IDENTIFYING AND OPTIMIZING VARIOUS TECHNIQUES IN THE GENERATION OF BIOGAS IN A GROWING ECONOMY

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ABSTRACT

Biogas as a source of power has continually gained strides considering the various benefit derived from the used of the said biogas. This review outlined various sources of production of the biogas and the economic importance as compared to other sources of power. Biogas can be generated from animal waste and plants, the amount of Biogas that can be generated from these renewal materials were reviewed. The safety aspect as it concerns the production of the Biogas was also elaborated and preventive measure to ensure there was no hazard during production. Operating parameters were considered such as microorganisms, total solid content, temperature, pH, retention time, organic loading rate, mixing of feed materials, inhibition and toxicity, additional succulent plant and algae because for adequate Production of Biogas were needed to maintain some certain constraints to achieve the maximum production. These various operating parameters were for an adequate biogas production to be achieved and all the operating parameters must be taken into cognizance. Finally the uniqueness of biogas was revealed and this paper has shown that biogas can easily be generated because of the availability of the raw materials required and the technical know on how to get the biogas generated, hence the acquisition is for the adoption.

Keywords: Biogas Generation, Growing Economy, Biodigester Designs, Cow Dung, Operating Parameters.

INTRODUCTION

Biogas is not popular in Nigeria, the awareness is still not as elaborate as it is in most European countries. Many European countries have established favorable condition for electricity generation from biogas. Germany has a leading role in Europe with over 4000 biogas plant most are for farm power generation. Other countries in Asia especially India has equally gain giant strides in the said biogas activities. Biogas covers a wide range of materials from Forest, farming, waste and animal waste. Its field of application includes combustion engine, gas turbine and electricity generation and co-generation of heat and Power. Biogas is Produce from organic waste by the action of various groups of anaerobic bacteria through anaerobic decomposition.

LITERATURE REVIEW

Different parameters have direct influence to the fermentation process. It is important to note that the carbon dioxide that is release when biogas is combust and mixed with oxygen in the air does not contribute to greenhouse effect, since the carbon in the biogas is already in the biosphere circulation above the earth crust. This shows the benefit in the use of biogas without adverse effect on the environment. Biogas has provided an economically viable and sustainable

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means of meeting the thermal energy needs, in china about 7.5 million people benefit from biogas (Doelle, 2015). Biogas as compared to other gas has significant benefit for the environment especially its friendly nature which does not affect or alter any aspect of the ecosystem. There need to identify and optimize various techniques in the generation of biogas in a growing economy to enabling harnessing of biogas. The aim of this study was to review the techniques in the generation of biogas using cow dung.

METHODOLOGY

Methods of Collection Biogas

Various means of collections of Biogas were identified, ranging from the buried biodigester, semi buried biodigester and finally the downward collection biodigester were all looked into and the best option was emphasis on. The rate of biogas collection was recorded using various parameters to support their superiority over the other design. The percentage compositions of the major gases during the process of biogas production are shown in Table1.

Table 1: Biogas Composition

Component	Symbol	Concentration
Methane	CH_4	50 – 75 Vol %
carbon dioxide	Co_2	25 – 45 Vol %
Water vapour	H_2O	< 2 Vol %
Nitrogen	N_2	< 2 Vol %
Ammonia	NH_3	< 1 Vol %
Hydrogen	H_2	< 1 Vol %
Hydrogen sulphide	H_2S	20 – 20.00 ppm

Table showed the various gases produce in biogas and their concentration, methane as shown is the highest with about 50 -75% followed by carbondioxide and the least being hydrogen sulphide. The above revealed that the materials used produced a good gas that can be utilized.

Percentage of Methane Content in Biogas from Different Feed Materials

Methane gas as the most viable gas gotten from the process of Biogas can be generated from several means; the common sources of methane gas generation are shown in Table 2 below.

Table 2: Sources of Methane Gas

Feed Materials	Methane Content %
Cattle Manure	65
Poultry Manure	60
Pig Manure	52
Farm Yard Manure	55
Straw	59
Grass	70
Leaves	58
Kitchen Waste	50
Algae	63
Water Hycinth	67

The feed materials in Table 2 can generate biogas in different percentages, even grasses, leaves kitchen waste that were undermined every other day can be source of power. Though the review emphasized on cow dung because of the environmental hazard associated with it, which if not properly handled can cause unplanned diseases. The feed materials clearly stated in the table 2 are all potential source of power and are readily available in our disposal to be used whenever choose. Lots of biogas can be generated from all the feed materials mentioned in Table 2 if the anaerobic Processes is strictly maintain and a conducive environment is used.

Important Operating Parameters in Anaerobic Digestion Process

There are several conditions and variables that must be maintained and applied in order to obtain a proper breakdown of the organic compound. The growth of microorganism is very vital in the anaerobic digestion process. Some of these parameters are listed and elaborated below (Verma, 2017; Monnet, 2013).

Total Solid Content of Anaerobic Digestion

Digestion can be classified base on the seizes of the feed materials to be used for the anaerobic process, Low solids system (L/S) contains less than 10% TS, Medium solids (MS) contains about 15% -20%, and high solids (HS) processes range from 22% - 40%, analysis shows that Total solids of less than 10% is most appropriate for anaerobic process, which will generate more Biogas.

Temperature of Anaerobic Digestion

Another important parameters is the temperature of the digester, there are two major temperatures that provides optimum digestion conditions for the production of biogas. The Mesophilic ranges is between 20 ^{0}C – 40 ^{0}C and optimum temperature is between 30 ^{0}C – 35 ^{O}C, and the thermophilic temperature ranges is between 50 ^{0}C – 65 ^{0}C (Verma 2017). Higher temperature in the process of biodegradation has found to reduce retention time, the optimum time temperature of the digestion may vary depending on the feedstock composition and the type of digester. Thermophilic digester (50 ^{0}C – 65 ^{0}C) has been observed to be more efficient in terms of retention time, loading rate and gas production. This because of the high level of heat requires, there is greater sensitivity to operating and environmental variables which makes the process more problematic than others. Monnet (2003) also reported that the sterilization of the waste is linked to the temperature; the higher it is the more effective it is in eliminating pathogens, viruses and seeds. On the other when ambient temperature goes down to 10 ^{0}C, gas production virtually stops (Karki *et al.*, 2005).

P^H of anaerobic Digester

The pH of the digester plays a major role in biogas production. The acidic condition is not favourable for methogenic process. Biogas production has been found to be effective and at its peak when the pH varies between the range of 6 and 7. It is important to note during the initial formation period of the digester a large amount of acid is produced by the acid forming bacteria in the digester, hence the pH is usually between the range of 4 and 5, this inhibit or rather stops the digestion process.

Retention Time

Another very important parameter is the retention time, this as to do with the time the micro-organisms start the biodrgradable process that eventually leads to the production of the biogas. Different feed materials have different retention time, in the case of cow dung the retention is calculated by dividing the volume of the digester by the volume of the slurry added daily. Though in real practical terms the slurry are added once and the digester seal tight to ensure an

anaerobic process. A retention time of 40- 60 days is required for cow dung depending on the temperature.
Other feed materials require the following time of fermentation and subsequent retention time.

- Liquid cow dung 20 – 30 days
- Liquid pig manure 15 – 25 days
- Liquid chicken Manure 20 – 40 days
- Animal manure mixed with plant materials 50 – 80 days

Retention time for completion of anaerobic digestion reaction varies with differing technologies, process, temperature and waste composition.

Organic loading rate (OLR) Volatile solids (VS)
Organic loading rate also affect the rate of biodegradation and subsequent production of biogas. Feeding the digester more than its sustainable organic loading rate will result in low biogas yield, due to accumulation of inhibiting substances in the digester slurry (fatty acid). Adequate separation of individual materials in the feed should be done before loading into the biodigester, since materials have been found to restrict production of biogas if mixed with the feed. Excessive loading can also reduce the allowable space needed for biodegradation process and subsequent biogas production.

Mixing of feed materials
Mixing within the digester improves the contact between the micro-organisms and substrate and improves bacteria population ability to obtain nutrient. Adequate mixing also prevents the formation of scum and the development of temperature gradient within the digester. However excessive mixing can also disrupt the micro-organism and therefore slow mixing is preferred (Monnet, 2013). Also, he revealed that in a situation where two different feed materials is to be used it is important mixing should be done separately before introducing into the biodigester.

Inhibition and toxicity
Heavy metals, mineral ions and other forms of metals and toxic materials inhibit the normal growth of pathogens in digester. It’s important to note that not all Bacteria are pathogen they are essential in the biodegradation and subsequent biogas production, so any form of inhibition will affect the biogas production. Though small amount of mineral ions like sodium, potassium, calcium, magnesium and sulphur can also stimulate the growth of bacteria while the reverse with restrict production (karki *et al* 2015).

Additional succulent plant and algae
Addition of succulent to an already existing feed material like cow dung can also help to increase biogas yield. Succulent like plant or algae can be added. Green alga, water hyacinth and lemon grass can help to improve the production of biogas. The amount of biogas generated when algae was added to cow dung was found to be almost twice as much as what was initially obtain when the succulent algae was not added. The Production period of course will also increase.

Digester Type Design and Description
Materials selection for construction biogas plant
Biogas plant is constructed using available materials that will suit the use of the cow dung, and appropriate result derives to suit the purpose of the research

- Can easily be moved/rolled
- Relatively cheap

Materials selected in the construction should be based on cost effective, durability, availability and should suit the weather condition of the area where the said bio digester will be situated.

Materials for bio-digester

The digester used is a 1000 liters GEEPEE tank with a suitable to withstand thickness to meet the following,

- Water/gas tightness to withstand pressure and prevent spillage that will result to threat to the soil and ground water. Gas tightness to ensure adequate containment of the biogas yield and ensuring air tight to prevent air from entering or leaving the digester from unusual places.

Biogas plant is constructed using available materials that will suit the use of the cow dung, and appropriate result derives to suit the purpose of the research.

Materials for gas pipe/hose

The materials used for the transfer of the gas from the bio digester to the gas holder are flexible hose hooked up plastics pipe depending on the configuration of the design. They are connected to different ball-valves that control the flow of the gas from different sections of the bio-digester. Flexible hose and plastic piping was chosen because its ability to withstand corrosion and its affordability

Gas pipe diameter

The gas produced is usually in a moderate pressure so the used for sophisticated pipe/hose will not be necessary. The diameter is selected based on the flow rate of the biogas and the distance to the gas holder from the bio digester.

Filter

For the purpose getting purified biogas that will be used to generate power, there is a need for the biogas to pass through filter. Filter was improvised with metal flex (sponge) introduced inside the filter. A slot is design for the entry of the biogas and another slot designed for the exits. The design is made of plastic and so can withstand all aspect of corrosion and is durable.

RESULTS

Various Biodigester Design

Figures 1 to 3 show various biodigester designs that can be adopted for design of biogas digester.

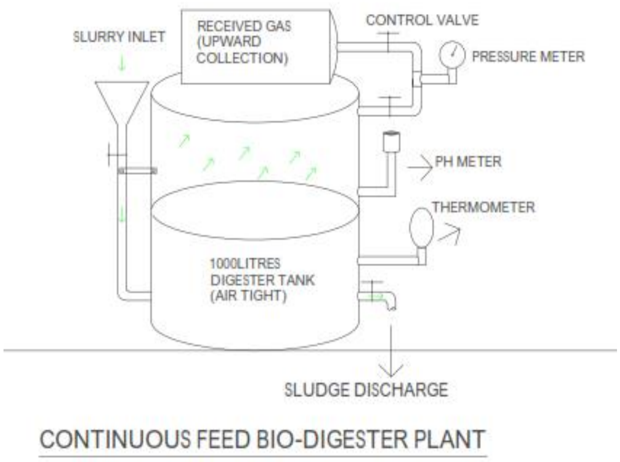

Fig. 1: Ideal biodigester (upward collection)

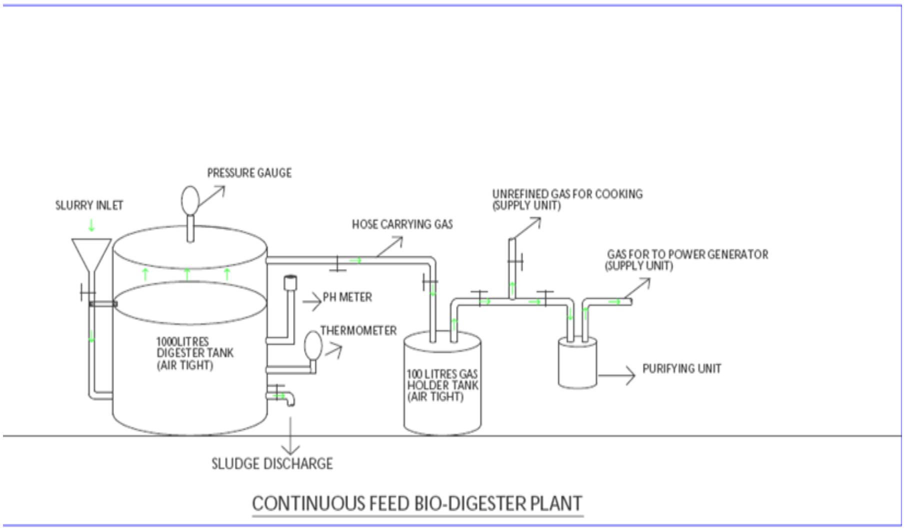

Fig. 2: Ground biodigester (Downward collection)

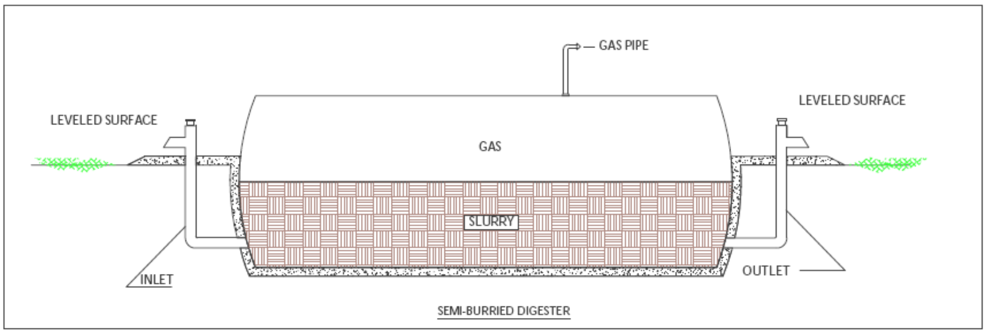

Fig. 3: Semi buried biodigester (upward collection)

DISCUSSION

Justification for the Selection of Ideal Biodigester

Ground biodigester (upward collection)

The biodigester is design with recent modification with instruments that can ascertain various parameters, its preferred because the gas is collected upward which makes it very easy at all times (Figure 1). The biodigester can be moved to any position and can be used in any environment. The issue of leakage can't be envisage because it is supported on an elevated platform, slurry can easily be removed after the digestion period and new dung can easily be introduced because of the nature of its design. Hence, there is need for the selection of this design.

Ground biodigester (downward collection)

This biodigester just like the "upward collection" biodigester is designed with lots of modern modifications; the feed is introduced from the top (Figure 2). In spite of the modification biogas collection is very slow, and collection can only be achieved during mesophilic stage of the biodegradation where the temperature is at the range of 50 ^{o}C – 65 ^{o}C when the microbial activities are very, hence increase in biogas production. For methane gas because of its very light nature, it is better collected upward, but in this design the gas is collected downward so a substantial amount of biogas is needed to put pressure on the gas in other to push it downward for collection. This makes this particular design not acceptable even though discharge of slurry is also easy.

Semi- buried biodigester

The semi buried biodigester is designed in such a way that half of the biodigester is buried underground, though feed stock is introduced from the side, the biogas is also collected from the top which makes it quite ideal (Figure 3). Unfortunately, it can't be used in swampy region because part of it is buried, and there is no guarantee that the buried section will not give way to corrosion and subsequent seepage into the soil and finally hit the water table causing unplanned pollution. Another disadvantage is the very aspect of evacuating the slurry after biodegradation period, and unlike the other is not potable and so can't be moved from one point to another.

The Uniqueness of Biogas

Biogas has some very unique characteristics that make it a preferable gas to use as against other natural gases.

- Biogas last longer in burning when compare with equal volume of natural gas
- Generate a higher level of power than other gases
- Burns with smokeless clear blue flame and not toxic
- Biogas does not affect the atmosphere because in the methane gas is already in a biosphere state.
- When use to generate power the maintenance cost is extremely low as compared to natural gas because of the low level carbon generated during combustion.

Safety Consideration in Biogas Production

Mentioning the various means of biogas production without safety consideration in the collection of the said biogas gas how inflammable it could be if not properly handled. Biogas contains a high amount of methane gas (50-70) which inflammable and could create a high level of hazard if safety measures are not put in place. Some of the safety measures that have been in cause of these reviews are as discussed below:

Fire/Explosion

Methane can easily form explosive mixture when expose to air, 8% of biogas form methane which makes it combustible. It is important to ensure that during biogas production all forms of naked flames are kept very far for biodegradable area where the biogas is generated. It is also very important that adequate safety measure are taken when carrying out different forms of test like dusulpurization and flammability test, a considerable distance should be maintain to avoid unplanned explosive. Four deaths were recorded in a biogas plant explosion Aluva in Ernakulam in 2009.

Disease

Huge population of bacteria are involve during biodegradation process, hence prevailing large amount of disease during the process should be avoid contact with the digester content be being conscious of procedure, hence proper washing of hands after working round the biodigester particularly before eating or drinking. The digestion process actually reduces the number of pathogenic bacteria especially at higher operating temperature, but it is still important to keep the biological process in mind.

Asphyxiation

Biogas is made mainly of CH_4 (Methane), some level of H_2S and other gases, these gases have different effect and so must be treated with care. Methane is lighter than air and easily collected in the roof and without proper ventilation to help dilute the concentration of the methane slight ignition can lead to explosion. Carbon dioxide which is heavier than air can cause respiration rate when slightly elevated. Hydrogen sulphide even though not as much methane and carbon dioxide can still affect the tissues and lungs because of the offensive smell (rotten egg).

CONCLUSIONS

Identifying and optimizing various techniques in the generation of biogas in a growing economy is a major concern. The useful on formation on the production of biogas has not been utilized by Nigerians, but the resources and the parameters needed are available for utilization for biogas production. With a warm, stable climate and easy availability of plant materials and animal waste i.e. cow dung, poultry droppings and pig excreta Nigeria will be in a good position for adopting and popularizing biogas use. The federal government has set up a National Biotechnological Development Agency (NABDA) whose mandate among others is to develop conservative strategies in promoting the sustainable utilization of huge biological resources that will encourage the use of biogas as sustainable means power generation. Biogas production is beginning to catch attention in different levels; a local NGO in Ibadan has joined with technology investors from Thailand to improve biogas innovation in Nigeria.
In spite of all the incoming plans to develop biogas Nigeria still far behind in terms of actualization, so many policies with lack of follow up has kept us where we in biogas in catching with other African countries. Nigeria can't boast of any biogas plant that can generate at least 350 MW of power. With all the potential all the materials/potentials require in the construction of biogas is abundant in Nigeria. So there shall not be any excuse relenting to start encouraging investors to start investing on biogas construction so that the over dependence of crude will lapse.

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