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# Review on Biogas Production in Nigeria

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***ABSTRACT:*** *One of the greatest challenges facing the Nigerian societies now and in the future is the reduction of green house gas emissions, energy generation, power supply and thus preventing the climate change. It is therefore necessary to look for an alternative with renewable and recycling sources, such as biogas. Biogas can be produced from various organic waste streams or as a byproduct from industrial processes. Beside energy production, the degradation of organic waste through anaerobic digestion offers other advantages, such as the prevention of odor release and the decrease of pathogens. Moreover, the nutrient rich digested residues can be utilized as fertilizer for recycling the nutrients back to the fields. However, the amount of organic materials currently available for biogas production is limited and new substrates as well as new effective technologies are therefore needed to facilitate the growth of the biogas industry all over the world. Hence, major developments have been made during the last decades regarding the utilization of lignocelluloses biomass, the development of high rate systems and the application of membrane technologies within the anaerobic digestion process in order to overcome the shortcomings encountered. The degradation of organic material requires a synchronized action of different groups of microorganisms with different metabolic capacities. Recent developments in molecular biology techniques have provided the research community with a valuable tool for improved understanding of this complex microbiological system, which in turn could help optimize and control the process in an effective way in the future.*

***Keywords:*** *Biogas, Digestion Technologies, Retention Time, Nigeria.*

## I. HISTORICAL DEVELOPMENT OF ANAEROBIC DIGESTION TECHNOLOGIES

Historical evidence indicates that the anaerobic digestion process is one of the oldest technologies (Monnet, 2003). Very old sources indicate that using wastewater and so-called renewable resources for the energy supply is not new, but were already known before the birth of Christ, (Deublein and Steinhauser, 2008). Biogas production through anaerobic digestion (AD) is an environmental friendly process utilizing the increasing amounts of organic waste produced worldwide. A wide range of waste streams, including industrial and municipal waste waters, agricultural, municipal, and food industrial wastes, as well as plant residues, can be treated with this technology

The first allusion to animal manure comes from Humphrey Davy, who reported early in the nineteenth century the presence of this combustible gas in fermenting farmyard manure. Davy is known for the invention of the miner's safety lamp. However, the industrialization of anaerobic digestion began in 1859 with the first digestion plant in Bombay. By 1895, biogas was recovered from a sewage treatment facility and used to fuel street lamps in Exeter, England (Nwanko and Joseph, 2014). Research led by Buswell Monnet (2003) and others, in the 1930s identified anaerobic bacteria and the conditions that promote methane production. As the understanding of the anaerobic digestion process and its benefits improved, more sophisticated equipments and operational techniques emerged. The result was the use of closed tank, heating and mixing systems to optimize anaerobic digestion. In 1900 a methane (biogas) generating plant from human wastes was constructed in a leper asylum in Matunga, India (Maramba, 1978).

In the years around 1940, many municipal sewage treatment plants in the United States and elsewhere were already employing anaerobic "digestion" as part of the treatment of municipal waste, and thereby generating methane which was used to generate electricity for the plant. This indicated that for pollution control, the anaerobic digestion process is proven effective with additional benefits in the form of a supply of a useful gas (Maramba, 1978).

China is one of the countries in the world where the use of biogas started at a very early Stage. In 1920, Mr. LuoGuorui built a biogas digester called "Chinese Guorui Natural Gas store", which was the first hydraulic digester in

China. This marked the beginning of rural biogas systems development in China (Ahmadu, 2009).'In 1978, 7million plants were built, but only 3 million were working. In 2009, about 17 million biogas plants which mainly use underground masonry plants of size 4 to 10m but less than 50% success was recorded (Fulford, 2011).

In Taiwan, more than 7,500 units of methane-generating device utilizing pig manure have been constructed. In the United States, there has been considerable interest in the process of anaerobic digestion. Digesters are aimed at meeting energy production and waste treatment, especially with regard to animals in - farms, allowing the manipulation of a material free of odors (Maramba, 1978).

## II. BIOGAS PROJECTS IN AFRICA

Biogas projects are on the rise throughout the world. They provide a method to produce methane used for cooking and lighting from the waste of animals and humans. In countries such as Nepal there is a large push to increase the number of biogas plants in the country. These projects usually use cow manure to produce the gas, but by making a small adjustment, a household latrine can be connected to a digester increasing gas production and providing an easy way to manage the human waste (Ocwieja, 2010).

In Rwanda, Kigali Institute of Science and Technology built sewage systems for overcrowded prisons (10,000 people) using underground masonry plant s with 100m3 volume, linked to make T,400m3. This development saved 50% of wood for cooking. In 2006, Biogas Technology West Africa Ltd won the Ashden Award by building sewage systems for hospitals, schools, colleges, etc using underground masonry dome systems of 60m to 160m3 volumes. The water recovered was used to flush the toilets while gas was collected and used for cooking, (Fulford, 2011).

In Nigeria, research into biogas technology and its practical application is on-going, though has not really received the deserved attention. The Sokoto Energy Research Centre, Usmanu Danfodio University, Sokoto has carried out a number of pilot projects on construction of household size digesters. In addition to this the centre has constructed biogas digester plants of 20m3 capacity at these locations: Zaria prisons, Kiri-kiri Prisons-Lagos, may flower School-Ikene, Ogun State, Ojokoro-Lagos and Maiduguri (Mshandete and Parawira, 2009).

There is a new African initiative to increase the number of biogas plants that was launched in 2007. The goal of this initiative is to provide 2 million households by 2020with biogas digesters. However, the number of biogas plants currently in Africa is unknown with most units installed in Tanzania (around 4,000). It has also been estimated that only 60% of these plants have remained in operation. The reasons for failure or unsatisfactory performance of these biogas systems can often be found in the mistakes made during the planning stages. Other reasons for failures include lack of interest and understanding by the community, construction faults, insufficient maintenance on the system, misconception of benefits of the system, lack of training new owners on the system, and budgeting errors, (Ocwieja ,2010).

## III. CONCEPT OF ANAEROBIC DIGESTION

Anaerobic digestion is the controlled degradation of organic waste in the absence of oxygen and in the presence of anaerobic micro-organisms. The digestion process is carried out using an airtight reactor and other equipment used for waste pre-treatment and gas retrieval. The process generates a product called "biogas" that is primarily composed of methane, carbon dioxide, and compost products suitable as soil conditioners on farmlands, (Ojolo et al., 2007).

The anaerobic digestion can be used either to treat biodegradable wastes or produce saleable products such as heat/electricity, soil amendment etc. the most valuable use of anaerobic digestion is to combine both waste management and the use of the bi-products. It is unlikely that anaerobic digestion will be a viable treatment without using the biogas and the digestate. The qualities of the biogas and digestate will vary depending on the feedstock and its contamination. Furthermore, the use of biogas and digestate can also involve further treatments, such as composting of digestate (Sárvári et al., 2016). The process of anaerobic digestion can be further divided into four stages: pre-treatment, digestion, gas upgrading and digestate treatment, the level of pre-treatment depends on the type of feedstock, for example, manures need to be mixed whereas municipal solid wastes (MSW) are sorted and shredded. The digestion stage takes place in the digester. There are different types of digesters with different temperature, mixing devices, etc. the digestion can be either dry or wet depending on the solid content. This implies that the feedstock can be mixed with water and other appropriate liquid wastes such as sludge or re-circulated liquid from digester effluent, (Monnet, 2003).

The final stage which is the upgrading of the biogas is necessary because it may contain impurities that can damage boilers or engines depending on what the gas is used problematic than mesophilic digestion. The sterilization of the waste is linked to the temperature; the higher it is the more effective it is in eliminating pathogens, viruses and seeds. On the other hand, when the ambient temperature goes down to 10°C, gas production virtually stops, (Karki et al., 2005).

PH of Anaerobic Digesters: The pH values of the input mixture play very important role in methane formation. The acidic condition is not favourable for methanogenic process. The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7. The pH in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process. Methanogenic bacteria are very sensitive to pH and do not thrive below a value of 6.0 (Karki et al., 2005).

Retention Time; Retention time (also detention time) is the average duration of time a sample remains in the digester. In a cow-dung plant, the detention time is calculated by dividing the total volume of the digester by the volume of slurry added daily. Usually, for an abattoir waste a retention time of 40 to 60 days is required depending upon the temperature. Thus, the fermenting pit should have a volume of from 40 to 60 times the slurry added daily. But for a night-soil digester, a longer retention time (70 to 90 days) is needed in order to kill the pathogens present in human faeces. For liquid manure undergoing fermentation in the mesophilic temperature range, (Karki et al., 2005) outlined the following approximate values of retention time:

- Liquid cow manure: 20-30 days
- Liquid pig manure: 15-25 days
- Liquid chicken manure: 20-40 days
- Animal manure mixed with plant material: 50-80 days

If the retention time is too short, the bacteria in the digester are "washed out" faster than they can reproduce, so that the fermentation practically comes to a standstill. This problem rarely occurs in agricultural biogas systems. Moreover, the required retention time for completion of the anaerobic digestion reactions varies with differing technologies, process temperature, and waste composition. The retention time for wastes treated in mesophilic digester range from 10 to 40 days (Nwanko and Joseph, 2014).

Organic Loading Rate (OLR) Volatile Solids (VS): Organic loading rate is a measure of the biological conversion capacity of the anaerobic digestion system. Feeding the system above its sustainable OLR results in low biogas yield due to accumulation of inhibiting substances in the digester slurry (i.e. fatty acids) under such circumstances, the feeding rate of the system must be reduced. OLR is a particularly important control parameter in continuous systems. Many plants have reported system failure due to overloading. OLR is expressed in kg Chemical Oxygen Demand (COD) or Volatile solids (VS) per cubic meter of reactor. It is linked with retention time for any particular feedstock and anaerobic reactor volume (Monnet, 2003). Volatile Solids (VS) represents the organic matter in a sample which is measured as solid content minus ash content, as obtained by complete combustion of the feed wastes. Volatile Solid comprises the biodegradable volatile solid (BVS) fraction and the refractory volatile solid (RVS). High volatile solid content with low RVS is more suitable for anaerobic digestion, (Verma, 2002).

Mixing Anaerobic Digester Content: Mixing within the digester improves the contact between the micro-organisms and substrate and improves bacterial population's ability to obtain nutrients. Mixing also prevents the formation of scum and the development of temperature gradients within the digester. However, excessive mixing can disrupt the micro-organisms and therefore slow mixing is preferred, (Monnet, 2003). In case of co-digestion, the different feedstock should be mixed before entering the digester to ensure a sufficient homogeneity. A well agitated substrate can, leaving other parameters constant, increase biogas production by 50%, (Monnet, 2003).

- Inhibition and Toxicity: Mineral ions, heavy metals and the detergents used in livestock husbandry are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of mineral ions (e.g. sodium, potassium, calcium, magnesium, ammonium and sulphur) also stimulates the growth of bacteria, while very heavy concentration of these ions will have toxic effect (Karki et al., 2005).
- Dilution and Consistency of Inputs: Before feeding the digester, the excreta such as fresh cattle dung has to be mixed thoroughly with water. For proper solubilization of organic materials, the ratio between solid and water should be 1:1 on unit volume basis (i.e. same volume of water for a given volume of solid) when the domestic wastes are used. The dilution should be made to maintain the total solids (TS) from' 5 to 10 percent. If the slurry mixture is too diluted, the solid particles can precipitate at the bottom of the digester and if it is too thick, the flow of gas can be impeded. In both cases, gas production will be less than optimum value, (Karki et al., 2005).

## IV. FACTORS AFFECTING MICROBIAL ACTIVITIES IN ANAEROBIC DIGESTION PROCESS

The following factors affect the microbial activities in an anaerobic digester. Nature of Slurry: For proper solubilization of organic materials, the ratio between solid and water should be 1:1 when the domestic wastes are used.

Seeding or Bacterial Population: Acetogenic and methanogenic bacteria are naturally present in cow dung. However, their number is quite small. Acid forming bacteria proliferate fast and increase their number, while methanogenic bacteria develop very slowly (Ukpai and Nnabuchi 2012). Therefore, for the initial reaction, small amount of sludge of another digester is generally used as seeding or inoculums. This sludge contains high concentration of acetogenic and methanogenic bacteria, which could enhance the process of anaerobic digestion of organic materials.

Nitrogen Concentration: Methane production is the activity of Carbon metabolism, thus excess amount of nitrogen inhibits the bacterial metabolism and lowers down the methane production (Sárvári et al., 2016).

Carbon-Nitrogen (C/N) Ratio of Feed Materials: This is the ratio of carbon to nitrogen present in the organic matter. Gas production is optimum when C/N ratio of the input is between 20 and 30. C/N ratio of cow/buffalo dung is about 25 and hence ideal for biogas production.

Maintaining Anaerobiosis in the Anaerobic Digesters: Methanogenic bacteria are anaerobic organisms. In aerobic condition, most of these bacteria are inactive in metabolism, thus digesters should be totally airtight to maintain strictly anaerobic condition. In many places, digesters are buried in the Earth to maintain anaerobiosis condition.

Addition of Succulent Plant or Algae: For the effective and high production of biogas from cow dung and animal dung many succulent plants or algae are added. Green algae, water hyacinth and lemon grass are added in the digester. The amount of biogas produced from the algae was twice (344 ml/g dry algae) of that obtained from cow dung (179/g dry cow dung) alone. Also, the duration of gas evolution increased with increasing the proportion of slurry. The calorific value of the gas was 4800 K cal/m3 and the percentage of methane was 55.4%, (Karki et al., 2005).

## V. END PRODUCTS OF ANAEROBIC DIGESTION

Anaerobic digestion is a cost effective way to manage biodegradable waste because it produces biogas and digestate. The use or sale of both can provide great financial incomes. However, in order to obtain the maximum value from these products, further processing may be necessary (Nwanko and Joseph, 2014).

The components of the biogas depend on the process of digestion, but are predominately methane and carbon dioxide. The solid is a humus-like stable, organic material, the quality and subsequent use of which is determined by the characteristics of the feedstock to the anaerobic digestion process. The liquid contains soluble materials, including dissolved organic compounds (Igboro, 2011).

**Biogas**

**STAGES OF ANAEROBIC DIGESTION**

There are four key biological and chemical stages of anaerobic digestion:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis (Watter, 2009).

In most cases, biomass is made up of large polymers. In order of the bacteria in anaerobic digestion to access the energy potential of the material, these chains most be broken down into their smaller constituent parts. These constituent or monomers such as sugars are readily available by other bacteria. The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis. Therefore, Hydrolysis of these high molecular-weight polymeric components is the necessary first step in anaerobic digestion. Through hydrolysis the complex organic molecules are broken into simple sugars, amino acids, and fatty acids(Sárvári et al., 2016)..

Acetate and hydrogen produced in the first stages can be used directly by methanogenesis. Other molecules such as volatile fatty acids (VFAs) with a chain length that is greater than that of acetate must first be catabolised into compounds that can be directly utilized by methanogens (Weiland, 2010; Watter, 2009).

The biological process of acidogenesis is where there is further breaking down of the remaining components by acidogenic (fermentative) bacteria. Here, VFAs are created along with ammonia, carbon dioxide, and hydrogen sulfide, as well as other by product. The process of acidogenesis is similar to the way that milk sours (Weiland, 2010).

The third stage of anaerobic digestion is acetogenesis. Here, simple molecules created through the acidogenesis phase are further digestion by acetogens to produce largely acetic acid as well as carbon dioxide and hydrogen.

The terminal sage of anaerobic digestion is the biological process of methanol genesis. Here, methanogens utilize the intermediate products of the preceding stages and convert them into methane, carbon dioxide, and water. It is these components that make up the majority of the biogas emitted from the system. Methanogenesis is sensitive to both high and low pH and occurs between PH 6.5 and pH 8. The remaining, along with any dead bacterial remains, constitutes the digester (Ukpai and Nnabuchi 2012).

**Uses of Biogas**

Like any other fuel, biogas can be used for household and industrial purposes; the main prerequisite being the availability of especially designed biogas burners or modified consumer appliances.

Cooking

Cooking is by far the most important use of biogas in the developing world. Biogas burners or stoves for domestic cooking work satisfactorily under a water pressure of 75 mm to 85mm, the stoves may be single or double varying in capacity from 0.22m to 1.1 Om3 gas consumption per hour.

**Lighting**

Biogas can be used for lighting in non-electrified rural areas. Special types of gauze mantle lamps consuming 0.07 m3 to 0.14m3 of gas per hour are used for household lighting.

Refrigeration

Biogas can be used for absorption type refrigerating machines operating on ammonia and water, and equipped with automatic thermo-siphon. Since biogas is only the refrigerator's external source of heat, the burner itself has to be modified. Refrigerators that are run with kerosene flame could be adapted to run on biogas.

**Biogas-fueled Engines**

Biogas can be used to operate four stroke diesel and spark ignition engines. Biogas engines are generally suitable for powering vehicles like tractors and light duty trucks as has been successfully experimented in China. When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2 percent. Using biogas to fuel vehicles is not so much of an attractive proposition as it would require carrying huge gas tanks on the vehicle (Ukpai and Nnabuchi 2012).

**Electricity Generation**

Generating electricity is a much more efficient use of biogas than using it for gas light. From energy utilization point of view, it is more economical to use biogas to generate electricity for lighting. In this process, the gas consumption is about 0.75 m3per kW hour with which 25-40 watt lamps can be lighted for one hour, whereas the same volume of biogas can serve only seven lamps for one hour. Small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings. Bio-digesters can be used to treat municipal waste and generate electricity (Karki et al., 2005).

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