CONSTRUCTION AND TESTING OF A BIOGAS COOKER USING COW DUNG AS A SOURCE OF FUEL

BY

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IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BARCHELOR OF ENGINEERING (B. ENG.) DEGREE IN CHEMICAL ENGINEERING.

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DECLARATION

I hereby declare that this project work was carried out by me under the supervision of Engr. Dim, P.E Information hereby obtained from published and unpublished work of others have been duly referenced and acknowledged.

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25/03/2010
DATE

CERTIFICATION

This is to certify that this research work titled "construction and testing of a biogas cooker using cow dung as a source of fuel " was carried out by Muhammad Gaddafi Muazu under the supervision of Engr. Dim, P.E and submitted to the department of chemical Engineering, Federal University of Technology Minna, in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng) degree in chemical Engineering.

.... 1/04/10 ....

ENGR. DIM, P.E (Project Supervisor) — DATE

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ENGR. J.O. OKAFOR (Head of Department) — DATE

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External Supervisor — DATE

DEDICATION

This work is indeed dedicated to my omnipotent creator (ALLAH) the almighty and my role model, admiring, Islamic icon and noble prophet (MUHAMMAD) Peace Be Upon Him as well as my lovely parent and siblings.

ACKNOWLEDGEMENT

The author's sincere appreciation and praise goes to the almighty Allah (SWT) the most gracious and most compassionate who have created, protected and guided me to a clear and illuminative way of life (i.e. Islam). And also to his ideal, unique, superior and noble prophet MUHAMMAD (SAW) whose way of life transmits ALLAH'S guidance to humanity in general.

I will like to say a big thank you to my project supervisor Engr. Dim, P.E for his elderly support and laudable encouragement during the course of this work. From the bottom of my heart i wish to express my love, appreciation and prayers to my great parents Alhaji Nuraddeen Muazu and Hajiya Binta N. Muazu who had given me the financial and moral support for the successful completion of this project work. Moreover, I am also glad to express my endless gratitude and prayers to my beloved siblings especially my late brother Yasir N. Muazu. May Almighty Allah forgive him, amen. I will finally like to thank my friends like Nasiru Salihu Gulma and my slave from Bida Abubakar A. Gana for being with me throughout my studies

ABSTRACT

An expansion design model of a biogas plant was developed in order to produce methane gas under anaerobic conditions. The biodigester which is the central part of the biogas plant was constructed. It is an enclosed air tight tank that contains the organic waste with some means of storing the produced gas and can be emptied of the digested slurry. An absorption chamber was also constructed for absorption of carbondioxide and a burner to burn and test the produced gas. The result shows that the methane gas was produced by anaerobic digestion of cow dung even though it was very low due to the fact that the necessary conditions for the formation were not met. The gas generated can be sustained by daily recharging of the slurry after the maximum hydraulic retention time (HRT). Gas consumption rate of the biogas burner is lower than the gas consumption rate of the family size burner. However, the low rate of consumption does not affect the overall performance of the burner. It was observed that there was a blue flame with a faint strip of yellow colour which might be attributed due to the presence of carbon dioxide and other inert gases in the biogas.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

For many years fuels supplies had been used and misused at will for countless decades. For example, in the United States, the average consumption of oil equates to three gallons per day. That is for every man, woman and child of the population. This makes an annual consumption of over 2 billion gallons. This practice will necessarily have to come to a halt at some point in the future, since the present rate of consumption should exhaust the known reserves of refinable crude oil in about thirty years. The constant effort of our oil companies to sell more and more of the black gold make it unlikely that today's consumption will not increase in the future. Obviously some serious thinking about the use of power per head and the need to find an alternative and ecological sound source of power for the future arise. Unless we want to face rocketing power prices and possible rationing in our lifetimes.

One of the huge sources that have barely been used up to now is methane. Millions of cubic metres of methane in the form of swamp gas or biogas are produced every year by the decomposition of organic matter, both plants and animals. It is almost identical to the natural gas pumped out of the ground by the oil companies and used by many of us for heating out houses and cooking our meals. In the past, however, biogas has been treated as a dangerous by-product that must be removed as quickly as possible, instead of being harnessed for any useful purposes. It is only really in very recent times that a few people have started to view biogas in an entirely different light, as a new sources of power for the future (Habmigern, 2003).

Renewable natural gas, that is, the gas that has been upgraded to a quality similar to natural gas becomes possible to distribute to the mass market via the existing gas grid. In 2006 about 18% of global final energy consumption came from renewable with 13% coming from traditional biomass, 3% from hydroelectricity and new renewable accounts for 2.4% and are growing very rapidly.

Biogas typically refers to gas produced by the biological decomposition or breaking down of organic matter. Basically there are two types of organic decompositions that can occur aerobic (in the presence of oxygen) and anaerobic (in the absence of oxygen) decomposition. All organic material, both animal and plant can be broken down by these two processes, but the product of decomposition will be quite different in the two cases. Aerobic decomposition (fermentation) will produce carbondioxide, ammonia and some other gases in small quantities, heat in large quantities and a final product that can be used as fertilizer. Anaerobic decomposition will produce methane, carbon dioxide, some hydrogen and other gases in traces, very little heat and a final product with a higher nitrogen content than is produced by aerobic fermentation.

Anaerobic decomposition is a two stage process as specific bacterial feed on certain organic materials. In the first stage, acidic bacteria dismantle the complex organic molecules into peptides, glycerol, alcohol and simpler sugar. When these compounds have been produce in sufficient quantities, a second type of bacteria starts to convert these simpler compounds into methane. These methane producing bacteria are particularly influenced by the ambient conditions, which can slow or halt the process completely if they do not lie within a fairly narrow band (Habmigern, 2003).

1.2 Aim and Objectives

This project aims at:

i. Production and testing of a biogas produced from animal waste product (cow dung).
ii. Construction of a biodigester for the production of the biogas (methane) use for burning
iii. Utilization of agricultural waste for producing an important source of renewable energy in order to reduce pollution and waste.

1.3 Justification of Study

The need for renewable energy in nature cannot be overemphasized. More so, now that this study intends to apply the use of cow dung which is an agricultural waste to produce methane gas. This process can be utilized in a number of ways.

i. It is an alternative source of fuel
ii. Anaerobic digestion technologies can help to reduce the emission of green house gases.
iii. It is a reliable and economical source of renewable energy and can replaces energy derived from fossil fuel.
iv. Utilization of agricultural waste into a valuable product (methane gas) use for heating purpose.

1.4 Scope and Limitation of Study

This work is stream lined to the determination of biogas present in an anaerobic digester. However, if gases in an anaerobic digester cannot be utilized due to poor gas trapping a trial will be given to constructing a pilot "plant digester".

CHAPTER TWO

LITERATURE REVIEW

History of Biogas

Anecdotal evidence indicates that biogas was used for heating both water in syria during the 10[th] century BC and in Persia during the 16[th] century AD usk@pipeline.com).

The technology, or process, dates back a long time. 1630 (Van Helmont), 1667 hirley) are some who mention about the gas as such. In 1808 H. Davy made periments with strawy manure in a report in a vacuum and collected biogas. He was not terested in the gas but rather rotten or not rotten manure (Tietjen, 1975 and Chawla 986).

The first digestion plant was built at a leper colony in Bombay, India in 1859 AD ached England in 1895 when biogas was recovered from a careful designed sewage eatment facility and used to fuel street lamps in Exeter. The development of icrobiology as a science led to research by Buswell and other in the 1930s to identify naerobic bacteria and the conditions that promote methane production. www.yahoosearch.com).

.1.1 Biogas composition

Biogas typically refers to a gas produced by biological breakdown of organic natter in the absence of oxygen. The term biogas is used to represent a mixture of lifferent gases (varied composition) produced as a result of anaerobic microorganisms on lomestic and agricultural waste. It contains methane in bulk (50-60%) and other gases in elatively low proportions viz, carbondioxide (25-30%), hydrogen (1-5%) and nitrogen (2-7%). The composition of biogas varies depending upon the origin of the anaerobic digestion process. Landfill gas typically has methane concentration around 50% advance waste treatment technology can produce biogas with 55-75% methane or higher using in situ purification techniques (Richard 1994) as produce. Biogas also contains water vapour with the fractional water vapour volume a function of biogas. Temperature correction of measured volume for water vapour content thermal expansion is easily done via algorithm. (www.molecular-plant-biotechnology.info)

2.2 Cow Dung

Cow dung is the waste of bovine animal species. These species includes domestic cattle ("cows"), bison ("buffalo") yak and water buffalo. Cow dung is the undigested residue of herbivorous matter which has passed through the animal's gut. The resultant faecal matter which is rich in minerals. Colour ranges from greenish to blackish, often darkening in colour soon after exposure to air (www.en.wikipedia.org)

2.2.1 Composition of cow dung

Cow dung slurry is composed of 1.8-2.4% nitrogen (N_2), 1.0-1.2% phosphorus (P_2O_2), 0.6-0.8% potassium (K_2O) and 50-75% organic humus. About one cubic foot of gas may be generated from one pound of cow manure at about 28 degree celcius. This is enough to cook day' 4-6 people. Cow dung gas is 55-65% methane, 30-35% it's heating value is around 600 B.T.U per cubic foot while natural gas consist of around 80% methane, yielding a B.T.U. value of about 1000. About 1.7 cubic metres of biogas equals one litre of gasoline. The manure produce by one cow in one year can be converted to methane which the equivalent of over 200 litres of gasoline. Gas engines requires about $0.5m^3$ of methane per horsepower per hour. Some care must be taken with the lubrication of engine using solely biogas doe to the "dry" nature of the fuel and some residual hydrogen sulphide, otherwise these are a simple conversion of a gasoline engine.

Biogas may be improved by filtering it through limewater to remove carbon dioxide, iron fillings to absorb corrosive hydrogen sulphide and calcium chlorides to extract water vapour after the other two processes (Habmigern 2003).

2.2.2 Uses of cow dung

Cow dung (usually combined with soiled bedding and urine) is often used as manure (agricultural fertilizer). If not recycled into the soil by species such as earthworms and dung beetles, cow dung can dry out and remain on the pasture, creating an area of grazing land which is unpalatable to livestock.

In many parts of the developing world, caked and dried cow dung is used as fuel.

Dung may also be collected and use to produce "biogas" to generate electricity and heat. The gas is rich in methane and is used in rural area to provide a renewable and stable source of electricity.

Cow dung is also used to line the floor and walls of buildings owing to it's insect repellent properties, with some types of insects (not flies or dung beetles). In central Africa, Masai village have burned cow dung inside to repel mosquitoes in cold places, cow dung is used to line the wall of rustic houses as a cheap thermal insulator.

It was also used extensively in Indian railway to seal smoke boxes on stream locomotives.

Cow dung is also an optional ingredient in the manufacture of adobe mud brick housing depending on the availability of materials at hand etc.

2.4 Methane

Methane (CH_4) is the lightest (least dense) and simplest hydrocarbon. It is the major constituent of natural gas, and a potent greenhouse gas. Many biological processes produce it, and it is produced (intentionally or unintentionally) as a byproduct of fermentatic and composting. It may be captured as biogas, or allowed to escape in which case it has a negative impact on the climate.

Although it is a potent greenhouse gas, it does not last as long in the atmosphere as many other such gases, eventually breaking down into carbon dioxide and water vapour (ask.com).

2.3.1 Application of methane

Methane can be utilized for electricity production and domestic heating in our houses for cooking and lighting if compressed it can also be used in vehicles where it can fuel an internal combustion engine or fuel cells etc. (www.claverton-energy.com).

2.4 Fermentation Process

Methane fermentation is a versatile biotechnology capable of converting almost all types of polymeric materials to methane and carbon dioxide under anaerobic conditions. This is achieved as a result of the consecutive biochemical breakdown of polymer to methane and carbondioxide in an environment in which variety of microorganisms which includes fermentative microbes (acidogens); hydrogen producing, acetate forming microbes (acetogens) and methane –producing microbes (methanogens) harmoniously grow and produce reduce and products. Anaerobes play important roles in establishing a stable environment at various stages of methane fermentation.

Given the geometric dimension of the digester for while working volume is;

$$V_{gs} + V_f = 0.032m^3$$

Gaddy and Usmani, (1981) gives the dimension of digester of a known volume and at a chosen hydraulic retention time (HRT). From the work of Yisa and Manga (2004), showing density is given as $p_m = 50kg/m^3$ and gas yield of $C = 0.2m^3 / kg$ for cattle

Applying equation 1-3

$$V_g = m_s X C \quad . \quad . \quad . \quad . \quad . \quad . \quad 1$$

$$V_f = m_s / \rho_m \quad . \quad . \quad . \quad . \quad . \quad . \quad 2$$

$$V_d = V_f T_r \quad . \quad . \quad . \quad . \quad . \quad . \quad 3$$

With

V_g = daily biogas yield (m^3/day)

$C = 0.2 kg^3/kg$; specific yield per substrate

m_s = mass of total solid in substrate (8% of m_o)

V_f = Daily slurry feed rate = Q_s

V_d = Digester volume ($0.04m^3$).

T_r = hydraulic retention time (14days).

From eqn 2, 3

$$V_f = \frac{Vd}{Tr} = \frac{0.04m3}{14\ days} = 0.00286m^3$$

Volumetric flow rate, $V_f = 0.0029m^3$ = 2.9 L/day.

From Eq 2,

$$V_f = m_o / \rho_m$$

$M_o = V_f \rho_m = 0.00286 \times 50 = 0.143 kg/d$

Hence, 80% of stung is the total solid

$m_s = 80\%$ of m_o

$= 0.08 \times 0.143 = 0.01144$ kg/d TS.

From Eqn 1,

$V_g = m_s \times C$

$= 0.01144 \times 0.2 = 0.002288 m^3/day$

$= 0.0023 m^3 / day$

= 2.3 L/day.

- Generation efficiency, $e = \frac{\text{Volume of gas generated}}{\text{Expected volume}} \times 100$

$$e = \frac{0.0023}{0.0038} \times 100 = 60.5\%$$

- Gas consumption, $C_g = \frac{\text{Volume of biogas}}{\text{Duration of use}}$

Assuming gas burner will be used averagely for 3hrs in a day.

Expected, $C_g = \frac{0.0038 m^3}{3hrs} = 0.0013 m^3/hr$

Consumption, $C_g = \frac{0.0023 m3}{3hr} = 0.00076 m3/hr$

Efficiency, $e = \frac{0.00076}{0.0013} = 58.5\%$

Total solid of fresh discharge = 10 kg x 0.16 = 1.6kg

In 8% of concentration of TS (to make favourable condition)

8% solid = 100kg influent

1.6kg solid = 100 x $^{1.6}/_{8}$ = 20kg influent

Total influent required 20kg

Water to be added to make the discharge 8% concentration of TS

= 20kg - 10kg = 10kg ($10m^3$)

i.e for 20kg influent.

Recall that influent (slung) density = 50 kg/m^3

$$Vol = \frac{mass}{density}$$

$$V = \frac{20kg}{50kg/m3} = 0.4m^3 = 400L.$$

By relation,

400L slung requires 10.000L.

Volume to be occupy by the shuning

$= V_f + V_s$

= 0.0282 + 0.006

= $0.0342m^3$

With

V_f = Volume of fermentation chamber

V_s = Volume of shigde layer

In the 40L digester plant where the shung volume = 34.2L

The substrate loading is thus;

Using, the relation,

Substrate input (Q_s) = Biomass (B) + Water (w) m^3/day

In the ratio B: W = 1:3 for cow dung.

$V_{slurry} = 34.2L$, $\quad B = \frac{V_{slurring}}{4} \times 1 = \frac{34.2}{4} = 8.55L$

$$W = \frac{V_{slurring}}{4} \times 3 = 8.55 \times 3 = 25.65L$$

Initial loading

To fill 34.2L slurring volume, 8.55L of biomass and 25.65L of water is required.

For continous loading

The influent flow rate daily

$Q_s = 2.9L$

This is equivalent to $\frac{2.9}{4} \times 1 = 0.725$ L of biomass

And $\frac{2.9}{4} \times 3 = 2.175$ L of water.

Unit 1 : Biodigester, $\quad V_1 = 40.0$ litres $= 0.04\ m^3$

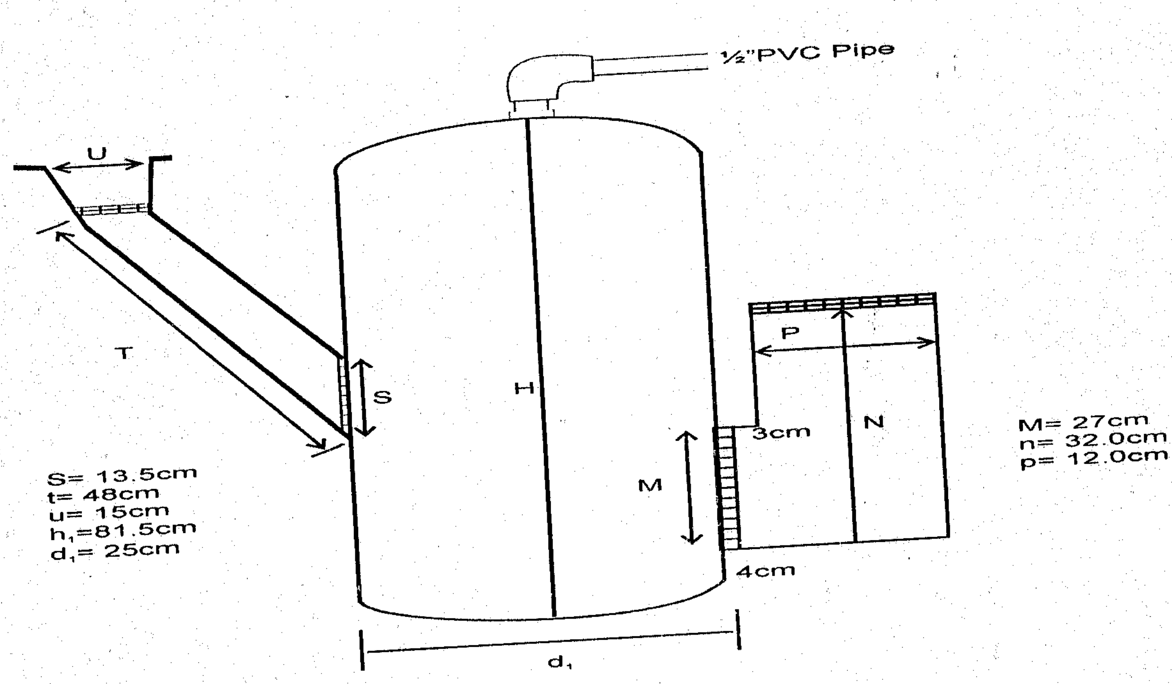

Figure 3.3 Geometric dimension of the biogas plant units.

Unit 2: CO2 Absorption Chamber

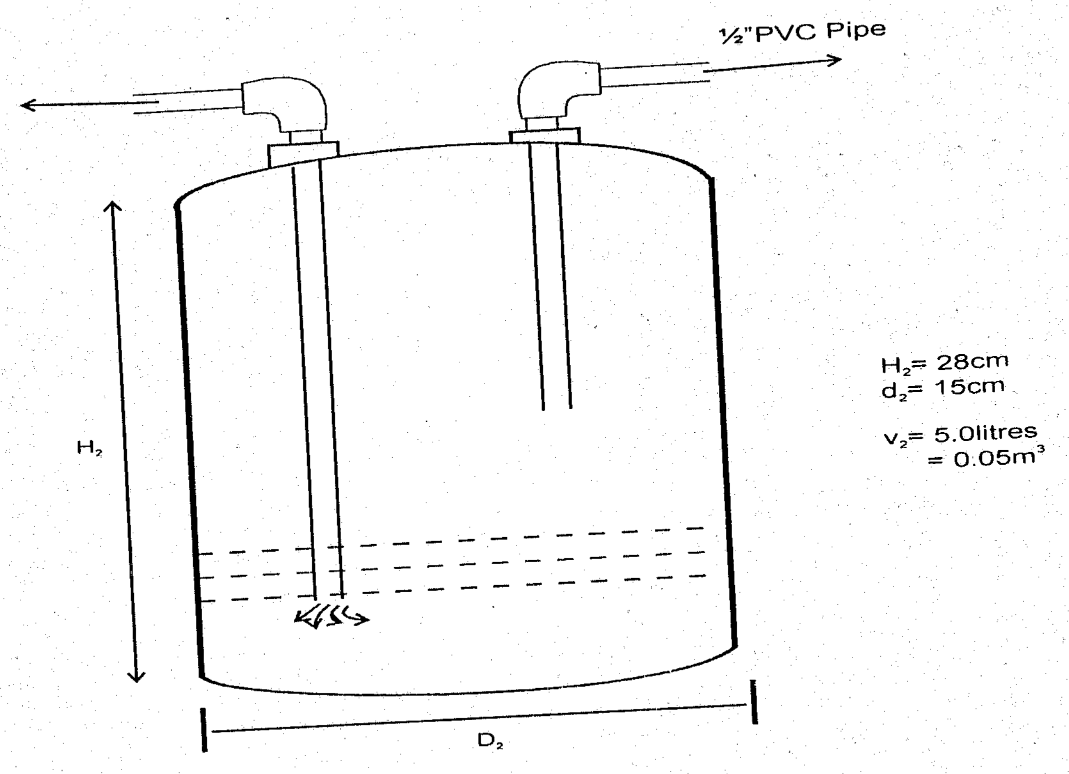

Figure 3.4 geometric dimension of the CO_2 absorption chamber.

3.5 Material Selection

The selection of materials for the construction of various units of the plant was based on their functional fabrication, and economic requirements. The digester requires a good tensile strength to withstand in-built pressures, conduct ambient temperatures, corrosion resistant, cheap and easy to construct and maintain.

An empty steel oil drum heavily coated with oil plant and its top sealed with a gauge using steel sheets for the construction. The gas boiler was also made from steel sheet as does the digester, but a thicker gauge, gauge 10 was used to give the weight that will pump the gas out of storage and create enough pressure for gas flow.

Resistance to heat and case of fabrication are the main service requirement of the burner head and mixing pipe. Stainless steel was used for the nozzle because of its resistance to corrosion.

3.5.1 Construction

The construction process involved cutting, welding, brazing, turning, and drilling. Individual components were constructed base on their developments and inter joined together to form units. The nozzle was constructed by turning and drilling a stainless steel rod on the lathe. Control valves and flexible hose of appropriate dimensions were bought and fixed at their proper positions.

3.5.2 Biogas production and purification

Materials: Cow dung (biomass), soda lime $Ca(OH)_2$, water, weighing spring, measuring cylinder, Ice block, pilot plant (Digester and chambers), Sodium bicarbonate.

Procedure:

- Empty digester cylinder and, carbon dioxide absorption chamber were prepared.
- Cowdung (Biomass) is mixed with appropriate amount of water in the ratio 1:3 to make up the required 8% total solid concentration.
- 500g of $Ca(OH)_2$ was dissolved in 5litres of water to form 5molar solution, of which 1.2litres is poured into the 5litre CO_2 absorption chamber.
- Sodium bicarbonate (baking soda) is added to reduce the acidity of the substrate to a pH of 7.5 or 8.
- The taps were closed and both the digester and CO_2 absorption chambers were air tight.
- The diagram for the process is shown in the diagram page.

3.5.3 Gas utilization

A copper nozzle pipe is constructed at the end of copper pipe. This help in the compression, ignition, and firing of the gas for efficient combustion in the burner.

3.6 Testing and performance evaluation

The testing of the plant basically start by close observation from the feeding day to the end of the hydraulic retention day to determine the generation rate of biogas among other efficiency determining factors. The biogas plant is test-run by igniting the burner. Furthermore thermal efficiency was analyzed by burning rate of the burner; hence the performance evaluation of the plant is on qualitative basis. Efficiency is analyzed by burning rate of the burner. Performance evaluation of the biogas plant is on qualitative basis while the quantitative analysis was on the feedback material and the generated biogas.

The generated biogas was tested for methane and carbon dioxide composition, which were in turn used to determine heating value of the gas. Other tests were for biogas generation, efficiency of the digester.

3.7 Process Diagram

The biogas plant is essentially made up of three different components; the bio-digester chamber, the pipeline distribution unit and the gas storage unit.

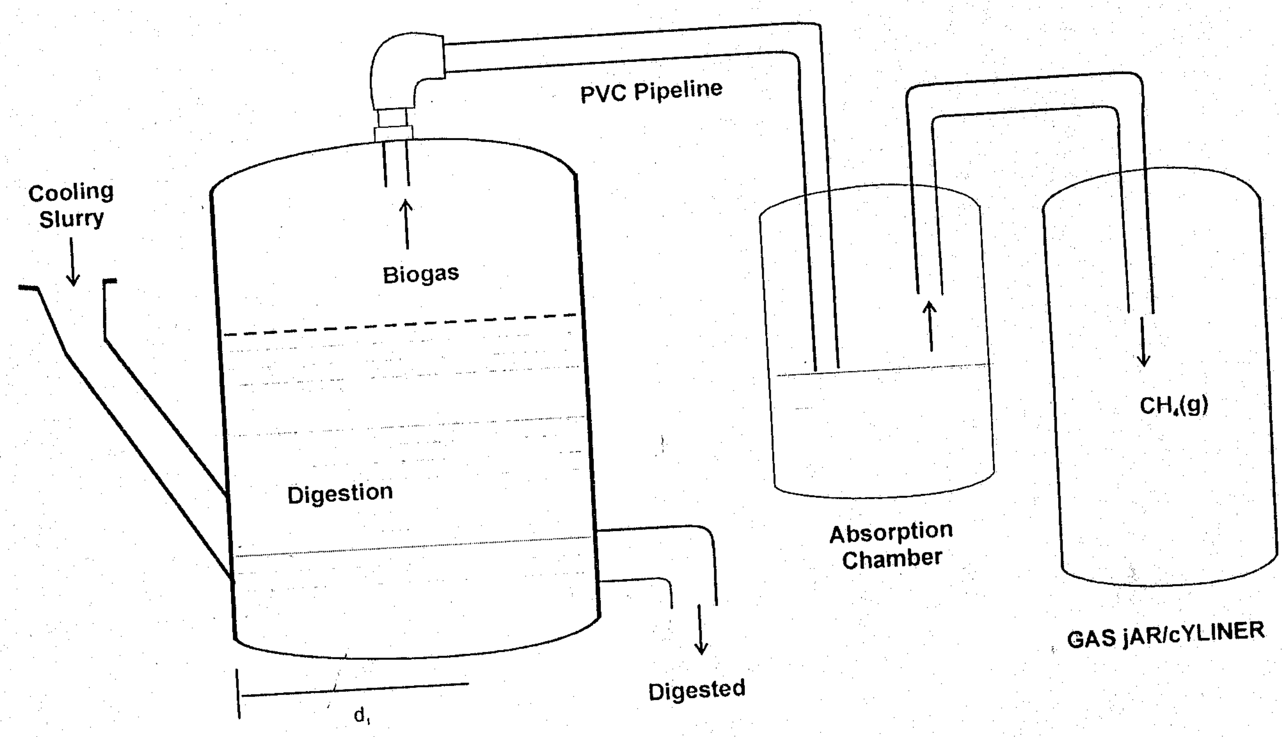

Figure 3.5 Process diagram

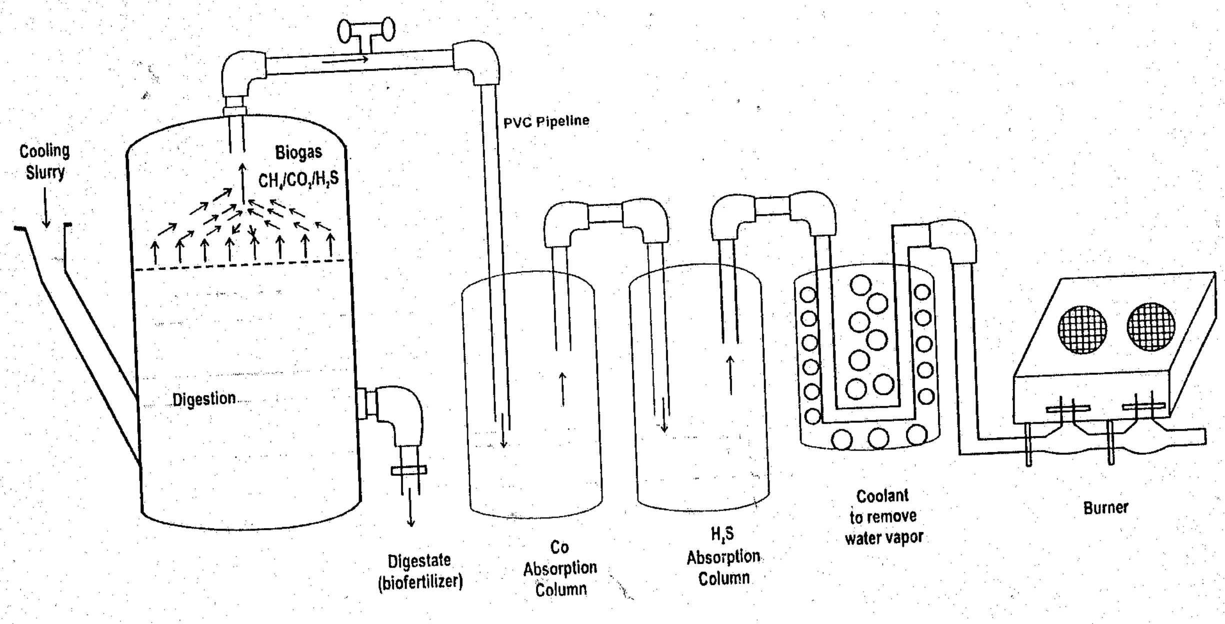

Figure 3.6 Detailed process diagram

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results

Chemical analysis of the feedstock (cow dung) used for testing the plants shows that if it has a C:N ratio of 21:1, and the presence of starch, protein and organic matter were confirmed. The biogas generated from the digester was found to contain 64% methane 35% carbondioxide and traces of hydrogen sulphide.

After the set up, the result of flame test were obtained and tabulated below.

Table 4.1 shows limited operating conditions under mesophile temperature (35^{o}C) without recharging at the end of the maximum hydraulic retention time (HRT) of 14 days

No. of experiment	Days	Feeding	Availability of gas	Flame test
1	1	Charged	No gas	No flame
2	3	Not charged	No gas	No flame
3	5	Not charged	No gas	No flame
4	7	Not charged	No gas	No flame
5	9	Not charged	No gas	No flame
6	11	Not charged	Traces	Faint flame
7	13	Not charged	Traces	Flame
8	14	Not charged	Gas	Meaningful flame
9	15	Not charged	Gas decline	Flame diminishing
10	16	Not charged	Gas decline	Flame diminishing
11	17	Not charged	Gas decline	Flame diminishing
12	18	Not charged	Gas decline	Flame diminishing

Table 4.2 Optimum operating conditions under mesophilic temperature (35°C), without recharging at the end of the maximum hydraulic retention time (HRT) of 14days.

No. of experiment	Days	Feeding	Availability of gas	Flame test
1	1	Charged	No gas	No flame
2	3	Not charged	No gas	No flame
3	5	Not charged	No gas	No flame
4	7	Not charged	No gas	No flame
5	9	Not charged	No gas	No flame
6	11	Not charged	Traces	Faint flame
7	13	Not charged	Traces	Flame
8	14	Not charged	Gas discharged	Sustained flame
9	15	Charged	Gas sustained	Sustained flame
10	16	Charged	Gas sustained	Sustained flame

4.2 Discussions

From the first run, it's observe that methane gas is produced from the digestion of cow dung (bio-mass), however it is very low and will not combust due to the fact that the necessary conditions formation of were not met. Gas generation can be sustained to meet daily design requirement by recharging with ($0.0029m^3$) 2.91 of slurry. The recharge should start on the 15th day of initial feeding of the digester. The biogas burner had an average gas consumption rate of $0.00076m^3/hr$. This rate is however smaller than the reported gas consumption rates. Its design rate of $0.0013m^3/hr$, and lower than reported gas consumption rate of family size gas burner of $0.45m^3/hr$ for digester volume ranging from ($6m^3$ – $15m^3$). Thus the burner had a low rate of gas consumption. The 60.5% thermal efficiency is higher than the reported efficiency of 55% given by SCNCER (1985), but falls within the range of 55-60% given by Musa (1999). This efficiency is far higher when compared with that of direct burning of biomass which is reported by Sambo (1997) to be less than 50%. A direct linear relationship between gas consumption and thermal efficiency was obtained which implied that the efficiency increases with gas consumption. However the low rate of consumption does not seem to affect the overall performance of the burner.

Emissions from the burner were not tested for. But it was observed that the flame was blue with a very faint strip of yellow color, which might be attributed to the presence of carbon dioxide and other inert gases in biogas.

Methane fermentation offers an effective means of pollution reduction, superior to that achieved via conventional aerobic processes. Although practiced for decades, interest in anaerobic fermentation has only recently focused on its use in the economic recovery of fuel gas from industrial and agricultural surpluses. (Guido 2005)

2.4.1 Anaerobic digestion process

Anaerobic decomposition process produces methane, carbon dioxide, some hydrogen and other gases in traces and a final product with higher nitrogen content. Anaerobic decomposition is a two-stage process as specific bacteria feed on a certain organic materials. In the first stage, acidic bacteria dismantle the complex organic molecules into peptides, glycerol, alcohol and simpler sugars. When these compound have been produced in sufficient quantities a second type of bacteria starts to convert these simpler compounds into methane. These methane producing bacteria are particularly influenced by the ambient conditions which can slow or halt the process completely if they do not lie within a fairly narrows band. Anaerobic digestion will occur best within a pH range of 6.8-8.0. More acidic or basic mixture will ferment at a lower speed. The introduction of raw materials will often lower the pH (make the mixture more acidic). Digestion will stop or slow dramatically until the bacteria have absorbed the acid. A high pH will encourage the production of acidic carbon dioxide to neutralize the mixture again. The bacteria responsible for the anaerobic process requires both element, as do all living organisms, but they consumes carbon roughly 30 times faster than nitrogen. Assuming all other conditions are favourable for biogas production a carbon-nitrogen ratio of about 30-1 is ideal for the raw material fed into a biogas plant. A higher ratio will leave carbon still available after the nitrogen has been consumed, starving some of the bacteria of these element. These will in turn die, returning nitrogen to the mixture, but slowing the process. Too much nitrogen will cause this to be left over at the end of the digestion (which stops when the carbon has been consumed) and reduce the quantity of the fertilizer produced by the biogas plant. The correct ratio of carbon-nitrogen will prevent loss of either fertilizer quality to methane content.

The anaerobic breakdown of waste occurs at temperatures lying between 0^0C and 69^0C, but the action of the digesting bacteria will decease sharply below 16^0C. Production of the gas is most rapid between 29^0C and 41^0C or between 49^0C and 60^0C. This is due to the fact that two different types of bacteria multiply best in these two different ranges, but the higher temperature bacteria are much more sensitive to ambient influences. A temperature between 32^0C and 35^0C has proven most efficient for stable influences. A temperature between 32^0C and 35^0C has proven most efficient for stable and continues production of methane. Biogas produced outside this range will have a higher percentage of carbon dioxide and other gases than within this range.

Anaerobic digestion of organics will proceed best if the input material consists of roughly 8% solids. In the case of fresh cow dung, this is the equivalent of dilution with roughly an equal quantity of water.

2.5 Biodigester

The central part of an anaerobic biogas plant is an enclosed tank known as the digester. This is an air tight tank filled with the organic waste, and which can be emptied of digested slurry with some means of catching the produced gas. Design differences mainly depends on the type of organic waste to be used as raw material, the temperature to be used in digestion and materials available for construction.

System intended for the digestion of liquid or suspended solid waste (cow dung is a typical example of the verity) are mostly filled or emptied using pumps and pipe work. A simpler version is a simply gravity feed the tank and allow the digested slurry to overflow the tank. This has the advantage of being able to consume more solid matter as well as, such as chopped vegetable waste, which would block a pump very quickly. This provides extra carbon to the system and raises the efficiency. Cow dung is very nitrogen rich and is improved by the addition of vegetable matter.

2.5.1 Continuous feed plant

The complete anaerobic digestion of cow dung takes about eight weeks at normally warm temperatures. One third of the total biogas will be produced in the first week, another quarter in the second week and the remainder of the biogas production will be spread over the remaining 6 weeks. Gas production can be accelerated and made more consistent by continuously feeding the digester with small amount of waste daily this also preserve nitrogen level in the slurry for use as fertilizer. If such a continuous feeding system is used, then it is essential to ensure that the digester is large enough to contain all the material that will be feed through in a whole digestion cycle. One solution is to use double digester, consuming the waste in two stages, with the main part of the biogas (methane) being produced in the first stage and the second stage finishing the digestion at a slower rate, but still producing another 20% or so of the total biogas.

2.5.2 Batch feed plant

There is biogas systems designed to digest solid vegetable waste alone, since plant solids will not flow through pipes, this type of digester is best used as a single batch digester. The tank is opened, old slurry is removed for used as fertilizer and the new charge is added. The tank is then resealed and ready for operation. Depending on the waste material and operating temperatures, a batch digester will start producing biogas after two to four weeks slowly increase in production then drop off after three to four month. Batch digester one therefore best operated in groups, so that at least one is always producing useful quantities of gas.

Most vegetable matter has a much higher carbon-nitrogen ratio than dung has, so some nitrogen producers (preferably organic) must generally be added to the vegetable matter, especially when batch digestion is used. Weight for weight, however, vegetable matter produces about eight times as much biogas as manure, so the quantity required is much smaller for the same biogas production. A mixture of dung and vegetable matter is hence ideal in most ways, with a majority of vegetable matter to provide the biogas and the valuable methane contained in it (sunder 1994)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Design Equipments

A biogas plant was designed to generate, store and distribute biogas. Similarly a burner was also designed to efficiently burn the gas and useful heat was also obtained. The design features are:

i. **A digester-** This is the central part of the biogas plant. It is an enclosed airtight tank and the unit that will generate the gas under anaerobic condition. The continuous flow fixed-done type is considered using the steel drum-type for small needs as suggested

by (Twidell at al, 1985).

ii. **A gas storage unit-**Though the biodigesters compactment is divided into two one for the fermentation chamber of the biomass and the other for the gas storage chamber. Alternatively, a separate gasholder that will store the gas can as well be designed.

iii. **A gas line** – To distribute the gas from storage to the burner at the desired quantity and rate. Also from digester to the absorption chamber. Alternatively, a non-returning valve here is a valuable investment to prevent air being drawn along the gas line.

iv. **A CO_2 absorption chamber-** this is a separate unit for sweetening and upgrading of the biogas, $Ca(OH)_{2(aq)}$ is used for the absorption of carbon(iv)oxide.

v. **A burner** - This will burn the gas to produce heat using the atmosphere method.

Other features of the plants include inlet and outlet channels for storage, stirrer and drain on the digester, control valve and moisture tray on the gas line; windshield, pot support and control valve on the burner.

3.2 Sizing a Biogas Plant.

The size of the biogas plant depends on the quantity, quality, and kind of available biomass and the digestion temperature.

3.2.1 Digester sizing

The size of the digester, V_d (Volume of digester), is determined on the basis of the chosen retention time (HRT) and the daily substrate input quantity Qs.

$$V_d = Q_s \times HRT \qquad (m^3 = m^3/day \times \text{number of days}).$$

The substrate input depends on how much water has to add to the substrate in order to arrive at a solids content of 4-8%.

$$\textbf{Substrate input } (Q_s) = \textbf{Biomass (B)} + \textbf{water (W)} \quad (m^3/day).$$

In most agricultural biogas plants, the mixing ratio for dung (cattle and/ or pigs) and water (B:W) amounts to between 1:3 and 2:1.

3.2.2 Daily gas production (V_g)

The amount of biogas generated each day V_g (m^3 gas/d), is calculated on the basis of the specific gas yield (K) of the substrate and daily substrate input Q_s.

- For the volatile solid content (m)

$$V_g = m \times K(\text{solids}) \qquad [m^3/d = kg \times m^3/(d \times kg)]$$

- For the weight of the moist mass (B)

$$V_g = B \times K(\text{moist mass}) \qquad [m^3/d = kg \times m^3/(d \times kg)]$$

3.2.3 Specific gas production (V_p)

This is daily gas generated per m^3 digester volume (V_d) is given thus;

$$V_p = V_g \div V_d \quad [(m^3 d)/m^3]$$

3.2.4 Digester loading (L_d)

The digester loading L_d is calculated from the daily total solids input (T_s/d) and the digester volume V_d.

$$L_{dT} = T_s/d \div V_d \quad [kg/(m^3 d)].$$

3.2.5 Sizing the gasholder

The size of the gasholder, i.e the gasholder volume V_g, depends on the relative rates of gas generation and gas consumption. The gasholder must be designed to;

i. Cover the peak consumption rate $g_{c\,max}$ (-> V_{g1}) and.

ii. Hold the gas produced during the longest zero-consumption period $t_{z\,max}$ (-> V_{g2})

$$V_{g1} = g_{c\,max} \times t_{c\,max} = V_{c\,max}$$
$$V_{g2} = Gh \times t_{z\,max}.$$

With

$g_{c\,max}$ = maximum hourly gas consumption (m^3/h)

t_{cmax} = time of maximum comsumption (h)

g_h = Hourly gas consumption (m^3/h) = $V_q \div 24h/d$

$t_{z\,max}$ = maximum zer0- consumption time (h)

The larger V_g – value (V_{g1} or V_{g2}) determine the size of the gasholder. A safety margin may be added.

$$V_g = 1.15(\pm 0.5) \times Max(V_{g1} \text{ or } Vg_2)$$

Practical experience shows that 40-60% of the daily gas production has to be stored.

The ratio (digester volume per gasholder volume) is a major factor with regard to be basic design of the biogas plant. For a typical agricultural biogas plant, the V_d/V_g ratio is within the range of 3:1 – 6:1 occurring most frequently (one 40:5 i.e. 8:1) (www.biogasdigest.com)

3.3 Design Parameters and Dimensions

The substrate feed into the anaerobic bio-digester is calculated in terms of total solid. The total solid (TS) contains concentration of organic materials that made up the feed composition;

Solid part: Total solid contain a certain amount of materials is usually used the material unit to indicate the biogas producing rate of the materials. Most favorable value desired is 0.8%.

Liquid part: The respective water content of each substrates are given

Favorable temperature, pH value and C/N ratio for good formation.

Temperature: Mesophilic; 20^0C to 35^0C

pH value: Natural pH and ranges 6.8 to 7.2

C/N ratio: Range from 20:1 to 30:1

Table 3.1 Shows discharge per day, TS value, fresh discharge and water to be added to make favorable TS conditions

Types	Body Weight (kg)	Discharge per day (kg)	TS value of fresh discharge (%by wt)	water to be added with fresh Discharge to make the TS Value 5%kg
Humans	50	0.5	20	0.75
Cow	200	10	16	10
Chicken	1.5	0.1	20	0.15
Pig	50	5	20	7.5

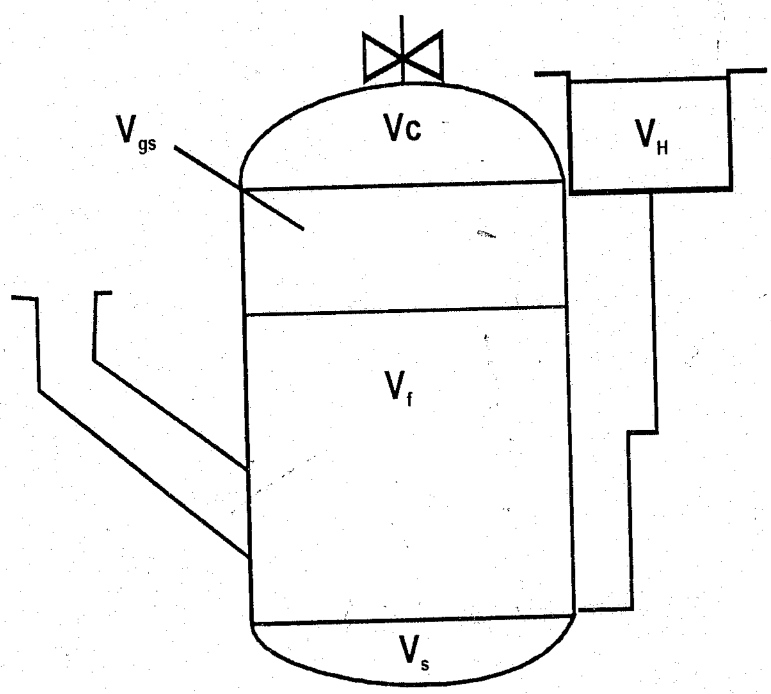

Figure 3.1 Cross-section of a digester

a. Volume of gas collecting chamber = V_c

b. Volume of gas storage chamber = V_{gs}

c. Volume of fermentation chamber = V_f

d. Volume of hydraulic chamber = V_H

e. Volume of sludge layer = V_s

Total volume of digester, $V = V_c + V_{gs} + V_f + V_s$

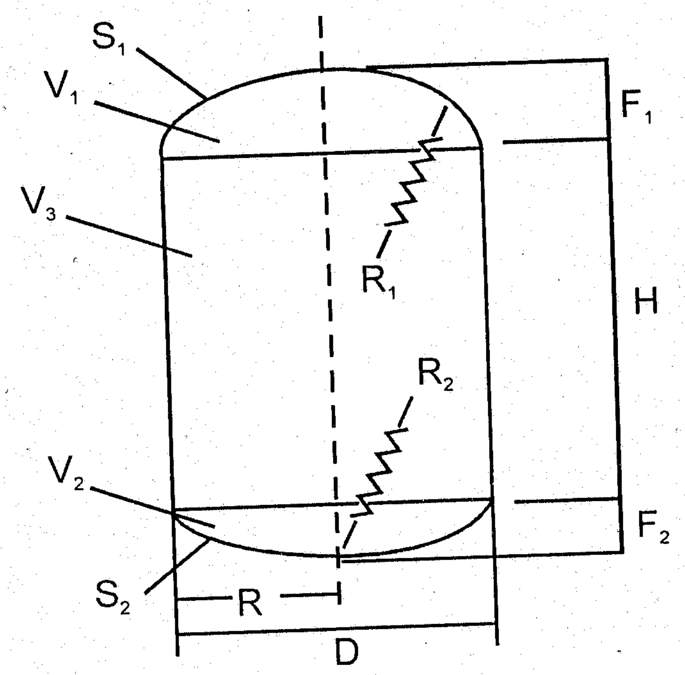

Figure 3.2 geometrical sketch of the cylindrical shaped biogas digester.

Table 3.2 Design geometrical assumptions

For Volume	For Geometrical Dimension
$V_c \leq 5\% V_d$	$D = 1.3078 \times V^{1/3}$
$V_s \leq 15\% V_d$	$V_1 = 0.0827 D^3$
$V_{gs} + V_f = 80\% V_d$	$V_2 = 0.05011 D^3$
$V_{gs} = V_H$	$V_3 = 0.3142 D^3$
$V_{gs} = 05 (V_{gs} + V_f + V_s) K$	$R_1 = 0.0725 D^3$
Where V_p = Gas production rate per day	$F_1 = D/S$
For Bangladesh $K = 0.4 m^3/m^3 d$	$F_2 = D/8$
For Nigeria $K = 0.2 - 0.3 m^3/m^3 d$	$S_1 = 0.911 D^2$
	$S_2 = 0.0824\ SD^2$

3.4 Volume calculation of digester and hydraulic chamber

3.4.1 Volume calculation of digester chamber

Given: 40litre steel drum to be used at a retention time of 14days (Yisa and Manga, 2004)

$$V = 40L = 0.04m^3$$

Volume of the gas collecting chamber, V_c

$$V_c \leq 5\% \, V$$

$$V_c = 5\% \text{ of } 0.04 = \frac{5}{100} \times 0.04 = 0.002 \, m^3$$

$$V_c = 0.002m^3 = 2.0L$$

- **Volume of sludge layer, V_s**

$$V_s \geq 15\% \, V$$

$$V_s = 15\% \text{ of } 0.04 = \frac{15}{100} \times 0.04 = 0.006 \, m^3$$

$$V_s = 0.006m^3 = 6.0L$$

- **Volume of gas storage chamber, V_{gs}**

$$V_{gs} + V_f = 80\% \quad \ldots \quad 1$$

$$V_{gs} = 0.5 \, (V_{gs} + V_f + V_f) \, K \quad \ldots \quad 2$$

From eqn (1)

$$V_{gs} + V_f = 80\% \text{ of } 0.04 = 0.032m^3$$

$$V_{gs} + V_f = 0.032m^3$$

$$V_{gs} = 0.032 - V_f \quad \ldots \quad 3$$

From eqn (2)

$$V_{gs} = 0.5 \, (V_{gs} + V_f + V_s) \, K$$

Where K = gas production rate per m^3 digester volume per day m^3/ m^3d. For cattle dung K = 0.2

$$V_{gs} = 0.5 \{(Vgs + Vf) + Vs\} K$$

$$= 0.5 (0.032 + 0.006) 0.2$$

$$= 0.0038m^3$$

$$V_{gs} = 0.0038m^3 = 3.8L$$

Volume of fermentation chamber, V_f

$$V_{gs} + V_f = 0.032m^3$$

$$V_f = 0.032 - V_{gs}$$

$$V_f = 0.032 - 0.0038 = 0.0282m^3$$

$$V_f = 0.028m^3 = 28.2 L$$

- **Volume of hydraulic chamber, V_H**

$$V_{gs} = V_H$$

$$V_{gs} = 0.0038m^3$$

$$V_H = 0.0038m^3 = 3.8L$$

Therefore; **total volume of the digester, V**

$$V = V_c + V_s + V_{gs} + V_f$$

$$= 0.002 + 0.006 + 0.0038 + 0.0282$$

$$= 0.04m^3$$

$$V = 0.04m^3 (40L).$$

3.4.2 Material balance of the digester.

Given: 1 cow of body weight 200kg

Temp. = 30^0C (average)

Considering HRT = 14 days (for temp. 30^oC)

Total discharge = 10kg x 1 = 10kg of dung/day.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A biogas plant was designed and constructed to generate biogas from organic waste and to effectively use the gas with the burner for cooking. During the digestion of cow dung (biomass), methane gas was produced. This however was possible through making the process effectively anaerobic (air free) and conditioning the state of digester to methane producing bacteria.

The designed units were tested. It was confirmed that the digester has a generation efficiency of 60.5% representing $0.0023m^3$ of the daily designed rate. Gas indicate explosion when lighted at the point of ignition demonstrating the presence of combustible substance in the bio-mass. The burner has an efficiency of 58.5% and average gas consumption of $0.00076m^3/hr$. The whole process took place under 15days, if left to stand for more days however, gas enough for conditions burning will be available for cooking.

The plant can be adapted and enlarged based on energy alternative to firewood, thereby reducing the rate of deforestation and ecological disturbance.

5.2 Recommendations

Biogas plant can be adapted for both household and industrial source of energy. Scarcity of equipment for measuring the process conditions like temperature, pressure and pH has brought about unsatisfactory account of process state. The researches of past student should be continuously improved to achieve a more reliable design of processes and to give a better justification of values and dates obtained during their researches.

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