REVIEW AND POSSIBILITIES OF WATER HYACINTH (*Eichhornia crassipes*) UTILIZATION FOR BIOGAS PRODUCTION BY RURAL COMMUNITIES IN KAINJI LAKE BASIN

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ABSTRACT

The paper gives some background information on the production of biogas using agricultural waste. Studies on biogas production with water hyacinth conducted in NIFFR using the floating type biogas digester complete with gas holder and an experimental metal digester with a measuring cylinder as gas collector are highlighted. A proposal for the construction of a dome – type biogas digester at Rofia and Zamare close to the boom are presented. This will ease utilization of water hyacinth harvested from the boom for biogas production .The gas will provide an energy source for the local community and the slurry will be a ready source of fertilizer for the farmland.

INTRODUCTION

Nigeria is a country blessed with abundant energy resources. These are the primary energy sources such as crude oil, natural gas and coal and renewable energy most of which are underutilized such as hydro, wind, solar, biomass and fuel wood.

Most of the energy needs of Nigerians for household and industrial use are petroleum-based namely petrol, diesel, kerosene and natural gas. While kerosene and gas are used extensively by most households in urban areas, the rural dwellers, which form 70-80% of the population, depend almost exclusively on fuel wood for household use. This high dependence on fuel wood for domestic and commercial purposes is a matter of public concern as it is the major cause of deforestation in many parts of the country. Since the rate of regeneration of wood is not commensurate with the high rate of consumption, there is an increasingly high rate of desert encroachment, soil erosion and loss of soil fertility in places with high rate of deforestation. Thus complete reliance on fuel wood to meet the domestic energy needs of rural communities enhances environmental degradation - a situation which is very difficult to reverse.

One of the ways of saving the environment from further deterioration and also supplement the energy needs of rural dwellers on Kainji Lake Basin is by the production of biogas. The technology of biogas production is not new. The development and construction of biogas digester started in the 1920s and has spread to several developing countries such as India, Taiwan etc. In these countries biogas technology has supplemented a large proportion of energy requirements of the rural majority. The availability of raw materials coupled with the ever-increasing prices of fossil fuel has made this technology attractive.

In India for example biogas generating plants using cow manure have been in operation for years. In Taiwan more than 7,500, methane-generating devices utilizing pig manure have been in construction. The technology of biogas production is therefore advantageous in that it can be used to provide energy for households and rural communities without tampering with fuel wood.

REVIEW OF BIOGAS PRODUCTION

Biogas is a mixture of colourless, flammable gases produced by anaerobic fermentation of organic waste materials. Biogas is a mixture of methane, carbon dioxide, small amounts of carbon monoxide, hydrogen, nitrogen, oxygen, hydrogen-sulphide and hydrocarbon gas. The actual percentage of each gas varies with raw materials, ratio of input materials, temperature and fermentation stages. Typically the composition of biogas is as follows (Fernando and Dangaggo 1986).

Methane	54 -70%
Carbon monoxide	0.1%
Carbon dioxide	27-45%
Oxygen	0.1%
Nitrogen	0.5-3%
Hydrogen sulphide	Trace
Hydrogen	1-10%.

Methane is the major combustible component of biogas. Others usually in small quantity are carbon dioxide, hydrogen and hydrogen sulphide.

Biogases are obtained by fermentation of organic materials such as animal, human, agricultural and industrial wastes. These include animal faeces, municipal sludge and garbage, abattoir waste, paper waste and waterweeds. The rate of conversion of the organic waste to the end products at appropriate temperature depends on the complexity of the waste. In the treatment of complex wastes such as sewage and slaughter house waste, generally slower loading rates should be used due to much slower conversion rate of the biodegradable suspended compounds than of the soluble compounds such as young plant materials. It is thus expected that the complexity of the waste is a significant factor that affects the rate of anaerobic digestion of any type of wasted. (Maishanu et.al., 1993).

The quantity, quality and composition of biogas produced vary from one animal waste to the other. So, also biogas produced from agricultural waste varies from that of animals. For this reason, investigation of the quantity, quality and composition of biogas produced from agricultural wastes is imperative. Biogas has been produced from the aquatic weed *Pistia stratoites* (Maishanu, 1992). It should also be possible to produce from water hyacinth. Accordingly, a report of the quantity and quality of biogas produced from water hyacinth (*Eichhornia crassipes*) has been shown here.

Chemistry of biogas production.

Anaerobic digestion of organic matter occurs in three phases; the first phase in which facultative micro-organisms convert complex organic compounds (polymers) examples starch, cellulose via enzymatic hydrolysis into less complex soluble organic compounds (monomers) examples glucose, fructose.

In the second phase, a group of bacteria collectively known as "acid formers" converts these soluble monomers into acids and in the third phase, the soluble organic acids constituting mainly acetic acids serve as substrate for methanogenic bacteria which are strictly anaerobic in nature.

Methanogenic bacteria can generate methane through two different routes; either by fermenting acetic acid to methane (CH_4) and carbondioxide ($C0_2$) or by reducing carbondioxide methane via hydrogen gas or formate generated by other bacterial species as shown in the reactions below:

$$n(C_6H_{10}O_5) + nH_2O \xrightarrow{\textit{Hydrolysis}} n(C_6H_{12}O_6)$$

$$n(C_6H_{12}O_6) \longrightarrow 3n\,CH_4 + 3n\,CO_2$$

$$CO_2 + 4H_2 \xrightarrow{\textit{Reduction}} CH_4 + 2H_2O$$

$$CO_2 + H_2O \xrightarrow{\textit{Hydrolysis}} H_2CO_3$$

$$n(C_6H_{12}O_6) + 3n\,H_2O \xrightarrow{\textit{Hydrolysis}} 3n\,CH4 + 3nH_2CO_3$$

$$H_2CO_3 + 4H_2 \xrightarrow{\textit{Reduction}} CH_4 + 3\,H_2O.$$

Factors affecting biogas production.

In order to enhance the performance of biogas generation process, and to prevent the process failure, certain operating parameters such as temperature, pH, nutrient addition, mixing ratio and retention period, all need to be. controlled. Micro-organisms are highly sensitive to pH changes. Buffering is necessary for pH control and therefore an essential step in the overall operation (Garba and Sambo 1992).

Temperature is an important physico-chemical factor in the degradation of organic wastes and as such the anaerobic process is dependent on temperature

Temperature has significant effect on biogas production more especially when fresh plant material is involved. Two temperature ranges have been reported to affect the overall process of biogas production. These are; the mesophilic temperatures and thermophilic temperatures. The mesophiilic temperature range of 30-40°C has been reported to effectively aid in degradation of organic wastes that are not lignified. Increased biogas production was reported in the digestion of fresh water weed known as *Pistia stratiotes* (water lettuce) at mesophilic temperature of 30 °C.). The mesophilic temperature range is preferred when fresh plant material is involved (Maishanu *et.al.*, 1993) Also, it is easier to maintain the digester at this temperature.

Methane-producing bacteria are very sensitive to sudden thermal changes and therefore any drastic change in temperature should be carefully avoided so that no abrupt decrease in gas production occurs. The digestion process must thus be designed to operate at constant temperature conditions. Temperatures above 65°C cause gas production to stop (Garba and Sambo, 1992).

Anaerobic digestion process can be operated over pH range of 6.0 – 7.0. As organic acids are produced during the breakdown of cellulose, when the pH drops below 7.0, there is a significant inhibition of methanogenic bacteria and the acid conditions of a pH of 4.0 are toxic to these bacteria. At pH of 4.0, the production of gas will be very low and later stops (Garba and Sambo 1992).

Several steps such as introduction of bacteria having cellulolytic capacity, preheating the media material, milling the media material, chemical treatments with NaOH etc, and drying have been shown to improve biogas yield (Itodo *et. al.*, 1992)

Small digester.

This ranges from $4m^3$ to $20m^3$. The size of the plant depends on the number of people in the house hold. On the average an individual require about 0.3% of biogas for cooking, heating and lighting in a day.

Medium digester

This has capacity ranging between $50m^3$ and $500\ m^3$. These are community-based biogas digesters. Biogas is supplied to the users via pipelines from one or more coupled digester.

Large-scale digester

This is usually for industrial production of agro-based residues and other waste products that are organic in nature. This requires building digester of $5000m^3$ capacity or more.

Use of water-hyacinth for biogas production

The menace of water hyacinth in Kainji lake reservoir with its unfavourable effect on navigation and aquatic life has raised public interest on its eradication without adverse effect on the aquatic flora and fauna as well as human life within and outside the lake basin. Among the three control methods i.e. biological, chemical and physical, the last is considered the safest method since it involves manual or mechanical harvesting of the weed. The harvested water hyacinth could find alternative use in the production of biogas at the community level. This added benefit will encourage community participation in the harvesting of the weed because of the gains derivable from biogas production.

Other raw materials

In the absence of water hyacinth, cow manure, which is also rampant in the area will, be an alternative raw material so that the plant will be kept running even after the water hyacinth has been eradicated.

Importance of biogas technology

Biogas technology has succeeded in generating a stable energy source that can be used for direct combination in cooking or lighting or indirectly to fuel combustion engines for delivery of electrical power.

- Production of stabilized residue (biogas slurry) that can be used as a fertilizer; an energy efficient means of manufacturing a nitrogen containing fertilizer.

- A process having the potential for waste sterilization which can inhibit pathogenic action and thus reduce public health hazards from faecal pathogens as well as inhibit pathogens (usually found in high concentration in manure) like *Ehizotomia solamia* of rice and *Helminthosporrium satium* of wheat.

- The various products of a biogas plant such as methane, carbon dioxide and hydrogen can be used in the production of many industrial chemicals; methane is used in the production of methanol an industrial alcohol used in the making of methylated spirit. The chlorination of methane through photocatalysis yield chloroform and carbon tetrachloride. Carbon tetrachloride is used in dry cleaning and in fire extinguishers.

- Carbon dioxide is used in the manufacture of ammonium sulphate from powdered anhydrite as described in the chemical reaction:

$$CaS0_4 + 2NH_40H + CO_2\ (g) \Rightarrow CaCO_3\ (s) + (NH_4)_2\ S0_4 + H_20.$$

It can also be used in the production of urea as shown in the reaction

$C0_2(g) + 2NH3\ (g) \longrightarrow CO_2(g) + 2NH_3\ (g)$. Urea can be utilized as fertilizer and in the manufacture of plastics. Other uses of carbon dioxide include the manufacture of organic chemicals, such as coolants in nuclear reactors, for the aeration of soft drinks, for storing fruits while blocks of solid carbon dioxide are used as refrigerant (Aliyu *et.al.*, 1996)

MATERIALS AND METHODS

Laboratory preparation

The procedure has been reported by Eyo and Madu (2000).

Fresh water hyacinth (500g) were cut into one inch sizes and placed in a two litre metal container with water at the ratio of 1:3 (w/v). The metal container served as the digester. A hole was bored on top of the digester and a rubber hose was inserted into the hole via a rubber cork and glued using araldite adhesive. The mixture was fed into the digester through the inlet on the digester. The inlet of the digester was then sealed to ensure that it was airtight. A one-litre measuring cylinder was used as a gas holder or gas collector. Retort stand and clamp were used to hold the measuring cylinder in a vertical position without slanting.

The unattached end of the rubber trough was placed in water in a trough and the one-litre measuring cylinder filled with water, was inverted into the trough such that the outlet of the rubber hose (delivery tube) was directed upwards within the measuring cylinder. Fig. 1 shows the experimental set up of the process. The downward displacement of the water in the measuring cylinder was used as a measure of the volume of biogas produced.

(ii) Experimental trial with floating type biogas digester.

Preparation of sample

Water hyacinth freshly harvested from Jebba lake by staff of Aquatic Weed Project was used for the experiment which commenced on Monday 14th July 1997.

Samples were initially subjected to grinding in a hammer mill and pounding in a mortar, respectively. When these two methods could not produce homogenous particles needed for the experiment it was decided to chop the weed into small pieces (1-2 in average length). The pieces were transferred into two large plastic bowls containing equal volume of water (W/V) and left overnight before pouring into the digester.

Loading the digester.

Since slurry could not be produced from the weed, it was not practicable to insert the material through the inlet pipe of the digester without blocking the pipe. The solution was to pass the material via the drain channel after removing the stopper. The digester was tilted to the offside position to facilitate loading the digester with sample.

The drain stopper was closed tightly after loading the digester. With the digester nearly filled up, an anaerobic environment was created which is a prerequisite for the activity of methanogenic bacteria. The digester was thereafter returned to its normal vertical position. The outlet pipe remained permanently closed throughout the experiment.

RESULTS AND DISCUSSION

Table 1 shows the volume of biogas produced during the experimental period. The quantity of biogas increased from 50 cm^3 in the first week to 82 cm^3 in the 2nd week. In the 3rd week the volume of biogas was 122 cm^3 increasing to 150cm^3 in the fourth week and reaching a peak at 170 cm3 in the 5th week after which the level of production declined. The volume of biogas collected on the ninth week was 80cm^3. Total biogas produced during the experimental period was 970 cm^3.

Temperature in the laboratory ranged from 24°C with a mean temperate of 27°C over the 63 days experimental period. This low mean temperature could affect the level of biogas production since temperature profoundly influence the action of methanogenic bacteria and the rate of hydrolysis (Aliyu *et al*, 1996; Garba and Sambo 1992; Garba *et al*, 1996: Fernando and Dangoggo 1986; Maishanu *et al*, 1993). Increased biogas production of water lettuce (*Pistia stratoites*) was reported at mesophilic temperature of 30°C (Maishanu *et al*, 1993).

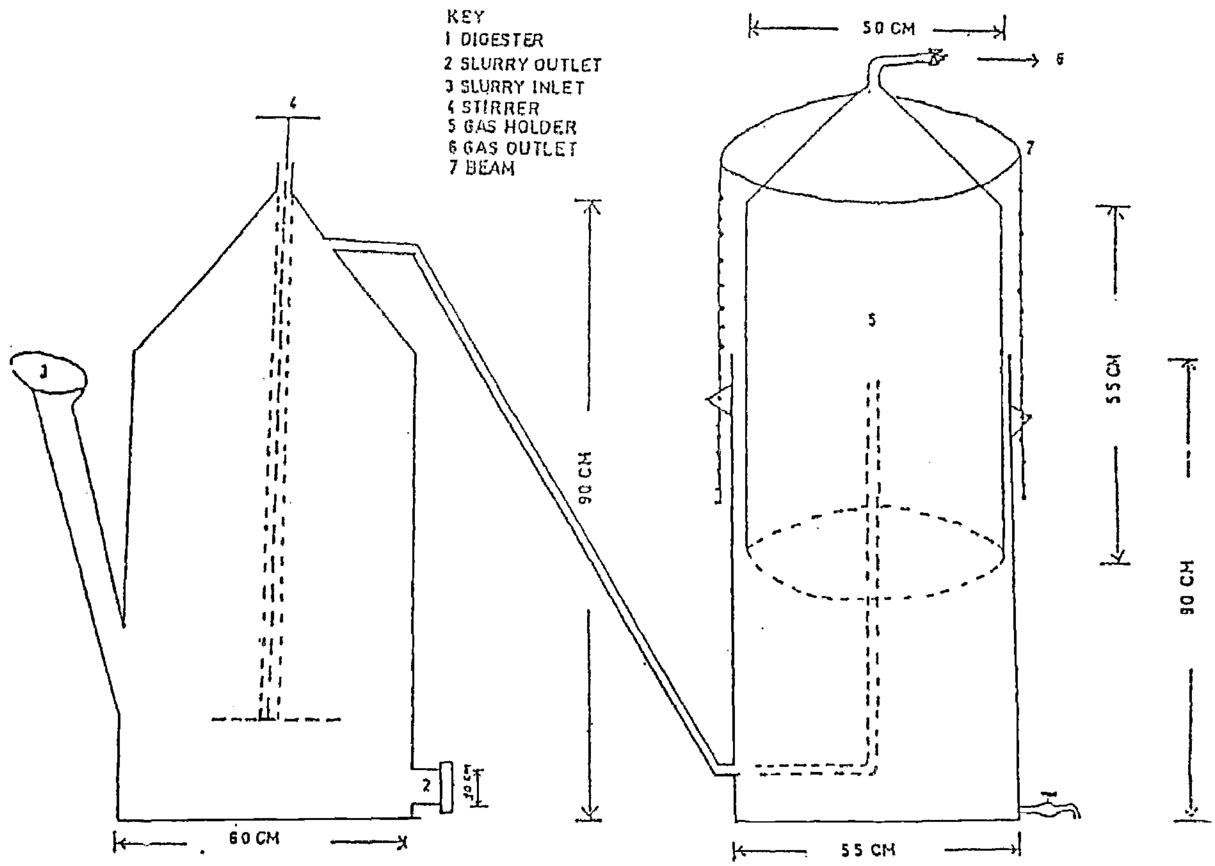

Fig.1. PORTABLE BIOGAS PLANT WITH SEPARATE GAS HOLDER (100 LITRES CAPACITY)

The mixing ratio of 1:3 (w/v) of water hyacinth and water could also affect the rate of biogas production. Aliyu *et al*, (1996) reported an increase in biogas production when the ratio of pigeon droppings with water was increased from 1:3 to 1:4. (w/v).

Table 1: Yield of Biogas from Water Hyacinth under Laboratory Conditions

	Day	Volume of Biogas Cm^3
	0 - 7	50
	8 - 14	82
	15 - 21	122
	22 - 28	150
	29 - 35	170
	36 - 42	150
	43 - 49	70
	50 - 56	90
	57 - 63	80
Total	63	970

Biogas production with the floating type biogas digester.

The apparatus was left with the two valves (digester and gas holder) open in the first week, to allow escape of the gas produced at the initial fermentation process, which contain very low methane. This gas would dilute the methane gas when it is subsequently produced and thereby affects combustion. The content was stirred daily to accelerate the rate of fermentation.

With the two valves closed a remarkable rise in the water level was discernible at the inlet pipe the next day. As the day progressed, the water level increased in volume and filled up the inlet pipe and started dropping. This overflow stopped when the digester gas valve was open. On the first day of the 3rd week, the two gas valves were again closed. When both valves were opened the next day gas started to ooze out from the gas pipe. When the gas was ignited it burst into a luminous blue flame. This fascinating sight was over in less than 10 minutes.

The digester was again closed and the same procedure was repeated the next day and the emitted gas was allowed to burn away. The peak of gas production appeared to have been reached one month after loading the digester. The gas produced as from that day has been on the decrease. As a result of the increased water level in the digester it was decided to repeat the experiment with dry water hyacinth.

PROCEDURE FOR THE SECOND TRIAL SAMPLE PREPARATION

1 kg of dried water hyacinth was measured and placed in the digester after which 5kg of fresh cow dung dissolved in 50 liter of water was poured into the digester through the inlet.

The apparatus was left for fermentation to take place with the digester valve open during the first 4 days. Thereafter the digester valve was closed and connected to the gas holder. The gas produced was ignited daily to determine the rate of production. This is shown in Table 2. This second experiment started on Tuesday 26th August, 1997.

Table 2 Quantity Of Biogas Flow From The Digester
***(As Measured By The Duration Of Burning)**

DATE	QUANTITY OF GAS
26/8/97	3 Minutes burning
27/8/97	2
28/8/97	2
29/8/91	2
30/8/91	1
31/8/91	Nil
1/9/97	Nil
2/9/97	Nil
3/9/97	1 minute 10 sec.
4/9/97	42 seconds
5/9/97	2 minute
6/9/97	2.40
7/9/97	4 minutes
8/9/97	3 "
9/9/97	2 "
10/9/97	3 "
11/9/97	3 "
12/9/97	6 "
13/9/97	3 "
14/9/97	5 "
15/9/97	5 "
16/9/97	5 "
18/9/97	5 "
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30/9/97	3 "
31/9/97	2 "
1/10/97	2 "
2/10/97	6 "
3/10/97	3 "
4/10/97	3 "
5/10/97	4 "
6/10/97	4 "
7/10/97	3 "
8/10/97	3 "
9/10/97	3 "
10/10/97	3 "
11/10/97	3 "
12/10/97	4 "
13/10/97	3 "
14/10/97	4 "
15/10/97	3 "

A proposal for the provision of biogas plants at Rofia and Zamare along the Lake Kainji Basin.

The use of the barrier (boom) to trap the water hyacinth mats as they flow into the Lake Kainji has provided water hyacinth which are easily harvestable and therefore available for biogas production. Below are costing for the construction of a portable floating gas holder which is for demonstration only (Table 3 and Fig1) and $4m^3$ fixed –Dome digester which is recommended for Rofia and Zamare (Table 4 and Fig. 2)

Costing

Tables 3 and 4 show costing for the construction of the Portable floating gas holder biogas Plant (for demonstration only) and construction of 4m3 fixed-Dome digester respectively. The prices are ex New Bussa and are due to change with time.

Table 3:Materials and Labour for the Construction of a Portable Floating Gas Holder Biogas Plant (For Demonstration Only)

	Materials	Quality	Unit Cost	Total Cost
A				
1.	18 guage Galvanised steel sheet	3 sheets	2,000	6,000.00
2.	½ steel G.I. pipe	1 length	500	500.00
3.	1" G.I. Pipe	1 "	750	750.00
4.	¾ " flat bar	1 "	150	150.00
5.	¾ " gate valve	1 "	600	600.00
6.	¾" nipple and socket	1 set	800	800.00
7.	Gas control valve (1/2")	2 Nos	850	1,700.00
8.	3" G.I.plug	3 "	100	300.00
9.	2" G.I. Socket	3 "	100	300.00
10.	10mm dia steel rod	1 length	300	300.00
11.	Eazec cooker gas stove	1 No.	5,000	5,000.00
12.	½" elbow	2 No	50	100.00
13.	¾" elbow	2 "	50	100.00
B.	Labour			16,600.00
	Sheet metal cutting and welding expenses.			5,000.00
C.	5% Contingency			1,080.00
D.	Consultancy			20,000.00
E.	Total.			**₦42,680.00**

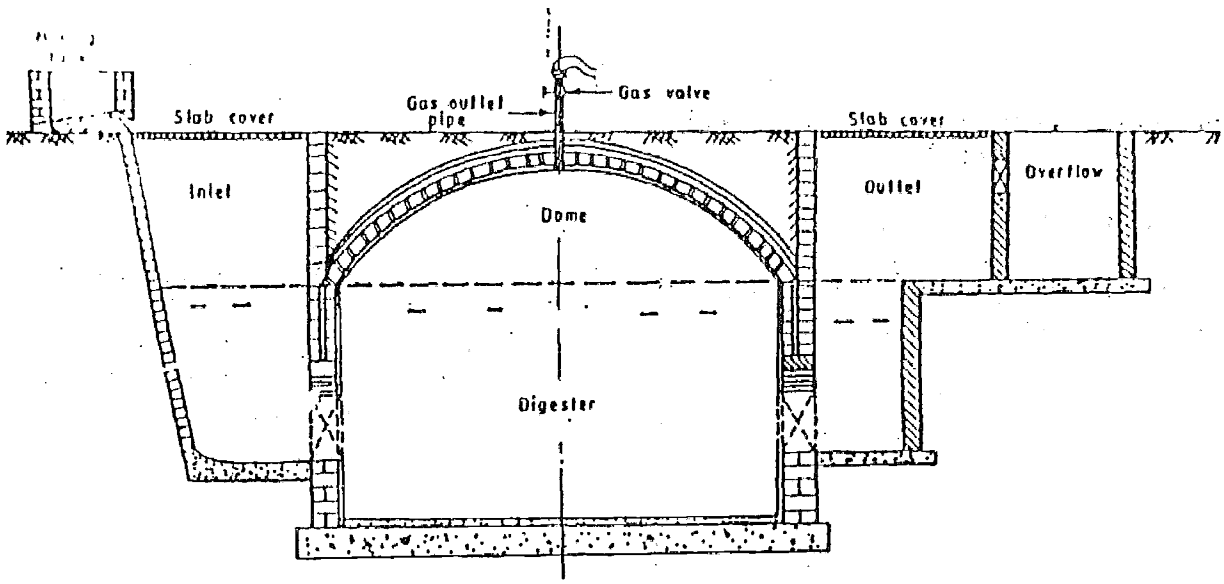

FIG.2(a) Fixed-dome type biogas plant

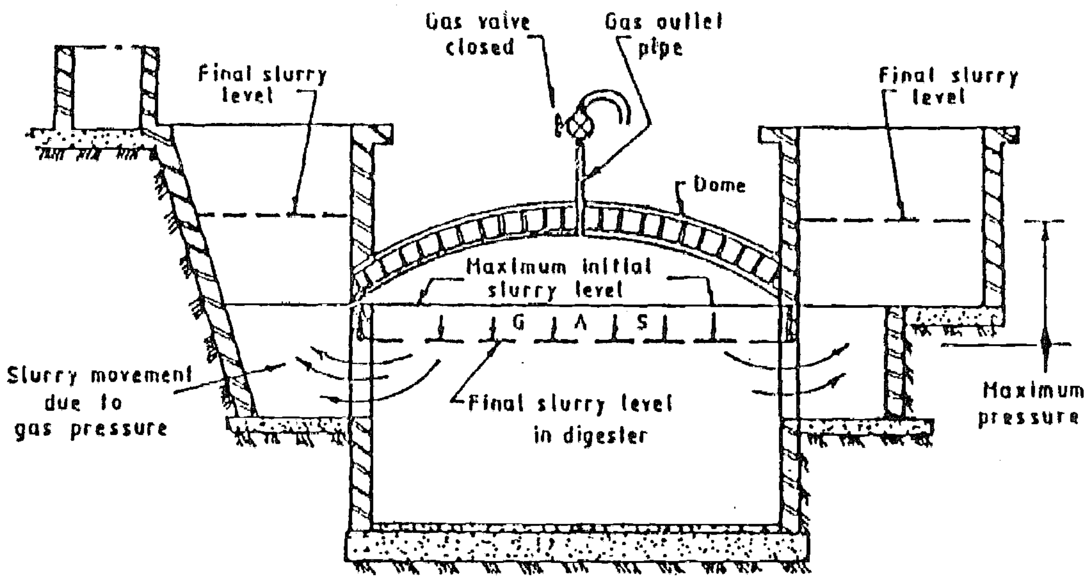

FIG.2(b) Working principle of fixed-dome type biogas plant

Table 4: Materials and labour for the construction of $4m^3$ fixed-dome digester.

S/No.	Materials	Quality	Unit Cost	Total Cost.
1.	46x22x12cm Cement blocks	150	35	5,250.00
2.	25x12x6cm Burnt bricks	200	25	5,000.00
3.	Cement (50kg)	20	600	12,000.00
4.	Sand $3.5m^3$ tipper	2	1,200	2,400.00
5.	Gravel $4m^3$ tipper	1	2,000	2,000.00
6.	PVC or Asbestos pipe (for inlet and outlet) full length % 20cm	2	3,000	6,000.00
7.	Steel rod (8mm diameter 9mm length)	2	700	1,400.00
8.	3/4" G.I.Pipe-full length.	1	600	600.00
9.	½" G.I. pipe full length	1	500	500.00
10.	Gas control valve	2	1,850	3,700.00
11.	Rubber hose for gas piping	-	1,400	1,400.00
12.	6" Paint brush	2	200	400.00
13.	4" " "	2	150	300.00
14.	Wire gauze for sieving sand	3	200	600.00
15.	2" x 12" x 12" wooden plank.	4	400	1,600.00
16.	3" nails	1kg	50	50.00
17.	Hacksaw blade	2	100	200.00
18.	6" G.I. Socket and plug	1	700	700.00

Table 4 (contd.)

S/No.	Materials	Quality	Unit Cost	Total Cost.
19.	3/4" Socket	3	35	105.00
20.	Biogas burner (2 way type)	1	5000	5,000.00
A.	Sub-Total for materials			49,375.00
	Labour			
21.	Site clearing and pits excavation	4 labourers working for 30 days from 8am – 5pm i.e. 300 x 3 x 4	300 per day per person	36,000.00
22.	Plant body construction	2 Masons for 7 days	500 per mason per day i.e. 500 x2x7	7,000.00
23	"	2 labourers x 7	200x2x7	2,800.00
B	Sub Total			45,800.00
C	Total for labour A & B			78,305.00
	5% contingency			3,915.25
D.	Grand total for materials, labour and variation			82,220.25
E.	Subsistence for Supervisors	Number of days	Rate	Amount.
S/No.	Category of staff days			
1.	2 Senior staff	14 days from the date work commence	2,500 per day x2x7	70,000.00
2.	1 Junior staff	"	1,500 per day x2x7	42,000.00
				112,000.00
F.	Transportation (2 trips)			40,000.00
G.	Honorarium or Consultancy charges			50,000.00
	Grand total D + E + F + G			₦244,220.25

CONCLUSION

Biogas can be produced from water hyacinth. The rate of production will depend on many factors including the size of the digester and the degree of dryness of the material. The use of the fixed dome type is recommended. The water hyacinth should be dried before use and seeding with cow manure will increase production.

Biogas can be used in the household, community farm or industry for:

(i) Heating, cooking and lighting using domestic biogas stoves and lamps.

(ii) Electricity generation in rural areas using internal combustion engines, which can be used for irrigation, lifting and pumping portable water, threshing, feed processing etc.

(iii) Agricultural production such as drying of crops, hatching eggs, grain storage, production of biomanure which can be used as fertilizers in farms and ponds etc.

(iv) Smoking or drying of fish by fish processors using the KainjiGas kiln.

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