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Biogas production from municipal organic waste

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Abstract

Proper disposal of municipal solid waste is one of the major challenges for responsible waste management authorities. Various studies reveal that about 50 to 70% of the generated waste is collected in Nigeria while the rest of the waste lies in the street, walkways and in vacant plots. The collected waste is dumped in the open and uncontrolled landfills without any energy recovery. The present study is an experimental study where an attempt is made to find out sustainable solution for the disposal of municipal organic waste of the country. In the present study it is found that biogas production from the municipal organic waste is a sustainable source of handling the waste. Hence, the biogas production will also help to achieve sustainable development in the country due to reducing the gap of demand and supply of electricity shortfall through renewable energy sources (biogas), greenhouse gas emission reduction substituting the fossil fuel and receiving the economic benefits from biogas. The maximum biogas yield from the experiment was 11.4 litres. There was no biogas yield from first day to the fourth day. The maximum slurry temperature recorded from the experiment was 42 °C.

Keywords: Municipal waste, Renewable Energy, Waste Management, Biogas, Electricity

1. Introduction

In Nigeria huge amount of municipal solid waste (MSW) is generated daily. Like other developing nations, MSW is highly neglected area in Nigeria pertaining to overall environmental management and energy recovery point of view [1]. Also the quantity of waste generated every day in the world is increasing due geometric population increase [2]. More specifically in the country about 6000 tons of municipal solid waste produce daily in different towns [3] with approximately 0.84 kg per capita waste generation rate [4]. In recent years anaerobic technology has been well established and satisfied performance in organic waste stabilization [5]. The management of this enormous amount of MSW is a big challenge for responsible authorities and visible problem and harmful effects of improper waste handling has been reported in many studies. Currently, in Nigeria 60% of the produced MSW is collected while the rest of the 40% waste remains uncollected and lies along roadsides, streets, railway lines, depressions, vacant plots, drains, storm drains and open sewers. The collected waste even improperly managed, disposed of in open dumps and in unstandardized landfills. This contributes to unattractive environment, poor sanitation conditions, disease, pollution of water bodies and environmental degradation [6]. The main problem concerning to proper disposal and treatment of MSW includes lack of reliable data and research, shortage of trained manpower, inadequate legal and regulatory cover, poor institutional and administrative arrangements, shortage of equipment, financial and technical difficulties and a serious shortage of competent private operators. The municipal solid waste (MSW) is treated differently in different parts of the world. The waste is naturally degraded in unstandardized landfills, burnt the waste in dump sites and through controlled aerobic and anaerobic digestion process. The first two processes are widely in operation in developing countries and large volume of methane and carbon dioxide is released into the atmosphere. The release of these gases into the atmosphere becomes very harmful for the environment [7]. The natural degradation of the organic matter is causing smell and spreading of diseases in the surroundings. Natural biodegradation of organic matters contributes approximately 590-800 million tons of methane in the atmosphere. Waste water and landfills constitute 90% of waste sector emissions and about 18% of global anthropogenic methane (CH_4) emissions [8]. The methane (CH_4) which has high potential of global warming either can be taped or freely released into the atmosphere. The latter situation take place when the organic matters are illegal disposed of or thrown away in the vacant places. The taped methane (Biogas) used as a source of energy while un-taped methane is very harmful for the environment [9]. Several researches have been conducted in the world to solve local, regional and global problems due to the improper disposal of MSW which are discussed in the previous sections. Most of these researches showed their reliance on renewable energy for sustainable development to meet their daily energy needs through waste to energy routes that cause less negative environmental and social impacts [10] as well as energy is recovered during the process. Several definitions of sustainable development have been put forth but the following is very common one ‘the development that meets present generation needs without compromising on future generation needs’ [11]. Environmental compatibility is a crucial asset of renewable energy. In line with other renewable resources waste to energy technology like biogas will become an attractive alternative of energy in near future [12]. Biogas is a renewable source of energy which is produced in the bioreactor through anaerobic digestion process by using waste as feedstock [13]. The waste includes municipal solid waste, industrial waste water, animal excreta and agricultural waste used for biogas production. Bond and Templeton illustrate that biogas is a holistic approach to get rid of from organic waste and producing energy through anaerobic digestion process which makes it a sustainable source of energy. Even though, in some cases biogas is preferred because of resource efficiency over other renewable energy sources like bioethanol and biodiesel as mitigation of GHG emissions [14]. Typically biogas contains 50-70% methane and 30-50% carbon dioxide and small amount of other gases. It has a calorific value of 21-24 MJ/m^3. Anaerobic digestion is the process and technique of decomposition of organic matter by a microbial process in an oxygen-free environment [15]. Controlled anaerobic digestion of organic wastes has multiple benefits. On one hand, it provides a renewable source of clean energy, while on the other side the digestates can be used as organic fertilizers in the agriculture sector. The electricity and fuel production from the biogas might strengthen the national energy supply, as well as reduce greenhouse gases (GHG) emissions [16] So far, Abuja compost plant is the only one plant in the country which recycles only 20% of the total Abuja collected municipal solid waste into organic rich fertilizer without recovering the energy. This study is an attempt to find out biogas potential from organic municipal solid waste in the Country. The study proposes a large scale biogas plant in different part of the City and demonstrates how it helps to achieve sustainable development in the city? The study also demonstrates biogas utilization and its benefits.

Design of Existing Biogas Plant

The design of biogas plant in the country is very simple. Mostly the plants are installed in the vicinity of home. This reduces transportation cost of substrate to feed biogas plant. The construction material is based on concrete, bricks and steel and traditional knowledge and local technology has been used. The cost is variable depending on the size of the biogas plants. For the average household biogas unit, the cost ranges from #35,000 to #50,000 which is around US$115. The floating drum is the most commonly used design in Pakistan Country [17]. Twenty one Chinese fixed domes were installed on pilot basis, but failed because of consistent leakage from the Hair line, seepage, and low gas pressure. The floating drum design become popular over Chinese fixed dome because of its less leakage. Later on, Indian Dheenbandhu and Nepali design GCC 2047 $6m^3$ designs were also introduced and being practiced in Country. These designs are also widely used and are successful because of less leakage and high gas yield [18]. The installed biogas plants are small in scale with varying capacity of 5-15 m^3 biogas production per day [19]. Organic waste which is a good substrate for biogas production is totally absent in the country. The installed biogas plants in Nigeria are fed by animal dung with the same amount of water. These small scale biogas plants are designed to meet the energy demand at household level. Beside these small scale plants, only 2 medium size 20 and 35 m^3 plants Nepali design GCC 2047 have been installed in some part of the country by the Rural Support Programme Network with the financial help of Foundation for Integrated Development Action.

Renewable Energy Policies

Pakistan has abundant renewable energy resources and so far these resources have not been employed for energy production except in hydroelectricity dams. About 99% of the supplied energy is produced from conventional sources such as oil, gas, hydro, and nuclear. On the other hand, only 1% of the energy is produced from micro renewable energy projects whereas the country has abundant of renewable resources [20].

To use the enormous renewable potential the Ministry of Water and Power initiated in 2005 and 2006 the development of renewable energy sector with a very comprehensive Alternative Renewable Energy Policy [21] in Pakistan. This policy was divided in three phases, short, medium and long term. Through this short term ARE 2006 Policy, the government started to offer strong incentives to attract local and international investor to the sector. Barrier to implementations was also removed. The ARE Policy 2006 in Pakistan ended in June, 2008, and this was replaced by medium term ARE Policy 2011. The experience and challenges in the short term policy provided the basis for the next medium term policy. The medium term policy 2011 includes more renewable resources, for example, waste to energy, geo thermal, biodiesel and ethanol. Hence these resources were not prioritized in the short term policy 2006. The government demonstrate in the Alternative Renewable Energy Policy 2011 document that; The GoP’s strategic objectives of Energy Security, Economic Benefits, Social Equity, Environmental Protection, Sustainable Growth and Gender Mainstreaming, now are further harnessed under the ARE Policy 2011, developed by the Ministry of Water and Power with the support of international agencies including Asian Development Bank (ADB), USAID, UNDP, German Technical Corporation (GTZ), Energia International and with consensus of all relevant stakeholder including provincial governments, private sector and academia. The ARE Policy 2011 will help to create a conducive environment for the growth of domestic ARE Sector. The Medium Term policy is the Consolidation Phase for sustainable growth of the renewable energy sector (2010–Dec 2014) and the Long Term policy will be the Maturity Phase for competitive growth which will start from January, 2015.

Barriers in the Renewable Energy Development

- Policy and regulatory barriers: Lack of well-defined policies for public and private partnership. And delay in the projects allotments and payments.
- Inadequate incentives for the power producers from renewable resources
- Institutional barriers: lack of coordination between different ministries, organizations, agencies and stakeholders. Lack of proper legislation and sometimes government provided incentives are misused
- Financial barriers: insufficient funds to develop renewable energy projects
- Local market barriers: lack of local market infrastructure to promote sale of renewable energy technologies and the end products
- Technology barriers: minimum standards in terms of durability, performance and reliability are not followed. Lack of technical renewable energy experts
- Information and social barriers.

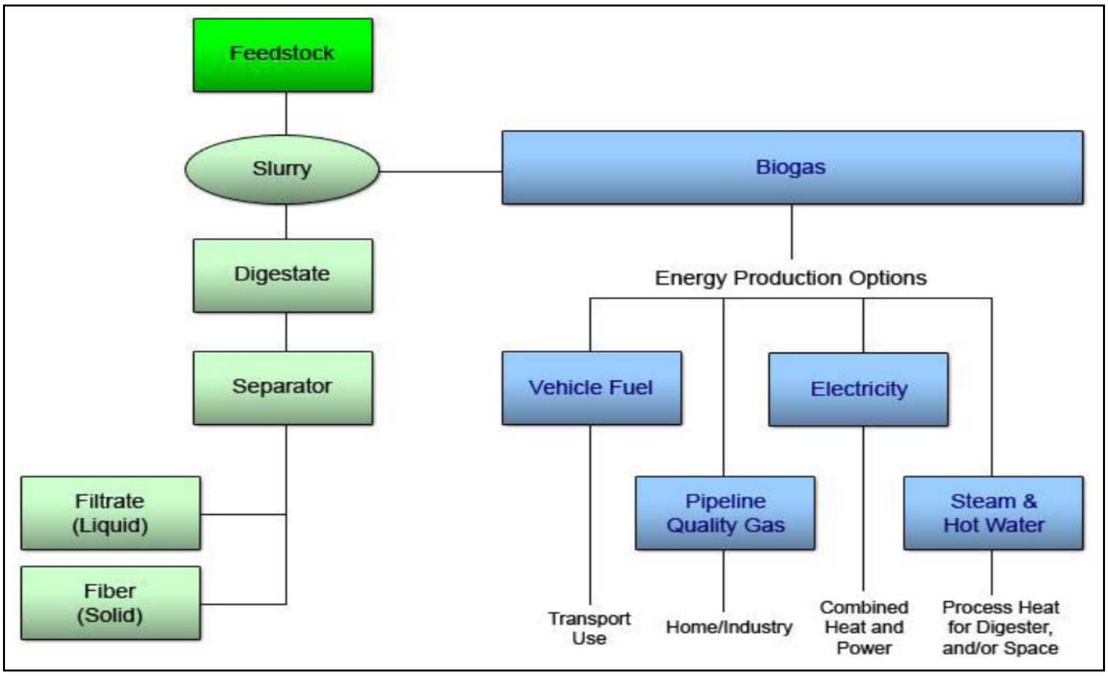

Fig 1a: Process of Biogas Energy System source: (Phase 3 Renewable, 2008)

2. Materials and Methods

Collection of Materials

The municipal waste was collected from Enugu North Local Government Area waste dumping ground at Government Reserved Area (GRA) Golf Estate Enugu. Also some wastes were collected from Ibagwa Nike in Enugu East Local Government Area of Enugu State. The wastes Collected were carefully removed of some non-biodegradable materials such as plastics, broken bottles, metal and some polyvinyl Chloride (PVC). After picking the non-biodegradable material the waste were put in an open space for few days to accumulative bacteria that will enhance anaerobic digestion.

Experimental Procedure

9kg of municipal waste was charged into the 50 litres digester with 18kg of water in the ratio of 1:2 of waste to water and the slurry was properly stirred. The mixing ratio was determined by the moisture content of the waste. The daily ambient and slurry temperatures were measured using thermometer (-10 to 110^{0}C), The pH Values were monitored on 3 days interval to determine the action of methanogens, which utilize the acids, carbon dioxide and hydrogen produced by non-methane producing bacterial using a digital pH meter (PHS-3c pH meter). The volume of biogas produced was measured by a downward displacement method using a transparent 13L calibrated plastic bucket as used by.

Determination of Moisture Content

The A.O.A.C method (1990) was used [22]. Porcelain crucibles were washed and dried in an oven at 100^{o}C for 30 minutes and allowed to cool in a desiccator. One gramme of the raw waste was placed into weighed crucibles and then put inside the oven set at 105^{o}C for 4 hours. The samples were removed from the oven after this period and then cooled and weighed. The drying was continued and all the samples with the crucibles weighed until a constant weight was obtained.

$$\% \text{ moisture} = \frac{A-B}{A} \times \frac{100}{1}$$

Where;

A = Original weight of sample

B = Weight of dried sample.

Determination of Total Solids

Total solid is made up of the digestible and non-digestible material in the waste. Meynell (1982) method was used. 3g of the raw waste was dried in an oven at 105^{o}C for 5 hours. The dried sample was cooled in a dessicator and then weighed. The weight obtained after all moisture loss is the total solid.

$$\% \text{ T.S} = \frac{B-C}{g} x \frac{100}{1}$$

Where;

T.S = Total solid

B = Weight of crucible + dry residue

C = Weight of crucible

g = Original weight of sample.

Determination of Volatile Solids

The volatile solid is the true organic matter available for bacterial action during digestion. The method of Meynell (1982) was used. The solid residue from the total solid determination was heated in a muffle furnace at 600^{o}C for 2 hours. The heated residue was cooled in a dessicator and weighed.

$$\text{Volatile solid (VS)} = \frac{B-C}{g} x \frac{100}{1}$$

B = Weight of dried residue from total solid determination

C = Weight of residue after further heating at 600^{o}C

g = Original weight of sample.

Ash Content Determination

The residue remaining after all the moisture have been removed and the fats, proteins, carbohydrates, vitamins and organic acids burnt away by ignition at about 600ºC is called ash. It is usually taken as a measure of the mineral content of the raw waste.

Using AOAC (1990) method, 1g of the finely ground samples were weighed into porcelain crucibles which have been washed, dried in an oven at 100ºC, cooled in a desiccator and weighed. They were then placed inside a muffle furnace and heated at 600ºC for 4 hours. After this, they were removed and cooled in a desiccator and then weighed.

$$\% \text{ Ash} = \frac{A - B}{C} \times \frac{100}{1}$$

Where;

A = Weight of crucible + ash
B = Weight of crucible
C = Weight of original sample

3. Result and Discussion

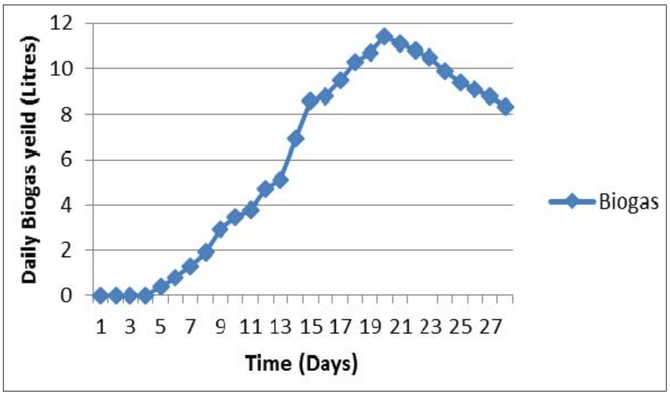

Fig 1: Daily Biogas Yield (Litres) Versus Time (Days)

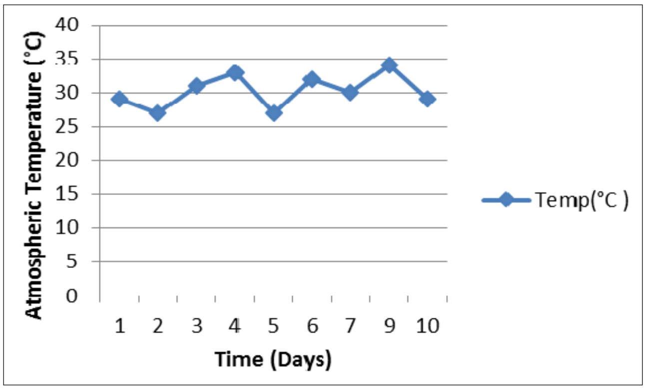

Fig 2: Atmospheric Temperature (°C) Versus Time (Days)

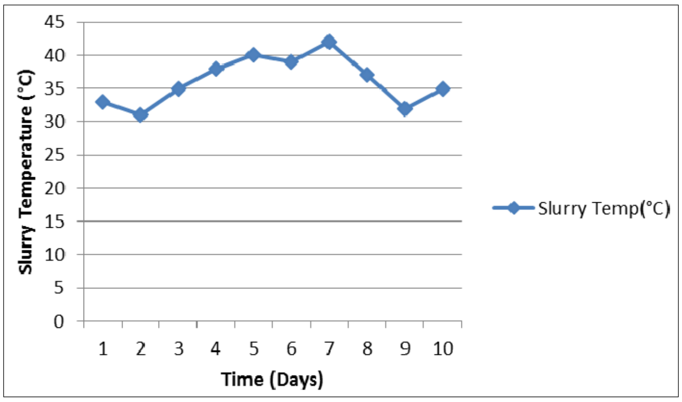

Fig 3: Slurry Temperature (°C) Versus Time (Days)

Fig 1 shows the 30 days daily and volume of biogas production for the waste. A close observation shows that it started daily production on the fourth day, reaching peak on the 20th day and yielding 11.4 litres of biogas. The delay in biogas production from day1 to day 2 was inadequate anaerobic bacteria that will boast the production at the early stage. It was also due to poor breakdown of complex organic compound (Carbohydrate, protein, lipids) to small soluble compounds (amino acid, sugar and fatty acids). A cumulative of 168.5 litres of biogas was produced at the end of the 30 days retention period from the municipal waste. The acidogenesis stage of anaerobic process gave rise to intermediate products such as CO_2, H_2, alcohols and organic acids. The acetogenesis stage produced acetate while methanogenesis process produced CH_4, $C0_2$ and water vapour. The fig 2 indicated variation in atmospheric temperature measured for the first 10 days of experiment. The maximum atmospheric temperature recorded during the experiment was 34 °C while the minimum atmospheric temperature recorded was 27 °C. The slurry temperature was also measure during the research work. It was observed that on day 7 was the highest slurry temperature of 42 °C recorded.

3. Conclusion.

The result of this research on the production of biogas from municipal waste has shown that flammable biogas can be produced from the waste through anaerobic digestion for biogas generation. This waste is always available in our environment and can be used as a source of fuel if managed properly. The study revealed further that municipal waste has great potentials for generation of biogas and its use should be encourage due to its early retention time and high volume of biogas yields. Also in this study, it has been found that temperature variation, PH and Concentration of Total solid etc., are some of the factors that affected the volume yield of biogas production.

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