JEAS

Journal of Engineering and Applied Sciences 3 (2007) 31- 34

JOURNAL OF ENGINEERING AND

Biogas generation: a viable cleaner alternative energy source in south-eastern region of Nigeria

C.H. Achebe, *S.C. Nwigbo, *E.C. Chinwuko, M.O. Odhomi

*Department of Mechanical Engineering *Department of Industrial/Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria*

Abstract

The problem of over-dependence on the nonrenewable and fast-depleting fossil fuels is one the world of science needs not wink at any longer. In Nigeria, the level of dependence on these fossil fuels has created a great disparity in the sourcing, harnessing, exploration and exploitation of these natural endowments vis-à-vis other energy sources. Virtually all other sources of energy are neglected, untapped, unutilized and/or underutilized. This research work was necessitated by the burden to create awareness on the quantity of energy lost as occasioned by this insensitive attitude of the society to these other forms of energy and the possible implications to the environment and economy. Diversification of our energy consumption is a potent panacea to the usual power shortages and high cost of energy in Nigeria. The research findings show that about 20.52% of domestic energy requirements of South-eastern region of Nigeria could be met through proper harnessing of biomass (biodegradable materials) for the production of biogas.

1. Introduction

The overall economic development of a country largely depends on the availability and consumption of energy. The categories of energy resources available can be classified into two: renewable and non-renewable. The non-renewable sources, also called fossil fuels are readily in use in Nigeria, and their energy deposits are continuously depleted by our withdrawals. However, the renewable sources of energy, which are being deposited everyday, are not fully in use. Bio-energy which is an alternative and cheap source of the renewable energy and which can be made available to both the rural and urban areas of the country spells a viable option.

Bio-energy is energy stored in biomass. Biomass materials include wood, grasses and other herbage, grain and sugar crops, crop residues, animal manure, food processing waste, kelp from ocean farms, oil bearing plants and other materials. Biomass can be converted to energy through direct combustion, thermo-chemical conversion processes, bio-photolysis and biological conversion processes. Biological conversion processes may either be by fermentation or by anaerobic digestion. The anaerobic bioconversion of biomass produces a mixture of carbon IV oxide, traces of other gases, and methane called biogas.

Apart from the problem of non-renewable nature of fossil fuels, these are also not domestically available when compared to biomass, which is always readily available and unutilized. The technological feasibility of obtaining fossil fuels is very low and economically demanding. In addition to these the problem of environmental pollution caused by oil exploration cannot be overemphasized. Also, the accumulative green house gases causing ozone layer depletion produced by oil fuel combustion can be reduced which would result in the abatement of climatic changes (Charles and Sanders, 1986).

In today's energy conscious world, alternative forms of energy are becoming more and more important in deciding the future of the world's energy needs. Anaerobic digestion is the most efficient process of capturing energy from biomass. Unlike fossil fuels, biomass is a natural by-product that is not hidden under the ground. It has no question of existence, does not require extraction from its source but is regularly deposited on daily basis and is economical. The purpose of this work is to promote anaerobic digestion as an environmentally friendly method of waste reduction and energy recovery. It also aims at providing an alternative energy supply for domestic purposes (cooking) such that

families can easily turn away from the traditional fire place and have a biogas plant installed to provide energy for cooking and even lighting. This provides a smoke-free and ash-free kitchen meaning that women will no longer be prone to lung and throat infections and can look forward to a longer life expectancy. Waste will no longer be stored in the home but will be fed directly into the biogas plant along with toilet waste thus resulting to improvement in the standard of hygiene and sanitary conditions. Biogas is used to heat and light homes, to cook and even to fuel buses. It has been called swamp gas or sewer gas at different points in time (Onyi, 2004).

Anaerobic digestion can be described as a two-stage process accomplished by several types of bacteria, which flourish in absence of oxygen. In the first stage (acidification), acid-forming bacteria called acidogens break complex organic waste down into simpler fatty acids. In the second stage (methane production stage), methane-forming bacteria (methanogens) consume the acids produced by the acidogens, generating biogas as a metabolic by-product.

Anaerobic processes can be managed in a "digester" (an air tight vessel) or a covered lagoon (a pond used to store manure) for waste treatment. The primary benefits of anaerobic digestion are nutrient recycling, waste treatment and odour control. Biogas produced in anaerobic digesters consists of methane (50%-80%), carbon IV oxide (20%-50%) and trace levels of other gases such as hydrogen, carbon II oxide, nitrogen and hydrogen sulphide. The relative percentage of these gases in biogas depends on the feed material and the management of the process. When burned 0.028 m^3 ($1ft^3$) of biogas yields about 2.52kcal (10 Btu) of heat energy per percentage of methane composition.

2. Materials and methods

This research work carried out on the South-eastern region of Nigeria was geared towards establishing a basis for encouraging the healthy attitude of exploiting the much available and cleaner alternative energy sources. The South-eastern region of Nigeria is a tropical rain forest belt which has a land mass of about eighty-three thousand, one hundred and thirty-nine square kilometers (83,139 Km^2). The climatic conditions of the region include the dry and wet seasons. A part of the dry season is the harmattan period, which accounts for only about 8% of the entire year. The population of the region is about 22,092,000 (22.10 million). The temperature record of the region consisting of the day-time and night-time ranges for the year 2006 was obtained from The Department of Meteorological Services, World Weather Information Service. We modified this record by plotting the available record on a graph for easy appreciation and use in determining the suitability of this research to our location (i.e. the south-eastern region of Nigeria). The temperature ranges obtained were used to ascertain the viability of the biogas option in terms of optimum gas yield in the region given the prevalent climatic conditions. This is further discussed in the results obtained below.

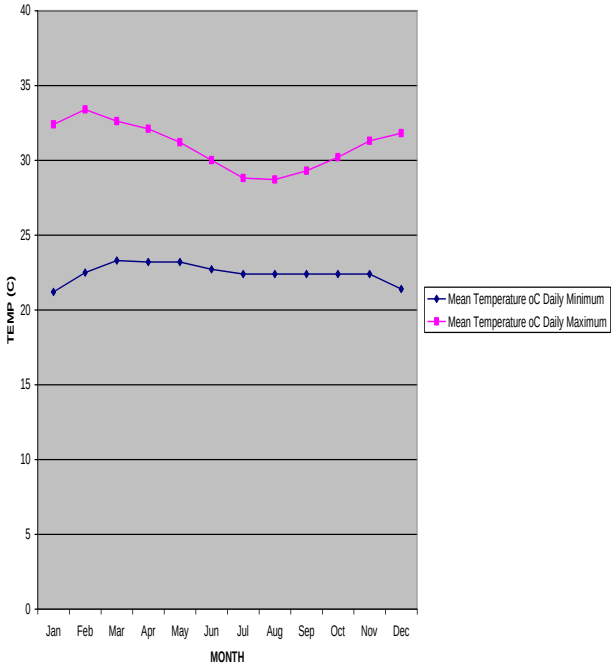

Fig. 1. Temperature records in south-eastern Nigeria in 2006.
(Adapted from: The Department of Meteorological Services, World Weather Information Service, 2006).

Much of the agricultural and biological wastes are good substrate for biogas production. Based on the options of availability and accessibility, coupled with the production levels of different wastes, a study to determine the quantity of biomass from various biodegradable sources available in the south-east Nigeria was undertaken. These included cow dung, poultry droppings, goat/sheep dung, crop and human wastes. Various consultations and collections were made to ascertain the population of the research objects and the average quantity of waste produced. Also, the average quantity of refuse disposed by the sanitation authorities over a one-year period was equally obtained from available records. The information so gathered was employed in calculating the volume of methane gas (biogas) derivable from the various sources. The next phase of work was the conversion of the volume of the derivable methane gas to the equivalent quantity of energy. Through this means the total derivable quantity of energy was deduced. Data on the domestic energy consumption rate of electric power was obtained from the records of the Power Holdings Nigeria for the year 2006. The quantity of kerosene supplied to the region by the NNPC/PPMC was obtained from the usual daily allocations and other independent marketer's quota estimation. The quantity of liquefied natural gas (LNG) and the average wood consumption rate were equally deduced based on the population that use these sources of energy.

These gave an estimate of the total energy requirement for domestic purposes in the region. The total derivable biogas energy as compared with the total energy requirements thus gave the percentage of the total energy requirements of the region which could be met by the biogas option, otherwise the quantity/percentage of energy lost as a result of unharnessed biomass energy available in the region.

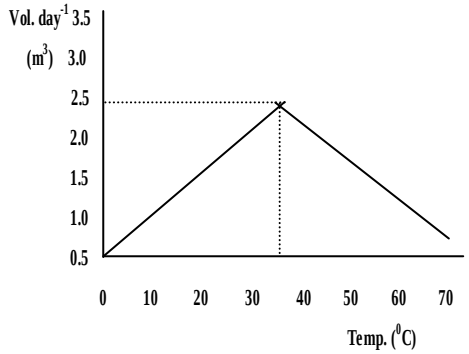

Fig. 2. Methane production per day at varying temperatures.

The graph above reveals that methane production is at maximum at temperature of 35^0C. This will be one of the factors to consider in determining the viability of the biogas option. It is however interesting to note that the temperature range in the region is quite favourable as it lies very close to this optimum condition throughout the year.

Table1
Biogas production from some common wastes

	Type of waste	Gas Production (dm^3/kg)
1.	Cattle dung	22-40
2.	Pig dung	40-60
3.	Poultry dropping	65-115
4.	Human (per person using toilet)	20-22
5.	Pre-treated crop waste	34-40
6.	Water Hyacinth	40-50

(Source: Dangoggo and Fernando, 1986)

Deductions were made using the information in the above table to ascertain the quantity of methane gas derivable from the various biodegradable materials available in the region. The available data is as presented in the table 3 below.

3. Results and discussion

Poly-plug digesters were set up and subjected to various temperature ranges and the quantity of gas obtained plotted against temperature as in Fig.3 below.

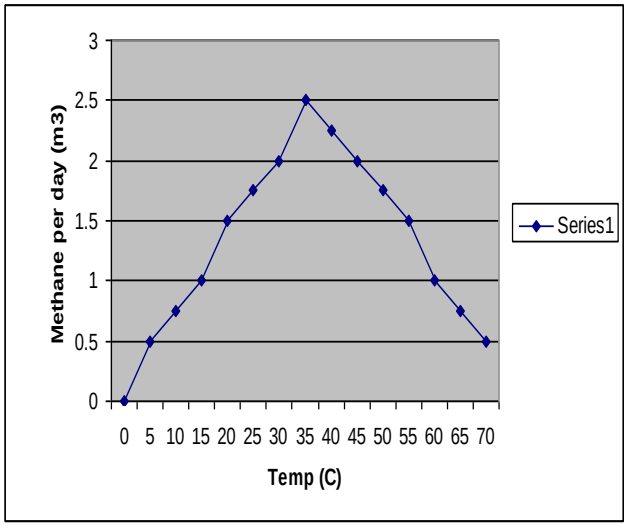

Fig. 3. Methane production per day at varying temperatures in South-eastern Nigeria.

The graph in Fig. 3 above shows the volume of methane produced per day at varying temperatures in South-eastern Nigeria. This compares favourably with that of Fig. 2 above. The temperature of $30\text{-}33^0$C is prevalent in the region through the greater part of the year except during the harmattan season, which due to the global climatic changes now lasts for a staggered 2 to 4 weeks. At such periods the temperature comes as low as 21^0C. This accounts for only about 8% of the total time through the year. Thus, the condition ensures optimum biogas yield through the year and such spells a good option as an alternative energy source.

Table 2
Estimated domestic energy consumption in south-eastern Nigeria for the year 2006

Energy Source	Quantity of fuel (kg)	Energy requirement per annum (MJ)
Electricity	-	$25.790\text{x}10^9$
Kerosene	5,647,180,170	$24.340\text{x}10^{10}$
LNG	1,129,436,034	$48.680\text{x}10^9$
Wood/Wood Wastes	4,517,744,136	$19.472\text{x}10^{10}$
Total		$51.259\text{x}10^{10}$

Note: Kerosene heating value (heat of combustion) is 43.1MJ/Kg (18500Btu/Ib).

The total domestic energy consumption in the region stands at $51.259\text{x}10^{10}$ MJ per annum. This includes all sources of energy currently in use. Fossil fuels however, provide the largest chunk of the energy requirements to the tune of about $29.208\text{x}10^{10}$ MJ per annum.

Table 3
Quantity of methane available and % energy losses

Biomass Source	Average mass of waste per item per day (Kg)	Mass of waste per annum (Kg)	Volatile Solid (VS) per Kg waste	Gas production (m^3/Kg)	Quantity of gas (m^3)	Energy value (MJ)	% of total energy requirement
Cattle dung	3.60	32,895,000	0.12	0.040	157,896	6,157,944	0.0012
Human waste	0.60	4,844,775,600	0.03	0.022	3,197,551.90	124,704,523.94	0.0243
Poultry droppings	$1.24x10^{-3}$	135,966	0.19	0.115	2,970.86	115,863.43	0.00002
Goat/Sheep dung	0.40	21,930,000	0.23	0.040	201,756	7,868,484	0.0015
Pig dung	0.50	1,827,500	0.10	0.060	10,965	427,635	0.00008
Refuse (bio-degradable)	1,000,000	365,500,000	0.30	0.064	7,017,600	273,686,400	0.0534
Crop waste	600,000,000	219,300,000,000	0.30	0.040	2,631,600,000	102,632,400,000	20.022
Water Hyacinth	10,000,000	3,655,000,000	0.30	0.050	54,825,000	2,138,175,000	0.4171
Total	-	228,222,064,066	-	-	2,697,013,739.76	105,183,535,850.37	20.52

Note: 1.00m^3 of methane gas yields 39MJ of energy (An, and Rodriguez, 1997).

4. Conclusion

The research findings show that about 20.52% of the total annual domestic energy requirements of the South-eastern region of Nigeria could be met through harnessing readily available biomass resources. This unfortunately, is lost and the generated Methane gas and other associated gases evolve into the atmosphere with the attendant negative implications. These include ozone layer depletion and the unfavourable green house effect. Also, the region and indeed the Nation at large should explore and exploit other alternative renewable greener energy sources which include wind, solar energy etc that are available in sufficient quantities in various parts of the country. This will reduce the current trend of over-dependence on the nonrenewable fossil fuels reserves. These reserves are fast depleting and the consequences, if not checked on time, would be of a grave sort.

References

An, B. X., Rodriguez, L., 1997. Installation and performance of low cost polyethylene tube digesters on small- scale farms. World Animal Review, 88, 1, 38 – 47.

Charles, L., Sanders, P., 1986. Toxicological Aspects of Energy Production. Battle Memorial Institute, Macmillan, New York.

Dangoggo, S.M., Fernando, C.E.C., 1986. Investigation of some parameters which affect the performance of biogas plants. Nigeria Journal of Solar Energy, 5, 142 – 146.

Onyi, P.N., 2004. Isolation of Anaerobic Bacteria Associated with the Production of Biogas from Abdominal Waste. City Publishers Ltd, Nigeria.