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Theoretical Evaluation of the Potential of Human Waste for Household Electrification

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ABSTRACT

The growing demand of electric power supply in Nigeria necessitates the integration of renewable energy resources into the country's energy mix which is in consonance with the global energy transition. This paper is an attempt to theoretically evaluate the potential of human waste (faeces) for the electrification of a modest residential building (3-bedroom flat) with six occupants. The daily electrical energy demand of the building is estimated to be 24.56 kWh while the daily electrical energy value of the biogas produced by the excreta of the six occupants is 0.4 kWh. This shows that the daily quantity of excreta of the six building occupants is inadequate to meet the daily electrical energy demand of the building. Therefore, hybrid system should be employed if the building is to be effectively electrified. Individuals and government at all levels are implored to embrace this emerging technology because of its potential of not only generating biogas for electricity generation or cooking, but also for fertilizer production, protection of the environment and mitigation of sanitation problems.

Keywords: Biogas, biomass, waste, electricity, building

INTRODUCTION

Energy is recognized as a crucial driving force for human well-being and a country's development. Human uses energy in different forms in almost every facet of their lives. Fossil based energy had indeed been very popular in Nigeria; at a point it was thought to be inexhaustible but it is now known to be untrue (Karekezi and Kithyoma, 2002; Sebitosi and Pillay, 2008). In addition to the problem of finiteness, environmental concerns also accompany the use of fossil based energy. Therefore, the situation where petrol/diesel generators run the Nigerian economy cannot be said to be sustainable to say the least.

In Nigeria today there is an increased power supply which can be attributed to the privatization of the power sector. But, the power supply is still inadequate coupled with the fact that there are many Nigerians living in remote areas that have not been connected to the grid. To ensure reliable and sustainable power supply to all Nigerians irrespective of where they live, renewable energy resources must be integrated into the country's energy mix which is in consonance with the global energy transition (Aremu et al, 2013).

Biomass is one of the emerging and promising renewable energy resources in the world today. Biogas is a gaseous fuel obtained by fermenting the biomass anaerobically. The technology of biomass production has a widespread attention because of the multifarious applications of resource.

Biogas produced by digestion of organic waste is colourless, flammable, and generally contains approximately 60 per cent methane and 40 per cent carbon dioxide, with small amounts of other gases such as hydrogen, nitrogen, and hydrogen sulphide. It has a calorific value of 20 MJ/m³ (Onojo et al, 2013). The methane content varies between 50 and 70 per cent depending on source. It has an energy content equivalent to about two-thirds that of natural gas and can be burnt, as produced in stationary engines or turbines to generate heat and mechanical or electrical energy (Rao and Parulekar, 2004).

The materials used for biogas production includes cow dung, buffalo dung, pig dung, poultry droppings, human wastes (faeces, urine and other wastes emanating from human occupation), agricultural wastes, wastes of aquatic origin (marine plants, algae, hyacinth and water weeds), and industrial wastes (sugar factory, tannery, paper, etc) (Rao and Parulekar, 2004).

Human faeces which are one of the materials used for biogas generation have a huge potential for electricity generation. Studies have shown that if all of the world's human waste were to be collected and used for biogas generation, the potential value ranges from US\$1.6 billion to 9.5 billion, the latter value being enough to offset electricity demands of over 138 million households, or roughly the number of households in Indonesia, Bangladesh and Ethiopia combined (UNICEF, 2015). The world's 7 billion people produce about 14 million tonnes of faeces every day and 25% of this has the potential power to produce roughly 40 000 MW of energy (Sujata, 2010).

Rwanda has installed 20 human waste power generating plants of 500 kW each at some of their big prisons where many thousands convicted of genocides are incarcerated (Onojo et al, 2013). Bill and Melinda GATES foundation has sponsored a project worth \$1.5 billion in Ghana for the utilization of human wastes for household power generation. The UN is also sponsoring a project for power generation from poultry wastes in Bangladesh (Sujata, 2010).

Despite the efforts made by some individuals and organizations to harness human wastes for power generation, yet the potential energy value of human wastes has been given much attention especially in developing countries like Nigeria. This paper therefore is an attempt to evaluate the potential of human waste for household electricity generation.

METHODOLOGY

A modest residential building (3-bedroom flat) is considered for this study. The building is considered to be occupied by two parents (husband and wife) and four children within the age bracket 14-22 years. The family is considered to have three square meals of balanced diets.

The electrical appliances used in the building as well as the daily estimated energy demand in *kWh/Day* of the building are presented in table 1.0.

The daily human wastes of the six occupants of the building are to be determined from the information contained in table 2.0. The daily biogas produced by the occupants that are to be converted to electrical energy in *kWh* is then determined.

The estimated daily energy demand of the building in *kWh* and the determined value of the electrical energy in *kWh* derivable from the human wastes of the occupants are to be compared.

Daily Energy Requirement of the Building

The estimated daily energy demand of the building (3-bedroom flat) is presented in Table 1.0.

Table 1.0: Estimated Daily Energy Demand of the Building

Load	Rated Power (W)	Quantity	Hour Used/Day	kW	kWh/Day
Lighting bulb	60	16	13	0.960	12.48
Ceiling fan	60	4	8	0.240	1.92
Standing fan	65	1	2	0.065	0.13
Television	180	1	8	0.180	1.44
Satellite receiver	30	1	8	0.030	0.24
DVD player	25	1	4	0.025	0.10
Radio	5	1	4	0.005	0.02
Refrigerator	260	1	4	0.260	1.04
Air conditioner	1000	1	4	1.000	4.00
Electric iron	1000	1	1	1.000	1.00
Laptop	50	1	3	0.050	0.15
Electric kettle	1200	1	2	1.200	2.40
TOTAL				5.015	24.56

Determination of Volume of Biogas produced by Occupants

The exact quantity of excreta from different animals and human beings is difficult to calculate. The quantity will depend on the age of the animal, its feed e.t.c, but the following average value taken for estimating the total excreta available for some animals are presented in table 2.0 (Rao and Parulekar, 2004).

Table 2.0: Average Quantity of Excreta per Animal	
Animal	Quantity of Excreta per Animal
Cows	10 kg per day
Chicken	0.18 kg
Bufallo	15 kg
Calves	5 kg
Horses	10 kg
Goat/sheep	5 kg
Human excreta per person	0.4 kg

Source: (Rao and Parulekar, 2004)

From table 2.0, it can be seen that human excreta per person is 0.4 kg/day, then for the six occupants of the building,

$$\begin{aligned} \text{Total quantity of excreta} &= 6 \times 0.4/\text{day} \\ &= 2.4 \text{ kg/day} \end{aligned}$$

Studies have shown that 1 kg of human excreta generates about 50 liters of biogas (WEC, 2013). This implies that:

$$\begin{aligned} \text{Volume of biogas from the six occupants} &= 2.4 \times 50 \text{ litres/day} \\ &= 120 \text{ litres/day} \\ &= 0.12 \text{ m}^3/\text{day} \end{aligned}$$

Determination of the Electrical Energy Value of Biogas

The electrical energy value of the biogas obtained from the building occupants can be determined from the following equation (Rao and Parulekar, 2004):

$$\text{Electrical energy value} = \text{Energy available from digester} \times \text{kWh conversion}$$

The energy available from digester (E) is given by the following equation (Rao and Parulekar, 2004):

$$E = \eta H_b V_b$$

Where η = combustion efficiency of burner, boiler, etc $\approx 60\%$

H_b = Heat of combustion per unit volume (caloric value) of biogas = 20 MJ/m³

V_b = volume of biogas in m³ = 0.12 m³ (determined previously)

$$\begin{aligned} \therefore E &= 0.6 \times 20 \text{ MJ/m}^3 \times 0.12 \text{ m}^3/\text{day} \\ &= 1.44 \text{ MJ/day} \end{aligned}$$

Studies have shown that the energy conversion is expressed as:

$$\begin{aligned} 1 \text{ MJ} &= \frac{1}{3.6} \text{ kWh} \\ \therefore \text{Electrical energy value} &= 1.44 \times \frac{1}{3.6} \text{ kWh} \\ &= 0.4 \text{ kWh/day} \end{aligned}$$

Number of days required for the biogas generated by the six occupants to meet the building energy demand

$$= \frac{\text{Daily electrical energy demand of the building}}{\text{Daily electrical energy generated by the occupants}}$$

$$= \frac{24.56}{0.4}$$

$$= 61.4 \text{ days } (\approx 2 \text{ months } 10 \text{ hours})$$

DISCUSSION

The total estimated daily energy demand of the modest residential building (93-bedroom flat) considered in this study is 24.56 kWh/day as shown in table 1.0. The total electrical energy that can be generated from biogas produced by the excreta of the six occupants of the building is determined to be 0.4 kWh/day . This result shows that the daily energy demand of the appliances considered cannot be met by the electrical energy value of the biogas produced by the six occupants.

A little consideration will show that the total quantity of excreta of the six occupants cannot meet the lighting requirement if 60 W bulbs are to be used. A little manipulation will show that about 369 adults are needed to produce excreta that can produce biogas of 24.56 kWh/day energy value. This of course is impractical to have 369 adults in a 3-bedroom flat consistently. Therefore, the option of using low energy consuming appliances and considering the appliances that can be powered by low capacity biogas generators should be adopted. Alternatively, if the electrical energy demand of the building is to be met, a hybrid system should be employed.

CONCLUSION AND RECOMMENDATION

The potential of human waste for the electrification of a modest residential building (3-bedroom flat) was theoretically evaluated. The study reveals that the total daily excreta of the six occupants is not enough to be utilized to electrify the modest residential building considered. However, the electrical energy generated from the biogas can be used to power some of the appliances especially the low energy consuming ones.

Individuals, organizations and government at all levels are implored to take advantage of this technology to advance development, protect the environment and help reduce sanitation problems causing one-tenth of all world illness.

REFERENCES

- Aremu, J.O; Aremu, D.A and Ibrahim, U.H. (2013): "A cost comparison of stand-alone solar PV and fuel generator for residential electrification". Proceedings of the Third International Conference on Research and Sustainable Development, Vol.3, No. 1
- Karekezi, S. and Kithyoma, W. (2002): Renewable energy strategies for rural Africa: is a PV Led renewable energy strategy the right approach for producing modern energy to the rural poor of Sub-saharan Africa. Energy Policy 30: 1071-1086.
- Onojo, O.J; Chukwudebe, G.A.; Okafor, E.N.C; Ononiwu, G.C.; Chukwuchekwa, N. Opara, R.O. and Dike, D.O (2013). "Estimation of the electric power potential of human waste using Students hostel soak-away pits". American Journal of Engineering Research. Vol.02, Issue-09, pp 198. www.ajer.or
- Rao, S. and Parulekar, B.B.(2004): Energy Technology-Nonconventional, Renewable and Conventional. Third Edition. KHANNA Publishers- NaiSarak, Delhi
- Sebitosi, A.B. and Pillay, P. (2008): Grappling with a Half-hearted Policy: The case of Renewable Energy and the Environment in South Africa, Energy Policy 36: 2513-2516.
- Sujata, G. (2010): Biogas comes from the cold, New Scientist Conference, London: Sunita Harrington pp14.
- UNICEF and WHO (2015): Progress on Sanitation and Drinking Water; 2015 update and MDG Assessment. http://www.wssinfo.org/fileadmin/user_upload/resources/Jmp_update_report_2015_English.pdf.
- World Energy Council Data (2013): Average Electricity Consumption per Electrified Household. http://www.wec_indicators.enerdata.eu/household_electricity_user.html.

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