DESIGN OF THE BIO-DIGESTER FOR BIOGAS PRODUCTION: REVIEW

Ishmael M Ramatsa, Esther T. Akinlabi, Daniel M. Madyira, Robert Huberts

Abstract: This review is a summary of different aspects of the design and operation of biogas digesters. Three types of digesters were reviewed, that is, the plug flow, floating drum and the fixed dome digester. Biogas is one of the products formed during the anaerobic digestion process. Anaerobic digestion is dependent on several factors such as the pH value, feeding material, temperature, pressure, organic loading rate, retention time and the Carbon-to-Nitrogen (C/N) ratio. The shape of the digester and the material for construction are also considered important during design stage.

Keywords: Biogas, construction material, plug flow, fixed dome and floating drum digester**.**

I. INTRODUCTION

The development of new methods of production and use of renewable energy sources that suit the economic and the geographical conditions of the developing countries will be required in order to solve the problems of energy crisis and climate change. Today, climate change is everyone's concern and is among the leading problems if not the only one linking the international community and drawing much attention. Fossil resources were given much attention in the past before climate change became a major concern. The time has come, and the time is now where attention should now be shifted from fossil fuels to renewable energy sources. The anaerobic bio digester process is not a new technique of converting waste material into usable product. However, there is a need for further investigation to improve the process especially in this era of climate change. Conventionally, the anaerobic digestion (AD) process should occur in a strict anaerobic environment with no free available oxygen. Such aerobic (oxygen presence) invasions can or may deteriorate the performance of the digestive system [1]. Under these conditions, i.e. oxygen deficient environment, biogas is produced. Biogas is a combustible gas consisting mainly of methane and carbon dioxide. Carbon dioxide being one of the principal greenhouse gases, its concentration in the atmosphere is increasing expeditiously since the advent of industrialization [2]. The aim of this paper is to review the design and the use of the most popular bio-digesters for the production of biogas. Reviewing the popular bio-digester is meant to get in-depth knowledge on bio-digester technology currently in use. This understanding is necessary for the development of biogas based renewable energy sources in the future.

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II. BIOGAS

The term "biogas" is commonly used to refer to a gas which has been produced by the biological breakdown of organic matter in the absence of oxygen. Biogas is one of the products formed during the anaerobic digestion process, and consists of CO_2, CH_4, H_2S, H_2, H_2O and some traces of other substances depending on the composition of the substrate

A. Methane formation pathways

The anaerobic digestion is characterized by a series of biochemical transformations caused by the degradation of organic matter. The whole process involves several distinct stages. i.e., hydrolysis, acidogenesis, acetogenesis and the final stage methanogenesis (Figure 1). In stage 1, fats, complex carbohydrate and proteins are hydrolysed to their monomeric form by enzymes. In stage 2, the monomers are further degraded into short chain acids and these short chain acids are converted to hydrogen, carbon dioxide and acetate and in the final stage which is stage 3, the intermediate products are converted to methane and carbon dioxide by methanogerns [3].

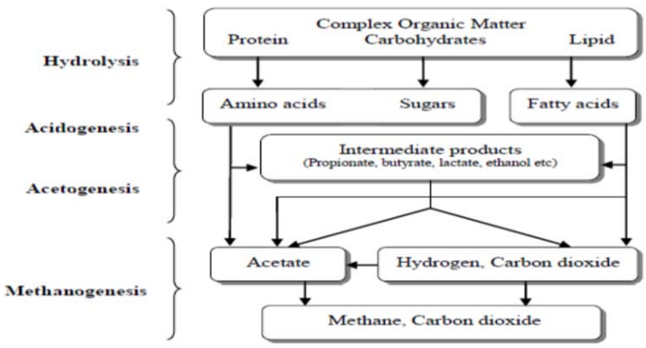

Figure 1: Anaerobic digestion pathways of organic degradable substrate [4].

B. Factors for optimum performance

Anaerobic digester is a promising technology for treating waste and producing energy at the same time. Digestion is dependent on several factors for the well-being of a stable digester. Factors such as pH, temperature, organic loading rate, hydraulic retention time and carbon-to-nitrogen (C/N) ratio play a significant role during the bio-degradation of the solid material. There are three temperature region in which anaerobic digestion can be conducted, pychrophilic (10-20°C), mesophilic (20-45°C) and thermophilic (45-68°C). The most common temperature ranges used to run anaerobic digesters are either mesophilic (with an optimum at 35°C) or thermophilic (with an optimum at 55°C) [5].

III. TYPES OF DIGESTERS

C. Plug flow digesters

This is a type of anaerobic digester that uses a long, narrow horizontal tank in which a material (manure) is added at a constant rate and that force other material to move through the tank and be digested Figure 2. Typically, a plug flow digester vessel is five times longer than it is wide, is insulated and heated, and is made or reinforced concrete, steel or fiberglass.

A plug flow digester has no means of agitation. The term "**plug flow**" derives from the fact that the manure in principle flows through the digester vessel as a "plug," gradually being pushed toward the outlet as new material is added. In fact, the situation is more complicated and some parts of the manure travel faster than others on their way through the vessel, or may even settle or float and remain in the digester [7]. The first documented use of this type of design was in South Africa in 1957 [8]. The main advantage of the plug-flow design is that it is simple and economical to install and operate. However, it is not as efficient or as consistent as the completely mixed design. Plug-flow units are limited to applications with low amounts of sand, dirt, or grit, because these substances will tend to stratify and settle out inside the digester, requiring significant effort to clean out [9]. Complete mix units are more expensive to install and operate than plug-flow units, because they require both the capital equipment and the energy for mixing [9].

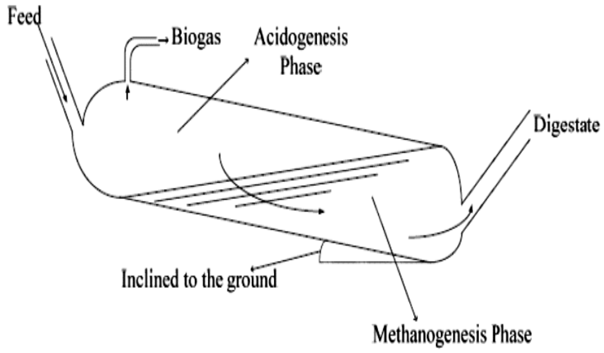

Figure 2: Schematic representation of a plug flow digester [10] .

D. Fixed dome digesters

A well and a dome are made out of cement concrete. Fixed dome Chinese model biogas plant (also called drumless digester) was built in China as early as 1936 [11]. Fixed dome digesters are usually built underground [12]. The dome is fixed and hence the name given to this type of plant is fixed dome type of biogas plant. The function of the modified fixed dome digester plant is similar to the floating holder type biogas plant as shown in Figure 3, the only difference is the fixed top part of the digester. The used slurry expands and overflows into the overflow tank [13]. Disadvantages of fixed-dome digesters are that special sealants are required, high technical skills are required for construction, and gas pressures fluctuate, which causes complication of gas use [11]. The difference between Figure 3 and 4 is that, in Figure 3 the upper part of the digester is fixed, i.e., it does not experience any movement on the upper side when the gas starts to fill up the available empty space as compared to the floating tank type digester.

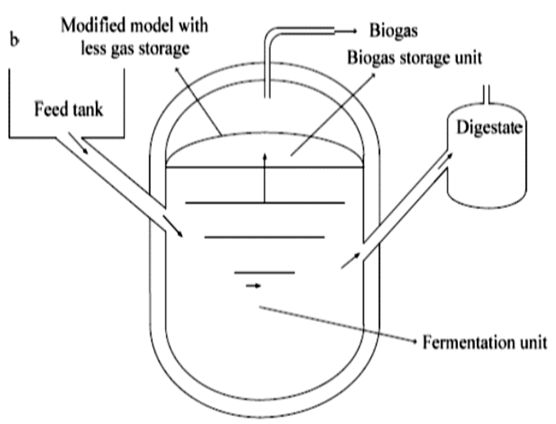

Figure 3: Schematic representation of a fixed dome digester [10].

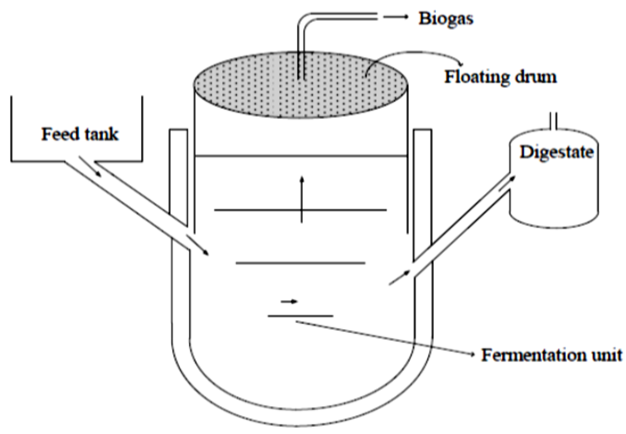

Figure 4: Schematic representation of a floating drum digester [10].

E. Floating drum digesters

An experiment on biogas technology in India began in 1937 [14]. In 1956, Jashu Bhai J Patel [14], developed a design of floating drum biogas plant popularly known as Gobar Gas plant. In 1962, Patel's design was approved by the Khadi and Village Industries Commission (KVIC) of India and this design soon became popular in India and the world [15]. It is divided into two parts. One side has the inlet, from where slurry is fed to the tank as shown in Figure 4. The tank has a cylindrical dome made of stainless steel that floats on the slurry and collects the gas generated. Hence the name given to this type of plant is floating gas holder type of biogas plant. The slurry is made to ferment for about 50 days. More gas is made by the bacterial fermentation, leading to the pressure inside the gas collecting dome to increase. The gas can be taken out through an outlet pipe. The decomposed matter expands and overflows into the next small holding tank [13].

The shortcomings of these digesters discussed above relative to this research is that the pressure cannot be manipulated or maintained to a specific value for a certain period of time in order to observe the effect it has on the composition of the gas and on the activity of the bacteria. The digester design for this particular research will take into account the accommodation of pressure manipulation.

IV. Design for the Current Study

As mentioned above that the shape and the material of construction plays a role during the design phase, as such, the current design shape considered will take a cylindrical shape and will be made of stainless steel to avoid it reacting with the contents of the digester. The digester will be fitted with an electronic relief valve to enable the monitoring of the effect of pressure on the composition of the biogas and the activity of the micro-organism during anaerobic digestion, the electronic valve will be adjusted every-time when a new pressure will be investigated and it will also be used to regulate the internal pressure of the digester, and the following pressure will be tested (101.321kPa to 101321.5kPa). The impeller will be used to mix the contents of the digester. The heating coils with thermostat will be used to heat-up the contents of the digester, and temperature range (32- 45 ^{o} C) will be tested. The operating principles are similar to that of the floating drum digester, the only difference is that the current design will monitor pressure by using relief valve Figure 5, which will allow the monitoring of the internal pressure of the digester over a range of constant pressures. Grass and garden wastes will be used as feeding material.

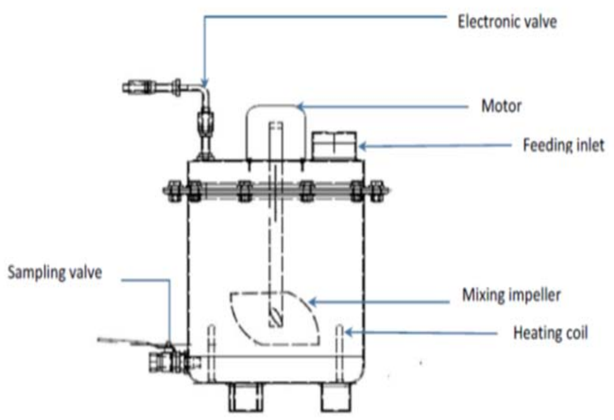

Figure 5: Schematic representation of a digester for the current study

V. CONSTRUCTION MATERIALS

High investment costs are normally required to build a proper working structure of a digester, and with the increase in technological advances, different materials with improved properties and lower cost have been introduced in the market in recent years. Digester construction materials are dependent on the geological, local condition and available materials for construction [16]. Different construction materials such as Poly Vinyl Chloride (PVC), Polyethylene (PE) have been used, but some of these materials have a short life span [17] - [19], again in another digester design the steel drum has been used and it was found to be susceptible to corrosion over a certain period of time during. [15].

VI. CONCLUSION

The design and use of common biogas digesters have been reviewed and presented in this paper. A limitation with respect to regulating the internal pressure to increase yield has also been highlighted. Choosing a relevant digester in practical application is a very important decision to make during the design stage. In this stage, factors such as solid material that need to be digested, the geological conditions, the shape of the digester, the yield and the availability of the construction material should be evaluated before the design is done. Materials for construction are also very important as they determine the life span of the digester.

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