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Quantifying Biogas Generation from Human and Biodegradable Wastes: A Case Studies of Three Estuarine Communities in Rivers State

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Abstract:- This study showed total excreta produced by 73 people (19 male adult, 19 female adult, 17 male children and 18 female children) was 18.97kg per day. Given an average household of 5, (2 adults and 3 children), 1321g (1.3kg) of feaces would be generated. Therefore, 500 households in any of the communities would generate 660,500g (660.5kg) of excreta. The cumulative volume of gas generated from 5kg of human excreta, combined with 15 kg of leftover rice; 5kg of vegetable waste and 25kg of water resulted in 0.167m^3 biogas. By extrapolation, 500 households, generating 515kg of excreta; using 1,546kg of waste rice; 515kg of vegetables waste and 2,579kg of water, can generate 83.5m^3 biogas. This quantity of biogas can power 55kw electricity generating set which can provide Community Street light for more than 6 hours. In the coastal communities of the Niger Delta where modern waste management practices are practically nonexistent, human excreta and household food wastes are discharged directly into the rivers and creeks, resulting in obnoxious effects such as foul smell, pollution and filth and even mosquito infestation. The outcome of this research has given a clear direction on how to treat domestic wastes (which in effect are resources) for bioconversion. As the world in general is changing from over reliance on fossil fuels, being wasting assets, coupled with the attendant pollution and degradation of the environment, investment into alternative energy sources such as biogas from wastes would contribute to the quest to reduce energy scarcity, guard against ecological disasters, elimination and/or control deforestation and erosion of the soil surface in particular and the environment in general. Therefore, for developing countries of Africa and especially Nigeria to surmount her current energy, environmental, food, health and unemployment crises, the anaerobic digestion of biodegradable wastes in general; excreta/household food wastes in particular should be given the attention it deserves.

Keywords:- *Human Excreta, Household Biodegradable Wastes, Coastal Communities, Anaerobic Digestion, Electricity Generation.*

I. INTRODUCTION

Manure from human beings, animals and poultry are easily biodegradable. These wastes have therefore over time, caused environmental degradation, pollution and resource depletion with dire environmental and health consequences (Ubong and Gobo, 2001). Other biodegradable materials include industrial waste like (saw dust, wastes from food processing industries); plant wastes (husk, grass, weed etc.), and domestic wastes (vegetables peels, waste food materials) Vinneras (2002). Human excreta consist of faeces and urine which are waste products of the body metabolism (Niwagaba *et al*, 2009) and consist of proteins, carbohydrates and fats. The appearance, physical and chemical characteristics of excreta depend largely on the health of the person excreting the material, as well as on the amount and type of food and liquid consumed (Lentner, *et al*., 1981; Feachem, *et al*., 1983). The only significant variation was that older people excreted larger amounts of total wet matter than the younger which could be attributed to a higher water intake to reduce the chances of constipation in the older people. The anaerobic decomposition of human excreta with kitchen wastes could be carried out in a bio-digester to produces methane gas which is a renewable energy with liquid and solid fertilizers as bi-products for organic farming, among other uses. In addition, recycling and reuse of human excreta with kitchen wastes for biogas generation is a very cost effective and natural way to get rid of health hazards associated with human excreter. Vinneras (2002) asserted that biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 – 750ºC. Biogas is a renewable and environmentally friendly energy source that will significantly promote sustainable development. Although a number of wastes from various types of anthropogenic activities have been and are being gathered, recycled and/or converted for reuse, this research specifically considered quantifying the capacity of the residents of the estuarine communities to generate enough wastes that will make the siting of biogas plant for domestic uses like heating, cooking, drying and even electricity for street lighting at night in the arears feasible. This becomes imperative when considered that the present methods of addressing the above issues have not only been detrimental to health, but have caused air pollution, deforestation, environmental degradation and therefore unsustainable.

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The objectives of this study are:

- What is the quantity of excreta (feace) excreted by children and adult per day?
- What are the quantities of household food wastes generation per day?
- What quantity of gas can be generated from mixed digestion of human excreta with household food wastes?
- Can the biogas generated in the communities justify/support the siting of biogas plants in the arears ?

II. STUDY LOCATION

The study locations fall between Latitude 4°45'N and Latitude 4°55'N, and Longitude 6°55'E and Longitude 7°05'E in Rivers State (Figure 1). The study areas which are parts of Port Harcourt and Obio/Akpor Local Government Arears of Rivers State, are predominantly estuaries, connected to several criss-crossing rivers and creeks, which empty into the Atlantic Ocean (Umenduji and Aisuebeogun (1999). According to Ede (1998), an extensive study of water quality throughout Rivers State, found that over 85% of samples contained total coliform counts above 40 coliform per 100ml, indicating feacal contamination. The extensive contamination could be attributed to the diurnal tidal cycles of these coastal communities. The population of the Port Harcourt metropolitan area (Greater Port Harcourt) according to the 2006 census was put at 1,196,788 persons made up of 610,784 males and 586,004 females (NBS, 2006). The Port Harcourt metropolitan area includes essentially three Local Government areas (LGAs) namely; Port Harcourt, Obio/Akpor and Eleme Local Government Arears LGAs. House types in Port Harcourt City range from the luxurious, posh to standard houses owned by the rich and middleclass persons to the single rooms, communal living, shanties and batchers owned by the urban poor. Some of the latter category of households use shared water closet systems on the inside, while majority use the VIP latrine systems outside their houses; particularly at the water fronts. With the VIP system, feces are passed directly into the rivers contaminating and polluting the environment while wasting valuable energy generating resource.

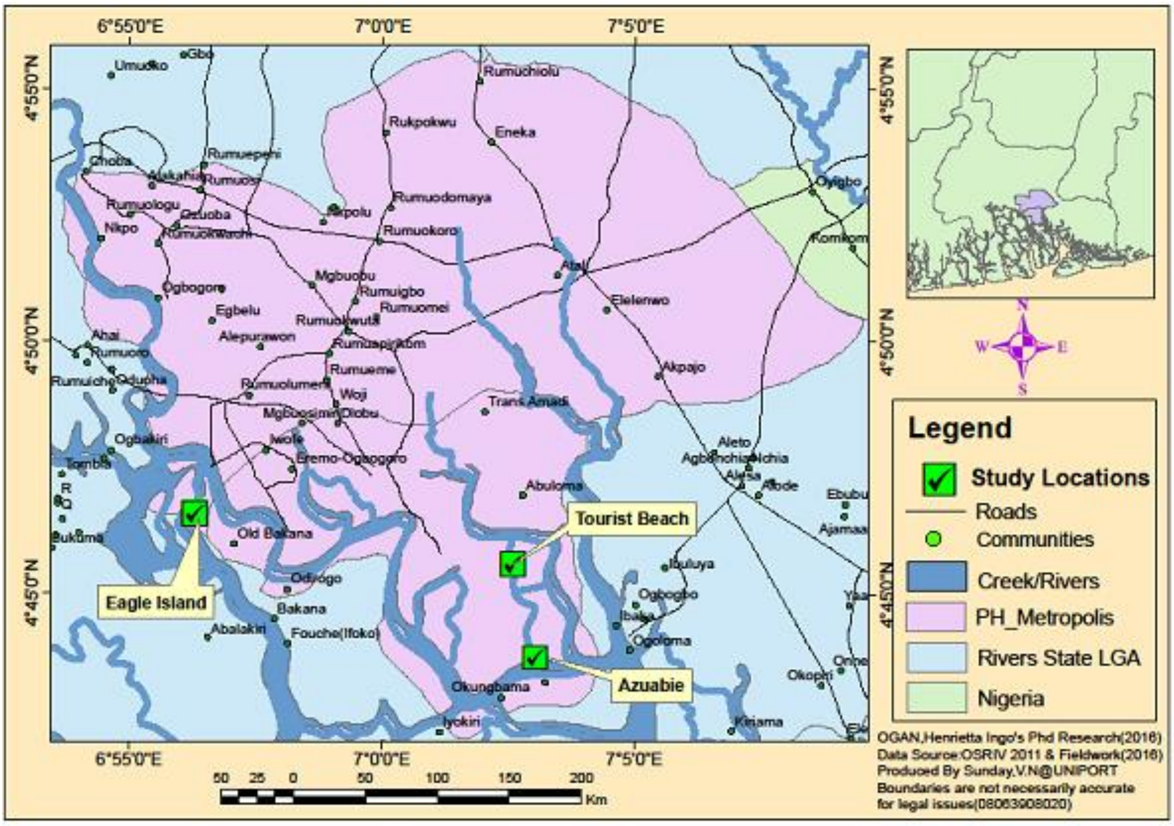

Fig 1:- Map of Port Harcourt Metropolis Showing Study Location

III. METHODS

- *Construction of Digester*

A 50-litre anaerobic digester was constructed with high density plastic material. The set up was made airtight to ensure anaerobic condition and kept in a garage to equally ensure that the normal prevailing temperature and pressure remain fairly the same throughout the period of the experiment. Dimensionally it is 42cm in diameter and 55cm in height. It was an adaptation of the Chinese fixed dome and the Dahunsi and Oranusi's (2013) models. It was designed to have two handles for easy carriage. It was fitted with a gas outlet and thermometer holder to measure the temperature in the digester. A scrubber was also constructed to filter the water vapour and other trace gases, giving off only methane gas. The methane gas produced was collected in the gas cylinder fitted with meter/pressure gage to measure the quantity of gas produced.

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➢ *Method of Collection and Digestion*

Human excreta from 8 volunteer households at the Eagle Island were collected for 4 days while rice leftovers and vegetable stems were collected from household kitchen wastes for over a period of one week. The vegetable stems were composted for 12 days and homogenized before being added into the tank, to begin the decomposition process. The food waste (rice) was equally homogenized using a blender to attain minimal particulate size suitable for easy digestion and then mixed evenly with the excreta and vegetable stem (Plate 1). Water was collected from a pig wastewater receptacle. This was because such wastewater already has methanogenic bacteria. Otherwise, we would have to seed the water with either or a combination of pig feaces and cow dung for between 28-32 days to form enough bacteria that would aid the digestion. These substrates were measured in percentage volume as follows: human excreta 10%, rice leftover 30%, and vegetable stems 10% and water 50%. The physico-chemical analyses were carried out before and after the bio-digestion process. During the 50-day experiment (from January 12, 2016 to February 21, 2016), the biogas generated was measured daily at specific time of the day (6pm) to ensure 24 hour gas production.

Plate 1: Research Assistant
Homogenizing Human Excreta with Food Waste

IV. RESULT

➢ *Weight of Excreta from Households*

Household	Male (Adult	Excreta weight (g)	Female (Adult)	Excreta weight (g)	Male (Child)	Excreta weight (g)	Female (Child)	Excreta weight (g)
1	1	301	1	387	2	411	1	222
2	3	890	1	311	3	512	3	494
3	4	1190	2	599	2	568	4	598
4	2	599	3	986	3	722	2	413
5	1	320	3	965	2	422	3	601
6	3	940	3	948	1	251	3	584
7	2	489	3	1011	2	491	1	232
8	3	888	3	991	2	433	1	201
Total	19	5617	19	6198	17	3810	18	3345
Mean		295.6		326.2		224.1		185.8

Table 1:- Quantity of Excreta (Feaces) from Sampled Households
Source: Field work, 2015.

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Table 1 shows the quantity of excrement (feaces) from the volunteer households. It is observed that the female adult pass more excreta (326.2g) per day as compared to the male counterpart (295.6g). On the other hand, the male child excretes more (224.1g) per day than their female counterpart (185.8g).

➢ *Household Solid Waste Generation*

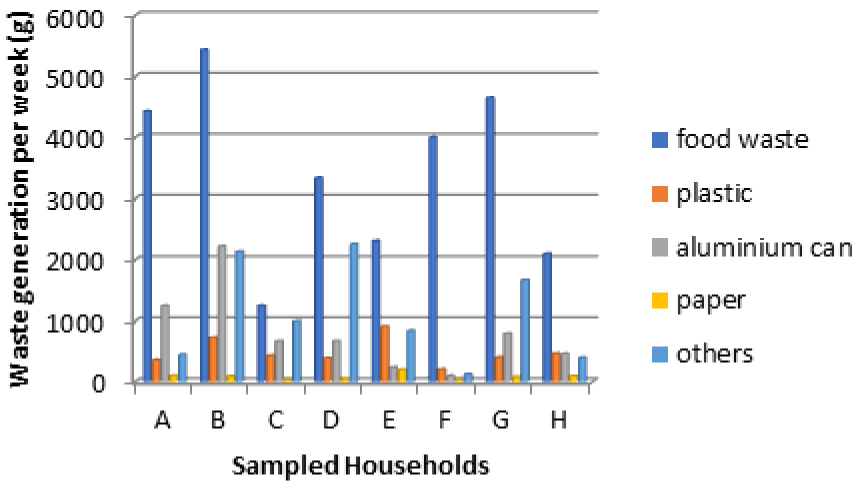

Fig 2:- Sampled Households Solid Waste Generation

Figure 2 shows the sampled households' solid waste generation per week, food waste represents 58.2%, plastic 8.2%, aluminum cans 13.5% while paper and other wastes streams represent 1.4% and 18.7% respectively.

➢ *Daily Gas Production*

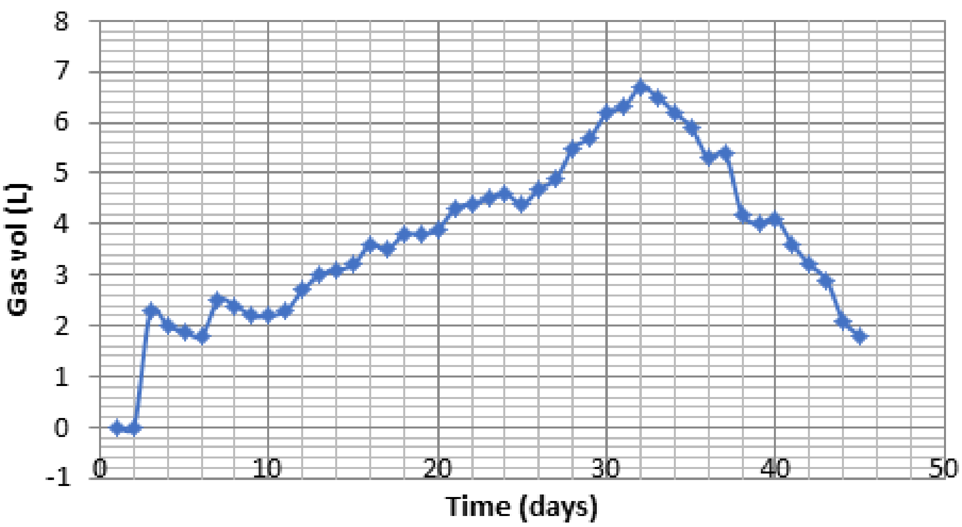

Fig 3:- Daily Gas Production

Figure 3 shows gas production started on the third day of digestion with 2.3 litres of gas and fell slightly from the fourth day until the eleventh day when it reached 2.3 litres. It steadily increased from the twelfth day reaching 2.7 litres. Thereafter, the gas production continued to increased reaching the highest production of 6.7 litres. On 32nd day the production then began to decline until it reach 1.8 litres on the last day (45th day).

➢ *Cumulative Gas Production*

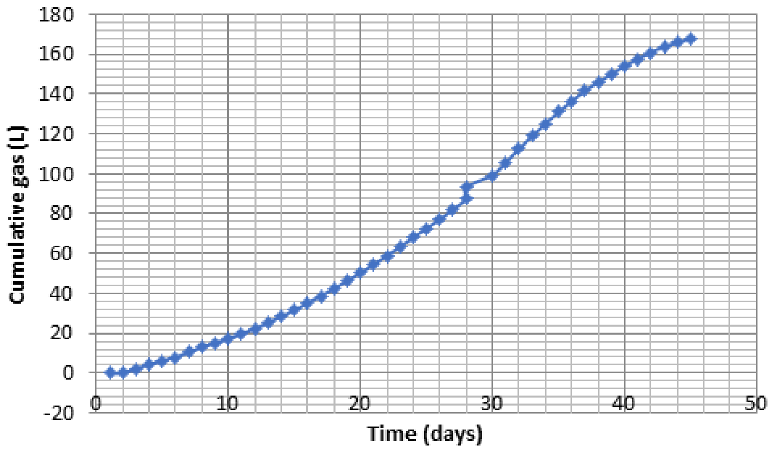

Fig 4:- Cumulative Gas Production

The graph on figure 4 showed after the third day the cumulative gas generation increased up to the forty-five day to 167.6 litres.

➢ *Ambient and Digester Temperature*

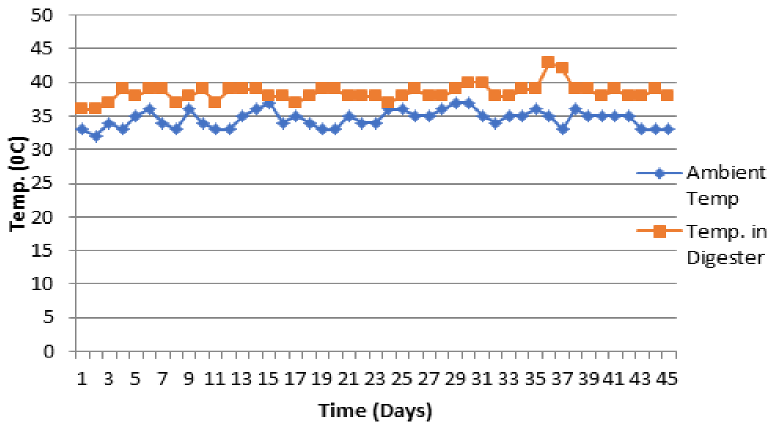

Fig 5:- Ambient and Digester Temperature

Figure 5 which shows the daily ambient and temperature of the digester, indicated the lowest ambient temperature (32ºC) was recorded on the second day of the study, while the highest ambient temperature was recorded on the twenty-eight day. In contrast, the lowest temperature of the digester was recorded on the first and second day (36ºC) while the highest (43ºC) temperature was recorded on the thirty-six day.

➢ *pH of the Feedstock in the Digester*

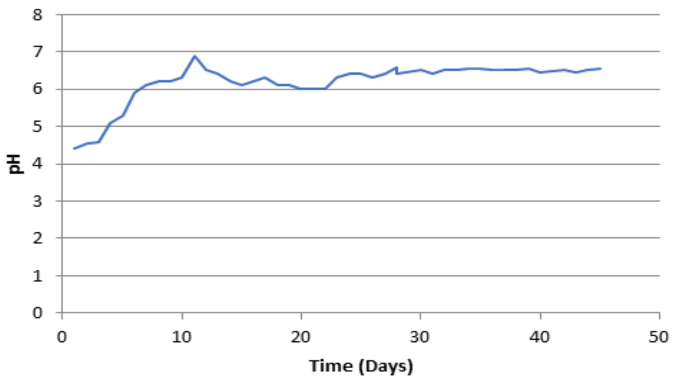

Fig 6:- pH of Feedstock in the Digester

V. DISCUSSIONS

The quantity of food wastes which is about 58.2% of household kitchen waste is consistent with the work of Ayotamuno and Gobo, 2004; and Ogbonna *et al*., 2007. The quantity of excreta recorded revealed that the female adult excrete more feaces (326.2g) per day, in comparism to the male counterpart (295.6g). On the other hand, the male child excretes more (224.1g) per day than their female counterpart (185.8g). Normal adult person produce 120-400g wet faeces/day (Schouw*et al*., 2002). Approximately 30-45kg (wet weight basis) of faeces is produced per person a year in developed countries, corresponding to 10-15kg of dry matter (Lentner, *et al*., 1981; Feachem*et al*., 1983; Schouw, *et al*., 2002; Jonsson and Vinneras, 2004; Jonsson, *et al*.,2005; Vinneras, *et al*., 2006).

Del Porto and Steinfeld, (1999) compiled data from several studies and reported an average feacal excretion rate of 150g/p,d, the actual quantity of faeces produced depending on the composition of the food consumed. Foods low in fibre such as meat and other products result in smaller amounts (mass and volume) of faeces (Guyton, 1992). Faecal excretion rates in developed countries are lower than those in developing countries, with the excretion rates for Americans and Europeans estimated at between 100 and 200g/p,d and those of developing countries estimated at 350g/p,d in rural areas and 250g/p,d in urban areas on the average (Feachem, *et al*.,1983). In China, Gao, *et al*. (2002) measured 315g/p,d while Pieper(1987) measured 520g/p,d in Kenya. In measurements by Schouw, *et al*.(2002) in Southern Thailand, wet faecal generation rates were found to be 120-400g/p,d. Vinneras, *et al*.(2006), using measurements from two blocks of flats in Sweden, estimated faecal excretion rate was 140g/p,d among the Swedes, with water content of about 78%. According to Feachem, *et al*., (1983), at faecal excretion rates between 100 and 150g/p,d water content is about 75% and that this increases with increasing weight, to approximately 90% of faecal weights of 500g/p,d. Faecal excretion is on the average one stool per person per day, but this may vary from one stool per week up to five stools per day (Lentner, *et al*.,1981).

This study showed total excreta generated by 73 people (19 male adult, 19 female adult, 17 male children and 18 female children) was 18.98kg per day. The cumulative volume of gas generated from 5kg of human excreta combined with 15 kg of leftover rice with 5kg of vegetable waste and 25kg of water resulted in $0.167m^3$ biogas. By extrapolation, 500 households, generating 515kg of excreta; using 1,546kg of waste rice with 515kg of vegetables waste and 2,579kg of water, can generate $83.5m^3$ biogas. This quantity of biogas can power 55kw electricity generating set which can provide Community Street light for more than 6 hours.

VI. CONCLUSION AND RECOMMENDATIONS

This study also showed total excreta produced by 73 people (19 male adult, 19 female adult, 17 male children and 18 female children) was 18.97kg per day. Given an average household of 5, (2 adults and 3 children), 1321g (1.3kg) of feaces would be generated. Therefore, 500 households in any of the communities would generate 660,500g (660.5kg) of excreta. The cumulative volume of gas generated from 5kg of human excreta combined with 15 kg of leftover rice with 5kg of vegetable waste and 25kg of water resulted in $0.167m^3$ biogas. By extrapolation, 500 households, generating 515kg of excreta; using 1,546kg of waste rice with 515kg of vegetables waste and 2,579kg of water, can generate $83.5m^3$biogas. This quantity of biogas can power 55kw electricity generating set which can provide Community Street light for more than 6 hours. In the coastal communities of the Niger Delta where modern waste management practices are practically nonexistent, human excreta and household food wastes are discharged directly into the rivers and creeks, resulting in obnoxious effects such as foul smell, pollution and filth and even mosquito infestation. The outcome of this research has given a clear direction on how to treat/convert these "domestic wastes" (which in effect are resources) through bio-digestion. As the world in general is changing from over reliance on fossil fuels, being wasting assets, coupled with the attendant pollution of the environment, investment in alternative energy sources such as biogas from biodegradable wastes would contribute to the quest to reduce energy scarcity, guard against ecosystems disasters, elimination and/or control deforestation and erosion of the soil surface in particular and the environment in general. Therefore, for developing countries of Africa and especially Nigeria to surmount her current energy, environmental, food, health and unemployment crises, the anaerobic digestion of biodegradable wastes in general; excreta/household food wastes in particular should be given the desired attention.

In consideration of the numerous health, environmental and economic benefits that will accrue from the anaerobic digestion of human excreta and household (food) wastes to produce biogas the study recommends as follows:

- Concerted and sustained education on the biogas concept/technology using human excreta and household (food) wastes by the State and Local Government operatives, Development agencies, Non-governmental organizations including Churches. The emphasis here is on both the corporate and individual benefits of the concept.
- The toilet and food wastes collection systems in the government private residential estates, local and urban markets etc should be remodelled/redesigned to include biogas generation and utilization plant.

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