CHARACTERISTICS OF PIG WASTES FEED STOCK FOR THE DETERMINATION OF DESIGN PARAMETERS FOR BIOGAS DIGESTER PLANTS

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ABSTRACT

The benefits of commercialising biogas technology include the reduction of pollutions and sanitation risks of rural organic wastes. It also include the production of two bye-products: biogas – used as energy source; and bio-fertilizer – the effluent, which is rich in organic fertilizer. This is done through the process of anaerobic digestion in a biogas plant. A detailed description of the biogas production process and factors affecting the amount of gas produced is given. A laboratory analysis of the pig wastes feed stick available at Ojokoro Cooperative Agricultural Multipurpose Society (OCAMS) Piggery farm in Lagos is carried out to determine design parameters of biogas reactor plants. The result shows the characteristics of input and output quantities of biogas and spent manure expected from a typical plant. It is presented here for use as design parameters for the design and construction of commercial biogas plant.

INTRODUCTION

Methane, a constituent of biogas, was first demonstrated as having practical and commercial value in 1890's in England where a special designed septic tank was used to generate the gas for street lighting. In India, Taiwan and China, there are millions of biogas plants utilising either cow-dungs, pig manure or poultry droppings (1-2). Biogas development efforts in Nigeria dates back to the 1970s. Since then more biogas plants have been put in place at:

(i) Village pinioneer project in Ajue near Ondo; (ii) the Agricultural Technology Research Farm of Obafemi Awolowo University (OAU), Ile Ife; (iii) Government House Annex and State Hospital, Oshogbo, Osun State (iv) the biogas plants at Sokoto Energy Research Centre, Sokoto (v) the biogas plant at Federal Institute of Industrial Research Oshodi (FIIRO) (vii) the floating gas holder and fixed done biogas plants at Ojokoro constructed by FIIRO and Sokoto Energy Centre. The problems encountered in most of the earlier projects ranged from stubborn leakage, lack of maintenance to high cost of initial investment in biogas constructions (1-5).

BIOGAS

Biogas is a flammable, colourless gas, obtained by anaerobic digestion of organic matter such as human, animal agricultural and industrial wastes. Examples of such organic matters in common use are poultry droppings, cow-dung, piggery wastes and water hyacinth. Biogas is obtained by the decomposition of these organic matters in the absence of oxygen. The gas is a mixture of methane and carbon dioxide. It contains about 50-70% methane, 30-40% Carbon dioxide and traces of hydrogen, nitrogen and hydrogen sulphide. The methane proportion of biogas which is usually up to 65% of the mixture is the combustible part. Biogas is smokeless unlike other fuels such as kerosine or hood etc.

It burns with non luminous blue hot flame without smell (1,3,6,7). It is used for cooking, lighting and space heating. The biogas manuals show that its fuel value depends on the methane content of the gas. A gas containing 65% methane and 32% CO_2 has a fuel value of 24MJ/m^3 while pure methane has a fuel value of 37MJ/m^3. A cubic metre of biogas is equivalent to 2kg of fuel wood, 0.6 litres of kerosine 0.5 litres of gasoline, 0.4 litres of diesel can generate 1.25Kwh of electricity and can be used in cooking three meals for a family of three to five people (1,6). The resultant efficient wastes or organic materials from the biogas plant is a very good manure, which is rich in nutrients, odourless, and free from other sources of infection. This bio fertilizer or manure could be sold and used on farms while the almost free gas supply is used as fuel for biogas store. The biogas is used for both industrial and domestic or household energy supply. They are ideal for hospitals, barracks and boarding houses (4,6-9).

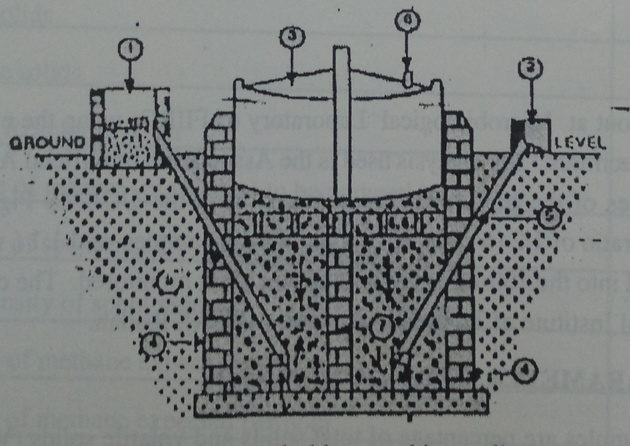
Experts say that the benefits of biogas generation are many. The use of rural wastes for biogas generation rather than directly as fertilizer yields three direct benefits which are: (i) the production of energy resources that can be stored or used more efficiently. (ii) the production of stabilised residue (the sludge) that retains the fertilizer value of the original material; (iii) the saving of the amount energy required to produce and equivalent amount of nitrogen containing fertilizer by synthetic process. The benefits include: (i) the potential for partial sterilization of waste during fermentation, with the consequent reduction of the public health hazard of faecal pathogens (ii) the reduction due to fermentation process of the transfer of fungal and other plant.

Pathogens from one year's crop residue to next year's crop (1,4,6,9). Here, an analysis of the pig wastes samples from the (OCAM) piggery farm is carried out at the FIIRO microbiology laboratory using the Association of Official Analytical Chemist Method (1980). The amount of biogas to be generated and the spent manure output were also estimated.

BIOGAS PRODUCTION

BIOGAS DIGESTER

Four different types of biogas digesters and stores have been developed in Nigeria at the SERC. Sokoto, FIIRO, Lagos and OAU, Ile-Ife. The digesters are of two types the floating gas holder and the fixed dome biogas plants. Variation or these models that are designed and constructed in Nigeria include (1-4). (i) the prototype floating gas holder Indian model, (ii) the prototype Indian model with separate storage and (iii) Horizontal prototype biogas with a partition between the digester and gas holders (iv) fixed-dome type of biogas plant Chinese model. Fig.1 shows the floating gas holder type while fig.2 shows the fixed-dome type biogas digesters. The digesters are of batch fed type or continuously - fed type. Fresh input materials are mixed with water in the ratio of 1.4 : 1, while dry organic materials are mixed with water in the ratio of 1:1.5 or 1:2 depending on the level of dryness feeding is done through the feeding at the intent. It takes up to 8 days to generate gas at the start of operation of the plant, after which gas is obtained regularly if feeding is done regularly in daily basis not necessarily combustible gas.



1. INLEWT TANK
2. OUTLET TANK
3. GAS HOLDER
4. DIGESTER WALL
5. A.C. PIPES
6. GAS OUTLET
7. PARTITION WALL

Fig. 1: Floating gas holder type biogas digester

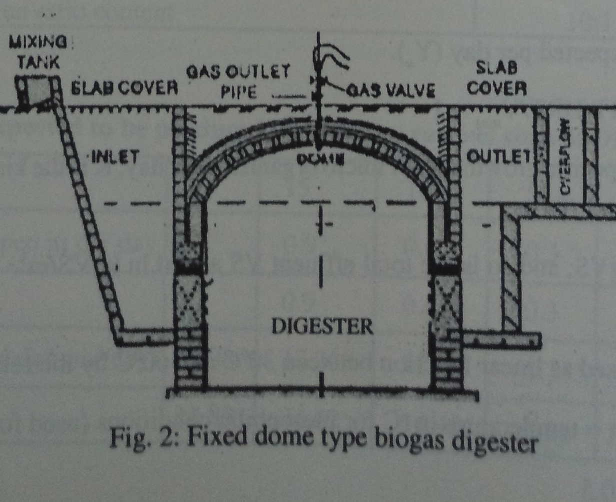


Fig. 2: Fixed dome type biogas digester

BIOGAS GENERATION

The generation of gas from a biogas plant involves three stages. The first stage involves the interaction between several species of cellulolytic and hydrolytic bacteria to decompose complex insoluble organic molecule to soluble organic. The second stage involves conversion of soluble organics or organic acids and primary acetic acid, In the third and last stage, methane is produced by either fermentation of acetic acid to metane and carbon dioxide or reading carbon dioxide to methane via hydrogen gas or formate generated (I). The gas produced is stored in the gas holder from where it is piped to the point of use. A air adjuster to allow for the appropriate mixture of air and biogas during combination is included in the burner. The Sokoto Energy Research Center have also designed and constructed biogas burner/stoves.

FACTOR AFFECTING BIOGAS PRODUCTION

The factor affecting biogas production include temperature ,pH , values, nature of waste, carbon-to-introgen ratio, stirring and seeding with bacterial where necssary . An optimal yield of biogas is obtained between 30^0-40^0c temperature range for mesophi and between 45 and above for termophilic processes. In the lower temperature range, fermentation was due to mesophilic bacterial while in the higher temperature range thermophilic bacteria were actively involved. There is low biogas production at lower temperature. The anaerobic microbic micro-organisms require a neutral environment for optimum functioning. The optimum pH is between 7.0 – 7.2 (1,7). The nature of waste affects production yield also. Organic waste which are easily digested produce more gas while materials with high cellulose produce less amount of gas. Dry vegetable matters and young plants produce more gas than green vegetable matters. The required carbon to-nitrogen ratio for optimum biogas production is ideally within the range of 10:1 and 30:1. However the ration for poultry manure could be in the range of 5:1 and 8:1 Organic matters with high nitrogen content produce high gas yield. The dilution ration could also affect gas production for dry materials such as cow-dung or poultry dropping, the best ratio water to material is 1.5:1 or 2:1. Stirring is necessary for increased gas production and should be done occasionally to prevent scum formation [1,7,10]. For other materials such as pig waste, cow-dung that are fresh, the ratio of material to heater should be kept at 1.4 : 1 so that a homogeneous slurry can be obtained.

METHODS OF ANALYSIS

Analysis of pigwaste feedstock.

Analysis of the pig wastes was carried out at Microbiological Laboratory of FIIRO using the exisiting 100 litres plant and the Microbiology laboratory facilities. The analysis used is the Association of Official Analytical Chemist (AOAC) method of 1980. Wet samples of the pig wastes are obtained from the OCAMS Piggery farms. The mixtures were prepared using a mixing ratio of 1:2 (weight or volume) for dry samples and 1:1 (weight or volume) for wet samples. The mixtures were fed into the 100-litres biogas digester plant monitored. The carbon-to-nitrogen ratio was determined at the International Institute of Tropical Agriculture (IITA), Ibadan.

DETERMINATION OF DESIGN PARAMETER FOR BIOGAS PLANTS

The parameters determined from the samples are percentage of total solids and volatile solids (VS); the volume of wastes to be pumped in per day and the volume of spent manure expected per day mere calculated using the relationship indicated below.

Volume of Gas (Methane) expected per day (Y_v).

$$Y_v = [BoSo(1\text{-}k)]/[HRT(HRT/V_{max} - 1$$

Where V_{max} is the maximum specific growth rate of micro organisms per day, K is the kinetic parameters dimensionless, HRT is the Hydraulic Retention Time;

Bo is methane yield in m^3/kgVS; and so is the total effluent VS added in kgVS/m^3. The values of HRT = 15, so = 370kgVS/m^3 and Bo = 0.5.

The values of V_{max} is expressed as linear function between 30°C and 60°C by the relation (12,13).

$V_{max} = 0.012t - 0.129$ where t = temperature in °C for mesophilic conditions (used for pig.wastes, t = 40°C).

$V_{max} = 391$ and $K = 0.5$

For thermophilic condition (used for cow-dung, t = 55°C)

$V_{Max} = 0.586$ and $K = 0.9$

The volume of wastes to be pump in per day (Xp) is calculated on the basis of 90% of reactor size (Rs) as

$Xp = (Rs \times 90\%)/HRT$

The total volume of methane generated per day (V_{md}) is given as

$V_{md} = Y_v.Rs(m^3/day)$.

The quantity of biogas per day is determined on the basis that methane constitutes 70% of the total biogas generated from the reactor.

RESULTS AND DISCUSSIONS

Table 1 shows the result of the analysis and computed quantities of biogas to be generated from $20m^3$ plant. The pig wastes consists of 4.02% total solids and 3.7% volatile solids. The carbon-to-nitrogen ratio is about 10:1 which is within the acceptable limit required for high gas yield [(2)]. It is expected that $32.83m^3$ per day of biogas would be generated from $1.2m^3$ of slurry pumped into the digester.

Also, $1.2m^3$ per day spent manure slurry is expected as output. When this is dried, it is expected that about $0.6m^3$ of spent manure would be expected daily from the plant as biofertilizer. Arrangement could be made to construct a solar drier and a packaging facility for the biofertilizer for commercial purposes. The gas generated would be piped to the service points for meat processing. It could also be used at the piggery sheds.

Table 2 shows the quantity of biogas and manure to be produced per day for various sizes of digesters from 100 litres.

Table 1: Values of Parameters determined for pig wastes

S/N	Parameters	Values
1	Total solids	14.02%
2	Volatile solids	3.7%
3.	Size of Reactor/digester	$20m^3$
4	Volume of manure (pigwastes) to be pumped in per day	$1.2m^3$
5	Volume of spent manure after digester	$1.2m^3$
6	Bulk density of spent manure	$0.58kg/m^3$
7.	Volume of methane expected per day	$22.98m^3/day$
8	Volume of methane expected per hour	$0.957m^3/hour$
9	Quantity of biogas expected per day	$32.83m^3/kg$
10	Total carbon: Nitrogen ratio content	10:1

Table 2: Quantity of Biogas expected to be produced per day for various sizes of Digesters.

Size of reactor/digester(m^3)	20	15	10	5	1	0.5	0.1
Volume of Pig wastes to be pumped in per day	1.2	0.9	0.6	0.3	0.06	0.03	0.006
Volume of spent manure (m^3)	1.2	0.9	0.6	0.3	0.06	0.03	0.006
Volume of methane expected per day (m^3/day)	22.98	17.235	11.49	5.745	1.149	0.575	0.115
Quantity of biogas	**32.83**	**24.62**	**16.421**	**8.21**	**1.642**	**0.821**	**0.164**

CONCLUSION

The ECN biogas pilot plant promotion programme is to encourage other NGOs and entrepreneurs in Nigeria to invest in the use of alternative energy sources. The advantages of environmental pollution control and cheap source of fuel should provide enough incentives for such projects. The ECN also tried to make the technology available in different parts of the country through capacity building on renewable energy resources.

The result of the analysis of the pig wastes feed stock shows that the total solids is 14.02% which volatile solids is 3.7%. The C:N ratio is found to be 10:1 which is the required limit for high gas yield. It shows that it is possible to generate 32.83m^3 per day of biogas and 1.2m^3 of spent manure slurry per day from 20m^3 digester plant.

However, the problems associated with biogas production should be examined and solution found in order to build-up confidence in the reliability of Biogas technology. These problems include stubborn gas leakages, low gas production during the cold and harmathan seasons in Nigeria, high initial cost of the plant, siting the plant where there is abundant input materials, social problem within the method production, maintenance problems, and transportation and bothing of gas.

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