of the codigestion of SC-OFMSW together with sewage sludge (SS) showed the advantages of this technique (MataAlvarez & Cecchi, 2009). Moreover, based on a preliminary comparative economic evaluation, it was the most profitable option (MataAlvarez et al., 2010).

Pretreatment and feed preparation

Dilution of the dry solid is 20% = 20% TS

20 000 kg OFMSW (0.3409kg TS/kg OFMSW) = 6 818 kg TS/d

= 13 818 kg H_2O/d

20 000 kg OFMSW (0.2989kg VS/kg OFMSW) = 5 978 kg VS/d

In order to calculate the required dilution based on 20% TS

6 818 kg TS/d = 0.20 (TF); TF(Total feed) = 34 090 kg Total Feed/d = 34 m^3/d

The required water for dilution is:

34 090 kg Total Feed/d = (6 818 kg TS/d + 13 818 kg H_2O/d) + dilution water

Dilution water = 13 454 kg H_2O

Reactor Design

In the present study, design of an anaerobic digester for the community of Apata with a current population of 40 000 people has been undertaken for treatment of OFMSW. The reactor design is tailor made to suit the OFMSW characteristics given in Table 4.

Total population in the community = 40,000

Average flow rate = 34 m^3 /day

Hydraulic retention time (HRT) = 20 days

To calculate the volume of the reactor, will be HRT * flow rate

Volume = 20 days * 34 m^3/day = 680 m^3

In order to calculate the diameter, the following calculation was made:

Volume = pi $D^2/4$ * H

Height is assumed 10 m based on literature.

Diameter = 9.30 m

Recalculating the diameter because the ratio of Height to diameter is too high and therefore assuming a new height of 6 m and the new diameter is 12 m. The ratio D/H = 12/6 = 2. This is a very common ratio in practical design of anaerobic digester

Estimation of biomethane production

From the experimental work, the methane productivity was

$$420\text{mL } CH_4/\text{gVS added} = 0{,}420 \text{ Nm}^3 \text{ } CH_4 \text{ / kg VS}_{\text{added}}$$

Now, the total amount of methane produce is

$$0{,}420 \text{ Nm}^3 \text{ } CH_4 \text{ / kg VS}_{\text{added}} \text{ (5 978 kg VS/d)} = 2\,510 \text{ Nm}^3 \text{ } CH_4\text{/d}$$

$$= 106 \text{ Nm}^3 \text{ } CH_4\text{/h}$$

According to the experimental and calculated data, figure 4 shows the design of the digester and the mass balance of all the main parameters.

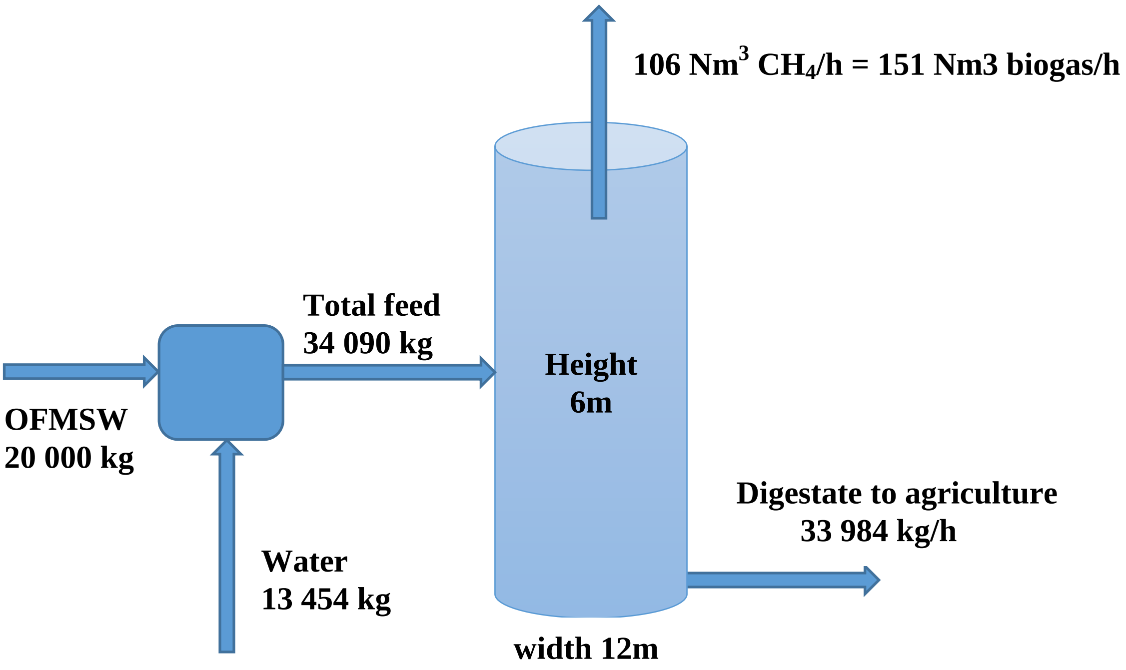

Figure 4: Designed Anaerobic digester and mass balance

Energy production

The potential energy that can be obtained based on the calculation and characterisation of the OFMSW is estimated below. This energy could either be used as heat/burning or as combined heat and power engine.

From literature, 1 Nm^3 CH_4 is equivalent to 11 kwh/Nm^3 CH_4

1. Boiler:

   To calculate the amount of energy produce burning biogas in a boiler considering the efficiency of boiler to be 90%

   = 0.9 * 106 Nm^3 CH_4/h * 11 kwh/Nm^3 CH_4

   = 1049 KW of heat energy can be produce

2. Combined heat and power (CHP)

   The biomethane produced can be burn in combined heat and power engine to generate electricity and heat. In this calculation, it is assume that only 35% of the energy produce is converted to electricity.

   0.35* 106 Nm^3 CH_4/h * 11 kwh/Nm^3 CH_4 = 408 KW of electricity.

CONCLUSIONS

Substrate to inoculum (S/I) ratios demonstrated that ratio1:1 is the ideal ratio for OFMSW digestion. Higher S/I ratio is not feasible due to the accumulation of inhibitor, VFAs, which is known as the main contributor to the low methane yield. Thus, it can be concluded that S/I plays a significant role in determining the feasibility and optimum ratio of substrate to be added to inoculum in order to achieve higher methane production. Lag phase occurrence and long digestion period must be expected when dealing with high substrate to inoculum ratio.

BMP experiments indicated that the digestion of OFMSW is feasible, highly biodegradable and positively affected methane production with $0.420Nm^3/kgVS_{added.}$ Furthermore, sludge from WWTP used in the experiments indicated suitability to be used as inoculating medium for OFMSW digestion.

A design of a plant to treat the OFMSW for a small community of 40 000 inhabitants was carried out, based on the results from the experimental study. Accepting, hydraulic retention time of 20 days, design parameters of the anaerobic digester has a height of 6m and diameter of 12m.

Burning the biogas in a combined heat and power engine, it is possible to produce 480KW electricity, which can be use to provide electricity for the community.

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APPENDIX A

Volume of substrate corresponding to a ratio (S/I)

Substrate/Inoculum calculation:

Ratio 1:1 $gVS_{substrate} / gVS_{inoculum}$,

V (ml) liquid = 700ml

The equation used is:

$$m(g)substrate = \frac{ratio(S/I) * weight\_inoculum(g) * SV\_inoculum(g/Kg)}{SV\_substrate(g/Kg)}$$

$$m(g)substrate = \frac{1*700*0.01195}{0.2989+(1*0.0195)} = \frac{8.365}{0.31085} = 26.9g$$

$$m(g)\ inoculum = 700 - 26.9 = 673.1g$$

Table A-1: Substrate/Inoculum 1:1 preparation

	S/I ratio: 1:1			bottle vol (ml)	2000	
sample code	Theoretical amount of innoculum (g)	Actual amount of innoculum (g)	Theoretical amount of substrate (g)	Actual amount of substrate (g)	liquid chamber volume (ml)	used gas chamber volume (ml)
V11	673.1	673.2	26.9	28.4	701.6	1298.4
V12	673.1	673.1	26.9	27.1	700.2	1299.8
V13	673.1	673.1	26.9	27.1	700.2	1299.8
VC11	691.7	691.8	8.3	8.3	700.1	1299.9
VC12	691.7	691.7	8.3	8.3	700	1300
VC13	691.7	691.7	8.3	8.3	700	1300
VB11	700	700.1	0	0	700.1	1299.9
VB12	700	700	0	0	700	1300
VB13	700	700	0	0	700	1300

Table A-2: Substrate/Inoculum 2:1 preparation

	S/I ratio: 2:1				bottle vol (ml)	2000
sample code	Theoretical amount of innoculum (g)	Actual amount of innoculum (g)	Theoretical amount of substrate (g)	Actual amount of substrate (g)	liquid chamber volume (ml)	used gas chamber volume (ml)
V21	673.1	673.1	53.8	54	727.1	1272.9
V22	673.1	673.1	53.8	54.2	727.3	1272.7
V23	673.1	673.1	53.8	53.9	727	1273
VC21	710.6	710.9	16.34	16.34	727.24	1272.76
VC22	710.6	711	16.34	16.34	727.34	1272.66
VC23	710.6	711.5	16.34	16.34	727.84	1272.16
VB21	726.9	726.9	0	0	726.9	1273.1
VB22	726.9	726.9	0	0	726.9	1273.1
VB23	726.9	727	0	0	727	1273

APPENDIX B

Table B: Experimental raw data

intial pressure (mbar)	**20**
temperature (K)	**273.15**
mesophilic temperature (C)	**35**

2017/05/03 **DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**

Sample code	CO2	H2S	O2	N2	CH4	pressure (m bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	biogas	Methane production, V(ml)
V11	67.7808	0	0.5344	2.2572	29.4276	995	975	0.98	1298.4	1122.15	330.22
V12	66.666	0.0093	0.2931	1.3599	31.6717	990	970	0.97	1299.8	1117.60	353.96
V13	65.9787	0.0087	0.3801	1.7003	31.9323	1035	1015	1.02	1299.8	1169.45	373.43
VC11	55.0902	0.0848	2.0867	11.3559	31.3824	200	180	0.18	1299.9	207.41	65.09
VC12	52.1472	0.049	1.4979	7.9474	38.3586	235	215	0.22	1300	247.75	95.04
VC13	57.0845	0.1072	1.4795	11.2309	30.0979	225	205	0.21	1300	236.23	71.10
VB11	86.3204	0.1954	2.4885	10.9542	30.0415	255	235	0.24	1299.9	270.78	81.35
VB12	53.5198	0.1481	1.282	5.9123	39.1378	245	225	0.23	1300	259.28	101.48
VB13	57.0594	0.3738	1.686	0	40.8808	245	225	0.23	1300	259.28	105.99
V21	75.7938	0.0271	0.1375	0.7996	23.242	1666	1646	1.65	1272.9	1857.22	431.65
V22	76.2628	0.0216	0.1862	1.1265	22.4029	1604	1584	1.58	1272.7	1786.98	400.34
V23	75.814	0.0262	0.1643	0.9546	23.0409	1534	1514	1.51	1273	1708.41	393.63
VC21	63.5789	0.2661	1.3762	9.1589	25.6199	195	175	0.18	1272.8	197.43	50.58
VC22	62.2675	0.1728	1.439	9.0386	27.0822	210	190	0.19	1272.7	214.34	58.05
VC23	61.8526	0.1138	1.8106	9.8968	26.3265	210	190	0.19	1272.2	214.26	56.41
VB21	55.0123	0.2664	1.2585	7.0793	36.3834	225	205	0.21	1273.1	231.34	84.17
VB22	51.0139	0.1623	2.1757	10.2736	36.3744	220	200	0.20	1273.1	225.70	82.10
VB23	56.3868	0.1196	1.3204	7.4382	34.735	225	205	0.21	1273	231.32	80.35

2017/05/04	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	biogas	Methane production, V(ml)
V11	62.0658	0.0107	0.0766	0.8816	36.9653	910	890	0.89	1298.4	1024.32	378.64
V12	60.5021	0	0.1745	0.7368	38.5866	915	895	0.90	1299.8	1031.19	397.90
V13	60.5262	0.0128	0.1758	0.7365	38.5488	865	845	0.85	1299.8	973.58	375.30
VC11	58.2837	0	0.7049	4.1734	36.838	245	225	0.23	1299.9	259.26	95.51
VC12	57.1801	0.0813	0.8319	0	41.9068	290	270	0.27	1300	311.13	130.39
VC13	58.9256	0.0719	0.9647	5.9	34.1379	250	230	0.23	1300	265.04	90.48
VB11	48.2079	0	0.7609	3.6653	47.3659	115	95	0.10	1299.9	109.46	51.85
VB12	46.8581	0.0728	1.4399	5.912	45.7172	120	100	0.10	1300	115.23	52.68
VB13	47.1969	0.0962	1.2565	5.3543	46.0961	120	100	0.10	1300	115.23	53.12
V21	72.4358	0.0291	0.24421	0.9471	26.3459	1045	1025	1.03	1272.9	1156.53	304.70
V22	74.1466	0.0348	0.1157	0.5469	25.156	915	895	0.90	1272.7	1009.69	254.00
V23	72.8615	0.0433	0.2326	0.9403	25.9223	1030	1010	1.01	1273	1139.70	295.44
VC21	63.8947	0.0337	0.8708	4.8459	30.3548	245	225	0.23	1272.76	253.84	77.05
VC22	65.1384	0.0354	0.3345	2.7675	31.7242	225	205	0.21	1272.66	231.26	73.37
VC23	63.5855	0.064	0.9129	4.6482	30.7894	240	220	0.22	1272.16	248.09	76.38
VB21	47.4897	0.1358	1.5429	7.0832	43.7484	90	70	0.07	1273.1	78.99	34.56
VB22	45.3348	0.1718	1.4723	7.2076	45.8134	110	90	0.09	1273.1	101.56	46.53
VB23	53.6824	0.2181	1.5553	0	44.5442	90	70	0.07	1273	78.99	35.18

2017/05/05	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	50.9096	0.0255	0.1835	0.7194	48.162	610	590	0.59	1298.4	679.05	327.04
V12	49.1646	0.0247	0.1693	0.6552	49.9862	615	595	0.60	1299.8	685.54	342.68
V13	49.3913	0.0429	0.2198	0.8576	49.4884	595	575	0.58	1299.8	662.50	327.86
VC11	65.1771	0	0.309	1.70047	32.8091	620	600	0.60	1299.9	691.35	226.83
VC12	64.4349	0.0715	0.6238	0	34.8697	630	610	0.61	1300	702.93	245.11
VC13	65.6906	0.037	0.3288	2.1078	31.8358	660	640	0.64	1300	737.50	234.79
VB11	43.79	0.1242	1.3297	5.438	49.3181	85	65	0.07	1299.9	74.90	36.94
VB12	44.9167	0.0819	0.491	2.3742	52.1362	85	65	0.07	1300	74.90	39.05
VB13	46.623	0.166	0	1.0999	52.1171	85	65	0.07	1300	74.90	39.04
V21	70.4536	0.0379	0.096	0.3709	29.0415	580	560	0.56	1272.9	631.86	183.50
V22	72.7365	0.014	0.1721	0.002	27.0753	525	505	0.51	1272.7	569.71	154.25
V23	70.7899	0.0414	0.1825	0.6915	28.2947	520	500	0.50	1273	564.21	159.64
VC21	74.8655	0.1041	0.4715	0	24.5589	955	935	0.94	1272.8	1054.87	259.06
VC22	72.387	0	0.2229	1.1928	26.1973	950	930	0.93	1272.7	1049.14	274.85
VC23	72.6943	0.00321	0.2151	1.1589	25.8996	925	905	0.91	1272.2	1020.54	264.32
VB21	43.5545	0.1125	1.3261	6.043	48.9639	80	60	0.06	1273.1	67.71	33.15
VB22	41.8138	0.1358	1.2085	5.8971	50.9447	80	60	0.06	1273.1	67.71	34.49
VB23	45.0224	0.0277	1.3766	6.6543	46.919	80	60	0.06	1273	67.70	31.77

2017/05/08	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	30.8849	0	0.0613	0.2363	68.8175	1744	1724	1.72	1298.4	1984.20	1365.47
V12	30.9945	0	0.0531	0.2034	68.7509	1672	1652	1.65	1299.8	1903.38	1308.59
V13	30.6205	0.0033	0.1161	0.4432	68.8169	1630	1610	1.61	1299.8	1854.99	1276.55
VC11	64.7889	0.0123	0.0966	0.4862	34.6161	1602	1582	1.58	1299.9	1822.87	631.01
VC12	61.0149	0.0109	0.0961	0.4446	38.4335	1698	1678	1.68	1300	1933.63	743.16
VC13	62.3752	0.0113	0.0987	0.5623	36.9525	1596	1576	1.58	1300	1816.10	671.09
VB11	38.1755	0.0666	0.8944	3.7276	57.1359	150	130	0.13	1299.9	149.79	85.59
VB12	38.6884	0.1329	0.7585	3.2327	57.1845	155	135	0.14	1300	155.57	88.96
VB13	40.2144	0.1025	0.8514	0	58.8317	160	140	0.14	1300	161.33	94.91
V21	51.0438	0.0317	0.1632	0.6002	48.161	890	870	0.87	1272.9	981.64	472.77
V22	58.5824	0.032	0.1218	0.4697	40.7942	695	675	0.68	1272.7	761.50	310.65
V23	52.7884	0.0109	0.0928	0.352	46.7559	825	805	0.81	1273	908.37	424.72
VC21	73.8216	0.0291	0.0683	0.368	25.7131	1332	1312	1.31	1272.8	1480.20	380.60
VC22	74.046	0.0289	0.0805	0.39	25.4546	1350	1330	1.33	1272.7	1500.39	381.92
VC23	74.4486	0.0439	0.122	0.5318	24.8538	1362	1342	1.34	1272.2	1513.33	376.12
VB21	37.2857	0.1322	0.855	4.359	57.6612	160	140	0.14	1273.1	157.99	91.10
VB22	37.4096	0	0.7976	3.8843	57.9085	155	135	0.14	1273.1	152.35	88.22
VB23	3.685	0	0.7311	3.6944	57.8895	170	150	0.15	1273	169.26	97.98

2017/05/09	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	33.924	0.0145	0.1441	0.5384	65.3789	540	520	0.5	1298.4	598.48	391.28
V12	35.4433	0	0.1513	0.554	63.8513	420	400	0.4	1299.8	460.87	294.27
V13	35.1649	0.0208	0.1888	0.6781	63.9473	420	400	0.4	1299.8	460.87	294.71
VC11	63.6791	0.0111	0.0993	0.4208	35.7896	480	460	0.5	1299.9	530.04	189.70
VC12	58.8381	0.0325	0.1534	0.5884	40.3876	540	520	0.5	1300	599.22	242.01
VC13	58.1821	0.0313	0.1297	0.5844	41.0733	550	530	0.5	1300	610.74	250.85
VB11	38.4229	0.0511	0.8752	3.675	56.9758	70	50	0.1	1299.9	57.61	32.83
VB12	38.5872	0.0781	0.9061	3.7027	56.7259	75	55	0.1	1300	63.38	35.95
VB13	38.5781	0.0157	0.8622	3.5308	57.0132	75	55	0.1	1300	63.38	36.13
V21	44.9499	0.0032	0.1555	0.5506	54.3409	480	460	0.5	1272.9	519.03	282.04
V22	52.0505	0.0404	0.1665	0.6112	47.1313	395	375	0.4	1272.7	423.05	199.39
V23	46.1345	0.007	0.1444	0.5208	53.1932	460	440	0.4	1273	496.50	264.10
VC21	76.9108	0.0248	0.1963	0.7664	22.1018	310	290	0.3	1272.8	327.18	72.31
VC22	76.7878	0.0534	0.1815	0.7198	22.2574	310	290	0.3	1272.7	327.15	72.82
VC23	77.1316	0.07	0.2345	0.8961	21.6679	310	290	0.3	1272.2	327.02	70.86
VB21	36.6496	0.0571	1.2632	5.2875	56.7427	70	50	0.1	1273.1	56.42	32.02
VB22	36.946	0.0295	0.9973	4.4377	57.5896	75	55	0.1	1273.1	62.07	35.74
VB23	36.4296	0.0497	1.0432	4.5534	57.9242	85	65	0.1	1273	73.35	42.49

2017/05/10	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	35.1223	0.0312	0.3153	1.1501	63.3811	255	235	0.24	1298.4	270.47	171.43
V12	35.5272	0.046	0.2155	0.7765	63.4348	255	235	0.24	1299.8	270.76	171.76
V13	35.4666	0.0471	0.2656	1.0107	63.2099	255	235	0.24	1299.8	270.76	171.15
VC11	54.2455	0.0453	0.216	0.8248	44.6684	385	365	0.37	1299.9	420.57	187.86
VC12	48.3152	0.049	0.1959	0.7222	50.7177	465	445	0.45	1300	512.79	260.08
VC13	46.8551	0.0445	0.212	0.825	52.0633	505	485	0.49	1300	558.89	290.98
VB11	37.8662	0.0685	0.9303	3.7374	57.3976	60	40	0.04	1299.9	46.09	26.45
VB12	38.0774	0.1239	0.9296	3.9573	56.9118	65	45	0.05	1300	51.86	29.51
VB13	39.5341	0.0606	0.974	0	59.4313	65	45	0.05	1300	51.86	30.82
V21	39.7444	0.0516	0.1761	0.6356	59.3922	400	380	0.38	1272.9	428.76	254.65
V22	42.1536	0.0515	0.1627	0.5987	57.00334	455	435	0.44	1272.7	490.74	279.74
V23	39.316	0.0543	0.206	0.7112	59.7125	420	400	0.40	1273	451.36	269.52
VC21	74.979	0.0862	0.3194	1.1719	23.4434	175	155	0.16	1272.8	174.87	41.00
VC22	74.7058	0.0737	0.3042	1.1354	23.781	180	160	0.16	1272.7	180.50	42.92
VC23	75.6738	0.0879	0.3326	1.2965	22.6092	175	155	0.16	1272.2	174.79	39.52
VB21	36.6827	0.1152	1.0101	4.4936	57.6984	60	40	0.04	1273.1	45.14	26.05
VB22	36.6047	0.0773	0.9551	4.175	58.188	65	45	0.05	1273.1	50.78	29.55
VB23	37.9116	0.1105	0.9118	0.0068	61.0593	65	45	0.05	1273	50.78	31.01

2017/05/11	DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION										
Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	Biogas production at normal condition V(ml)	Methane production, V(ml)
V11	34.5965	0.0371	0.3558	1.3086	63.7019	185	165	0.17	1298.4	189.90	120.97
V12	34.6886	0.0399	0.3968	1.4774	63.3973	175	155	0.16	1299.8	178.59	113.22
V13	34.7869	0.048	0.3351	1.2073	63.6228	175	155	0.16	1299.8	178.59	113.62
VC11	45.4477	0.0348	0.1598	0.613	53.7446	360	340	0.34	1299.9	391.77	210.55
VC12	40.3498	0.031	0.229	0.8211	58.5691	405	385	0.39	1300	443.65	259.84
VC13	42.3617	0.0368	0.2341	0.91	56.4575	330	310	0.31	1300	357.23	201.68
VB11	36.9684	0.0564	1.0861	4.31	57.5791	45	25	0.03	1299.9	28.81	16.59
VB12	36.7921	0.075	1.2653	4.9551	56.9125	45	25	0.03	1300	28.81	16.40
VB13	36.9316	0.0848	1.1529	4.6018	57.2289	45	25	0.03	1300	28.81	16.49
V21	35.4428	0.0388	0.1654	0.5998	63.7533	475	455	0.46	1272.9	513.39	327.30
V22	37.4709	0.0602	0.1967	0.7048	61.5675	345	325	0.33	1272.7	366.65	225.74
V23	35.9553	0.0358	0.1698	0.6105	63.2287	405	385	0.39	1273	434.44	274.69
VC21	72.9497	0.0749	0.3845	1.4172	25.1737	135	115	0.12	1272.8	129.74	32.66
VC22	74.1237	0.0757	0.2944	0	25.5062	140	120	0.12	1272.7	135.37	34.53
VC23	73.7632	0.0703	0.3981	1.4726	24.2958	125	105	0.11	1272.2	118.41	28.77
VB21	37.923	0.0945	1.2493	0	60.7332	40	20	0.02	1273.1	22.57	13.71
VB22	37.8447	0.1352	1.2208	0	60.7994	40	20	0.02	1273.1	22.57	13.72
VB23	35.3427	0.0921	1.1235	4.8023	58.6394	40	20	0.02	1273	22.57	13.23

2017/05/12	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	33.7892	0.0369	0.2812	1.0203	64.8724	175	155	0.16	1298.4	178.39	115.73
V12	34.1388	0.0415	0.3177	1.1743	64.3277	170	150	0.15	1299.8	172.83	111.17
V13	34.3442	0.0505	0.3381	1.2347	64.0326	160	140	0.14	1299.8	161.30	103.29
VC11	36.0912	0.0347	0.235	0.8506	62.7884	480	460	0.46	1299.9	530.04	332.80
VC12	35.2953	0.0434	0.1665	0.6013	63.8934	430	410	0.41	1300	472.46	301.87
VC13	36.8626	0.0341	0.5634	2.1089	60.431	405	385	0.39	1300	443.65	268.10
VB11	36.6256	0.0796	0.9762	3.9137	58.4049	45	25	0.03	1299.9	28.81	16.82
VB12	36.6878	0.0659	1.0854	4.3024	57.8584	45	25	0.03	1300	28.81	16.67
VB13	36.6539	0.0699	1.0592	4.1788	58.0383	40	20	0.02	1300	23.05	13.38
V21	31.2948	0.0459	0.1775	0.6425	67.8392	610	590	0.59	1272.9	665.71	451.61
V22	34.2573	0.0367	0.2063	0.7382	64.7615	490	470	0.47	1272.7	530.23	343.38
V23	30.7014	0.038	0.1728	0.6053	68.4825	655	635	0.64	1273	716.54	490.71
VC21	71.0251	0.0924	0.3097	1.1491	27.4237	200	180	0.18	1272.8	203.08	55.69
VC22	70.7319	0.1055	0.3381	1.2314	27.5932	220	200	0.20	1272.7	225.62	62.26
VC23	71.615	0.1047	0.3435	1.2857	26.6512	200	180	0.18	1272.2	202.98	54.10
VB21	37.3542	0.0782	1.0692	0	61.4983	40	20	0.02	1273.1	22.57	13.88
VB22	35.2321	0.0774	1.1355	4.753	58.0802	40	20	0.02	1273.1	22.57	13.11
VB23	35.0767	0.0889	1.02	4.4501	59.3643	45	25	0.03	1273	28.21	16.75

2017/05/15	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	Biogas production at normal condition V(ml)	Methane production, V(ml)
V11	32.5397	0.0367	0.2234	0.8318	66.3684	245	225	0.23	1298.4	258.96	171.87
V12	33.0286	0.0431	0.2519	0.9054	65.771	230	210	0.21	1299.8	241.96	159.14
V13	32.5886	0.0346	0.2851	1.0314	66.0603	255	235	0.24	1299.8	270.76	178.86
VC11	31.7529	0	0.1928	0.7019	67.3524	555	535	0.54	1299.9	616.46	415.20
VC12	34.882	0.034	0.1621	0.5847	64.3372	340	320	0.32	1300	368.75	237.24
VC13	34.3553	0.0188	0.1972	0.7327	64.6959	400	380	0.38	1300	437.89	283.30
VB11	35.5093	0.0805	0.9766	3.8312	59.6024	70	50	0.05	1299.9	57.61	34.34
VB12	35.9221	0.0653	0.7988	3.2389	59.9748	65	45	0.05	1300	51.86	31.10
VB13	35.7021	0.0719	0.9479	3.6988	59.5793	65	45	0.05	1300	51.86	30.90
V21	25.2872	0.0024	0.0713	0.2524	74.3867	1364	1344	1.34	1272.9	1516.47	1128.05
V22	25.8002	0.0039	0.0703	0.2553	73.8702	1332	1312	1.31	1272.7	1480.13	1093.37
V23	25.4917	0	0.0509	0.1766	74.2808	1226	1206	1.21	1273	1360.86	1010.86
VC21	69.6305	0.1607	0.1409	0	30.0678	340	320	0.32	1272.8	361.02	108.55
VC22	69.0763	0.174	0.2311	0.8535	29.665	340	320	0.32	1272.7	361.00	107.09
VC23	69.6328	0.1942	0.2356	0.8745	29.0628	320	300	0.30	1272.2	338.30	98.32
VB21	36.4768	0.1359	1.0257	0	62.3617	65	45	0.05	1273.1	50.78	31.67
VB22	34.7139	0.102	0.8412	3.6453	60.6976	65	45	0.05	1273.1	50.78	30.82
VB23	34.2927	0.1225	1.0219	4.4771	60.0859	65	45	0.05	1273	50.78	30.51

2017/05/16	DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	33.576	0.0326	0.3842	1.4222	64.585	100	80	0.08	1298.4	92.07	59.47
V12	34.1933	0.0128	0.0128	1.4541	63.9575	95	75	0.075	1299.8	86.41	55.27
V13	34.4261	0.0357	0.4115	0	65.1266	100	80	0.08	1299.8	92.17	60.03
VC11	33.7141	0.0287	0.2235	0.8043	65.2295	195	175	0.175	1299.9	201.64	131.53
VC12	36.3909	0.0037	0.3105	1.1173	62.1443	115	95	0.095	1300	109.47	68.03
VC13	35.6043	0.0299	0.2953	1.0535	63.0171	160	140	0.14	1300	161.33	101.66
VB11	35.7864	0.0669	0.9903	4.0268	59.1297	50	30	0.03	1299.9	34.57	20.44
VB12	35.9477	0.0485	0.961	3.9458	59.097	50	30	0.03	1300	34.57	20.43
VB13	35.8216	0.057	0.9494	3.6982	59.4738	55	35	0.035	1300	40.33	23.99
V21	28.836	0	0.1315	0.4627	70.5698	540	520	0.52	1272.9	586.73	414.05
V22	29.8437	0	0.1082	0.3641	69.684	540	520	0.52	1272.7	586.64	408.79
V23	28.4007	0	0.0827	0	71.5166	580	560	0.56	1273	631.91	451.92
VC21	70.408	0.1905	0.258	0.9691	28.1743	115	95	0.095	1272.8	107.18	30.20
VC22	69.9234	0.2336	0.4486	1.6446	27.7497	110	90	0.09	1272.7	101.53	28.17
VC23	70.7419	0.2421	0.3761	1.3692	27.2707	115	95	0.095	1272.2	107.13	29.21
VB21	35.0084	0.0575	0.8707	3.6987	60.3647	50	30	0.03	1273.1	33.85	20.44
VB22	34.9306	0.0588	0.8422	3.6278	60.5406	55	35	0.035	1273.1	39.50	23.91
VB23	34.726	0.0582	0.9263	3.9153	60.3742	55	35	0.035	1273	39.49	23.84

2017/05/19	DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION										
Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	Biogas production at normal condition V(ml)	Methane production, V(ml)
V11	33.5941	0	0.2581	0.9269	65.221	145	125	0.125	1298.4	143.87	93.83
V12	33.6937	0.0519	0.2254	0.8246	65.2203	155	135	0.135	1299.8	155.54	101.45
V13	33.4842	0.0609	0.2138	0.7919	65.4583	165	145	0.145	1299.8	167.06	109.36
VC11	33.2527	0.0494	0.1966	0.7301	65.7597	210	190	0.19	1299.9	218.93	143.97
VC12	35.2627	0.0635	0.1807	0.6666	63.8405	205	185	0.185	1300	213.18	136.10
VC13	34.6823	0.0688	0.1763	0.6497	64.4281	210	190	0.19	1300	218.95	141.06
VB11	35.2182	0.0316	0.6991	2.8411	61.1728	70	50	0.05	1299.9	57.61	35.24
VB12	35.4172	0.0632	0.6844	2.7909	61.0759	75	55	0.055	1300	63.38	38.71
VB13	35.1133	0.036	0.6975	2.8403	61.2857	75	55	0.055	1300	63.38	38.84
V21	25.8476	0	0.0758	0.2569	73.7837	835	815	0.815	1272.9	919.58	678.50
V22	25.6129	0	0.0927	0.3255	73.9689	1146	1126	1.126	1272.7	1270.29	939.62
V23	25.1278	0.2851	0.0694	0.2544	74.5484	960	940	0.94	1273	1060.71	790.74
VC21	70.2165	0.2704	0.2742	1.0238	28.0005	90	70	0.07	1272.8	78.97	22.11
VC22	70.4497	0.2835	0.2757	1.0257	27.978	75	55	0.055	1272.7	62.05	17.36
VC23	71.0454	0.0724	0.3033	1.1221	27.2456	75	55	0.055	1272.2	62.02	16.90
VB21	33.9349	0.0724	0.9574	3.9321	61.1032	75	55	0.055	1273.1	62.07	37.93
VB22	33.7573	0.0743	0.913	3.8148	61.4407	75	55	0.055	1273.1	62.07	38.13
VB23	33.7106	0.1133	0.9797	4.222	60.9745	70	50	0.05	1273	56.42	34.40

2017/05/22 **DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**

Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	Biogas production at normal condition V(ml)	Methane production, V(ml)
V11	33.8087	0.0315	0.2505	0.9301	64.9792	170	150	0.15	1298.4	172.64	112.18
V12	34.2298	0.0436	0.2134	0.7777	64.7354	140	120	0.12	1299.8	138.26	89.50
V13	33.5305	0.0386	0.2627	0.952	65.2162	170	150	0.15	1299.8	172.83	112.71
VC11	33.735	0.0507	0.274	0.9972	64.9431	155	135	0.135	1299.9	155.55	101.02
VC12	35.7907	0.0257	0.336	1.2881	62.5594	130	110	0.11	1300	126.76	79.30
VC13	35.4779	0	0.3158	1.2325	62.9738	125	105	0.105	1300	121.00	76.20
VB11	34.8253	0.0489	0.7668	3.0576	61.3014	75	55	0.055	1299.9	63.37	38.85
VB12	34.9603	0.0592	1.0109	4.0704	59.8992	75	55	0.055	1300	63.38	37.96
VB13	35.1886	0.0118	0.6748	2.863	61.2619	80	60	0.06	1300	69.14	42.36
V21	24.4737	0	0.069	0.2419	75.2155	860	840	0.84	1272.9	947.79	712.89
V22	25.9327	0	0.0776	0.264	73.7257	830	810	0.81	1272.7	913.80	673.70
V23	24.835	0	0.0622	0.2016	74.9012	810	790	0.79	1273	891.44	667.70
VC21	70.0459	0.2389	0.3823	1.4135	27.9193	75	55	0.055	1272.8	62.05	17.32
VC22	70.3955	0.2494	0.3088	1.1651	27.8811	75	55	0.055	1272.7	62.05	17.30
VC23	70.1796	0.2454	0.589	2.2448	26.7412	75	55	0.055	1272.2	62.02	16.59
VB21	34.7583	0.0503	0.6642	2.8691	61.6581	110	90	0.09	1273.1	101.56	62.62
VB22	34.534	0	0.5782	2.5636	62.3242	105	85	0.085	1273.1	95.92	59.78
VB23	34.1552	0.0303	0.7946	3.3615	61.6584	100	80	0.08	1273	90.27	55.66

2017/05/25	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	34.437	0	0.3121	1.1695	64.0814	105	85	0.085	1298.4	97.83	62.69
V12	34.8429	0.0296	0.2744	0.9877	63.8655	105	85	0.085	1299.8	97.93	62.55
V13	34.3093	0	0.3203	1.1637	64.2067	120	100	0.1	1299.8	115.22	73.98
VC11	34.3386	0.0299	0.2767	1.0111	64.3437	115	95	0.095	1299.9	109.46	70.43
VC12	36.3297	0.0273	0.2943	1.0606	62.288	115	95	0.095	1300	109.47	68.19
VC13	35.525	0	0.3213	1.1717	62.982	120	100	0.1	1300	115.23	72.58
VB11	34.9373	0.0464	0.6817	2.7579	61.5768	75	55	0.055	1299.9	63.37	39.02
VB12	35.4414	0.0062	0.7111	2.952	60.8892	75	55	0.055	1300	63.38	38.59
VB13	35.2401	0.0121	0.6927	2.7402	61.315	75	55	0.055	1300	63.38	38.86
V21	25.3523	0	0.1553	0.5595	73.9328	630	610	0.61	1272.9	688.28	508.86
V22	25.4083	0	0.1008	0.3537	74.1372	740	720	0.72	1272.7	812.26	602.19
V23	28.1995	0.0276	0.4236	1.5155	69.8344	375	355	0.355	1273	400.59	279.75
VC21	69.5998	0.0193	0.3575	1.4028	28.6206	95	75	0.075	1272.8	84.61	24.22
VC22	68.774	0.2197	0.5071	1.9567	28.5425	100	80	0.08	1272.7	90.25	25.76
VC23	69.8591	0.2287	0.2989	1.1235	28.4898	105	85	0.085	1272.2	95.85	27.31
VB21	34.9154	0	0.7239	2.9943	61.3665	80	60	0.06	1273.1	67.71	41.55
VB22	34.6463	0.0131	0.7516	3.1312	61.4579	90	70	0.07	1273.1	78.99	48.55
VB23	33.8725	0.0057	1.0044	4.2386	60.8788	85	65	0.065	1273	73.35	44.65

2017/05/30	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V11	34.0494	0.0286	0.334	1.2242	64.3467	115	95	0.095	1298.4	109.34	70.36
V12	34.5361	0.0534	0.346	1.2641	63.8005	115	95	0.095	1299.8	109.46	69.83
V13	34.1334	0.0036	0.2225	0.8268	64.8137	130	110	0.11	1299.8	126.74	82.14
VC11	34.0287	0.0363	0.3891	1.4279	64.1181	140	120	0.12	1299.9	138.27	88.66
VC12	35.803	0.053	0.3665	1.3269	62.4505	135	115	0.115	1300	132.52	82.76
VC13	35.4819	0.0323	0.2983	1.1019	63.0855	125	105	0.105	1300	121.00	76.33
VB11	33.8938	0.054	1.0304	3.9911	61.0306	85	65	0.065	1299.9	74.90	45.71
VB12	34.9867	0	0.5719	2.3054	62.136	85	65	0.065	1300	74.90	46.54
VB13	34.9464	0.0344	0.4568	1.9161	62.6462	85	65	0.065	1300	74.90	46.92
V21	28.2073	0	0.0999	0.3549	71.338	390	370	0.37	1272.9	417.48	297.82
V22	25.6582	0	0.1259	0.4508	73.765	800	780	0.78	1272.7	879.95	649.10
V23	29.5119	0	0.2253	0.8078	69.455	300	280	0.28	1273	315.96	219.45
VC21	43.0518	0	0.0748	0.2804	56.593	1300	1280	1.28	1272.8	1444.09	817.26
VC22	40.9703	0	0.0949	0.3487	58.5861	1400	1380	1.38	1272.7	1556.79	912.06
VC23	43.001	0.0105	0.0941	0.363	56.5314	1328	1308	1.308	1272.2	1474.99	833.83
VB21	34.1237	0	0.6229	2.623	62.6303	105	85	0.085	1273.1	95.92	60.08
VB22	34.3297	0	0.4959	2.1616	63.0128	100	80	0.08	1273.1	90.28	56.89
VB23	33.8376	0	0.6047	2.5907	62.967	100	80	0.08	1273	90.27	56.84

2017/06/01	DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION										
Sample code	CO2	H2S	O2	N2	CH4	pressure (ml bar)	Pressure difference (mbar)	pressure (bar)	used gas chamber volume (ml)	Biogas production at normal condition V(ml)	Methane production, V(ml)
V11	34.5196	0	0.5514	2.0085	62.9205	60	40	0.04	1298.4	46.04	28.97
V12	34.8831	0	0.3946	1.4873	63.235	60	40	0.04	1299.8	46.09	29.14
V13	34.6959	0	0.3049	1.133	63.8663	70	50	0.05	1299.8	57.61	36.79
VC11	34.7556	0	0.4182	1.5426	63.284	75	55	0.055	1299.9	63.37	40.11
VC12	36.1707	0.0049	0.4564	1.6597	61.7084	65	45	0.045	1300	51.86	32.00
VC13	36.192	0	0.31	1.1445	62.3534	60	40	0.04	1300	46.09	28.74
VB11	34.8586	0	0.6457	2.5986	61.9021	50	30	0.03	1299.9	34.57	21.40
VB12	35.146	0	0.7188	2.8411	61.2941	50	30	0.03	1300	34.57	21.19
VB13	34.5381	0	1.0096	3.8638	60.5885	50	30	0.03	1300	34.57	20.95

2017/06/07	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V21	29.791	0	0.0879	0.3397	69.7815	280	260	0.26	1272.9	293.36	204.71
V22	29.5513	0	0.1243	0.4487	69.8757	360	340	0.34	1272.7	383.57	268.02
V23	30.6007	0	0.2121	0.7728	68.4144	275	255	0.255	1273	287.74	196.86
VC21	48.4589	0.0039	0.062	0.2405	51.2346	1005	985	0.985	1272.8	1111.28	569.36
VC22	47.1422	0	0.0295	0.1256	52.7027	1150	1130	1.13	1272.7	1274.76	671.84
VC23	48.0973	0	0.0537	0.2097	51.6393	970	950	0.95	1272.2	1071.28	553.20
VB21	34.3306	0	0.3102	1.4169	63.9422	125	105	0.105	1273.1	118.49	75.77
VB22	33.9916	0	0.3554	1.657	63.996	125	105	0.105	1273.1	118.49	75.83
VB23	33.5907	0.4861	0.4861	2.1276	63.7955	120	100	0.1	1273	112.84	71.99

2017/06/16	**DAILY MEASUREMENT OF GC COMPOSITION OF BIOGAS PRODUCTION**										
Sample code	**CO2**	**H2S**	**O2**	**N2**	**CH4**	**pressure (ml bar)**	**Pressure difference (mbar)**	**pressure (bar)**	**used gas chamber volume (ml)**	**Biogas production at normal condition V(ml)**	**Methane production, V(ml)**
V21	30.887	0	0.094	0.3687	68.6504	235	215	0.215	1272.9	242.59	166.54
V22	31.4185	0	0.1401	0.5315	67.9098	305	285	0.285	1272.7	321.52	218.34
V23	32.1022	0	0.1572	0.6149	67.1256	240	220	0.22	1273	248.25	166.64
VC21	39.6126	0.0054	0.0506	0.2008	60.1306	820	800	0.8	1272.8	902.56	542.71
VC22	40.8444	0.0036	0.0905	0.3305	58.731	790	770	0.77	1272.7	868.64	510.16
VC23	39.0856	0	0.0581	0.2197	60.6366	840	820	0.82	1272.2	924.69	560.70
VB21	34.2615	0	0.3684	1.6743	63.6958	130	110	0.11	1273.1	124.13	79.07
VB22	33.8166	0	0.4183	1.901	63.8641	130	110	0.11	1273.1	124.13	79.28
VB23	33.7812	0	0.4354	1.9765	63.8069	125	105	0.105	1273	118.48	75.60

	ACCUMULATIONS												
		V11	V12	V13	VB11	VB12	VB13	V21	V22	V23	VB21	VB22	VB23
DATE	**DAY0**	0	0	0	0	0	0	0	0	0	0	0	0
03/05/2017	DAY1	330.22	353.96	373.43	81.35	101.48	105.99	431.65	400.34	393.63	84.17	82.10	80.35
04/05/2017	DAY2	708.87	751.86	748.74	133.20	154.16	159.11	736.35	654.33	689.07	118.73	128.63	115.54
05/05/2017	DAY3	1035.91	1094.54	1076.59	170.13	193.21	198.15	919.86	808.59	848.71	151.88	163.12	147.30
08/05/2017	DAY6	2401.38	2403.13	2353.14	255.72	282.17	293.06	1392.62	1119.23	1273.43	242.98	251.34	245.29
09/05/2017	DAY7	2792.67	2697.40	2647.85	288.54	318.12	329.20	1674.67	1318.62	1537.53	275.00	287.09	287.77
10/05/2017	DAY8	2964.09	2869.16	2819.00	315.00	347.63	360.02	1929.32	1598.36	1807.05	301.04	316.64	318.78
11/05/2017	DAY9	3085.06	2982.37	2932.62	331.59	364.03	376.50	2256.62	1824.10	2081.74	314.75	330.36	332.01
12/05/2017	DAY10	3200.79	3093.55	3035.91	348.41	380.70	389.88	2708.23	2167.48	2572.45	328.63	343.47	348.76
15/05/2017	DAY13	3372.66	3252.69	3214.77	382.75	411.80	420.77	3836.28	3260.86	3583.31	360.30	374.29	379.27
16/05/2017	DAY14	3432.12	3307.95	3274.80	403.19	432.23	444.76	4250.33	3669.65	4035.23	380.74	398.20	403.11
19/05/2017	DAY17	3525.95	3409.40	3384.16	438.431	470.936	483.602	4928.84	4609.27	4825.97	418.66	436.34	34.40
22/05/2017	DAY20	3638.13	3498.90	3496.87	477.28	508.90	525.96	5641.72	5282.97	5493.67	481.29	496.12	90.06
25/05/2017	DAY23	3700.82	3561.45	3570.85	516.30	547.49	564.82	6150.58	5885.16	5773.42	522.84	544.67	134.72
30/05/2017	DAY28	3771.18	3631.28	3652.99	562.01	594.03	611.74	6448.41	6534.26	5992.87	582.91	601.56	191.56
01/06/2017	DAY29	3800.14	3660.42	3689.78	583.41	615.22	632.69	6448.41	6534.26	5992.87	582.91	601.56	191.56
07/06/2017	DAY36	3800.14	3660.42	3689.78	583.41	615.22	632.69	6653.12	6802.28	6189.72	658.68	677.39	263.55
16/06/2017	DAY45	3800.14	3660.42	3689.78	583.41	615.22	632.69	6819.66	7020.63	6356.36	737.75	756.67	339.15