Organization of Islamic Cooperation

Biogas Production from Effluent Treatment Plant (ETP) Sludge

A thesis submitted for the Degree of Bachelor of Science in Mechanical and Chemical Engineering.

Prepared by

S. M. Saif Raihan (091424)

S. M. Nafis Fuad (091429)

Supervised by

Dr. Faisal Kader

Associate Professor, Department of Mechanical and Chemical Engineering (MCE)

Islamic University of Technology (IUT)

The Organization of Islamic Cooperation (OIC)

DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Signature of the Candidate

S. M. Saif Raihan

Student No. 091424

Department of Mechanical & Chemical Engineering

(MCE)

Islamic University of Technology (IUT), OIC

Signature of the Candidate

S. M. Nafis Fuad

Student No. 091429

Department of Mechanical & Chemical Engineering

(MCE)

Islamic University of Technology (IUT), OIC

Signature of the Supervisor

Dr. Faisal Kader

Associate Professor

Department of Mechanical and Chemical Engineering (MCE)

Islamic University of Technology (IUT), OIC

Signature of the Head of the Department

Dr. Md. Abdur Razzaq Akhanda

Professor

Department of Mechanical and Chemical Engineering

Islamic University of Technology (IUT), OIC

Dedicated

To

Our Beloved Parents & Teachers

Acknowledgement

The authors express gratefulness to almighty Allah for His blessings to complete this thesis successfully.

The authors express gratitude to the honorable supervisor Dr. Faisal Kader, associate professor, Mechanical and Chemical Engineering Department, IUT for his continuous guidance and helpful suggestions.

The authors express their gratitude to the honorable Head of the Department, Mechanical and Chemical Engineering Department, IUT for his guidance.

The authors are grateful to Ms. Tanuja Bhattacharjee for making the collaboration with GIZ and her continuous help, guidance and suggestions.

The authors specially thank to A. N. M. Jubayer of GIZ for his continuous help with the thesis.

The authors are also grateful to Mr. Roton and Mr. Jahid from Mymun Textile LTD. for their continuous ETP sludge Supply and kind cooperation.

Lastly the authors want to thank every faculty and staff member who was with this thesis.

Abstract

The study based on the possibilities of anaerobic digestion of textile Effluent Treatment Plant (ETP) sludge in mesophilic (32˚-35˚C) condition. A 20 L transparent pot was used as the lab scale digestion chamber. For the fast generation of anaerobic microorganisms cow dung was used with ETP sludge in different percentages in different stages. The duration of the study was 60 days. The study reveals comparative representation of gas production and gas pressure for different ratio of Cow dung and ETP sludge. The gas produced in this lab scale plant was tested and the percentage of methane was 65.2% which is satisfactory. The positive outcome of this thesis paper reveals that the hazardous ETP sludge can be used in renewable natural gas production.

TABLE OF CONTENT

Chapter 1: Introduction

Chapter 2: Background

Chapter 3: Literature Review

Chapter 4: Design and Experimental Setup

Chapter 5: Test Production

5.1 Testing with Cow dung

5.2 Testing with Sludge

5.2.1 Testing with 25% sludge & 75% CD

5.2.2 Testing with 50% sludge & 50% CD

Chapter 6: Results & Discussions

6.1 Results

List of Tables and Figures

List of Tables:

List of Figures:

Chapter 1

1.1 General Introduction

Considering the increasing population, the pollution and the increasing pressure on natural resources for energy demand, the use of sustainable and renewable energy is becoming precious to the whole world. In Bangladesh these problems are acute. Specially the demand of natural gas for different purposes like cooking and production in industries is increasing rapidly. But it is almost next to impossible to meet up even the present demand completely. The worst case scenario is seen in the rural areas in Bangladesh. So to reduce the demanding pressure on natural resources importance to biogas production should be given.

Biogas typically refers to a gas produced by the breakdown of organic matter in the absence of oxygen. Biogas is a renewable energy and is produced from wastes and it turns wastes into less harmful objects. So it is environment friendly.

Textile industries play a merciful role in the developing economy of our country. But textile sludge is one of the most harmful wastes in Bangladesh. Sludge refers to the residual, semi-solid material left from industrial wastewater or sewage treatment processes. Now the main problem is the disposal of the sludge produced by the industries. Even after going through the Effluent Treatment Plant (ETP) the sludge is not safe to dispose anywhere. So if this ETP sludge can be used to produce biogas it would be a great relief for textile industries.

As the main theme of biogas production is the anaerobic digestion of wastes so the anaerobic digestion of ETP sludge would work to produce biogas. Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The very first biogas plant in Bangladesh was constructed in 1972, but the anaerobic technology became popular after 1990.

In this project the anaerobic digestion process is used to produce biogas from textile ETP sludge. Biogas production from cow dung and food wastes is popular in Bangladesh but there is not much work with textile ETP sludge. So in the project a lab scale plant is used as anaerobic digestion chamber for a test production.

1.2 Objectives

- Main objective is to use the hazardous textile sludge in renewable energy sector.
- To evaluate the characteristics of ETP sludge.
- To determine the amount of Methane produced from the anaerobic digestion of Textile ETP sludge during biogas production.
- To determine the composition of biogas produced.
- To compare the results with optimum output for that of cow dung so that we can say whether it is commercially feasible or not.

Chapter 2

Background

2.1 Condition of Bangladesh

The textile industries play a very important role in the economic growth of Bangladesh as the garment sector now accounts for about 77% of the foreign exchange earnings and 50% of the industrial workforce. In the same time textile dying industries are accused of being one of the most harmful fields for environment pollution.

According to the record of BKMEA and BTMA at present 1700 wet processing industries are running in the country. From confidential sources of the Department of Environment it was found that around 700 factories implement Effluent Treatment Plant (ETP) in their factories. Department of Environment also believe that within next five years, the number will increase up to 1200. According to the Department, 60% of the effluent treatment plant is physico-chemical (almost 400 of 700 are physicio chemical in nature). The capacity of the ETP varies from 5-350 m^3/hr. The average capacity is about 45 m^3/hr. From various research studies, it was found that an effluent treatment of 1 m^3/hr physicio chemical treatment plant produce 30 kg dry sludge per day. So, in an average around 950 tons of dry sludge produced in the country at present.

In Bangladesh Textile Dyeing is categorized as a Red Category Industry according to the Environmental Conservation Act (1995). In accordance to the Act and Environmental Rules (1997) it is mandatory for textile dyeing factories to have their own Effluent Treatment Plant (ETP) to treat the waste water before leaving the factory premises. It is hopeful that now most of the textile dyeing industries has their own ETP.

It is sad but true that even after effluent treatment the slurry cannot be disposed at the same time as the waste water. This slurry needs to be preserved for about 6 months in the factory premises and then can be disposed. It is a big problem for a factory to hold a huge amount of slurry for a long time. Because it is time, space and labor consuming.

So this slurry (Activated Sludge) before dewatering should be used in a technique so that it needs not to be held in factory premises for a long time. The aim of this project is to produce biogas from this activated sludge.

2.2 Eligibility of Sludge

Textile sludge generated in the effluent treatment plant is almost a semi solid compound which usually contains 20-60% moisture. The moisture content depends how factory treat the sludge. In most of the factory use traditional air drying methods which require at least 2 weeks time to reach the moisture content less than 20%. However, in some factories sludge are produced with less than 10% moisture content. It can be expect that, the Department of Environment will control the moisture content of sludge by legal bindings and sludge with 5-10% moisture content seems very dry.

Besides moisture content, the organic matter content is also a factor for textile sludge, from the sludge characteristics of 25 factories; it was found that the average carbon content is 24% but the Physico-Chemical effluent treatment plant contains less organic carbon (6-12%) organic carbon where as biological effluent treatment plant contains 25-48% organic carbon.

In most cases, textile sludge is alkaline to neutral in nature (pH 6.9-10.5). But in some cases, some sludge was found slightly acidic in nature.

So, from these characteristics it can be expected to produce biogas from textile ETP sludge.

Chapter 3

Literature Review

Main theme of this project is the anaerobic digestion of the textile ETP sludge and cow dung and produce biogas. So the conditions and methodology of anaerobic digestion should be known and followed.

3.1 Anaerobic Digestion

3.1.1 What is Anaerobic Digestion?

Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste and/or to produce fuels.

The digestion process begins with bacterial hydrolysis of the input materials. Insoluble organic polymers, such as carbohydrates, are broken down to soluble derivatives that become available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. These bacteria convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. The methanogenic archaea populations play an indispensable role in anaerobic wastewater treatments. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.

A range of anaerobic digestion technologies are converting livestock manure, municipal wastewater solids, food waste, high strength industrial wastewater and residuals, fats, oils and grease (FOG), and various other organic waste streams into biogas, 24 hours a day, 7 days a week. Separated digested solids can be composted, utilized for dairy bedding, directly applied to cropland or converted into other products. Nutrients in the liquid stream are used in agriculture as fertilizer.

3.1.2 Steps of Anaerobic Digestion

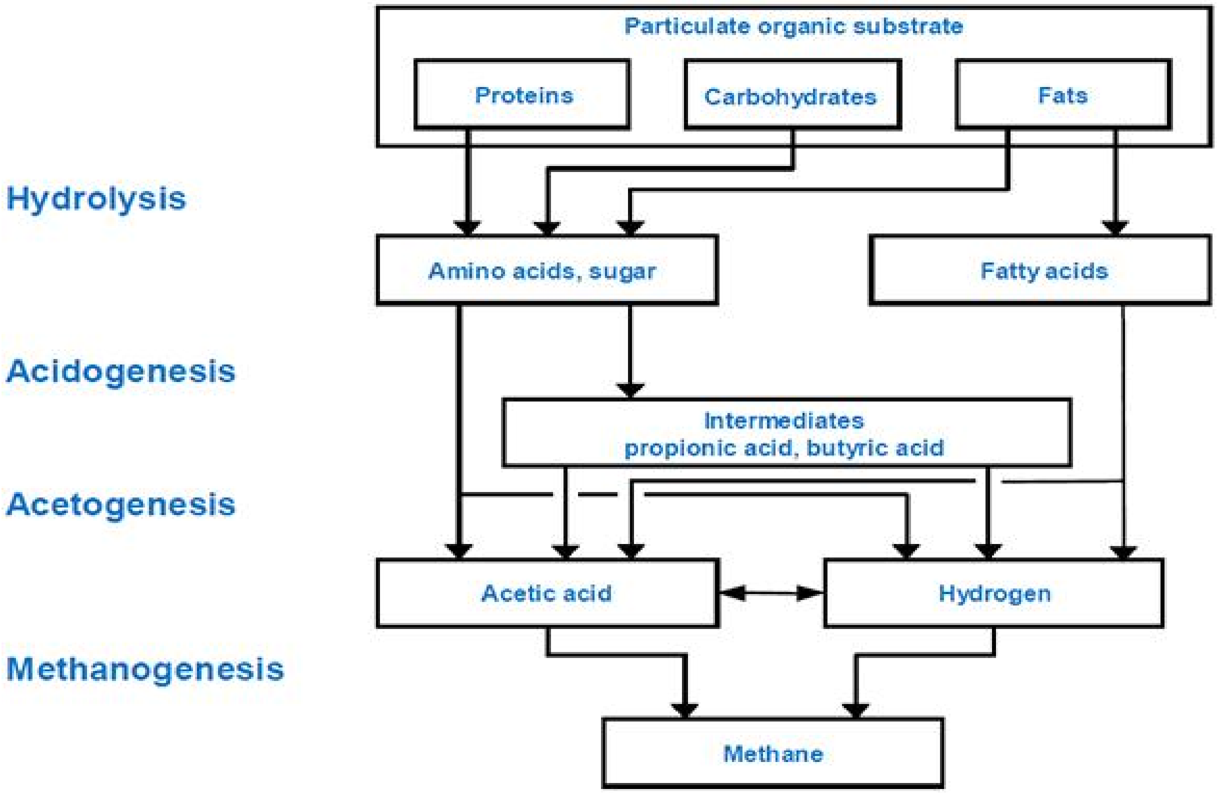


Figure 3.1: Degradation Steps of Anaerobic Digestion Process

(I) Hydrolysis

During hydrolysis, the first stage, bacteria transform the particulate organic substrate into liquefied monomers and polymers i.e. proteins, carbohydrates and fats are transformed to amino acids, monosaccharides and fatty acids respectively. The following equation shows an example of a hydrolysis reaction where organic waste is broken down into a simple sugar, in this case, glucose.

Equation 1: $C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_{2.}$

Hydrolysis reaction Activators:

Lipids →Fatty Acids

Polysaccharides →Monosaccharides

Protein →Amino Acids

Nucleic Acids →Purines & Pyrimidines

(II) Acidogenesis

In the second stage, acidogenic bacteria transform the products of the first reaction into short chain volatile acids, ketones, alcohols, hydrogen and carbon dioxide. The principal acidogenesis stage products are propionic acid (CH_3CH_2COOH), butyric acid ($CH_3CH_2CH_2COOH$), acetic acid (CH_3COOH), formic acid ($HCOOH$), lactic acid ($C_3H_6O_3$), ethanol (C_2H_5OH) and methanol (CH_3OH), among other. From these products, the hydrogen, carbon dioxide and acetic acid will skip the third stage, acetogenesis, and be utilized directly by the methanogenic bacteria in the final stage (Figure 2). Equations 2, 3 (Ostrem, 2004) and 4 (Bilitewski et al., 1997) represent three typical acidogenesis reactions where glucose is converted to ethanol, propionate and acetic acid respectively.

Equation 2: $C_6H_{12}O_6 \leftrightarrow 2CH_3CH_2OH + 2CO_2$

Equation 3: $C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2H_2O$

Equation 4: $C_6H_{12}O_6 \rightarrow 3CH_3COOH$

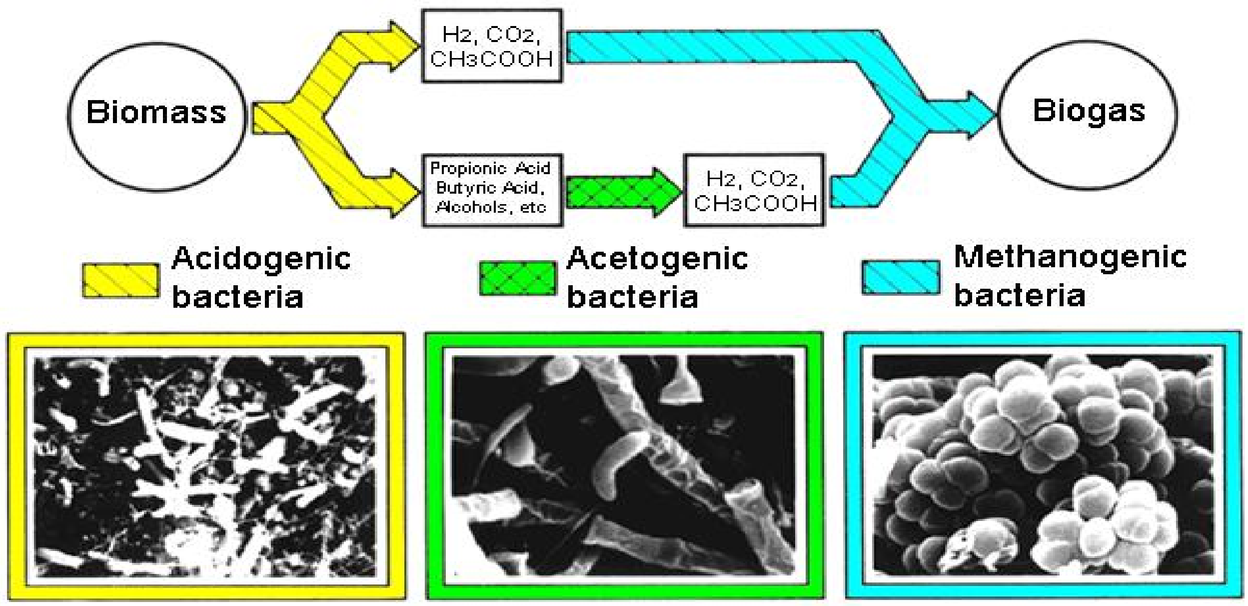


Figure 3.2: Schematic representation of the course of anaerobic methane generation from complex organic substances showing scanning electron micrographs of individual microorganisms involved

(III) Acetogenesis

In the third stage, known as acetogenesis, the rest of the acidogenesis products like the propionic acid, butyric acid and alcohols are transformed by acetogenic bacteria into hydrogen, carbon dioxide and acetic acid (Figure 2). Hydrogen plays an important intermediary role in this process, as the reaction will only occur if the hydrogen partial pressure is low enough to thermodynamically allow the conversion of all the acids. Such lowering of the partial pressure is carried out by hydrogen scavenging bacteria, thus the hydrogen concentration of a digester is an indicator of its health (Mata-Alvarez, 2003). Equation 5 represents the conversion of propionate to acetate, only achievable at low hydrogen pressure. Glucose (Equation 6) and ethanol (Equation 7) among others are also converted to acetate during the third stage of anaerobic fermentation (Ostrem, 2004).

Equation 5: $CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$

Equation 6: $C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$

Equation 7: $CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 2H_2 + H^+$

(IV) Methanogenesis

The fourth and final stage is called methanogenesis. During this stage, microorganisms convert the hydrogen and acetic acid formed by the acid formers to methane gas and carbon dioxide (Equations 8, 9 & 10) (Verma, 2002). The bacteria responsible for this conversion are called methanogens and are strict anaerobes. Waste stabilization is accomplished when methane gas and carbon dioxide are produced.

Equation 8: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Equation 9: $2C_2H_5OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$

Equation 10: $CH_3COOH \rightarrow CH_4 + CO_2$.

3.1.3 Important operating parameters in Anaerobic Digestion

(I) Batch or Continuous Charge

Anaerobic digestion can be performed as a batch process or a continuous process.

In a batch system biomass is added to the reactor at the start of the process. The reactor is then sealed for the duration of the process.

In its simplest form batch processing needs inoculation with already processed material to start the anaerobic digestion. In a typical scenario, biogas production will be formed with a normal distribution pattern over time. Operators can use this fact to determine when they believe the process of digestion of the organic matter has completed.

In continuous digestion processes, organic matter is constantly added (continuous complete mixed) or added in stages to the reactor (continuous plug flow; first in – first out). Here, the end products are constantly or periodically removed, resulting in constant production of biogas. A single or multiple digesters in sequence may be used.

(II) Volatile Solid

The wastes treated by AD may comprise biodegradable organic fraction, a combustible and an inert fraction. The biodegradable organic fraction includes kitchen scraps, food residue, and grass and tree cuttings. The combustible fraction includes slowly degrading lignocellulosic organic matter containing coarser wood, paper, and cardboard. As these lignocellulosic organic materials do not readily degrade under anaerobic conditions, they are better suited for waste-to-energy plants. Finally, the inert fraction ideally should be removed, recycled or used as land fill.

The volatile solids (VS) in organic wastes are measured as total solids minus the ash content, as obtained by complete combustion of the feed wastes.

(III) Temperature

There are mainly two temperature ranges that provide optimum digestion conditions for the production of methane – the mesophilic and thermophilic ranges.

The mesophilic range is between 20°C-40°C and the optimum temperature is considered to be 30°C-35°C.

The thermophilic temperature range is between 50°C-65°C (RISEAT, 1998). It has been observed that higher temperatures in the thermophilic range reduce the required retention time (National Renewable Energy Laboratory, 1992)

(IV) pH Value

Anaerobic bacteria, specially the methanogens, are sensitive to the acid concentration within the digester and their growth can be inhibited by acidic conditions. The acid concentration in aqueous system is expressed by pH value.

During digestion, the two processes of acidification and methanogenesis require different pH levels for optimal process control. The retention time of digestate affects the pH value and in a batch reactor acetogenesis occurs at a rapid pace. Acetogenesis can lead to accumulation of large amounts of organic acids resulting in pH below 5.

As digestion reaches the methanogenesis stage, the concentration of ammonia increases and the pH value can increase to above 8. The optimal range for methanogenesis is between 6.6 and 8.5.Once methane production is stabilized, the pH level stays between 7.2 and 8.2.

(V) Carbon-Nitrogen Ratio:

The relationship between the amount of carbon and nitrogen present in organic materials is represented by the C/N ratio. Optimum C/N ratios in anaerobic digesters are between 20–30. A high C/N ratio is an indication of rapid consumption of nitrogen by methanogens and results in lower gas production. On the other hand, a lower C/N ratio causes ammonia accumulation and pH values exceeding 8.5, which is toxic to methanogenic bacteria. Optimum C/N ratios of the digester materials can be achieved by mixing materials of high and low C/N ratios, such as organic solid waste mixed with sewage or animal manure.

(VI) Organic Loading Rate (OLR):

There are three different ranges of solid contents. Low solids (LS) AD systems contain less than 10 % TS, medium solids (MS) about 15-20% and high solids (HS) processes range from 22% to 40% (Tchobanoglous, 1993). An increase in TS in the reactor results in a corresponding decrease in reactor volume.

Organic loading rate (OLR) is a measure of the biological conversion capacity of the AD system. Feeding the system above its sustainable OLR results in low biogas yield due to accumulation of inhibiting substances such as fatty acids in the digester slurry (Vandevivere, 1999).

(VII) Retention Time

Retention time is the time needed to achieve the complete degradation of the organic matter. The retention time varies with process parameters, such as process temperature and waste composition. The retention time for waste treated in a mesophilic digester ranges from 15 to 30 days and 12-14 days for thermophilic digester. Retention time is calculated by the following equation:

$$Retention\ Time\ \emptyset\ (Days) = \frac{\text{Operation Volume, V } (\mathrm{m}^3)}{\text{Flow Rate, Q } (\frac{\mathrm{m}^3}{\mathrm{day}})}$$

(VIII) Mixing

The purpose of mixing in a digester is to blend the fresh material with digestate containing microbes. Furthermore, mixing prevents scum formation and avoids temperature gradients within the digester. However excessive mixing can disrupt the microbes so slow mixing is preferred. The kind of mixing equipment and amount of mixing varies with the type of reactor and the solids content in the digester.

Chapter 4

Design and Experimental Setup

4.1.1 Design

For any experiment design of equipment is the most important. The success of the project depends on the design specification and accuracy. So at first the design of the plant was done in solid works. The main parts of the plant are Inlet chamber, fermentation chamber, gas outlet pipe and hydraulic chamber. Firstly an inlet cylindrical pipe was designed. Then the digestion or fermentation chamber was designed which was given a shape of dome as shown in figure-3. After that a gas outlet pipe is also designed. Then the hydraulic chamber was designed which is connected to an outlet pipe. Then lastly all parts were assemble together to fulfill the plant design.

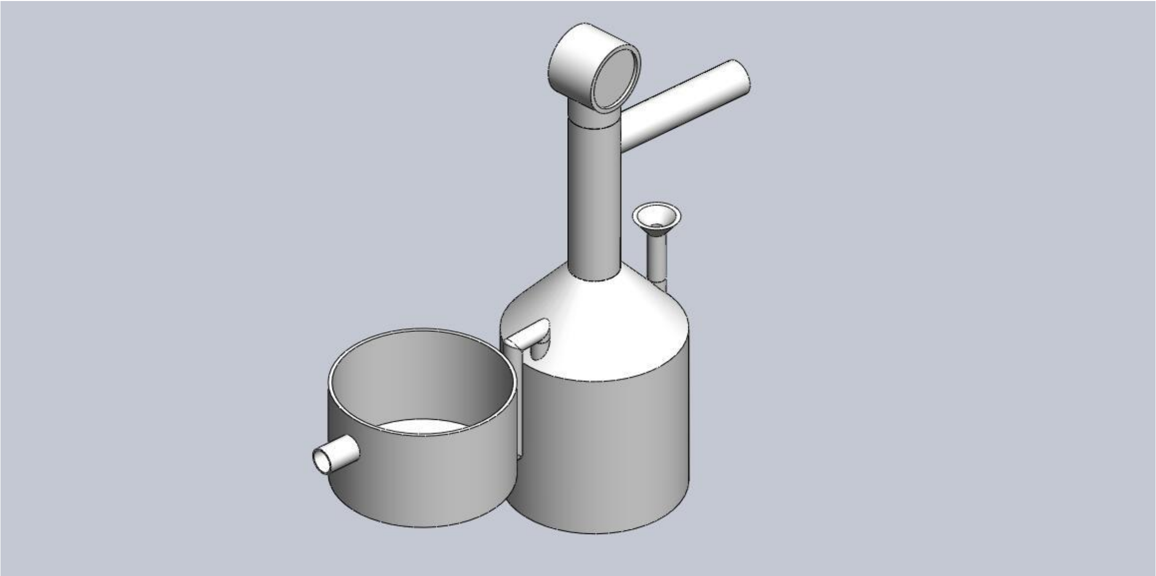


Figure-4.1: Schematic Design of the Digester.

The inlet chamber is used for the charging purpose of feedstock into the digestion chamber. The fermentation of the feedstock takes place in the digestion chamber. Eventually the produced gas is stored in the upper portion of the digestion chamber and gas can be collected from the gas outlet pipe. As soon as gas starts to produce the gas creates pressure on the feedstock in the digestion chamber and the slurry starts to be placed into the hydraulic chamber. The volume of the hydraulic chamber indicates the volume of gas in the digester.

4.1.2 Design Specification

In figure 4 a cross section of the plan is also shown to make the design clear. In this figure the design specification of the lab scale plant can be shown.

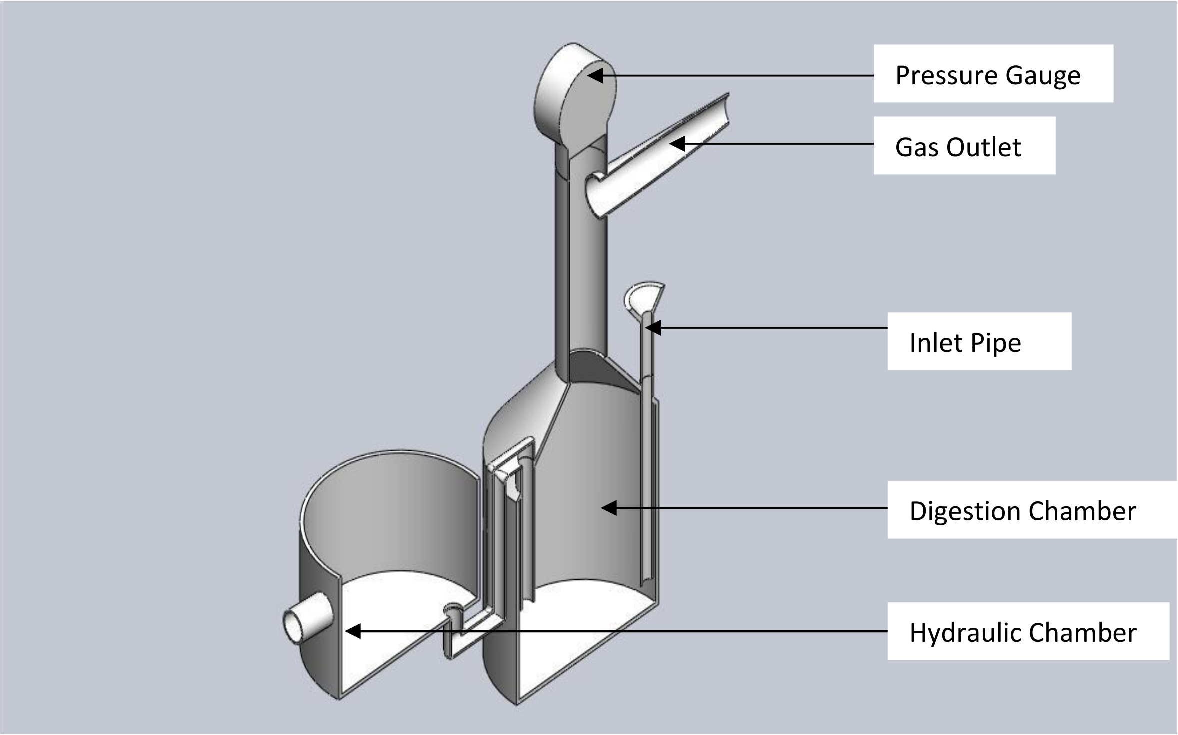


Figure 4.2: Schematic Cross Section of the Digester.

- Volume of Digestion Chamber: 20 L
- Volume of Hydraulic Chamber: 10.5 L
- Material of Digestion and Hydraulic Chamber: PVC
- Material of gas outlet pipe: PVC
- Material of Inlet pipe: Acrolien Sheet
- Inlet Pipe enters 90% into the Digestion Chamber
- Connecting pipe enters 60% into the Digestion Chamber

4.2 Experimental Setup

According to the design a lab scale biogas plant was constructed in IUT. A bottle made of PVC of 20 L was used as the digestion chamber. Additional two holes were made at the top of the bottle. Altogether there were three holes at the top of the digestion chamber.

A pipe made of acrolien sheet (transparent) of 1 inch diameter was inserted into the chamber through one hole. The pipe was joined so carefully such that no air can enter into the chamber. It was inserted about 90% of the digestion chamber. This was used as the inlet of the feedstock.

Another pipe made of PVC of ¾ inch was fitted to another hole with the help of a reducer as the hole was large compared to the pipe diameter. This pipe was used as the gas outlet pipe. A pressure gauge was connected at the top of this pipe to measure the gas pressure produced.

Now another pipe made of PVC of ¾ inch diameter was inserted and joined air tightly with the help of gum. In the other end of this pipe was fitted to the bottom of the hydraulic chamber. This pipe was used as the outlet of the slurry.

Another bottle of 10.5 L which is made of PVC was used as the hydraulic chamber. It was connected to the outlet pipe of slurry and was opened to the atmosphere. An outlet pipe was also connected to the other side of the hydraulic chamber so that when the gas volume exceeds the volume of hydraulic chamber the slurry could overflow in that way.

In the following photograph the original plant that is set up in IUT for the project purpose is shown. As discussed before in the design the inlet pipe, digestion chamber, gas outlet pipe, milibar pressure gauge, slurry outlet pipe, hydraulic chamber and the disposal tank was connected together in a required sequence to fulfill the project purpose.

Figure 4.3: Photograph of the Original Plant

Chapter 5

Test Production

5.1 Testing with Cow Dung

5.1.1 Feed Stock Collection

To test the plant whether it is suitable for biogas production ant to generate the microorganisms that break down biodegradable material, cow dung (CD) was charged firstly. As cow dung is very much available anywhere in Bangladesh, feed stock was collected near from IUT.

5.1.2 Feeding Plan

At first cow dung (CD) was charged at a higher loading rate. As the batch charging method was used CD was charged once and the plant was sealed. It is well known that for biogas production from CD there is an optimum mixture ratio. So first time CD and water were mixed completely at the ratio of 1:2. In that proportion the volume of CD was 6 L and the volume of water was 12 L. Total 18 L of feed was charged in the digestion chamber capable of 20 L. The experiments were done in mesophilic (30-35˚C) condition.

5.1.3 Observation & Measuring

After charging it's time to observe daily when the gas production was started in what rate. After 24 hours ½ L feedstock was replaced to the hydraulic chamber from the digestion chamber. A centimeter scale was fitted to the body of hydraulic chamber. So the height covered by the feedstock can be also measured in centimeter. From this the volume of the replaced feedstock was measured and that is exactly the volume of gas produced in the digester chamber.

This volume was measured by,

$$\mathbf{V = \pi r^2 h}$$

Where, r = Radius of the hydraulic chamber

h = height of the replaced feedstock in hydraulic chamber.

Thus by daily observation at an interval of 24 hours the daily volume of gas produced was measured. Then cumulative gas production in 5 days was calculated. The daily pressure of the gas produced was noted from the milibar pressure gauge. Then the cumulative pressure was calculated from the daily reading.

Observation Table 5.1

The following observation table was made on the basis of gas produced from CD charged in the first stage of the project.

Date	**Time (pm)**	**Charging Volume (L)**	**pH**	**Temp (˚C)**	**Gas Production (m^3)**	**Cumulative gas Produced (m^3)**	**Cumulative Gas Pressure (mbar)**
23.08.13	**1:30**	**CD- 6 L + Water-12 L**	**7.4**	**32**	**0**	**0**	**0**
24.08.13	**-**	**-**	**-**	**-**	**0.00045**	**0.00045**	**11**
25.08.13	**-**	**-**	**-**	**-**	**0.00126**	**0.00171**	**24.75**
26.08.13	**-**	**-**	**-**	**-**	**0.00136**	**0.00307**	**36.85**
27.08.13	**-**	**-**	**-**	**-**	**0.00149**	**0.00456**	**49.5**
28.08.13	**-**	**-**	**-**	**-**	**0.00145**	**0.00601**	**60.85**

5.2 Testing with Sludge

After testing the plant by charging CD and producing biogas it was clear that the plat set up was accurate and is feasible for random gas production. So in the 2nd stage sludge was used with CD to check whether the sludge has potential to produce biogas or not.

5.2.1 Testing with 25% sludge & 75% CD

5.2.1.1 Feedstock Collection

The textile ETP (Effluent Treatment Plant) sludge was supplied by Mymun, Hamza, DB Tex & Thanbee Print World Ltd, DBL Group, Kashimpur, Gazipur. In the 2nd stage of this project ETP sludge was mixed with CD. At a time two 20 L jar were filled by the textile industry for the feeding purpose. In the following chart the effluent treatment of the sludge of dyeing industry is shown. The ETP sludge was collected from the stage of sludge recirculation pit.

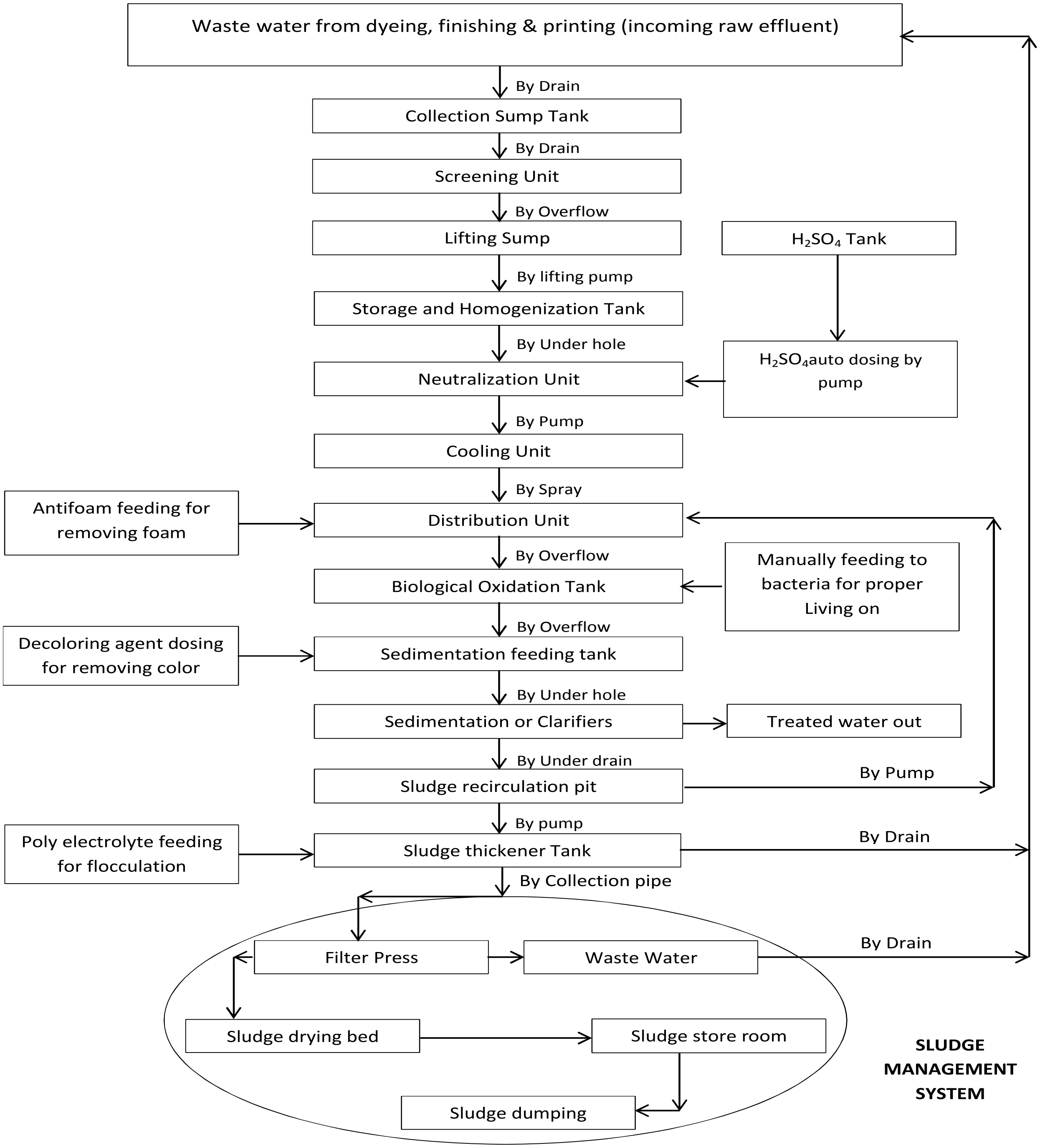
5.2.1.2 Feeding plan

As it is said before in this stage 25% sludge and 75% (CD + water) were charged at 6th september, 2013. In the first day 4 L of CD was mixed completely with 8 L of water and charging was done. This helped to generate microorganisms in the digester. In the very next day 4 L of ETP sludge was charged and digester was sealed. After that the plant was under daily close observation.

5.2.1.3 Observation & Measuring

Measurement system was exactly the same as the first stage of the project. This time the volume and pressure of produced gas were measured. Temperature and pH value was recorded at the charging date.

5.2.1.4 ETP Flow Diagram



5.2.1.5 Characteristics of Waste Water

Analysis Report of waste Water Sample

Sample Location	Parameters	Unit	Concentration	Place to Discharge		
				Subsoil Water	Sewerage Canal	Irrigation Land
Equalization Tank (Inlet of ETP)	Raw effluent	m^3/hr	140			
	Raw effluent P^H		9.2			
	Raw effluent temperature	°C	44°C			
	Raw effluent COD	mg/l	396			
	Total Dissolve Solids	mg/l	2240			
Oxidation Tank	Temperature	°C	33°C			
	Effluent P^H		7.50			
	Sludge quantity (wet)	ml/Lt	550			
	Sludge quantity dry (MLSS)	gm/Lt	2.60			
Clarifier Tank (Out Let of ETP)	Temperature	°C	33°C			
	P^H		7.50	6 to 9	6 to 9	6 to 9
	DO	mg/l	5.8	4.5-8	4.5-8	4.5-8
	COD	mg/l	94	200	400	400
	Total Suspended Solids	mg/l	12	150	500	200
	Total Dissolve Solids	mg/l	1460	2100	2100	2100
	BODs	mg/l	19	50	250	100

Observation Table 5.2 (for 25% ETP Sludge & 75% CD)

Date	Time (pm)	Charging Volume (L)	pH	Temp (˚C)	Gas Production (m³)	Cumulative gas Produced (m³)	Cumulative Gas Pressure (mbar)
06.09.13	**1:30**	**4 L CD + 8 L Water**	**6.9**	**35**	**0**	**0**	**0**
07.09.13	**1:30**	**4 L ETP Sludge**	**-**	**-**	**0.000452**	**0.000452**	**11**
08.09.13	**-**	**-**	**-**	**-**	**0.00113**	**0.00156**	**23.65**
09.09.13	**-**	**-**	**-**	**-**	**0.00136**	**0.00294**	**35.2**
10.09.13	**-**	**-**	**-**	**-**	**0.00136**	**0.0043**	**42.9**
11.09.13	**-**	**-**	**-**	**-**	**0.00145**	**0.00575**	**55**

5.2.2 Testing with 50% ETP Sludge & 50% CD

Now to be ensured about the potential of the ETP sludge the percentage of

5.2.2.1 Feedstock Collection

The source of textile ETP sludge was the same as before. ETP sludge was supplied by the same textile in the same manner.

5.2.2.2 Feeding Plan

In this stage 50% sludge and 50% (CD + water) were charged. In the first day 3 L of CD was mixed completely with 6 L of water and charging was done. This helped to generate microorganisms in the digester. In the very next day 9 L of ETP sludge was charged and digester was sealed. After that the plant was kept under daily close observation.

5.2.2.3 Observation & Measuring

The measurement of the daily gas volume and the pressure of the gas produced were taken same as described in the first stage. pH and temperature reading was taken at the charging date.

Observation Table 5.3 (for 50% ETP Sludge & 50% CD)

Date	**Time (pm)**	**Charging Volume (L)**	**pH**	**Temp (˚C)**	**Gas Production (m³)**	**Cumulative gas Produced (m³)**	**Cumulative Gas Pressure (mbar)**
29.09.13	**1:30**	**4 L CD + 8 L Water**	**6.9**	**33**	**0**	**0**	**0**
30.09.13	**1:30**	**4 L ETP Sludge**	**-**	**-**	**0.00045**	**0.00045**	**11**
01.10.13	**-**	**-**	**-**	**-**	**0.0009**	**0.00135**	**20.2**
02.10.13	**-**	**-**	**-**	**-**	**0.0009**	**0.00225**	**30.25**
03.10.13	**-**	**-**	**-**	**-**	**0.00081**	**0.00306**	**38.5**
04.10.13	**-**	**-**	**-**	**-**	**0.0009**	**0.00396**	**46.75**

Chapter 6 Results & Discussions

6.1 Results

6.1.1 Graphical Representation of Experiments

From the observation tables given in chapter 5 graphs can be plotted. The graphs were plotted for volume of gas produced against days for different ratios of ETP sludge and CD from observation table 1, 2 & 3.

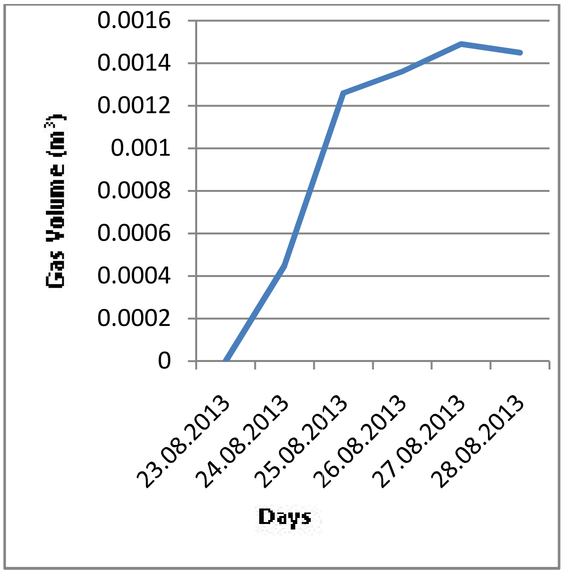


Fig. 6.1: for 100% CD

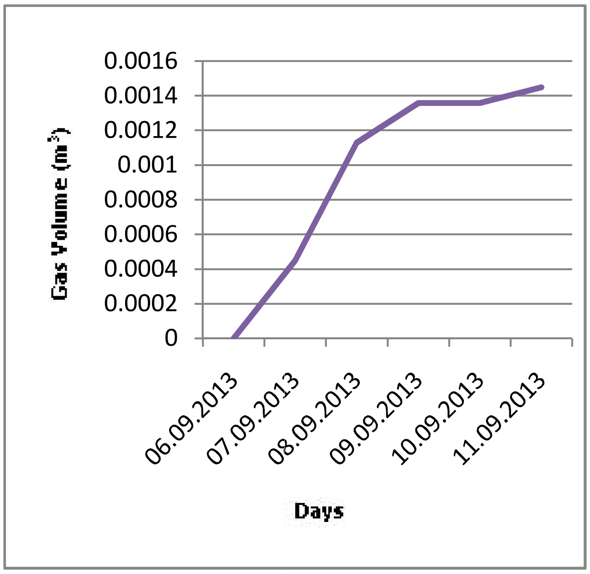


Fig. 6.2: for 25% ETP Sludge & 75% CD

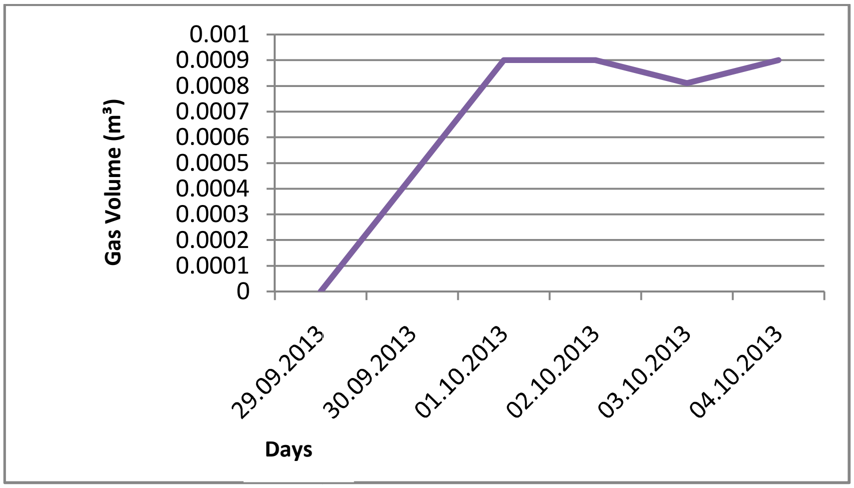


Fig. 6.3: For 50% ETP Sludge & 50% CD

Graphs of Cumulative Gas Volume Vs Days:

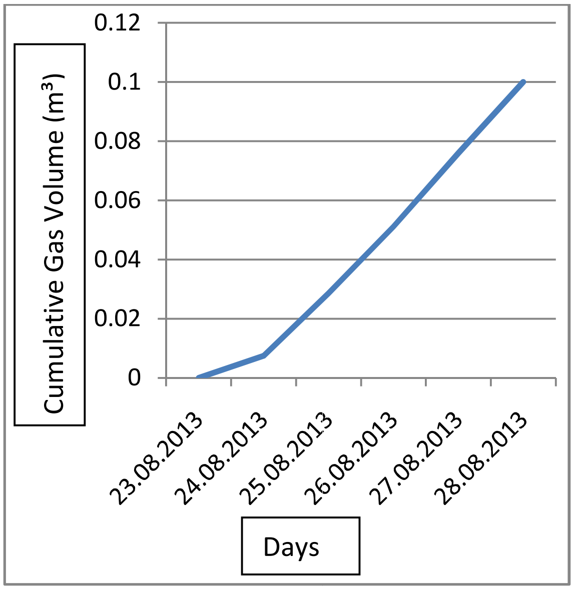


Fig. 6.4: for 100% CD

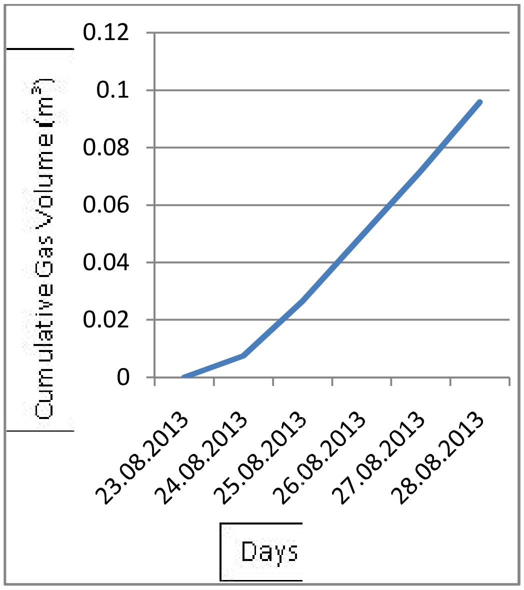


Fig. 6.5: for 25% ETP Sludge & 75% CD

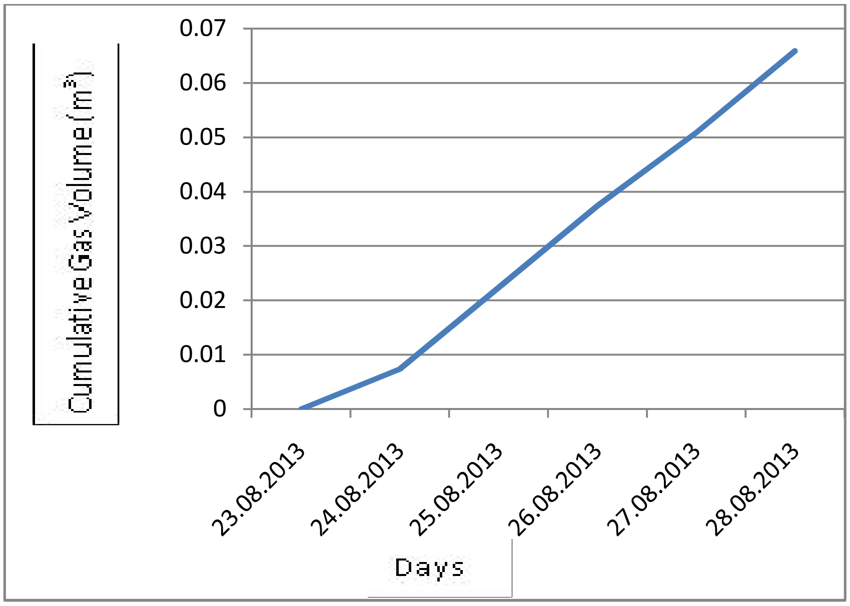


Fig. 6.6: For 50% ETP Sludge & 50% CD

Graphs of Cumulative Pressure Vs Days:

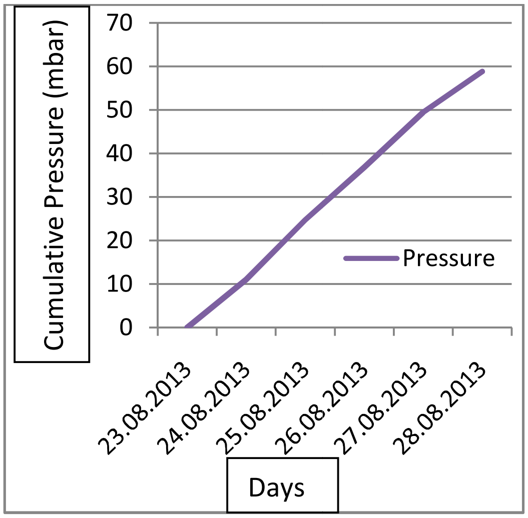


Fig. 6.7: for 100% CD

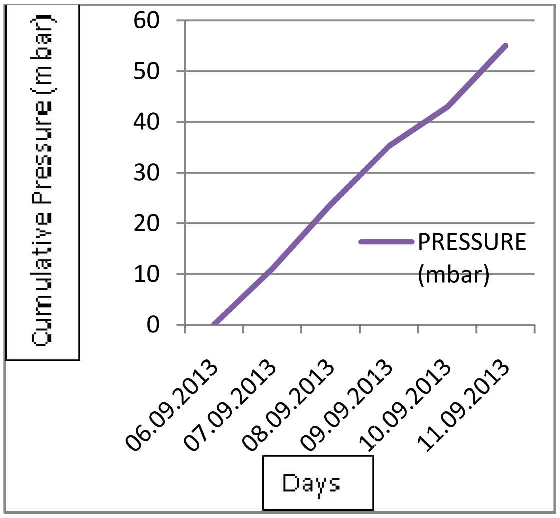


Fig. 6.8: for 25% ETP Sludge & 75% CD

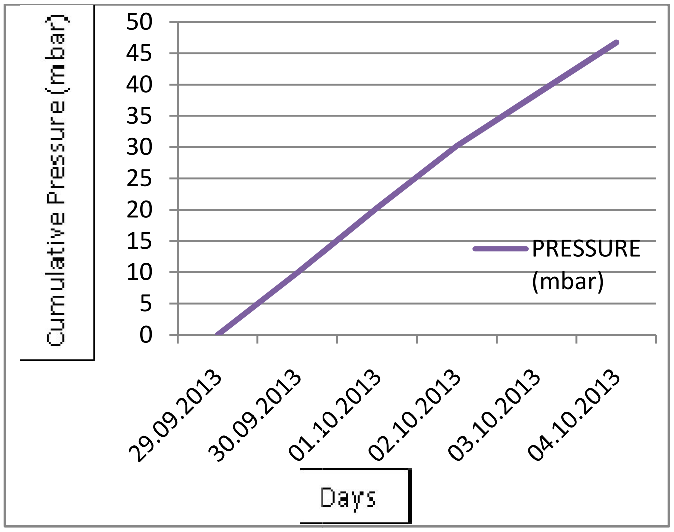


Fig. 6.9: For 50% ETP Sludge & 50% CD

6.1.2 Comparative Graphical Representation

In previous pages the graphs are shown individually. To get a comparative study they should be plotted all together. The comparisons between the 3 stages (100% CD, 25% ETP Sludge & 75% CD and 50% ETP Sludge & 50% CD) described in chapter 5 are shown below.

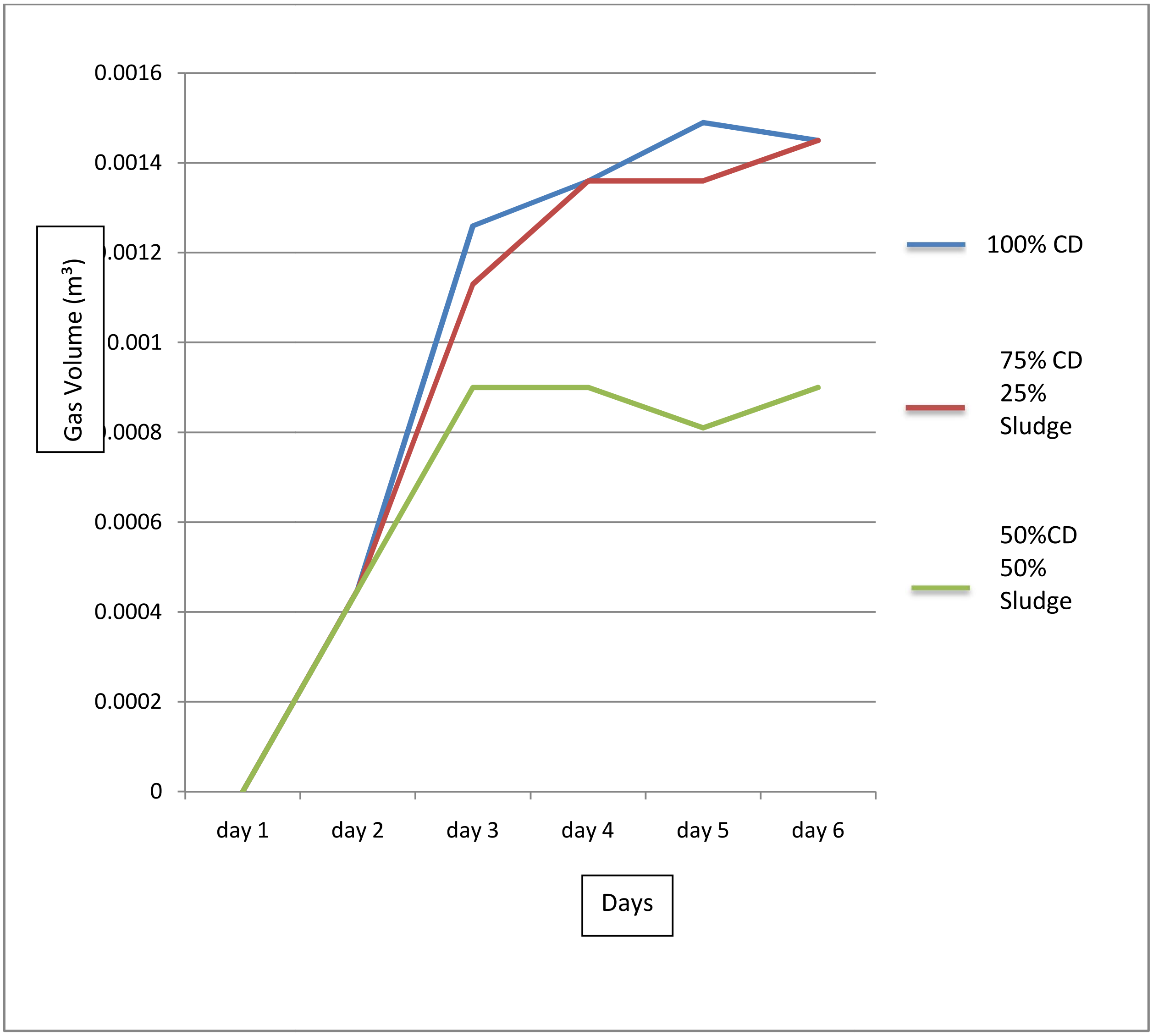


Fig. 6.10: Graphical Comparison of Daily Gas Volume

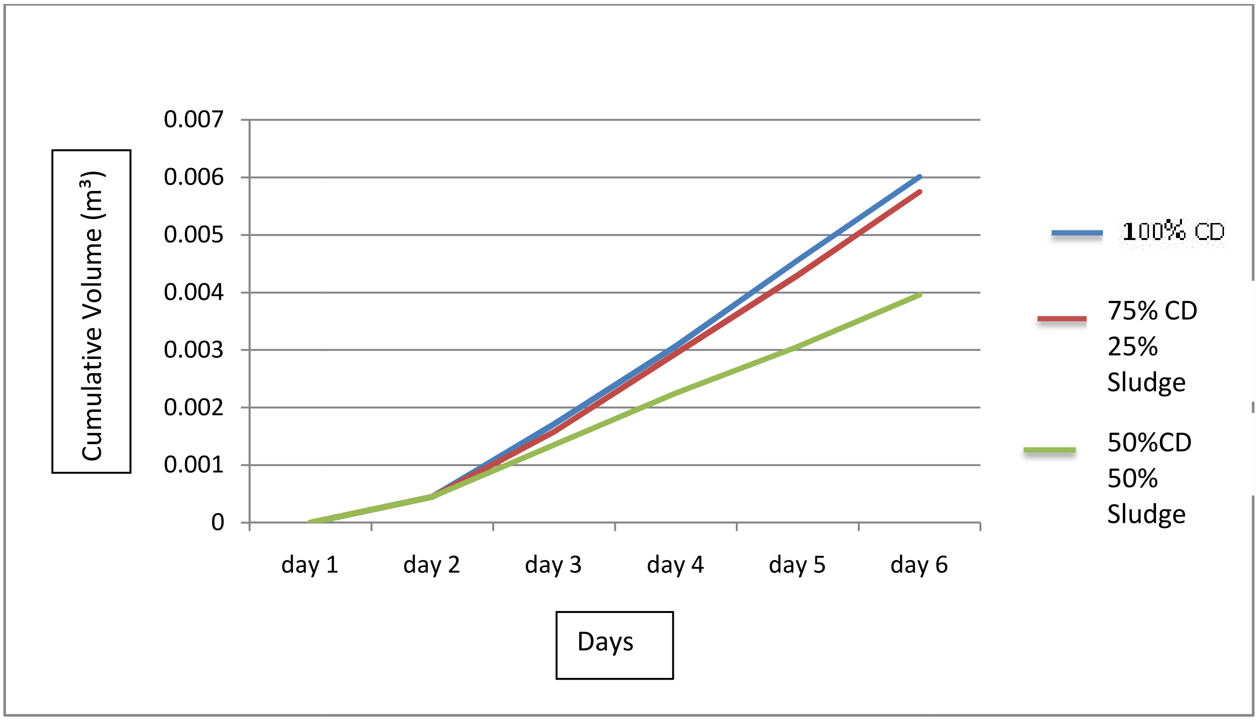


Fig. 6.11: Graphical Comparison of Cumulative Gas Volume

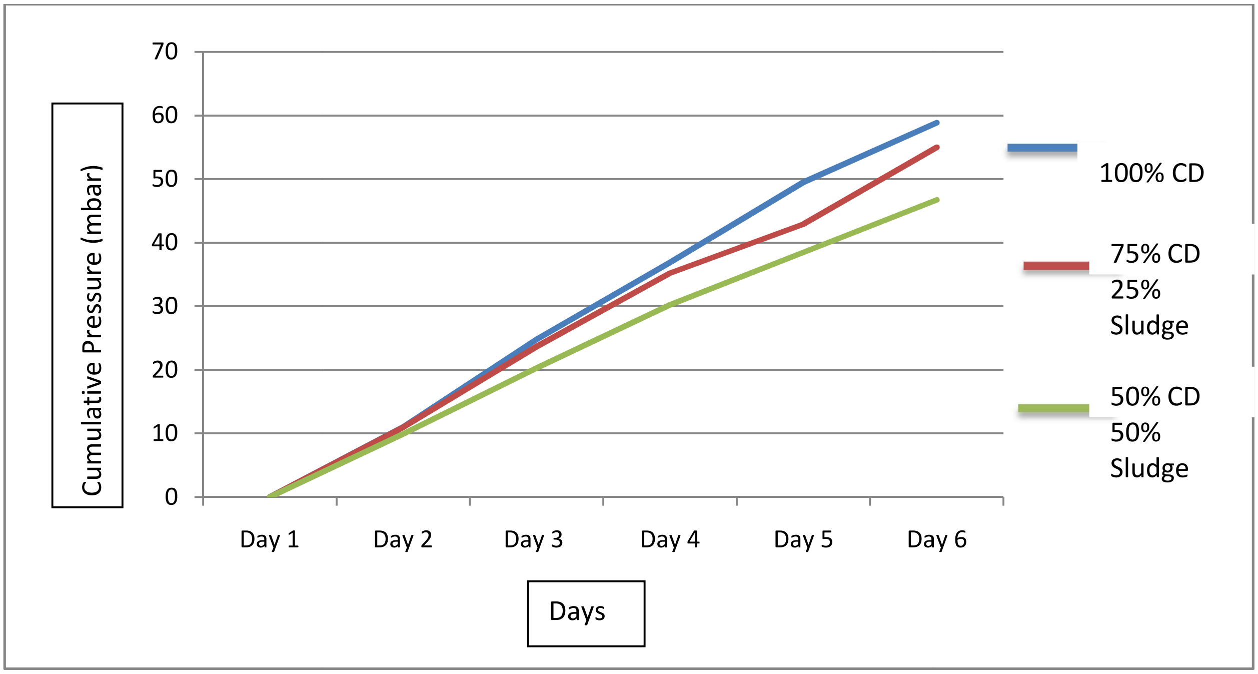


Fig. 6.12: Graphical Comparison of Cumulative Gas Pressure

6.1.3 Percentage of Methane

The potential of biogas is measured by the percentage of methane. The sample gas produced in the 3rd stage (50% ETP sludge and 50% CD) was tested in BCSIR. From the test result the sample biogas has 65.2% of Methane (CH_4) and 33% of Carbon Dioxide (CO_2). Besides this test the gas was also burnt and the gas was lit up with flame as shown in figure.

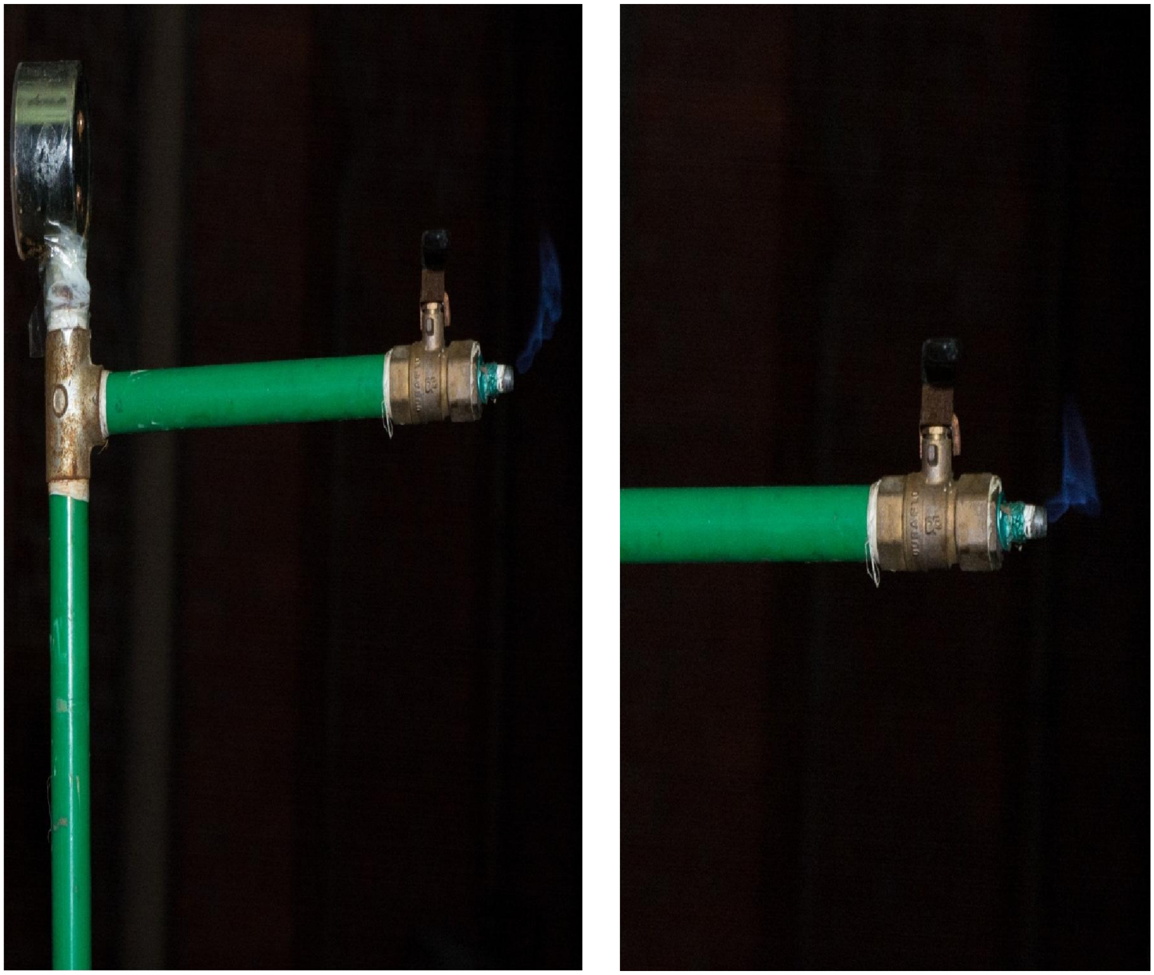


Figure: Flames from Gas Burning

6.2 Discussions

Main theme of this project was to produce biogas from hazardous textile ETP sludge. To create anaerobic microorganisms cow dung was used in different percentage to calibrate the potential of ETP sludge. From the observation tables of 3 stages of this project it is clear that ETP sludge has the potential of bio gas production.

When 100% cow dung (CD) was used as feedstock the cumulative gas volume was 0.00601 $m^3$and cumulative pressure of gas was 60.85 mbar.

When 25% ETP sludge and 75% CD was used the cumulative gas volume was 0.00575 m^3 and the cumulative pressure of gas was 55 mbar.

When 50% ETP sludge and 50% CD was used the cumulative gas volume was 0.00396 m^3 and the cumulative pressure of gas was 46.75 mbar.

So in the 2nd stage the gas production reduced to 4.3% and pressure of gas reduced to 9.6% compared to the first stage.

In the 3rd stage the gas production reduced to 34.1% and pressure of gas reduced to 23.1% compared to the first stage.

The percentage of methane in gas is 65.2% and carbon dioxide is 33% which is also satisfactory (tested by BCSIR).

In some cases daily gas production and pressure of gas were varied due to the factors affecting anaerobic digestion. By better controlling of pH value and temperature the variation can be minimized.

Though the gas production rate was decreased for using ETP sludge with CD it is not much in percentage and it can be increased with controlling different factors affecting gas production.

Conclusion

The purpose of this project was to use hazardous and toxic textile ETP sludge in some renewable energy field. The outcome of this project was very much positive. The ETP sludge has some potential to produce renewable natural gas in which there is satisfactory amount of methane.

The disposal of the toxic ETP sludge is very harmful for environment and also much effort requires handling this sludge by the textile industry. As the sludge used in this project was collected from the stage of “Sludge Recirculation Pit” of Effluent Treatment Plant the textile industry doesn’t have to do further treatment after this stage. This is also a positive side of using ETP sludge foe biogas production.

In future if this project is done in large scale the outcome may be much more fruitful and the gas produced from this can be supplied commercially.

References

Promotion of Social & Environmental Standards (PSES) in the Industry, German Development Cooperation GIZ, Bangladesh

Bernd Bilitewski; Georg Härdtle; Klaus Marek (1997): Waste Management. Springer, Berlin, ISBN: 3-540-59210-5

Mata-Alvarez, J. 2003: Biomethanization of the organic fraction of municipal solid wastes.

Ostrem, K. 2004: Greening Waste: Anaerobic Digestion For Treating The Organic Fraction Of Municipal Solid Wastes. Earth Engineering Center, Columbia University.

United Tech, I. (2003). Anaerobic Digestion, UTI Web Design.

Verma, S., 2002: Anaerobic Digestion Of Biodegradable Organics In Municipal Solid Wastes. Department of Earth & Environmental Engineering (Henry Krumb School of Mines) Fu Foundation School of Engineering & Applied Science Columbia University.

SHEFALI VERMA, May, 2002. ANAEROBIC DIGESTION OF BIODEGRADABLE ORGANICS IN MUNICIPAL SOLID WASTES.

Biogas Digest, Volume IV, Biogas-Country report, Information and Advisory Service on Appropriate Technology by GTZ.

Felix W Ntengwe, Laurence Njovu, George Kasali and Lordwell K Witika. BIOGAS PRODUCTION IN CONE-CLOSED FLOATINGDOME BATCH DIGESTER UNDER TROPICAL CONDITIONS. International Journal of ChemTech Research CODEN(USA): IJCRGG ISSN : 0974-4290, Vol.2, No.1, pp 483-492, Jan-Mar 2010.

Fabien Monnet. An Introduction to Anaerobic Digestion of organic Wastes. November,2003.