# PRODUCTION OF BIOGAS FROM SLUGDE FROM WATER PURIFICATION PLANT
# (TEMPERATURE AND PH VERIATION)
# (CASE STUDY: NIGER STATE WATER BOARD)


**BY**

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**2003/15083EH**


**A PROJECT SUBMITTED TO THE DEPARMENT OF CHEMICAL ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY.**


**FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.**

**NIGER STATE**

**NIGERIA**


**IN PARTIAL FULFILMENT OF THE REQUIMEMT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN CHEMICAL ENGINEERING.**

**NOVEMBER, 2008.**

## DECLERATION

I, IGWE OFULUE PAUL with matriculation number 2003/15083EH declare that this research project report is my original work and has not been presented else where to the best of my knowledge.

.....
**Signature**

10/11/08
.....
Date

## CERTIFICATION

This to certify that, the project titled "production of biogas from sludge" carried out by IGWE OFULUE PAUL meet the demand for the award of degree of Bachelor of Engineering (B.Eng) in chemical Engineering department at Federal University of Technology, Minna, Niger State.

.....  10/11/08.....

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# DEDICATION

This research project is dedicated to Mr. and Mrs. Ben Aweretefe and to my father and his late wife, Mr. and Mrs. Nathan Igwe for their support and commitment towards my academic advancement, may Almighty God bless and protect them (Amen).

## ACKNOWLEDGEMENT

I express my sincere gratitude to Almighty God for sparing my life up to this present moment and for letting this degree programme a success. All praise belongs to him.

My profound gratitude goes to my parent, Mr. and Mrs. Benjamin Aweretefe, and to my father and my late mother, Mr. and Mrs. Nathan Igwe for their dedication, financial and moral support towards my educational advancement. May God bless and reward them (Amen).

Special thanks go my elder brother, Mr. Azuka Nwokolo for his words of encouragement and financial support. And to my family who have stood by me throughout the course of this programme. God bless you all (Amen).

Appreciation to my love ones and colleagues for their support and care, Mr. and Mrs. Moses Nwokolo, Mr. Ndidi Afoke, Mr. Onos Ogiridu, Okpolo Faith, David Ajayi, , Emma okolobia.

Finally, kudos to Dr D.O Agbejelola , Engineer M.A. Olutoye, Prof K.R.Onifede, Dr Edoga .M. for their inspirational method of lecturing and fatherly advice and the entire lecturers of Chemical Engineering Department, God Bless you all (Amen)

# ABSTRACT

Biogas is a clean and renewable form of energy which is very well substitute for conventional sources of energy (fossil fuels, oil, etc.) which helps in controlling ecological–environmental problems. A laboratory-scale experiment was carried out to assess the influence of temperature and and its corresponding pH value on thermophilic and mesophilic anaerobic digestion of sludge organic waste (from a water purification plant). Temperature was varied from 25 °C to 70 °C, causing corresponding variation of pH values obtained. Biogas production was produced less at a temperature change of 30°C to 40°C and was produced more at a temperature of 65°C to 70°C, which implies the temperature the higher the amount of biogas produced and the lesser the amount of biogas produced.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Biogas is clear and renewable form of energy which is a substitute for conventional resources of energy (De Baere and Verstraete, 1994). Any living organism that produces gas is called a biogas (Nozhevnikova et al, 1999). It is only the mixture of gases produced by anaerobic bacteria that it is commonly called biogas.

Anaerobic digestion is a process in which micro organisms break down biodegradable materials in the absences of air (McDermott et al, 2001). The process is used to treat waste water sludge because it reduces the volume and mass reduction of the input material, thereby serving as a means of reduction of environmental pollution. As part of integrated waste management system, anaerobic digestion reduces the emission of land fill gas into the atmosphere (De Baere and Verstraete, 1994).

The process of obtaining biogas from sludge of waste water is called anaerobic digestion or fermentation, converting bacteria from organic material into biogas. Sludge can be divided mainly into organic sludge which consist of sewage from domestic waste water and inorganic sludge, which are chrome, acidic, detergent waste water and sludge from water treatment facilities (Aubart C.N., 1983). Anaerobic treatment reduces the amount of organic pollutant in waste water into small amount of sludge and a large amount of biogas, which promotes the maintain anaerobic digester coupled with high capital cost and lower process efficiencies have so far limited the level of industrial application as a waste treatment technology (Chandra R. et al ,1997). It also emphasis on the advantage as a means of waste management on environmental pollution and as source of energy.

Sludge is been obtain from waste water which is characterised by suspended solids, colour and biochemical oxygen demand. The suspended solid is a measure of the solid that are suspended (not dissolved) in the waste water after it has been treated, which reduce the amount of oxygen and settles over a period of time with a layer called sludge (McDermott et al,2001). Sludge is a settle able form of waste water which are thickened material that are generated in a primary sedimentation of a water treatment plant. The biochemical oxygen measures the amount the demand for oxygen that can be consumed by the living organism in the waste water (Chandr R. et al,1997). Water with high biochemical oxygen demand is characterised by low oxygen and high biological activity, biodegradable organisms in water are consisting principally on proteins, carbohydrates and fats. When the untreated sludge is discharged into the to the environment it causes a biological stabilization which leads to depletion of natural oxygen resources, septic conditions in rivers (Wolverton et al,1981).

Waste water characteristics depend largely on the mass loading rate flowing from various sources in the collection system, the flow is combined with composite domestic and industrial water waste. During wet weather, the addition of the rain collected from the combined sewer system changes the characteristic of the waste water due to the increase of the flow to the treatment plant. Highly acidic or basic wastewaters are undesirable for two reasons. First, they can adversely impact the aquatic life in receiving waters; second, they might significantly affect the performance of downstream biological treatment processes at the plant site or at a publicly owned treatment works.

### 1.1 Aim and Objectives

The aim of this research project is to produce biogas from sludge of a water treatment plant. This can be achieved by the following objectives:

- Preparation of the sludge.
- Digestion of the sludge.
- Study of the effect of temperature and pH on the amount of biogas produced.

### 1.2 Scope of Work

The scope of work of this project is to produce biogas from sludge of a water treatment plant (Niger state water board).Variation of the parameters which affects production of the gas in particular the temperature and alkanality (pH) using various temperature, to be able to determine at what point the gas produces more at a particular temperature and at what pH value. This is being determined by weighing the various gases produced with a weighing balance. A setup was carried out to which the bioreactor(measuring cylinder) would be cork not to allow air to enter the system, two holes are bole in which the pH electrode is inserted into the reactor and the other hole where the gas passes into an empty bag.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

Biogas methane is methane created from biologically created organic mater. Fossil fuel derived methane is known as Natural Gas and biogas derived methane from fossil fuel methane (Clark P.B. and Hillman P.F., 1995). Methane from any source when emitted and rise from the ground level to the atmosphere are thought to be potent causes of greenhouse warming. Methane is about 20 times more active in absorbing the sun's heat and causing global warming, than Carbon (IV) oxide.

Biogas is clean and renewable form of energy which is a substitute for conventional resources of energy (fossil fuel, oil, etc) which are causing ecological environmental problems and at the same depleting at faster rate in the atmosphere. Anaerobic digestion is a process in which micro organisms break down biodegradable materials in the absence of air, which is widely used to treat waste water sludge and organic waste because it provides volume and mass reduction of the input materials (Dhawale M.R., 1996). As part of integrated waste management system, anaerobic digestion reduces the emission of land fill gas into the atmosphere. Anaerobic digestion is a renewable energy source because of its enrichment of methane and carbon dioxide rich biogas suitable for energy production helping to replace other sources of energy such as fossil fuel, lubricants and petrol (Van der Berg L. and Kennedy K.J., 1983)

Scientific interest in the gases produced by the natural decomposition of organic matter was first reported in the sixteen century by Robert Boyle's and Stephen Hale, who noted inflammable gas, was disturbing the sediments of streams and lakes. The first dual purposed tank for both sedimentation and sludge treatment was installed in England at Hampton. Through scientific research, anaerobic digestion gained academic recognition in the 1930's which led to discovery of aerobic bacteria, the micro organism that facilitates the process in the production of biogas.

### 2.1 The Process

There are numbers of bacteria that are involved in the process of anaerobic digestion including acetic acid forming bacteria and methane forming bacteria. The bacteria feed upon the initial feedstock, which undergoes a number of different processes converting it to intermediate molecules including sugars, hydrogen and acetic acid before finally converted to biogas (Idnani M.A. and Laura R.D., 1971). Different species of bacteria are able to survive at different temperature ranges to produce biogas.

### 2.1.1 Mesophilic bacteria

Mesophile is an organism that grows best in a moderate temperature, neither too hot nor too cold, typical temperature between 15 – 40°C which is mainly applied to micro organism. Greater numbers of species are formed in the mesophile organisms which are more stable in the digestion system (Baier U. and Schmidheiny P. 1997.) The mesophile bacteria more biogas at a temperature of 34 – 42°C which are very stable in the production of biogas.

### 2.1.2 Thermophilic bacteria

Thermophilic bacteria are bacteria that can survive at a hotter and more hostile condition of 55 – 70°C. Methanogens comes from a primitive group of archaea, and can grow in a hostile condition of hydrothermal vents (Angelidaki I. and Ahring B.K., 1994) These species are more resistant to heat and can therefore operate at thermophilic temperature, thermophilic digestions are considered less stable or unstable. However increase in temperature facilitates faster reaction rate and hence faster yields of biogas production.

### 2.1.3 Bacteria growth

Bacteria growth is obtained experimentally by transfer of incoculum to fresh culture, record and measure of number of viable cell at regular intervals, and logarithum of population against time of growth (Engr Alhassan`, 2008).

### 2.1.4 Phases of the growth bacteria

- LAGPHASE: This is the time required by inoculated cells in fresh medium to adapt to a new environment before the start of cell division. These phases is characterised of a constant cell number but an increase in metabolic activities of the cells
- EXPONENTIAL PHASE: This is the phase where undergoes a maximum rate of cell division. These phases is characterised by a constant doubling of cell population.
- STATIONARY PHASE: At this phase the rate of cell multiplication slows down due to nutrients and builds up of toxics. The rate of reproduction equals to the rate of death so, the number of bacteria remains constant.
- DEATH PHASE: Cells are decreased as growth stops and the existing cells die off.

### 2.1.5 Micro biology and biochemistry of methane-producing gas

Biogas production involves micro biology and biochemistry of the different micro organism engaged in fermentation of the raw materials required for the process.It was observed that straw, mixed grasses, animal and human wastes, garbage and husks among the raw materials which are degraded under anaerobic conditions produce methane. The author represents (Alexander M., 1961) orts that methane producing bacteria are widely distributed in nature and are common in lakes, manure pits, sewage. Methonogens was described as a group of highly specific organisms

which are highly sensitive to oxygen and oxides and utilise simple organic and inorganic compounds of hydrogen and carbon (IV) oxide as substrates to yield methane (Karki and Dixit, 1984).Some species of methonogens can utilise formic acid, methanol, methyl amine and acetic acid to produce methane.

### 2.1.6 Component of biogas

2.1.6.1 Methane

Methane is a member of the alkane or paraffin series of hydrocarbons with formulae of $CH_4$. Methane is called marsh gas because it forms by anaerobic bacterial decomposition of vegetable matter in swampy land. It forms in large amounts in sewage disposal processes especially in anaerobic digestion. As a liquid, it freezes at -182.6°c and boils at 161.6°c. Methane is practically insoluble in water and moderately soluble in alcohol or ether. The gas burns when ignited in air with a pale faintly luminous flame, forming an explosive mixture with air between gas concentrates of 5% and 13%.

The gas, methane is the principal constituent of natural gas averaging 75% by weight. On combustion, it burns to give water and carbon dioxide. Other properties of methane include;

| | | |
|---|---|---|
| Vapour Pressure at 20°c | = | -191.8mmHg |
| Density | = | 0.7167 G/T |
| Specific Gravity | = | 0.415 |
| Solubility in Water | = | 0.4 CC |
| Initial Weight | = | 16.04 |

#### 2.1.6.2 Carbon dioxide

Carbon dioxide $CO_2$, formulae weight 44.01 is colourless, odourless and non toxic gas at standard conditions. It also has a density of 1.9769 G/L, specific gravity of 1.53 (air = 1.00), melting point of -56.6°C. Solid $CO_2$ sublimes at -79°C, a critical pressure of 73 atoms and temperature of 31°C.

Carbon dioxide is soluble in water, soluble in alcohol and is readily absorbed by most alkaline solutions. It is denser than air and has the ability to extinguish fire. Others properties of $CO_2$ include;

| | | |
|---|---|---|
| Vapour Pressure at 20°C | = | -114.4mmHg |
| Head of Fusion | = | 1900 Cal/Mol |
| Boiling Point | = | 78.4°c |
| Heat of Vaporization | = | 6030 Cal/Mol |

## 2.2 Biological and Chemical Stages of Anaerobic Digestion

### 2.2.1 Digestion

Digestion refers to the various reactions and interaction that takes place among the methanogens, non methanogens and substrates fed into the digester as inputs.

### 2.2.2 Hydrolysis

Digestion process begins with bacteria hydrolysis of the input materials in order to breakdown the insoluble organic polymers such as carbohydrates, proteins, lipids and make available bacteria. Large complex substances are solubilized into simpler ones with the help of extracellular enzymes released by the bacteria; this stage is known as polymer breakdown stage. For example cellulose consisting of polymerised glucose is broken down to dimetric and then to monometric sugar molecules (glucose) by cellulolytic bacteria. Polysaccharides are converted into monosaccharide, and proteins are split into petides and amino acids (Karki and Dixit, 1984).

### 2.2.3 Acidogenesis

The monomer such as glucose, which is produced in the first stage, is fermented under anaerobic condition into various acids with the help of enzymes produced by the acid forming bacteria. The acid forming bacteria at this stage, converts the intermediates of fermenting bacteria into acetic acid (Ethanoic acid), propanoic acid, hydrogen and carbon dioxide. This bacteria are facultative anaerobic and can grow under acid condition (Alexander M., 1961) To produce acetic acid, they need oxygen and carbon for this they use the oxygen solved in the solution whereby acid producing bacteria create an anaerobic condition which is essential for maintained producing organism. Moreover, they reduce the compound with low molecular weight into alcohols, organic acid, amino acid, carbon dioxide, hydrogen sulphide and traces of ammonia.

### 2.2.4 Acetogenesis

Acetogenesis is where simple molecules created through acidogenesis phase are further digested by acetogens to produce large acetic acid as well as carbon dioxide and hydrogen.

### 2.2.5 Methanogenesis

Methanogenesis is the formation of methane by microbes. This is an important and wide spread form of microbial metabolism and it is the final step in the decomposition of organic matter. Organisms capable of methanogenesis are called methanogens. This organism has no nucleus or membranes bound organelles, they are prokaryotes. Methanogens do not use oxygen to breath, oxygen are deadly poison to methanogens and kills all methanogens in very tiny concentration.

The terminal electron acceptor in methanogenesis is not oxygen, but carbon. The carbon occurs in a small number of organic compounds, all with low molecular weight. The two best described pathways involve the best use of acetic acid carbon dioxide as terminal electron acceptors. Methanogens cannot exit in the presence of oxygen, so they are only found in environment in which the oxygen has been depleted. Only methanogenesis and fermentation can occur in the absence of electro acceptor other than carbon. Fermentation only allows the breakdown of larger organic compounds and produce small organic compounds. Methanogenesis effectively removes semi-final products of decay such as hydrogen, small organics and carbon dioxide. This reaction that takes place in the process of biogas is called methanization.

$CH_3COOH \longrightarrow CH_4 + CO_2$ .....2.1

Acetic acid — Methane — Carbon (IV) oxide

$2CH_3CH_2OH + CO_2 \longrightarrow CH_4 + CH_3COOH$.....2.2

Ethanol — Carbon(iv) oxide — Methane — Acetic acid

$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_20$..... .....2.3

Carbon (IV) oxide — Hydrogen — Methane — Water

The above equations shows the by products and the intermediate are produced in the process of digestion in an anaerobic conditions.

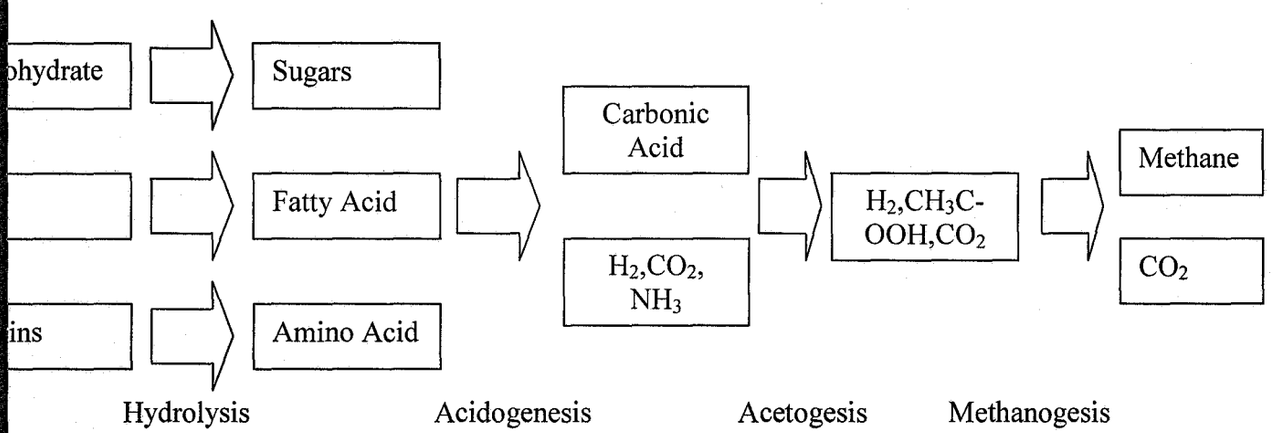


Figure 2.1: Stages of Biogas Production

### 2.2.6 Symbiosis of bacteria

Methane and acid producing bacteria act in a symbiotical way. On the one hand, acidproducing bacteria create an atmosphere with ideal parameters for methane-producing bacteria (anaerobic conditions, compounds with a low molecular weight). On the other hand, methane-producing microorganisms use the intermediates of the acid-producing bacteria. Without consuming them, toxic conditions for the acid-producing microorganisms would develop. In practical fermentation processes the metabolic actions of various bacteria all act in concert. No single bacteria are able to produce fermentation products alone.

## 2.3 Factors Affecting Biogas Production

### 2.3.1 PH value

The optimum gas production is achieved when the pH value of the input mixture in the digester is between6 – 7; the pH in the biogas digester is also a function time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits stops the digestion of fermentation process, methonogens bacteria are very sensitive to pH and do not thrive below the value of 6.5. Later, as the digestion continues, concentration of ammonium increases due to digestion of nitrogen which can increase the pH to above 8. When the methane production is stabilised, the pH range remains buffered between 7.2 to 8.2.

PH is important parameters affecting the growth of microbes during fermentation which should be kept within a desire range of 6.8 to 7.2 by feeding it at an optimum loading rate. The amount of carbon (IV) oxide and volatile fatty acid produced during anaerobic process affects the pH of the digester contents. For an anaerobic fermentation to proceed normally concentration of volatile fatty acid acetic acid in particular should be below 2000 mg/L. It was formed that above pH of 5.0, the efficiency of methane production was more than 75% (Jain & Mattiasson, 1998).

### 2.3.2 Effects of temperature

Temperature inside the digester has a major effect on the biogas production process. There are different temperature ranges during which anaerobic fermentation can be carried out: Phychrophilic (0 to 30°C), mesophilic (30 – 42°C) and thermophilic (50 – 65°C), however anaerobic are most active in the mesophilic and thermophilic temperature range (Umetsu et al, 1996). The length of fermentation period id dependent on temperature when ammonia is high, reduction of temperature drops below 55°C, results to increase in biogas yield and better process stability. Methonogens are sensitive to sudden thermal changes; therefore any drastic change in temperature is avoided.

When an ambient temperature is 30°C or less, the average temperature within remains 4°c above the ambient temperature.Two step anaerobic treatment of sludge was proposed (Nozhevnikova et al, 1999) i.e

i. Acidogenic fermentation at high temperature between 50 – 82°C
ii. Separation of solid and liquid fractions and treating the liquid manure under low temperature conditions (5 – 20°C).

Long term adaptation of active phychrophilic microbial communities was found to be essential for efficient treatment of sludge.

### 2.3.3 Particle size

Though particle size is not that important parameters as temperature or pH of the digester content, it stills has some influence on gas production. The size of sludge should not be too large otherwise it would be difficult for microbes to carry out its digestion. Smaller particles on the other hand would provide larger surface area of absorbing the substrate that would result in increase of microbial activities and hence increase gas production.

### 2.3.4 Carbon - Nitrogen ratio

It is necessary to maintain the proper composition of the sludge for efficient plant operation so that the carbon – nitrogen ratio remains in a desired range. It is generally found that during anaerobic digestion, micro organism utilise 25 – 30 times faster than nitrogen. Thus to meet this requirements microbes need 20 – 30:1 ratio of carbon to nitrogen with the largest percentage of carbon being readily degradable (malik et al, 1987). Waste materials that are low in carbon can be combined with material high in nitrogen to attain desired carbon/nitrogen ratio 30:1. Some research has suggested that the carbon nitrogen ratio varies with temperature according to the study conducted by (Sanders F.A. and Bloodgood D.E., 1965),

### 2.3.5 Toxicity

Minerals ions, heavy metals and the detergents are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of mineral ions e.g sodium, potassium, calcium, magnesium, ammonium and sulphur also stimulates the growth of bacteria, while some heavy concentration of these ions with the toxic effect such as ammonium presence from 50 to 200Mg/L stimulates the growth of microbes, whereas its concentration above 1500Mg/L produces toxicity. Toxicity on bacteria growth are listed below given on Table 2.1.

Table 2.1: Toxic Level of Various Inhibitors (BRTC, 1989)

| Inhibitors | Inhibiting Concentration |
|---|---|
| Sulphate ( $SO_4$ ) | 5000 PPM |
| Sodium Chloride | 40000 PPM |
| Nitrate | 0.05 Mg/Ml |
| Copper (Cu+++ ) | 100 Mg/Ml |
| Chromium ( Cr+++) | 200 Mg/L |
| Nickel ( Ni+++) | 200 – 500 Mg/L |
| Sodium (Na+) | 3500 – 5500 Mg/L |
| Calcium (Ca++) | 2500 – 4500Mg/L |
| Magnesium (Mg++) | 1000 – 1500 Mg/L |
| Manganese (Mn++) | Above 1500 Mg/L |

Source: The Biogas Technology in China, BRTC, China (1989)

### 2.3.6 Organic Loading Rate

Gas production rate is highly dependent on loading rate. Biogas yield was formed to increase with reduction in loading rate (Vartaket et al, 1997). In another study carried out in Pennsylvania on a $100cm^3$ biogas plant on sludge, when it was varied from 346 Kg/day to 1030 kg/day, gas increased from 67 to 202 $m^3$/day. The optimum feed rate for a particular size of plant, which will be produced by maximum gas and beyond which further increases in the quantity of substrate which is not proportionately to produce more gas.

### 2.3.7 Retention time

Retention time (also known as detention time) is the average period that a given quantity of input remains in the digester to be acted upon by the methanogens. In a sludge plant, the retention time is calculated by dividing the total volume of the digester by the volume of input added daily. Thus, digester should have a volume of 50 to 60 times the scurry added daily. Retention time depends on the temperature and up to 35°C, the higher the temperature, the lower the retention time (Lagrange, 1979). Short retention time is likely to face the risk of washout of active bacteria population while longer retention time requires a large volume of the digester. It is possible to carry out methanogenic fermentation at low retention time without stressing the fermentation process at mesophilic and thermophilic temperature ranges (Zennaki et al, 1996).There was an improvement in organic matter removal on increasing the retention time.

## 2.4 Techniques for Enhancing Biogas Production

Different methods are used to enhance biogas production which can be classified into the following categories

- ❖ Uses of additives
- ❖ Recycling of slurry and slurry filtrate
- ❖ Use of fixed biofilters

### 2.4.1 Uses of additives

Increase of biogas production by stimulating the microbal activity using various biological and chemical additives under different operating condition has been attempted by various researches on how to improve the production. The suitability of additive is expected to be strongly dependent on the type of substrate.

#### 2.4.1.1 Green biomass

Powdered leaves of some plants and legumes (like Gulmohar, leucacena, leucocephala) have been formed to stimulate production 18% and 40% (Chowdhry et al, 1994). Increase in biogas production due to certain additives appears to be due to adoption of the substrate on the surface of the additives. This leads to high - localized substrate concentration and a more favourable environment for growth of microbes. The additives help to maintain favourable condition for rapid gas production in the reactor, such as pH, inhibitors, promotion of the acetogenesis and methonogenesis for the best yield.

#### 2.4.1.2 Microbal strains

Strains of some bacteria and fungi have also been found to enhance gas production by stimulating the activity of particular enzymes. Cellulolytic strains of bacteria like actinonymycetes and mixed consortia have been found to improve biogas production in the range of 8.4% to 44%. (Attar et al, 1998). All the strains exhibited a range of activity of all the enzymes involved in cellulose degradation, for hydrolysis of cellulose endogluccanase activity is an important hydrolysis of cellulose (Tirumale and Nand, 1994).

#### 2.4.1.3 Inorganic additives

Inorganic additives have improved gas production, with higher concentration of bacteria which is used in the digester by the addition of metal cations. Since cations increase density of bacteria, this is capable of aggregating by themselves. It was found that the plant with a higher content of heavy metals (Cr, Cu, Ni and Zn) had a higher biogas yield than the control (Wong and Cheing, 1995). The addition of iron salts at various concentrations ($FeSo_4$, $FeCl_3$) has been found to enhance gas production rate.

Certain absorbents are also reported to improve gas production (Madamwar and Mithal, 1996) obtain a maximum enhancement of over 150% with higher biogas content (65% $CH_4$) on addition of 10g/l commercial pectin using Calcium and magnesium salts as energy supplements, $CH_4$ production was enhanced and foaming was avoided ( Mathiese, 1989).

### 2.4.2 Gas enhancement through recycling of digested slurry /slurry filtrate

The recirculation of digested slurry back into the reactor has been shown to improve the gas production marginally, since the microbes washed away are reintroduced back into the reactor, thereby producing an additional microbal population. The recycling of the digested slurry along the filtrate has been tried out to conserve water and to enhance biogas production (Malik and Dahiya, 1990). It was discovered that more biogas production can be obtained by recycling the digested slurry. The recycling of the digested slurry along the fresh sludge helps to overcome the problem of underfed biogas plants as well as maintaining higher gas production and the problem of precipitation of substrate increase acidity/alkanity and ammonia toxicity.

### 2.4.3 Biofilters / fixed film digester

Fixed film reactors have been used to treat wastewater where they help to reduce the retention time (Kloss, 1991). The reactor comes under the category of advanced reactors like fluidized bed, up flow anaerobic filters. They help to enhance the performance of waste water treatment systems by providing an increase surface area for attached growth of the microbes in the form of a fixed film on an inert medium leading to increased population of microbes in the reactor and their retention in the digester even after the digested slurry flows out (Vander Berg and Kennedy, 1983). Fixed film techniques have been used commonly for substrates very low solids contents where the filters of very large surface area used. Different materials like nylon sponge; PVC, Clay Pipes, etc had been used as support medium for fixed film reactor (wilkie et al, 1984).

## 2.5 Biodigesters

The biodigester is a physical structure, commonly known as the biogas plant. Various chemical and microbiological reactions take place in the digester, it is known as bio – reactor or anaerobic reactor. The main function of this structure is to provide condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size. Construction of the structure forms a major part of the investment cost. Some of the commonly used designs are discussed below (Massé D.I. and Masse L., 2000).

### 2.5.1 Batch digester

There is biogas systems designed to digest solid waste alone, since the plant solids will not flow through pipes, this type of digester is best used as a single batch digester (Borax et al, 1994). The tank is opened, old slurry is removed for the use of fertilizer and the new charge is added. This is then released and ready for operation (Masse et al, 1996) Dependent on the waste materials and operating temperature, a batch digester will start producing biogas after two to four weeks slowly increases in production then drop off after three or four months. Batch digesters are therefore best operated in groups so that at least one is always producing useful quantities of gas (Zheng, Y. and Wu W., 1985)

Most laboratory studies on anaerobic treatment of sludge waste water have been conducted with anaerobic filters reactors (AFR) or upflow anaerobic sludge blanket (UASB) reactors. The anaerobic efficiently used for filters reactors sustain high loading rates when the water contains mostly soluble chemical oxygen demand (Aurora and Roth, 1980)

Upflow anaerobic sludge blanket reactors are efficiently used for treating low soluble sludge waste water. At 35°c, chemical oxygen demand reduces by more than 90% at the organic loading rate up to 6.4 $kgm^{-3}d^{-1}$ (Borga et al, 1994)

Table 2.2: Composition of Biogas

| Substances | Symbols | Percentages |
|---|---|---|
| Methane | $CH_4$ | 50-70 |
| Carbon dioxide | $CO_2$ | 30-40 |
| Hydrogen | $H_2$ | 5-10 |
| Nitrogen | $N_2$ | 1-2 |
| Hydrogen sulphide | $H_2S$ | Traces |

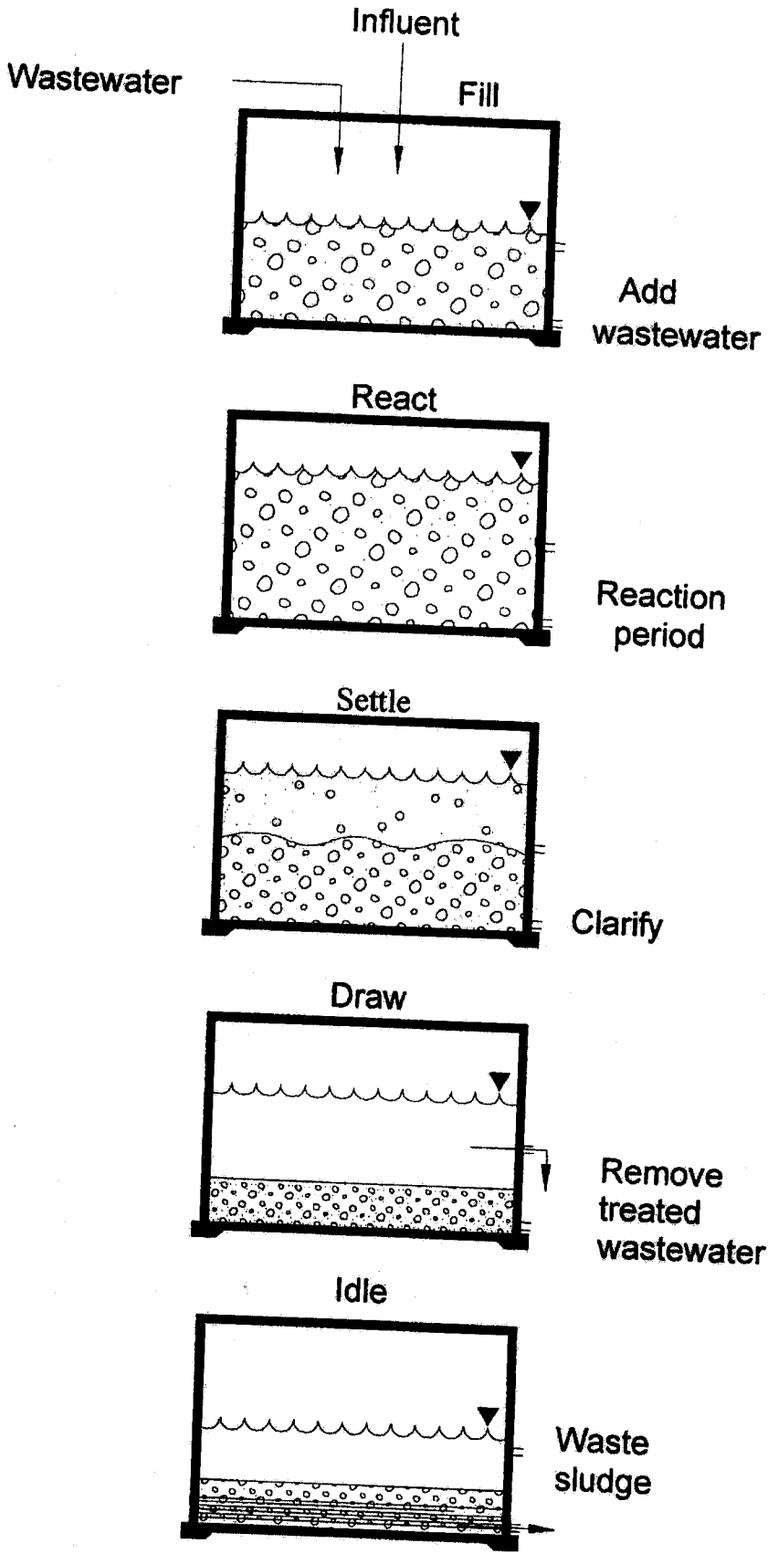


Figure 2.2: Operation of the Anaerobic Sequence of a Batch Reactor

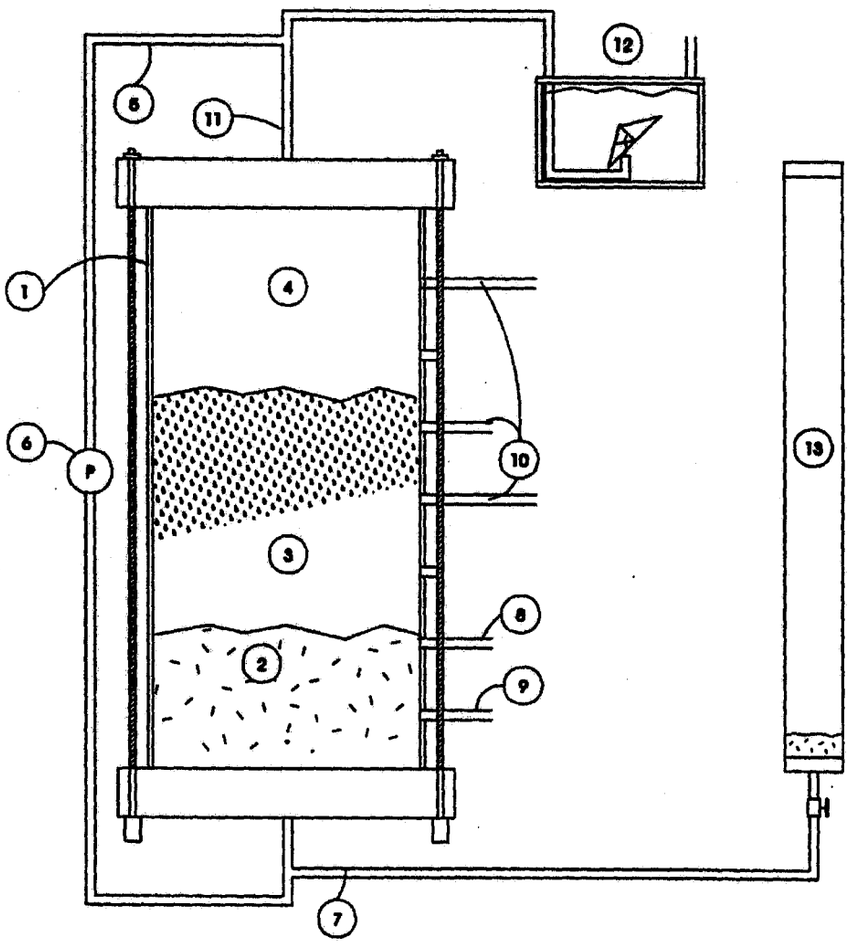


Figure 2.3: Laboratory Batch Reactors

1 300 mm diameter plexiglas digester
2 Sludge bed zone
3 Variable volume zone
4 Head space zone
5 Gas recirculation line
6 Biogas recirculation pump
7 Influent line
8 Effluent line
9 Sludge sampling port, also used for sludge wastage
10 Mixed-liquor or supernatant sampling port
11 Gas outlet
12 Gas meter
13 Feeder tube

### 2.5.2 Floating drum digester

A floating drum digester is a plant made up of brick masonry in a cement mortar. A mild steel drum is placed on the top of the digester to collect the biogas produced from the digester. Thus, there are two separate structures with gas production and collection. A floating drum plant is obsolete because of comparatively high investment and maintenance cost along with other design weakness compared to other digester (Bhai Patel, 1956).

### 2.5.3 Fixed dome digester

Fixed dome digester also known as drumless digester was built in 1936 in China; it consists of an underground break masonry compartment (fermentation chamber) with a dome on the top for gas storage. In the design, fermentation chamber and gas holder are combined as a unit. This design eliminates the use of costlier mild steel gas holder which is susceptible to corrosion. The life of a fixed doom plant is longer from 20 to 50 years compared to the floating drum digester.

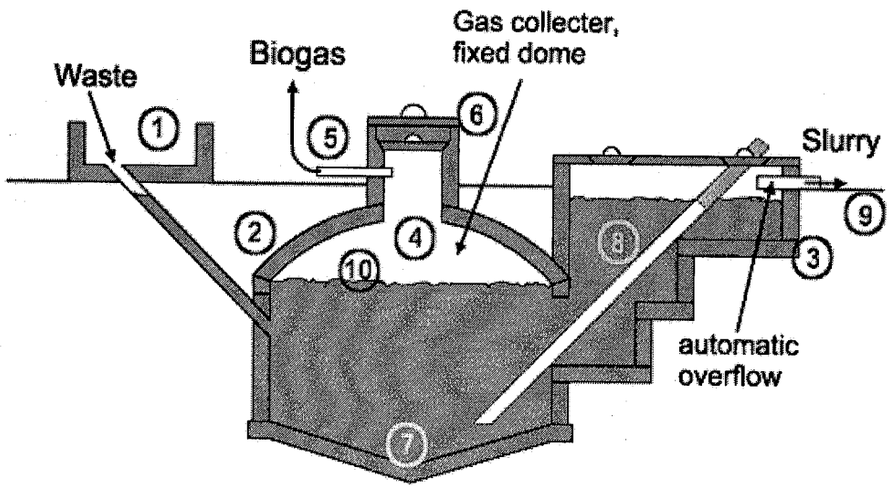


Figure 2.4: A Dome Digester

Fixed dome plant design: 1. Mixing tank with inlet pipe and sand trap. 2. Digester. 3. Compensation and removal tank. 4. Gasholder. 5. Gaspipe. 6. Entry hatch,
With gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level.
10. Supernatant scum, broken up by varying level.

### 2.5.4 Bag digester

This design was developed in 1960's in Asia (Taiwan, China and Japan). It consists of a long cylinder made up of a PVC or red mud plastic. The bag digester was developed to solve the problems experienced with break and metal digester. A PVC bag digester was also tested in Nepal in 1986 which the study concluded that the PVC bag digester would be successful only if the PVC bag is easily available, pressure inside the digester is increased and welding facilities are easily available (Tritt W.P., 1992).

### 2.5.5 Plug flow digester

The plug flow digester is similar to the bag digester, it consists of a trench (Trench length have to be considerably greater than the width and the depth) lined with concrete or impermeable membrane. The reactor is covered with either a flexible cover gas holder anchored to the ground, concrete or galvanised iron top (Sung S.N. and Dague R.R, 1995). The first documented use of this type of design was in South Africa in 1957.

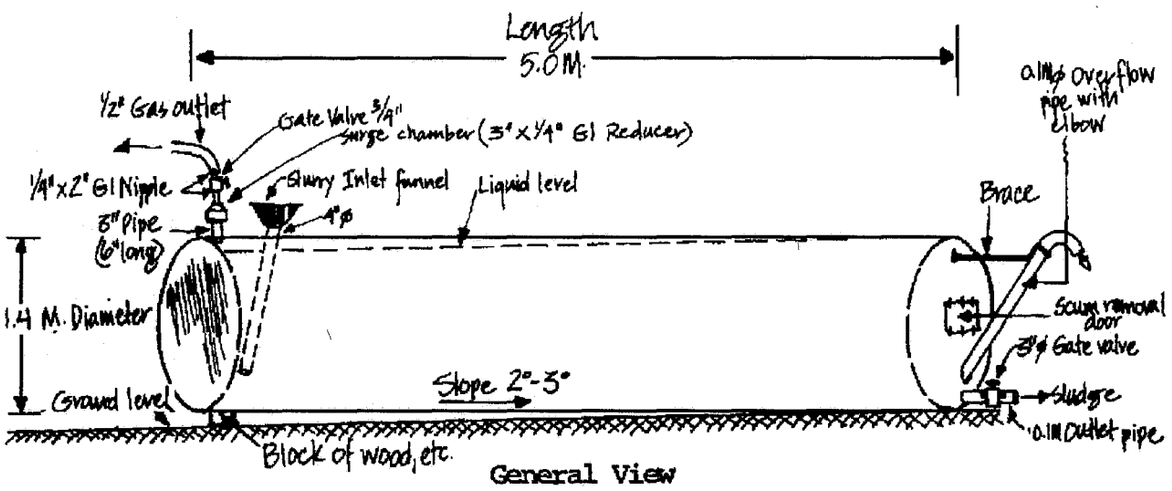


Figure 2.5: Plug Flow Digester

### 2.5.6 Anaerobic filters

This type of anaerobic digester was developed in the 1950's to use relatively dilute and soluble waste water with low level of suspended solid. It is one of the earliest and simplest types of design developed to reduce the reactor volume. It consists of column, filled with packing medium. A great variety of non biodegradable materials have been used as packing media for anaerobic filters reactors such as stones, plastics, corals, mussel shells, and bamboo rings. The methane forming bacteria form a film on a large surface of a packing medium and not carried out of the digester with the effluent. For this reason, the reactor is known as Fixed Film or Retained Film Digester (Bioenergy System Report 1984).

## 2.6 Odorization

Upgraded biogas must be odorized in order to ensure that gas leaks will be detected. This applies to cases where the biomethane will be injected into dedicated biogas pipelines, the natural gas pipeline network or used as a vehicle fuel for CNG vehicles. When biomethane is liquefied for use with liquefied natural gas (LNG) vehicles, odorization is not practical and therefore not required. (Note that vehicles using LNG fuel are required to have methane gas detectors for the fuel system.) (Young J.C. and Song K.H., 1984).

Odorization is normally accomplished by introducing tetrahydrotiophen (THT) or mercaptans into the gas via a controlled dosing process. Concentrations are typically in the range of 5 – 30 mg/

## 2.7 Bio Fertilizer

Literature on biogas is generally silent about the toxic effect of biogas digester sludge. The sludge is hailed as an excellent fertilizer. That all is not well, however, is hinted at in the statement that the sludge must be allowed to ripen before it is used as a fertilizer. Indeed, the freshly discharged sludge is very toxic to fish and plants, even when greatly diluted with water. Tilapia, a fish noted for its ability to survive in very hostile environments, dies in fresh sludge. A hardy water loving plant, kangkong, fails to develop, and even grass withers when watered with fresh sludge (Sayed S.K.I. et al, 1984).

The cause of this toxicity could be the lack of oxygen in fresh sludge, the osmotic effect of high salt levels in sludge, or the presence of toxic substances. Recent cause of toxicity of the sludge is hydrogen sulfide, and then detoxification can be achieved by oxidizing the hydrogen sulfide. In other words: expose the sludge to air for 15 to 30 days before using it (Robbins, J.E. et al, 1983).

Well aerated sludge is free from the sulfide odor and is no longer toxic to fish or plants. Even before it dries, aerated solid sludge attracts ants, insects, chickens, etc., a sure sign of detoxification. It is also a sign that the sludge may have feed value (Jain M.K. et al, 1981). When dissolved in water, hydrogen sulfide is, within weeks, broken down by the oxygen in water hence the need to create conditions for effective aeration (exposure to air), such as bubbling air through the sludge and or exposure of large surface areas of sludge to air

A sludge aging pond is usually a biogas system necessity; algae and fish ponds are also included if they serve the purposes of a biogas system's design. If all the ponds are down hill from the digester, gravity will carry the sludge from pond to pond, and pumps or water wheels will not be needed to lift the sludge from pond to pond.

## 2.8 Uses of Biogas

In its raw state, biogas has a relatively low calorific (heating) value (directly proportional to the methane vs. $CO_2$ content of the biogas) and a moderate level of potentially damaging contaminants. The primary usage of biogas is as a fuel for burners and generator-sets ("gen-sets") specifically designed or modified to operate with biogas. Note that in some cases, a limited amount of "clean up" is performed on the biogas to reduce $H_2S$, $H_2O$ and particulates to acceptable levels prior to combustion (Klass D.L., 1984)

## 2.9 Energy Content of Biogas

The useful part of energy of biogas is the calorific value of its methane gas content. The other components have energy content but they do not participate in the combustion process instead of contributing, the rather absorb energy usually leaving a process at higher temperature.

### 2.9.1 Production of heat, power and mechanical work

Burners to produce heat and gen-sets which produce electrical power and heat (often referred to as combined heat and power or CHP) are the most common uses for biogas. Gen-sets are commercially available in sizes ranging from approximately 75 KW – 1.5 MW. In addition, biogas can be used as a fuel for similarly modified engines to perform mechanical work. In most cases, the heat, electricity, and/or mechanical work performed by burning biogas is consumed locally, for example, to operate lighting and other electrical equipment on a large farm.

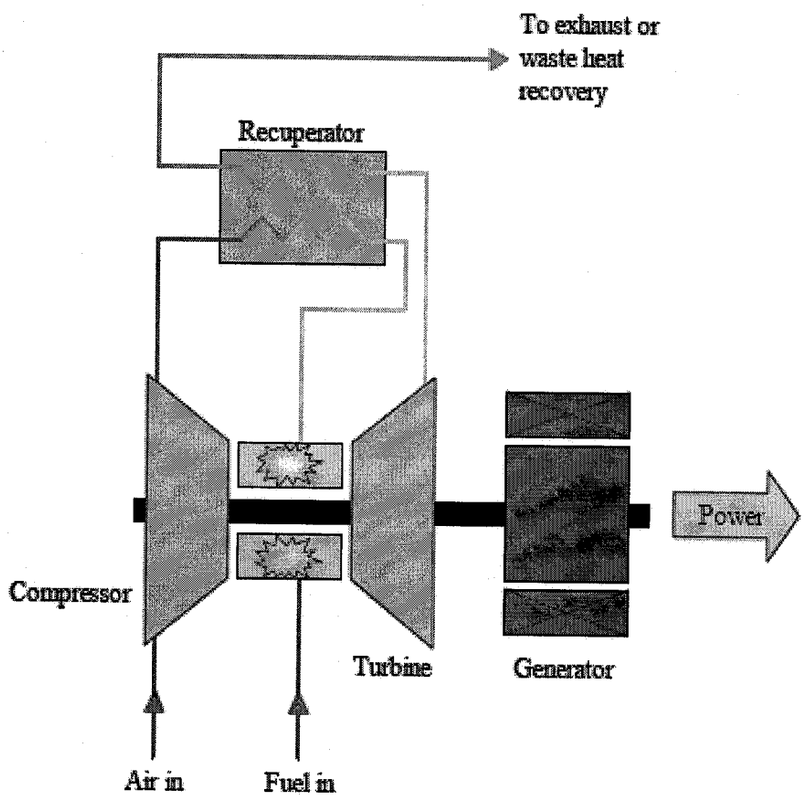


Figure 2.6: Operating Principle of a Gas Turbine

# CHAPTER 3

## 3.0 METHODOLOGY

In the production of biogas, a batch laboratory set up was employed in figure represented the flow part for digestion of the sludge.

### 3.1: Materials and Equipment

Table 3.1: Material and Equipment

| Material | Source | Comment |
|---|---|---|
| Measuring cylinder | Chemical Laboratory | 250ml |
| Beaker | Chemical Laboratory | 50ml |
| Electronic weighing balance | Chemical Laboratory | SWB Model Pm 2000 |
| Rubber cork stopper | Chemical Laboratory | _ |
| PH meter | Chemical Laboratory | Mettler Delta Model 340 |
| Water bath | Chemical Laboratory | SWB Model. Model 5550 |
| Thermometer | Chemical Laboratory | _ |
| Delivery Tube | Chemical Laboratory | Plastic |
| Distilled water | Chemical Laboratory | _ |
| 20 grams of corn cob | Food science laboratory | _ |
| Buffer tablet | Chemical Laboratory | 4 to 9 buffer tablet |
| Stirrer | Chemical Laboratory | _ |
| Sludge from a water treatment plant | Niger state water board | _ |

## 3.2 EXPERIMENTAL METHOD

### 3.2.1 Experimental Set up

An experimental setup was carried out in order to obtained biogas from waste water sludge. Temperature and pH (alkanality) were verified with the use of a thermometer and a pH meter.

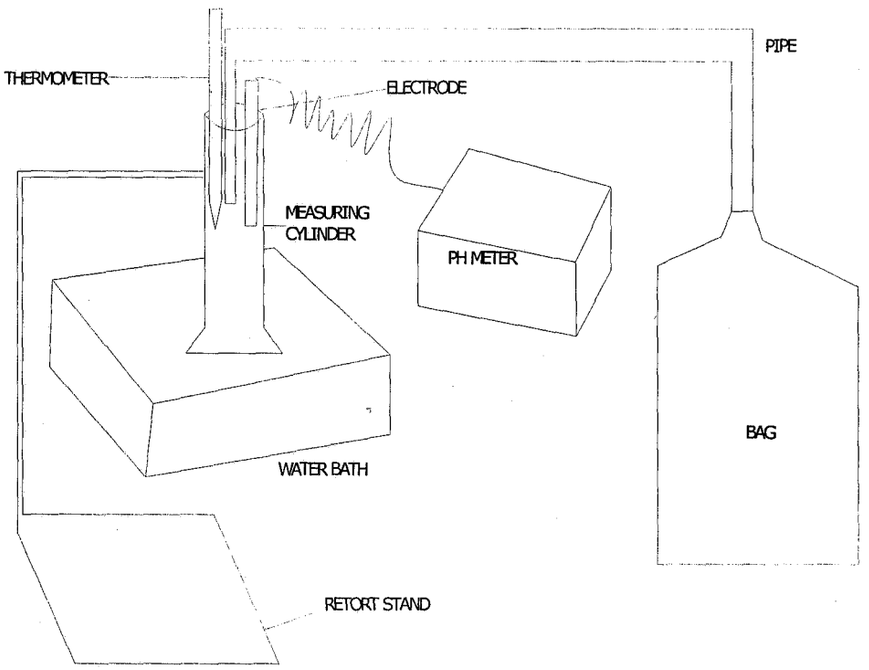


Figure 3.1: Experimental Set up for the Production of Biogas

### 3.2.2 Measuring Cylinder (digester)

A measuring cylinder with a working volume of 250ml was used; the vials were closed with a cork rubber stopper equipped with a glass tube for the gas removal and effluent/influent. The cork rubber stopper has two holes created to be able to insert a pH electrode to determine the pH value at a particular temperature.

The reactor temperature was regulated by controlling water temperature in the water bath in which the reactor was placed and maintained with 25°C ambient temperature at steady state which was assumed to have a stable temperature and pH. The digesters were stirred by hand for 5 minutes before and after feeding otherwise the digesters were unstirred. Temperate variation was from 25°C to 70°C based on their thermopholic and mesophilic conditions.

### 3.2.3 Preparation of buffer solution

A 4 to 9 buffer tablet was used which was meshed and mixed with a distilled water to obtain a perfect solution. The pH electrode was inserted into the solution to obtain a standard reading of 4.0 from the pH meter to enable the electrode perform perfectly during the experiment.

### 3.2.4 Preparation of sample (sludge)

A90g sludge was poured into a 50 ml beaker and a little quantity of water was added and stirred continuously to obtain a perfect texture. The procedure was done for different bioreactors to be able to perform different set up.

### 3.2.5 Flow diagram of biogas production from sludge

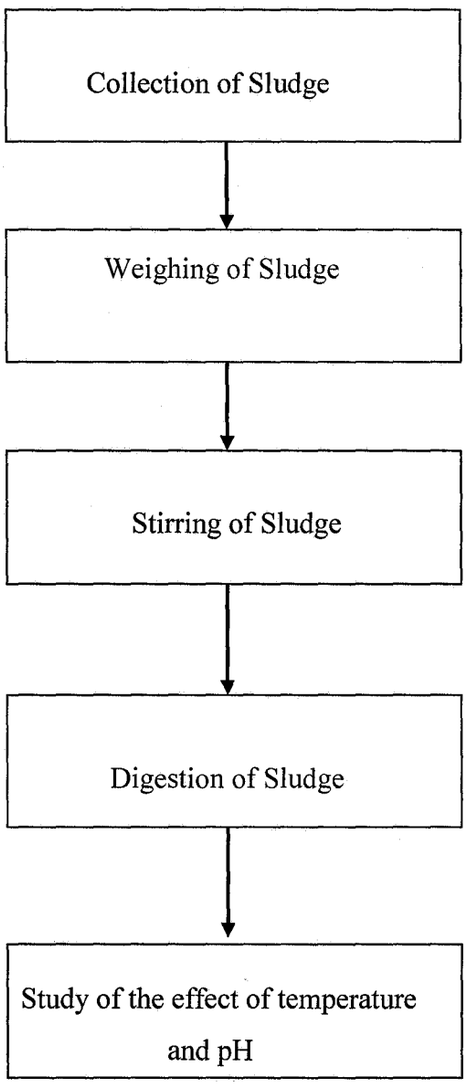


Figure 3.2: Flow Diagram of Biogas Production from Sludge.

# CHAPTER 4

## 4.0 RESULTS AND OBSERVATIONS

From the research being carried out, the following results were obtained. The weight of the empty bag which the gas was being collected was weighed as 24.0g. The experiment was carried out at a temperature ranging from 25°C to 70 °C.

### 4.1 Results of Temperature and pH Variation in Biogas Production.

Table 4.1: Effect of Temperature on Biogas Yield

| Temperature (°C) | pH value | Weight of bag | Weight of bag plus gas (g) | Weight of gas (g) |
|---|---|---|---|---|
| 25 | 6.91 | 24.0 | 25.2 | 1.2 |
| 30 | 7.03 | 24.0 | 25.4 | 1.4 |
| 35 | 7.12 | 24.0 | 25.7 | 1.7 |
| 40 | 7.14 | 24.0 | 25.8 | 1.8 |
| 45 | 7.17 | 24.0 | 26.1 | 2.1 |
| 50 | 7.23 | 24.0 | 28.3 | 4.3 |
| 55 | 7.24 | 24.0 | 30.4 | 6.4 |
| 60 | 7.28 | 24.0 | 32.7 | 8.7 |
| 65 | 7.29 | 24.0 | 33.3 | 9.7 |
| 70 | 7.31 | 24.0 | 34.1 | 10.1 |

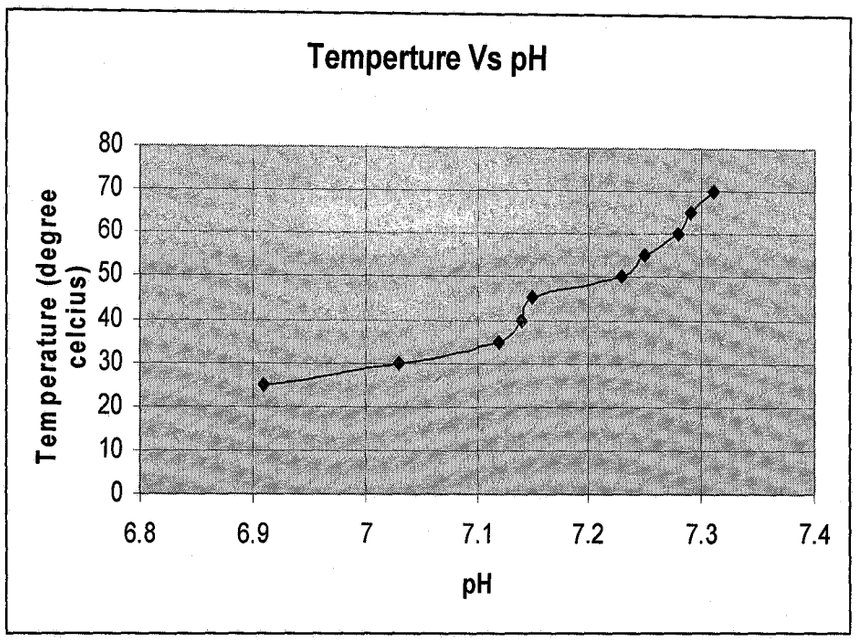


Figure4.1: Temperature against pH on Biogas Production

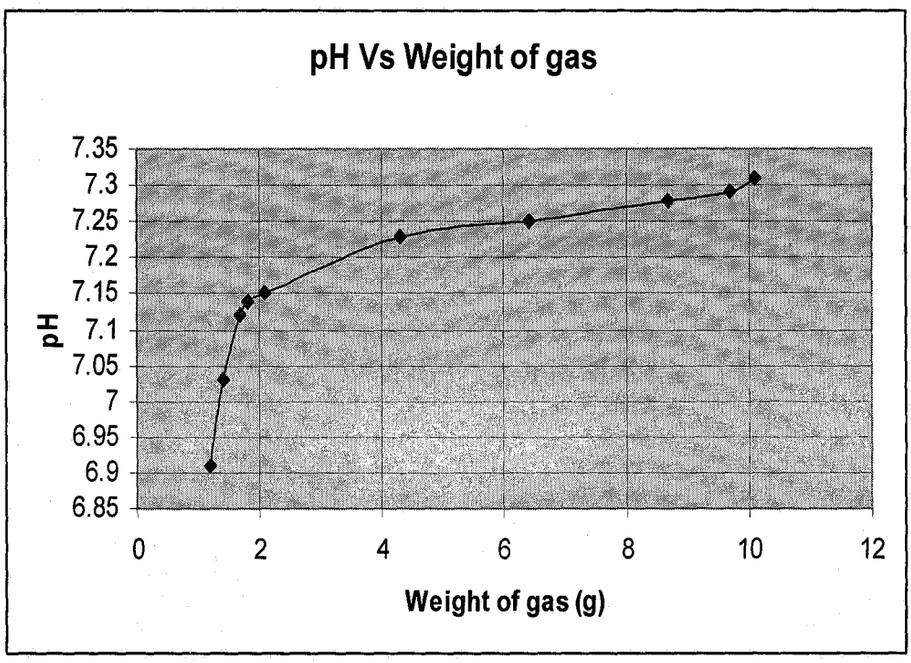


Figure4.2: pH against Weight of gas.

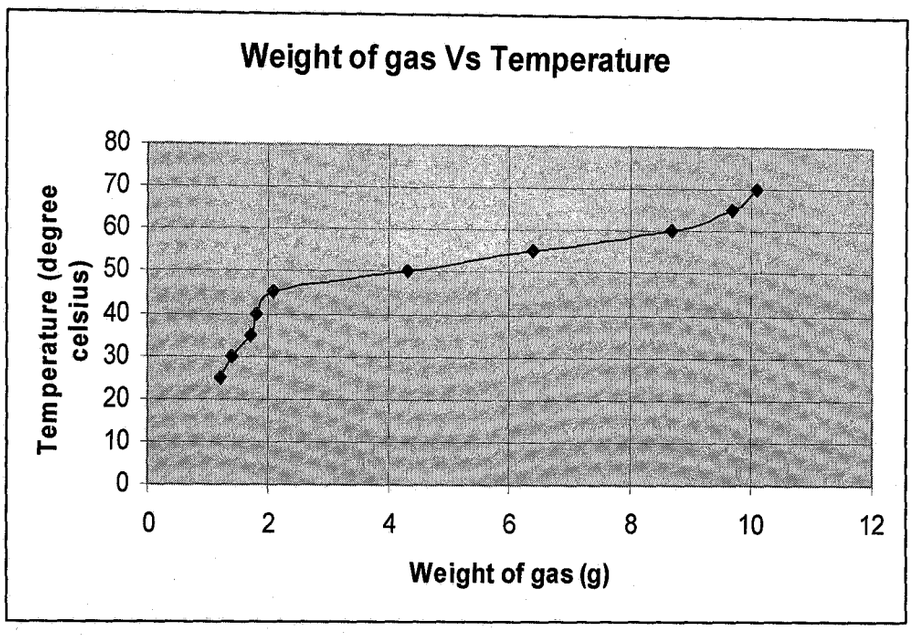


Figure4.3: Weight of Gas against Temperature.

### 4.2 Discussion of Results

From figure 4.1 it shows that the pH value of the digestion of the sludge was increasing gradually at a temperature of 25°C to 35 °C, as the temperature was increased from 35 °C to 40 °C the pH value of the digestion increased from 7.1 to 7.4. At a temperature of 50 °C to 70 °C the digestion increased with a corresponding pH from 7.23 to 7.34 which implies that an increase in temperature leads to an increase in pH value.

Figure 4.2 shows that the amount of biogas produced from 1.2g to 1.4g with a corresponding pH value from 6.9 to 6.95 was acidic, as the pH value increase 7.05 to 7.15 the amount of biogas produced was increasing from 1.4 to 1.9. The rate at which the biogas was produced increased at a higher pH value, more biogas was produced at a pH value from 7.24 to 7.34. The lesser the pH value the less biogas is formed and the higher the pH the more biogas that is form.

From figure 4.3, it shows that amount of biogas produced at a temperature of 25 °C to 45 °C the gas produced were less and at a temperature of 50 °C to 70 °C the amount of biogas increased form 4.3 to 10.1. From the results obtained it shows that biogas productions are favourable at a higher temperature from 50 °C to 70 °C and at a pH value 7.23 to 7.31.

## 4.3 Conclusion

From research carried out it was confirmed that biogas production from sludge (from a water treatment plant) is produced less at a temperature of 30°C to 40°C at a pH of 7.14 to7.17 and at temperature of 65°C to 70°C produces more biogas and at a pH 7.23 to 7.34. The longer the temperature interval last, the more the methanogenic bacteria would decay through hydrolysis, acidification and methanogensis.

## 4.4 Recommendation

1. A batch reactor type of digestion should be looked into and suitable for analysis in the chemical laboratory.
2. A pilot plant should be built in the school to enable further experiment to be performed to the variation of parameter in the production of biogas.
3. A purification chamber should be built enable purified the gas when produced.
4. A device should be provided in line with the water bath so there would loss in temperature during the process of digestion.

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