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Comparative Economic Assessment of Methane Gas and Liquefied Petroleum Gas (A Community Research Initiative for Patani, Delta State)

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ABSTRACT: The paper presents a research on comparative economic assessment of methane gas and Liquefied Petroleum gas through blending of water hyacinth and poultry dropping by anaerobic digestion in a digester for effective production of biogas. The study was done in a batch feed digester, attempts were made to reach an optimum condition to produce maximum amount of gas at temperature 35^0C, pH value 6 – 7 and retention time 10 - 60 days. A fixed dome digester with a volume of $15m^3$ was designed for a family of seven in Patani LGA, to produce methane gas as a result of the dwindling supply of fossil fuels such as oil and natural gas. With a daily supply of 51kg feedstock over a period of 40 days the digester produced $1.02m^3$ / day of biogas (0.7kg biogas/day). The result of the economic evaluation of this digester showed that the cost of $1m^3$ biogas is N 6,645.9 Therefore a volume of $0.0247m^3$ will cost N 164.15 as against the current price of butane gas of same volume that is sold for about N 4,000.00. This implies that the sum of N 3,835.85 is saved which led to the economic decision that biogas is cheaper, affordable, renewable and readily available source of energy for rural community dwellers. The livelihood Improvement Family Enterprises-Niger Delta (LIFE-ND) project funded by International Fund for Agricultural Development (IFAD) adopted the economic analysis and costing to be used for the demonstration and promotion of the biogas digester.

KEY WORDS : Methane Gas, Economic Analysis, Biodigester

I.INTRODUCTION

The availability of energy and its consumption is a requirement for the socio-economic development of a country. The non-renewable sources of energy are finite e.g. coal, natural gas, firewood etc. while the renewable ones are not finite e.g. solar energy, hydro-electric, wind, tidal powers, organic wastes from animal and human wastes, and aquatic plants like water hyacinth. Energy deposits are continuously depleted by withdrawals in the non-renewable energy source, whereas in the renewable energy source, energy is being deposited every day. Because of this continuous depletion in the natural resources by an increased consumption of energy, alternatives to fossil fuels have to be searched out. Therefore, an alternative source of energy that is cheap and renewable has to be made available to the rural populace of this country. This source is no other than bioenergy from BIOMASS

There is an urgent need to safeguard the resources base and improve the quality of life, and way of achieving it is the production of biogas from agricultural waste, and water hyacinth through anaerobic digestion that is applied in a biogas plant. This can result to sustainable benefit at small-scale levels like in individual households, farm levels or rural communities (both upland and riverine).

A biogas plant (biodigester) is a gas (air) tight completely sealed tank made of steel, concrete, brick or plastic physical structure that provides an anaerobic condition which stimulates various chemical and micro-biological reactions resulting in the decomposition of input slurries and the production of biogas (Chawla, 1986). Since various chemical and microbiological reactions take place in the biodigester, it is also known as bio-reactor or anaerobic reactor. Construction of this structure forms a major part of the investment cost (Singh et al., 1987). All engineering projects involve investment of capital for a period of time for such duration that the effect of time on the capital must be considered. Capital is a dynamic and productive factor in business (Canada and Degarmo 1973).

II. SIGNIFICANCE

The paper mainly focuses on co- digesting water hyacinth and poultry droppings which is a potential source of energy that if properly harnessed will provide energy to the rural populace of Patani community where the weed and poultry droppings are in abundance, that have little or no access to cooking gas, but are dependent on firewood to meet their cooking need. The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses the future study and Conclusion.

III. LITERATURE SURVEY

Biogas is an odourless, colourless and combustible gas produced when organic matter is degraded or fermented in the absence of oxygen and air in certain temperature ranges moisture content and acidities by anaerobic microbes through a process known as anaerobic digestion. Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650^0C to 750^0C. It burns with blue flame similar to that of LPG gas (Njogu et al. 2015). Its calorific value is $20MJ/m^3$ and burns with 60% efficiency in conventional stove. It is best used directly for cooking/heating, lighting or even absorption refrigeration rather than the complication and energy waste of trying to make electricity from biogas.

The relative percentage of the gases that biogas is composed ofare Methane(50-70%), Carbon dioxide(30-40%), Hydrogen(5-10%), Nitrogen(1-2%), Water Vapour(0.3%) and hydrogen Sulphide(traces)Yadav and Hesse, 1981. Anaerobic digestion is the most flexible biomass conversion option for biogas production. It is essentially a multi-step process of differential reaction processes, which is accomplished by a consortium of microorganisms (Pavlostathis and Giraldo-Gomez, 1991). It consists of three stages (Gray, 1989) which are Hydrolysis, Acid formation and Methane formation.

There are many facilitating and inhibiting factors that play their role in the process of anaerobic digestion/gas yield. These parameters are divided into two parts namely the environmental factors and the operational factors. The environmental factors include:

(a) Temperature: The temperature range for anaerobic digestion is divided into three classes. The temperature ranges are:
   (i) Psychrophilic 5-25^0C, (optimum temp = 10^0C)
   (ii) Mesophilic, 25 – 38^0C, (optimum temp = 35^0C)
   (iii) Thermophilic, 50 –70^0C, (optimum temp = 55^0C)

As observed by Gray (1989), usually, anaerobic factors are operated under mesophilic conditions with an optimum temperature of 35^0C.

(b) pH Value: This is the degree of acidity or basicity of a solution. The bacteria which provide these anaerobic processes are particularly sensitive to pH. A pH value near neutral is the optimum for anaerobic digestion, and below 6.8 methanogenic activity is inhibited and gas generation drops, this is often the result of overloading.

(c.) Nutrient Concentration:One factor to reach an efficient process is to ensure steady Carbon/Nitrogen (C/N) ratios.

The operational factors contributing to the gas production process include: Raw Material, Retention Time, Slurry Concentration, Seeding, Mixing And Stirring and Loading Rateetc

IV. METHODOLOGY

Experimentation site: Patani is a local government Area in Delta State, Nigeria. Its headquaters is Patani town with area of $217km^2$ (Figures 1 and 2.). Its geographical Coordinates is 5^0 14′ 0″ North, 6^0 12′ 0″East. The rural dwellers engage majorly in fishing and the community has over forty (40) poultry farmers that discharge poultry droppings into its river.

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Figure 1.0: Google Map of Delta State showing Forcados Rivers Patani
(Source: Google map2019)

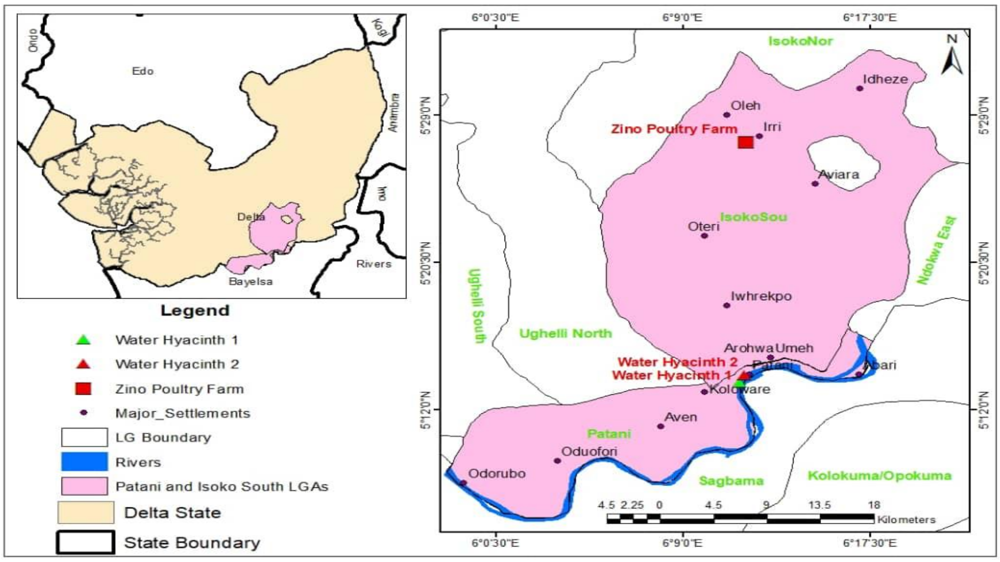

Figure 2: Location Map and sampling point of study area.

Experimental Design

Experiment was carried out to determine the production rate of biogas from a blend mix of water hyacinth, poultry droppings (inoculums) and water

A mixture made of 50gm of chopped water hyacinth mixed with 250ml of water as little as 0.6ml of freshly prepared poultry dropping at moisture content of 70% was placed in a flask equipped with rubber stoppers and a plastic hose. The 1000ml container was filled with water and inverted into a glass basin filled to half its total volume with water. A manometer was placed at the top of the inverted base of the container to indicate how much gas is being generated. A hose was inserted into each container and the volume of biogas produced was recorded over duration of 40 days. Production-rate readings were taken at intervals of 5-day period. The flask (digester) was kept in an air thermostat to maintain temperature at 30°C.. A schematic of the laboratory apparatus used in conducting the experiment is shown in Figure 3.

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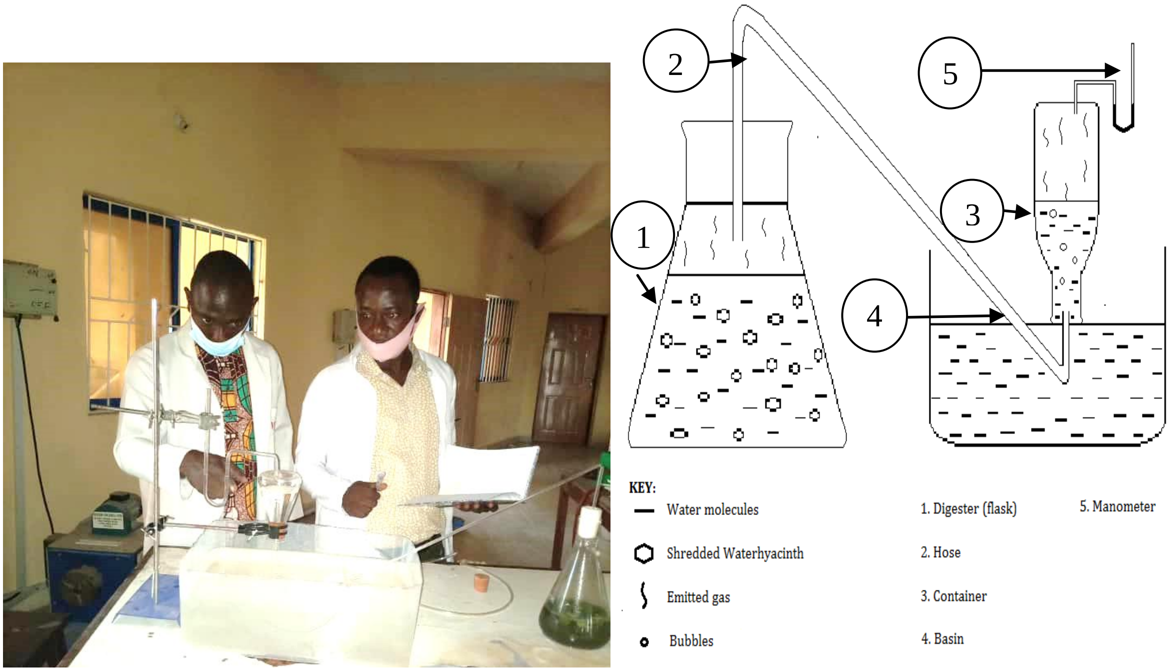

Figure 3: Experimental set up for demonstration of Gas evolution

V. EXPERIMENTAL RESULTS

Result of the experiment is show in Figure 4.

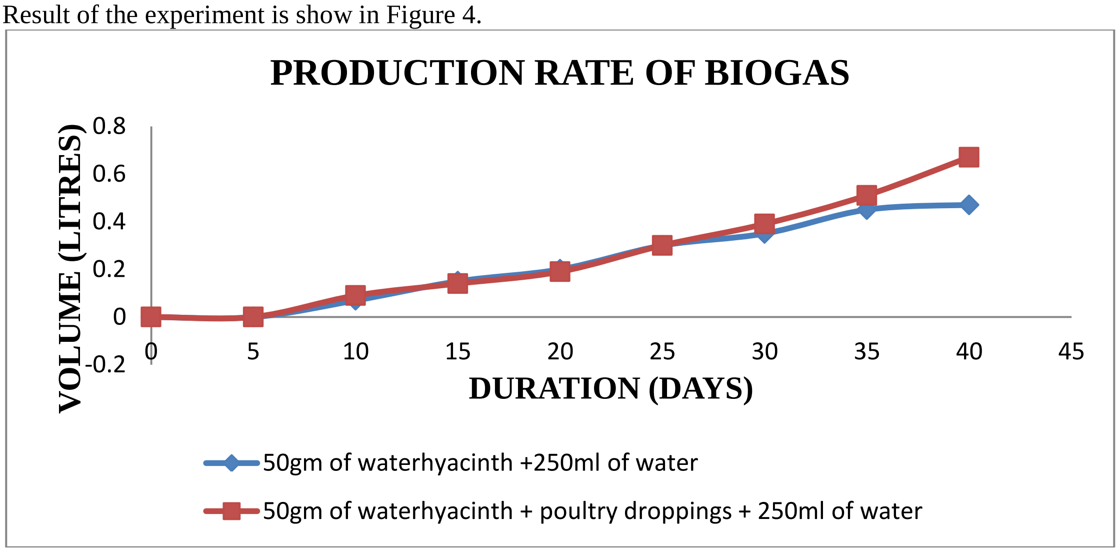

Figure 4. Effect of addition of poultry droppings (inoculums) + 250ml of water

The individual volumes for both experiments were obtained from the relationship

i. Pressure, density, acceleration due to gravity and height which is expressed as;

$$P = \rho g h \quad (1)$$

Where:

P = pressure measured in Pascals

ρ= density of mercury taken as 13600kg/m^3

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h = height measured in meters

ii. Ideal-gas equation which is expressed as;

$PV = nRT$ (2)

Where:

P = pressure measured in Pascals

V = volume measured in m^3

n = number of moles

R = universal gas constant, taken as 8.314 $JK^{-1}mole^{-1}$

T = temperature in Kelvin

From experiment conducted, 0.67m^3 of gas was obtained from a mix of 50gm of chopped water hyacinth, 250ml of water and 0.6ml of freshly prepared poultry droppings over a duration of 40 days. The Ortolani's model was used to size the cylindrical shaped biogas digester for volume and Geometrical dimension as show in Figure 5 and Table 1

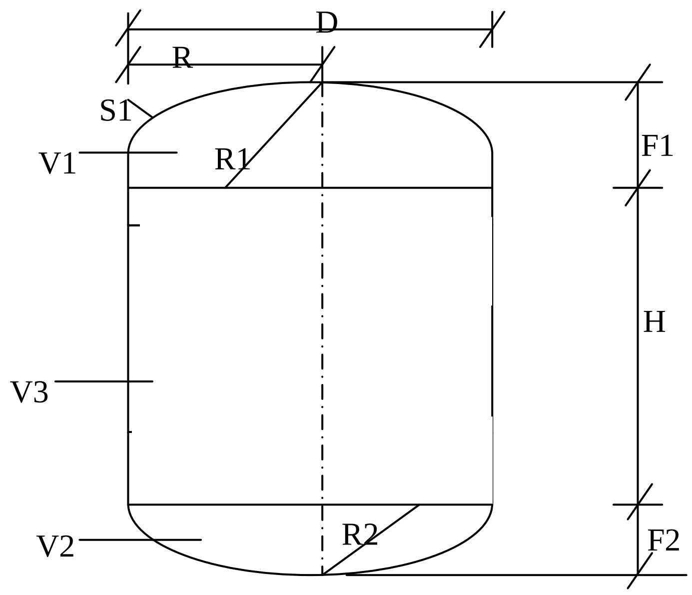

Figure 5: Geometrical dimension of the cylindrical shaped biogas digesters
(Source: Ortolani et al 1991)

V_c = Volume of gas collection chamber

V_{gs} = Volume of gas storage chamber

V_f = Volume of fermented chambers

V_h = Volume of hydraulic chamber (Outlet pit)

V_s = Volume of sludge layer

Total Volume of Digester $V = V_c + V_{gs} + V_f + V_s$

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Table 1: Dimensioning values for fixed dome digester

For Volume	For Geometrical dimension
$V_c \leq 5\%\ V$ $V_s \leq 15\%\ V$ $V_{gs} + V_f = 80\%V$ $V_{gs} = V_H$ $V_{gs} = 0.5\ (V_{gs} + V_f + V_c)\ k$ Where k = gas production rate per m^3 digester volume per day for tropical countries $k = 0.4\ m^3/m^3d$	$D = 1.3078 \times V^{1/3}$ $V_1 = 0.08270D^3$ $V_2 = 0.05011D^3$ $V_3 = 0.3142D^3$ $R_1 = 0.725D$ $R_2 = 1.0625D$ $F_1 = D/5$ $F_2 = D/8$ $S_1 = 0.911D^2$ $S_2 = 0.8345D^2$

(Source: Ortolani et al 1991)

Therefore, Xm^3 of gas is produced in 1 day

$X = \frac{(0.67m^3\ x\ 1\ day)}{40\ days}$ ∴ $X = 0.017m^3 \approx 0.02m^3$

(i) Estimation of Family Requirement per Day

Converting $0.02m^3$ to litres

We have that; $1m^3$ = 1000litres

$0.02m^3 = 0.02\ x\ 1000 = 20\ litres$

Now a peasant farmer requires 4000 to 5000 litres per month. Taking an average:

A peasant farmer requirement = $\frac{(4000+5000)}{2} = 4{,}500\ litres\ per\ month$

Therefore, for a family of seven persons we have:

$A\ peasant\ farmer\ requirement$ x 7 = $4500\ x\ 7 = 31{,}500\ litres\ per\ month$

Family requirement per day:

1 month = 31 days

Family requirement for 1 month = $\frac{31{,}500\ litres}{31\ days}$ = 1016.129 litres

(ii) Determination of the Mass of Water hyacinth required to produce desired Volume

Gas production rate from experiment per day = 20 litres/kg

Mass of water hyacinth required to produce the volume of gas required for a family of seven is $= \frac{Family\ requirement\ per\ day}{Gas\ production\ per\ day} = \frac{1016.129\ litres}{20\ litres/kg} = 50.81kg,\ say\ 51kg$

(iii.) Volume occupied in the digester by the water hyacinth

According to (Van Buren, et al 1979), $1m^3$ of biogas can serve one of the following purposes:

(a) Cooking 3 meals for a family of 5 – 7 persons

(b) Lighting an equivalent of 60-100 watt bulbs for 6 hours

Density of chopped water hyacinth = $670kg/m^3$

Mass of chopped water hyacinth used= 51kg

From formula;

$$Volume = \frac{Mass}{Density} \quad (3)$$

$$Volume\ occupied\ by\ water\ hyacinth = \frac{Mass\ of\ chopped\ water\ hyacinth}{density\ of\ chopped\ water\ hyacinth} \quad (4)$$

$$= \frac{51kg}{670kg/m^3} = 0.076m^3$$

(iv) Volume occupied by water in the digester

For a 1:5 mix ratio of water hyacinth to water

$$Volume\ of\ water\ used\ = 5\ x\ 0.076 =\ 0.38m^3$$

(v) Volume occupied by poultry dropping (Inoculum)

Since 50gm of water hyacinth required 0.6ml of inoculums

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$$Density\ of\ poultry\ droppings = 0.1gm/cm^3$$

51kg of water hyacinth would require;

$$\frac{(51\ x\ 0.6\ x\ 1000)}{50} = 612ml = 0.0612kg$$

(vi.) Estimation of Volume of feedstock for the digester
By conversion, 1ml = 10^{-3}litres
$612ml = 612\ x\ 10^{-3} = 0.612\ litres$
Also as earlier stated,
$1m^3$ = 1000litres
Ym^3 = 0.612 litres
$Y = \frac{0.612\ litres}{1000\ litres} = 0.000612m^3$
$total\ volume\ of\ feedstock\ used = chopped\ waterhyacinth + water + poultry\ dropping$
$= 0.075 + 0.375 + 0.000612 = 0.450612m^3\ \ say\ 0.5m^3$
Thus $0.5m^3$ of feedstock will produce $1m^3$ of biogas
(vii.) Volume of digester requirement
The volume of a digester should be at least 30 times the volume of the daily input.
So taking 30, $volume\ of\ digester, V = 30\ x\ 0.5m^3 = 15m^3$
DIMENSIONED DIGESTER
(a) Volume Determination
From Table 1
$V_c\ \leq 5\%V$
$5\%\ x\ 15 = 0.75m^3$
$V_s\ \leq 15\%V$
$V_{gs} +\ V_f = 80\%V$
$80\%\ x\ 15 = 12m^3$
$V_{gs} +\ V_f =\ 12m^3$
$V_{gs} = 0.5(V_{gs} +\ V_f + V_c)k$
$0.5(12 + 1)0.4$ where $V_{gs} + V_f =\ 12m^3$ and k = 0.4
$V_{gs} = 2.6m^3$
Since $V_{gs} = V_h$
$V_h =\ 2.6m^3$
(b) Geometeric Dimensioning
Also from table 3.1 the geometric dimensions for the digester is calculated as follows:
Diameter $D = 1.3078\ \ x\,V^{1/3} =\ 1.3078\ \ x\ 15^{1/3} =\ \ 3.23$m
$V_1\ =\ 0.08270\ D^3 =\ 0.08270\ x\ \ 3.23^3\ = 2.79m^3$
$V_2\ =\ 0.05011\ D^3 =\ 0.05011\ x\ \ 3.23^3\ = 1.69m^3$
$V_3\ =\ 0.3142\ D^3 =\ 0.3142\ x\ \ 3.23^3\ = 10.58m^3$
Also, $V_3 =\ \pi D^2H/4$ Where Volume of cylinder = $\pi D^2H/4$
Equating both for expression V_3

$$0.3142\ D^3 =\ \pi D^2H/4$$

$H = \frac{4\ x\ 0.3142\ x\ 3.23^3}{3.142\ x\ \ 3.23^3} = 1.29m$ where $\pi\ =\ 3.142$ and $D\ =\ 3.23$
Thus $D\ =\ 3.23m\ \&\ H\ =\ 1.29m$
Solving for F_1, F_2, R_1& R_2
$F_1 = {}^{D}/_{5} = {}^{3.23}/_{5} = 0.65m$
$F_2 = {}^{D}/_{8} = {}^{3.23}/_{8} = 0.4m$
$R_1 =\ 0.725D = 0.725\ x\ 3.23 = 2.34m$
$R_2 =\ 1.0625D\ = 1.0625\ x\ 3.23 = 3.43$

The designed digesters are shown in Figures 6 and 7

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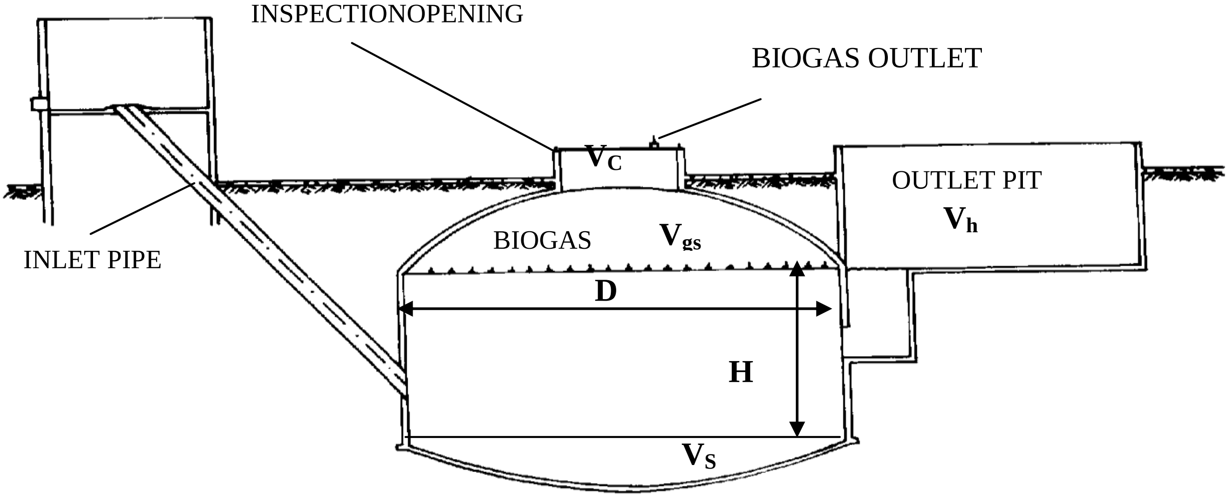

Figure 6: Anaerobic digester

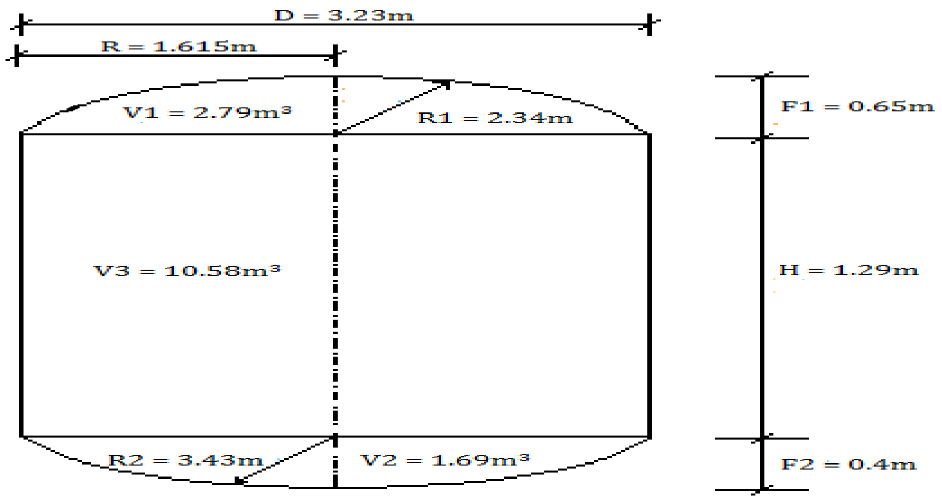

Figure 7: Designed Prototype Digester

ECONOMIC EVALUATION OF BIOGAS PRODUCTION

To determine the economic viability of biogas system and to evaluate the ability of the technology to comply with Nigerian environmental (air and water) regulations, an economic analysis of the project is carried out. To know the cost of $1m^3$ biogas, the economic analysis and cash flow are applied on the digester of the calculated design volume. (Leland and Anthony 1998). The cash flow of a fixed dome digester is show in Figure 8

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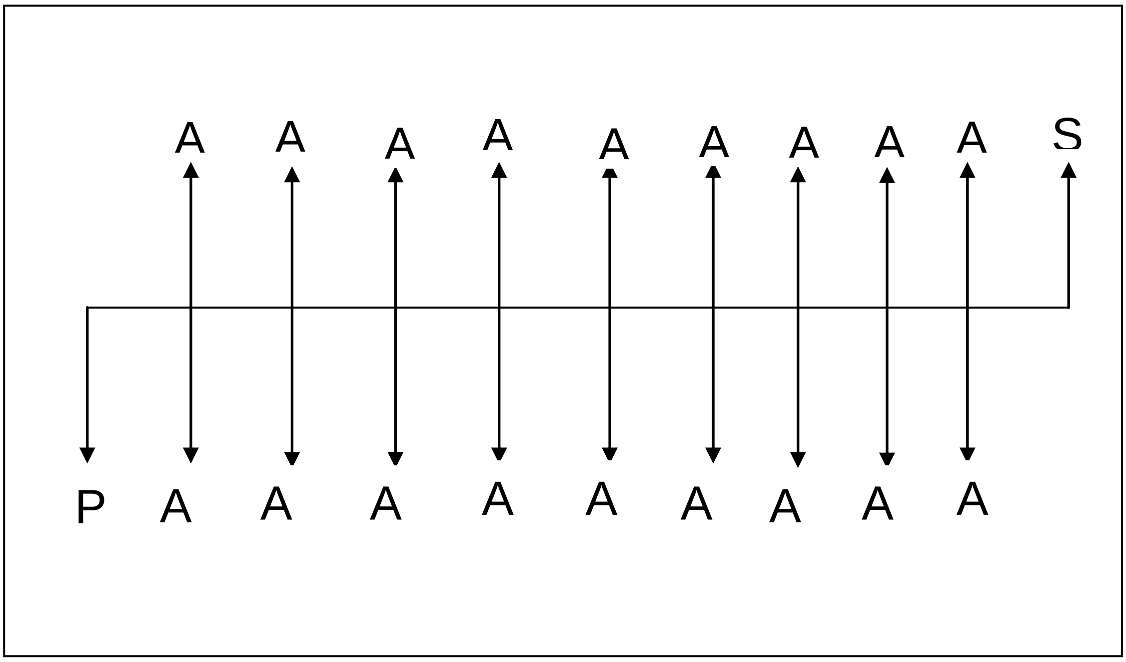

Figure 8: Cash flow of fixed dome digester in Nigeria
(Source: Leland and Anthony 1998)

(i) Capital cost (P) = N 400,000.00 (Medyan A. M. H., 2004, LIFE-ND Budget 2021).
Annual income value (A) = cost of biogas + cost of fertilizer + cost of slurry liquid
Running cost = (A1) , Salvage value (S = F) = 0, Life time in years (n) = 20 years
Interest rate (i) = 5% (CBN March 1st, 2020)
(ii.) Estimation of organic fertilizer produced
Volume of daily fertilizer produced = volume of daily waste fed (Medyan A. M. H., 2004).
Volume of daily fertilizer production = 76L of water hyacinth and poultry droppings/day
Yearly fertilizer produced = 24320L/year = 24.32ton/year i.e. Mondays to Saturdays
The manufactured fertilizer of the lowest price available in the local markets is N.P.K fertilizer which is sold to the farmer at about N 5,000/bag of 50 kg (*Vanguard April 15, 2020*) to cushion the effect of the Covid-19 pandemic on farmers
Assuming that each ton of the digested organic waste (organic matter got out of the digester) will be sold for 30 % of N.P.K. price, then the price of 1 ton of the digested organic waste = 30% x 5,000.00 = N 1,500.00/bag of 50kg (0.05ton). Therefore 1ton = N 30,000.00
Therefore; the investment for organic fertilizer from biogas plant:-
= N 30,000.00 x 24.32ton = N 729,600.00/year
(iii.) Running Cost
A1= annual cost of digester maintenance + running cost of labours salary + running cost of water hyacinth + running cost of feedstock + running cost of water.
Digester maintenance = N 12,000.00/year = (10% from digester cost) (Medyan A.M.H, 2004).
Labours salaries = N 360,000.00/year (2 unskilled workers @ 15,000.00/month)
Cost of collecting and shredding of water hyacinth=
=18,616kg/year @ 150.00/kg = N 2,792,400.00/year
Feedstock feeding cost will be calculated as follows:
22.34kg/year of feedstock @ 100.00/kg = N 2,234.00/year
Cost of water used will be calculated as follows:
138,700litres @ N10.00/20litres = N 69,350.00/year
Total cost for feeding (Water hyacinth + poultry droppings + water)
= N 2,863,984.00/year
A1 = labour salaries + digester maintenance + cost for feeding

A1 = N 360,000.00 + 12,000.00 + 2,863,984.00 = N 3,235,984.00/year

(iv.) Cash Flow Result

$$F = P\left(\frac{F}{Pi}, n\right) - A1\left(\frac{F}{Ai}, n\right) + A\left(\frac{F}{Ai}, n\right) = 0 \ (Leland, P.E, et\ al, 1998) \quad (5)$$

This equation comes from future worth analysis where the factors are

$\frac{F}{Pi}, n$ = called the single payment compound amount and come from the formula of

$$F = P(1+i)^n \quad (6)$$

$\frac{F}{Ai}, n$ = called the uniform-series compound amount and come from the formula of:

$$F = A\left\{\frac{((1+i)^n - 1)}{i}\right\} \quad (7)$$

P = 400,000, i = 5%, and n = 20 years therefore,

$$F = P(1+i)^n \quad (8)$$

$(1+0.05)^{20} = 2.6533$

$$F = A\left\{\frac{((1+i)^n - 1)}{i}\right\}$$

Given A1 = 3,235,984.00

$$\frac{((1+i)^n - 1)}{i} = \frac{((1+0.05)^{20} - 1)}{0.05} = 33.066$$

Using the above calculation in the future worth analysis becomes:

$0 = (400{,}000\ x\ 2.6533) - (3{,}235{,}984\ x\ 33.066) + (A\ x\ 33.066)$

$A =$ N $3{,}203{,}886.981/year$

Biogas cost =3,203,886.981 – 729,600 = N 2,474,286.981/year this is the cost of yearly biogas production from 500L digester feed (1.02m^3 biogas/day)

The cost of 372.30m^3/year biogas = N 2,474,286.981/year

Then; the cost of 1m^3 biogas = N 6,645.9

Therefore a 12kg cylinder with a volume of 0.0247m^3 will cost N 164.15 as against the current price of butane gas of same volume that is sold for about N 4,000.00. This implies that the sum of N 3,835.85 is saved.

VI.CONCLUSION AND FUTURE WORK

The use of biogas technology improves the standard of living and can contribute to the economic and social development of rural dwellers. Biogas saves the sum of N 3,835.85 per 12kg LPG cylinder. This implies that rural poverty will be reduced drastically to the barest minimum with the use of biogas

REFERENCES

[1] Chawla, O,PAdvances in Biogas Technology. New Delhi, Indian Council Of Agricultural Research.. 1986.

[2] Canada, J., R and Degarmo, E., P. *Engineering Economy*, 5th Edition, MacmillianPublishing Company, Inc. New York.1973.

[3] Fulford, D. Running a Biogas Programme: A Handbook, London, Intermidiate Technology publications..1988.

[4] Leland, P. E. and Anthony, P. E. Engineering Economy, 8th Edition. McGraw Hill Education pp. 133 – 1401998.

[5]Medyan, A. M. HThe Feasibility of Biogas Production from Mixed Organic Wastes in Palestinian Rural areas, Msc thesis, An Najah National University.2004.

[6] Ortolani, A. F., Benincasa, M. and Junior, J. L. Biodigestores rurais: ModelosIndiano, Chinês e Batelada. Jaboticabal: FCAV, UNESP, 351991.

[7] Singh, J. B., R. Myles, andDhussa, AManual on Deenbandhu Biogas Plant. Tata McGraw Hill Publishing Company Limited, India.. 1987.

[8] Uzochukwu, E., Nwosu, H., U. and Ajabuego, G., O. *Engineering Economy fundamentals*Printed and Published in Nigeria by Stallion press Abia State. 2014.

[9]. Van Buren, A., Ed. A Chinese biogas Plant: *Popularizing technology in the Countryside. London, Intermediate Technical Publications.* Mid-West Energy Research Centre Turning Manure Into Gold: Converting agricultural waste to energy. The Ohio Biomass energy program, Public Utilities Commission of Ohio, Columbus.1979

[10] Njogu, P., Robert, K., Purity, M., and Yusuyuki, N.). Biogas Production Using Water Hyacinth (Eichhornia Crassipes) for Electricity Generation in Kenya. Institute of Energy and Environmental Respources for the Niger Delta Region. *Journal of Sustainable Development Studies, 2. 115-137.* 2015

[11] Parlostathis, S. G., and Giraldo – Gomez, E. Critical Reviews in Environmental Control *2, (5, 6): 411-490.*1991.

[12] Yadava, L. S., and Hesse, P. R. *The Development and Use of Biogas Technology in Rural areas of Asia.* A Status Report. Improving Soil Fertility through Organic Recycling, Food and Agriculture Organization FAO and United Nations Development program UNEP.1981.

[13] Gray, N. F. *Biology of wastewater Treatment New York, NY:* Oxford University press. 1989