Anaerobic Digestion Technology: An Underutilized Technology in Nigeria

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ABSTRACT

In this work we have attempted to simplify anaerobic digestion with the accompanying benefits such as environmental management strategy, energy recovery potential, and biofertilizer production capability. We have demonstrated that it is an appropriate technology that has gained and still gaining widespread attention. But the technology requires proper training and adequate knowledge, which will help to dispel fear of failure. For any reasonable biomass digestion project, certified engineers, masons, plumbers must be engaged. Adhering to construction manual and strict compliance with regulations, any nation can fully maximize the huge benefits that accrue from anaerobic digestion of organic substrate.Government and non-government organizations play significant roles in the areas of subsidies, incentives and other relevant supports, such as education and training through extension services. With the cooperation of all stakeholders in no too-distant-future, the benefits of the technology would become fully utilized in Nigeria.

Keywords: Anaerobic digestion, Biogas, Energy recovery, Effluent, Feedstock.

Aims Research Journal Reference Format:
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1. INTRODUCTION

Anaerobic digestion technology has gained widespread acceptance in various countries of the world. Therefore, one can say that it is an appropriate technology. That a country lags behind in utilizing the great benefits that accrue from such technology does not make the technology inappropriate. The problem lies largely on the country's ability to adapt to it. This is true for Nigeria. As a country we have not been able to maximally utilize the gains of this technology in the areas of waste treatment, energy recovery, and manure production. Proper waste management is a major problem of urbanization. Mass movement of people to urban centres creates waste management problem, because of increase in waste volume generated. As a result of this, traditional landfills get filled up quicker. But if the biodegradable constituents of these wastes could actually be used as feedstock in biogas digesters it will go a long way in mitigating the environmental consequences that emanate from untreated waste. (Tobore, n.d.) reported that the average rate of waste generation in Nigeria is 0.5kg/capita/day and biodegradable wastes account for over 50%. This means that 45,000tons of biodegradable waste is generated per day for average population of 180 million.

Huge recoverable energy is also lost when biodegradable components of waste are disposed untreated. This energy, if harnessed using anaerobic digestion technology could be put to any of the traditional uses that wood fuels and fossil fuels are being employed (Ashimedua, 2015). This could play significant role in rural areas where energy supplies are limited. It could also be used to supplement the energy needs of the sites where these wastes are generated. Thus, it could reduce the costs incurred on energy used on these sites. Effluents from biogas digesters are good sources of organic manure for agricultural purposes. It is nutrient-rich and nitrogen-rich fertilizer (United States Forces – Afghanistan, Joint Engineer Directorate, 2011). Reports abound on increase in crop yield by pouring digestates on farmlands. It does not have negative environmental consequences, because it is purely organic. Only rich farmers are able to afford the high cost of inorganic fertilizers. Poor farmers could avail themselves of this opportunity.

2. THE ORIGIN OF ANAEROBIC DIGESTION

The discovery of biogas can be first traced back to the 17th century when Van Helmot noticed flickering lights beneath the surface of swamps and connected it to a flammable gas produced by decaying organic matter. In the scientific world, Volta noted as early as 1776 that biogas production is a function of the amount of decaying plant material and that the biogas is flammable under certain conditions. By 1884, a student of Pasteur in France, Gauon, had anaerobically produced biogas by suspending cattle manure in a water solution at $35^{\circ}C$. At that time he was able to obtain 100 liters of biogas per cubic meter of cattle manure (Harilal, 2012).

2.1 Biogas

Biogas typically refers to a gas produced by the anaerobic decomposition of organic matter. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), hydrogen (H_2) and moisture (Harilal, 2012). Methane, the desired component of biogas, is a colourless, blue-flame burning gas used for cooking, heating, and lighting. Biogas is a clean, efficient, and renewable source of energy.

2.2 Anaerobic Digester Design Models

Digester designs vary based on the geographical location, availability of substrate, and climatic conditions. For tropical countries, it is preferred to have digesters underground due to the geothermal energy(Ashimedua, 2015). Out of all the different digesters developed, the fixed-dome model developed by China and the floating-drum model developed by India have continued to perform until today. Recently, balloon type digesters are gaining attention due to its portability and ease of operation (Karthik, 2012).

2.3 Fixed-dome

The fixed dome biogas digester has four basic component parts:

Mixing chamber: This is where the biomass is mixed with water before it is poured into digester chamber.

Digester chamber: This is where biomass and water mixture undergo anaerobic decomposition. Methane and other gases will be produced in the chamber and stored in the gasholder.

Gasholder(Dome): This is where the biogas formed is stored. Gases formed here will push manure and slurry at bottom of the floor into expansion chamber.

Expansion chamber (compensation tank): collects excess manure and slurry. When gas is being used, manure and slurry will flow back into digester chamber to push gas up for usage. When the excess manure exceeds the volume of the chamber, the manure will be drained out. This system is called dynamic system. When gas is produced inside the chamber, the gas pressure will push manure and slurry at the bottom of the chamber to flow up into the expansion chamber. When this gas is used the slurry in the expansion chamber will flow back into the digester chamber to push the gas up for usage. The plant will be operated efficiently for a long period of time if the gasholder does not crack and the system runs regularly. The strength of the plant depends on fine construction, specification of materials according to the criteria suggested by the Biogas Programme, and strict adherence to the instruction manual on the maintenance of the biogas reactor (Construction Manual of Bio-gas Reactor, n.d.). The advantages of the fixed dome plant include the simplicity of design, few moving parts, low cost to construct and low maintenance. The disadvantages when compared to a floating-drum digester are primarily the inability to store gas for use on demand; gas from the fixed dome digester must be used as generated or expelled to avoid damaging the digester.

2.4 Floating drum

Indian design model which began in the late 1930 and in 1962 the model gained the popularity in India. In the Khadi and Village Industries Commission (KVIC) design, the digester chamber is made of brick masonry in cement mortar. A mild steel drum is placed on top of the digester chamber to store the gas produced. Thus, there are two separate structures for gas production and gas collection. When biogas gas is produced, the gas pressure pushes the mild steel drum upwards and as the gas is being used the drum gradually lowers down. Thus, by observing the level of drum, one can assess the available gas volume as long as the mild steel drum floats above the digestion chamber. With the introduction of the fixed dome Chinese model biogas digester, the floating drum biogas plant model has become obsolete due to comparatively high investment, maintenance cost and some design weaknesses (Cyimana, 2013).

The disadvantage is that the steel drum is relatively expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly. The life-time of the drum is short (in tropical coastal regions about five years). If fibrous substrates are used, the gasholder shows a tendency to get "stuck" in the resultant floating scum.They provide gas at a constant pressure, and the stored gas volume is immediately recognizable by the position of the drum. Gas tightness is no problem, provided the gasholder is de-rusted and painted regularly(Ahmed, 2012).

2.5 Balloon-Flow Digester Design

The first balloon plant was designed in Taiwan in the 1960s with the aim of avoiding some problems encountered with the classical fixed dome and floating drum digesters. However, this innovative technology was introduced in African regions in 1993 through a technical cooperation program conducted by the FAO (Food and Agriculture Organization of the United Nations) in Tanzania (Yasmine, 2017). A balloon digester plant is a long tube made of plastics. The gasholder and the digester are both part of the tube. The gasholder is at the top and the digestion part is just below it. Unlike fixed dome and floating drum digesters, the two parts are in the same container and are directly communicating. As for the inlet and the outlet pipes they are made of the same material as the “balloon” and are directly linked to it. The high gas pressure that we can find in fixed dome and floating drum digesters can be increased by weight placed on the balloon. To avoid damage in the balloon, it is preferable to use safety valves in the case of high gas pressure. The Balloon plant is well known because it is a cheap digestion plant, it is very light (generally less than 30 kg), hence very easy to transport. The construction is low cost and doesn’t need experts in the field. It is easy to use and easy to maintain. The drawback of the system include short life span (2 to 5 years), and the low gas pressure.

3. ANAEROBIC DIGESTION STEPS

There are four fundamental steps of anaerobic digestion that include hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Throughout this entire process, large organic polymers that make up biomass are broken down into smaller molecules by chemicals and microorganisms. Upon completion of the anaerobic digestion process, the biomass is converted into biogas, namely carbon dioxide and methane, as well as digestate.

3.1 Feedstock Selection

Feedstock can include animal manures, agricultural crops, agro-food processing residues, food residues, the organic fraction of household waste, organic fraction of industrial waste and by-products, sewage sludge, municipal solid waste, etc. Feedstock can be a single input (e.g. animal manure) or a mixture of two or more feedstock type (this is called co-digestion). Anaerobic micro-organisms can decompose all kinds of organic materials. Among these materials, short chain hydrocarbons such as sugars, are easiest to decompose. Longer chain hydrocarbons, such as celluloses and hemicelluloses, are more difficult to decompose and digestion will therefore take longer. Woody materials that contain long chain hydrocarbons, such as lignin, are not suitable for decomposition by micro-organism(Lukehurst, 2010).

3.2 Applications

By-products of anaerobic digestion may require further processing before application depending on the needs of end users.

Biogas can be:

- Burned to generate electricity
- Burned to produce heat
- Compressed for vehicle fuel
- Added to natural gas pipelines

Digestate applications include:

- Soil amendment, direct land application
- Soil amendment, processed, bagged, and sold as biofertilazers.
- Animal bedding
- Alternative daily cover for landfills (Chen, 2014)

3.3Economics

According to (Allison, 2015) the following factors have been observed to affect the economics and operations of anaerobic digestion systems:

- The economic viability of an anaerobic digestion project depends on the type and availability of feedstock, regional price of energy, the cost and type of transportation, amount of biogas produced, local air quality standards, tipping fees received for co-substrates, availability of greenhouse gas (GHG) reduction or other credits, incentives and subsidies, and the quality and local demand or options for utilization for resulting products.
- Seasonality of operations (i.e. wet vs dry or hot vs cold).
- Geography (i.e. temperate vs arid climate, or proximity to food processing manufacturers, population centres or farmlands).
- Regulations/Legislation
- Other market forces (e.g. competition with low tipping fees at a nearby landfill)

3.4 Institutions in Nigeria where biogas plants could be installed

Areas of application of this technology abound. These include, but are not limited to, large poultry farms, piggeries, cattle ranches, and public places like large markets, hospitals, school hostels, and places like military barracks and prisons.

3.5 Benefits of biogas digestion

The following benefits of anaerobic digestion were outlined by (Chen, 2014):

- reducing odour emissions, which improves air quality
- reduction of emission of greenhouse gases to the atmosphere
- protecting water quality by reducing the potential for pathogens to enter surface and/or groundwater
- generating energy(electricity, gas, heat) that can be sold for on-farm or off-farm uses
- killing weed seeds in manure, which reduces the costs of weed control
- reducing bedding costs by using digested fibre
- improving manure nutrients availability to plants, reducing fertilizer costs
- being a better neighbour

Other Advantages

- The generated biogas can supplement traditional energy sources like firewood and animal dung, thus contributing to combat deforestation and soil depletion.
- Improvement of hygienic conditions through reduction of pathogens, worm eggs and flies.
- Reduction of workload, mainly for women, in firewood collection and cooking.
- Environmental advantages through protectionof soil, water, air and woody vegetation.
- Micro-economic benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture (Harilal, 2012).

3.6 Maintenance of Biogas Digesters

A biogas digester will be a quality system if the engineer, mason and plumber follow the construction manual instructions. A well-planned, constructed and maintained plant will benefit the owner for their investment, ultimately provide positive return and meet their expectations. This may persuade his relatives and neighbours to invest in a biogas plant while a poorly constructed plant will do harm to the reputation of biogas technology. A biogas digester will last from 20 to 50 years if properly maintained(United States Forces – Afghanistan, Joint Engineer Directorate, 2011).

4. CONCLUSION

Anaerobic digestion of biomass using biogas digesters is an appropriate technology. Looking at the benefits in areas of environmental management, energy recovery, and biofertilizer production, the country should encourage the application of the technology in various areas that have been outlined in this paper and other areas not mentioned here where the availability of feedstock will not be a problem. The government should also help in the area of information dissemination and extension support services using its staff in the ministry of energy.

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