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Biogas generation from sewage in four public universities in Ghana: A solution to potential health risk

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ABSTRACT

Apart from waste treatment, anaerobic digestion is a reliable method for biogas generation. The digested sludge from anaerobic digesters can also be used to enhance the fertility of the soil. This paper assesses the biogas potential from the sewage generated in four public universities in Ghana for the 2008/2009 academic year. In the estimation of the amount of sewage generated in each university, the population was used and was categorized into residential and non-residential staff and students. The population of the universities varies throughout the year due to the vacation periods hence the sewage generated varies accordingly. The estimated population for the four universities was 100,313 when in session and 20,903 on vacation and the estimated daily sewage generated is 1379.9 m^3 and 327.8 m^3, when the universities were in session and on vacation respectively. This study revealed that an annual biogas potential of about 815,109 m^3 could be obtained which is equivalent to about 4,891 MWh of energy or can replace about 4532 tonnes of firewood or 326.4 tonnes of LPG which can reduce the pressure on the forest and the use of LPG.

1. Introduction

The biomass resources available in Ghana include sawmill residue, agricultural waste, animal waste, municipal waste and energy crops. Well tested applications for biomass-based technologies are cogeneration, biogas production from anaerobic digestion, and very recently bio-diesel production. However, biogas is yet to make significant impact in the energy sector in Ghana despite its potential for electricity, lighting (biogas lamps) and cooking in institutions, abattoirs and households. Anaerobic digestion is a widely used method for the treatment of sewage sludge [1]. In addition, feedstock for anaerobic digestion include cattle dung and manure, goat dung, chicken droppings, abattoir byproducts, kitchen waste, food processing factory wastes and human excreta [2,18]. Typically biogas from digesters is composed of 55–75% methane, 30–45% carbon dioxide, and trace amounts of other gases, as shown in Table 1.

Sanitation has become a major development issue in recent years. The increasing amount of organic waste material in both urban and rural communities and also the production of thousands of tonnes of sludge from sewage and wastewater from different agricultural and food industries lead to severe economic and environmental difficulties [4].

The gas yield of an organic material depends on the type of substrate and the Volatile Solids (VS) present as shown in Table 2. The slurry should neither be too thick (more than 14%) nor too thin (less than 6%) but should be 8–10% of Total Solids

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Table 1 – Composition of biogas [3].

Constituent	Composition
Methane (CH_4)	55–75%
Carbon dioxide (CO_2)	30–45%
Hydrogen Sulphide (H_2S)	1–2%
Nitrogen (N_2)	0–1%
Hydrogen (H_2)	0–1%
Carbon monoxide (CO)	Traces
Oxygen (O_2)	Traces

(TS) content [5]. Sludge thickening before digestion results in sludge volume reduction which reduces digesters' volumes and heat requirements for the process [6]. Other parameters such temperature, carbon-nitrogen (C/N) ratio, loading rate, Hydraulic Retention Time (HRT) also affect biogas yield of feedstock.

The sewage generated in some of the public universities in Ghana is partially treated whiles in others they are conveyed by sewage tankers to damping sites designated by the municipal assemblies where the universities are located. These practices have enormous impact on the communities around the damping sites considering the fact that raw sewage serve as breeding sites for microbes that cause diseases if not handled properly. In addition to this, if the sewage generated is not treated large volumes of methane (CH_4) with a Global Warming Potential of 23 [7] and carbon dioxide (CO_2) gases enter the atmosphere, which have a climate change impact [8]. In comparison with other methods of waste treatment, such as land filling, incineration and composting, anaerobic digestion has the advantages of reducing the amount of waste [1] and generating biogas which is a renewable energy source [4]. In addition, the digester effluent has little odor and an increased concentration of dissolved nutrients, which provides farmers with an improved organic fertilizer [13].

This paper looks at the biogas potential of the sewage generated in four public universities in Ghana namely: Kwame Nkrumah University of Science and Technology (KNUST), University of Ghana (UG), University of Cape Coast (UCC) and University for Development Studies (UDS). This however, can be extended to other public and private universities to help mitigate the effect of disposing the raw sewage into the environment and utilize the biogas generated to augment their energy requirement.

Table 2 – Gas yields and methane content for some kinds of substrates [6].

Substrate	Gas yield (litres/kg VS)	Methane Content
Vegetable residue	330–360	–
Pig manure	340–550	65–70
Poultry droppings	310–620	60
Fallen leaves	210 – 290	58
Sewage sludge	310–740	–
Cow	90–310	65

2. Biogas technologies in Ghana

2.1. *Overview of biogas in Ghana*

Interest in biogas technology in Ghana began in the late 1960s but it was not until the middle 1980s did biogas technology receive the needed attention from government [10]. However, the development of anaerobic digestion systems for conversion of waste to biogas for cooking and lighting became popular in when the government and its environmental agencies became alarmed about the rapid devastation of large tracts of forest land for charcoal and firewood production [11]. Most plants, however, collapsed shortly after duration of project due to immature technologies and poor dissemination strategies [12]. In 1992 The Ministry of Energy, Ghana establishes a biogas plant as a demonstration project at Appolonia [6]. The "Integrated Rural Energy and Environmental Project" at Apollonia, a village located some 46 km from Accra. The Apollonia Biogas Plant used animal dung and human excreta to generate 12.5 kW of electric power for street and home lighting as well as cooking [9,11], while the bio-slurry was used for agriculture. However, the plant is not functioning at full capacity due to lack feedstocks materials [6,13].

Apart from these isolated cases which are largely donor-driven initiatives, there has not been any systematic attempt at promoting the biogas technology on a large scale in Ghana. In 1996 the Ministry of Energy commissioned a study – the National Biogas Resource Assessment (NBRA) Project to be conducted to assess the biogas energy potential of various geographical areas of the country, with the aim of promoting the dissemination of biogas technology nationwide to suitable rural communities, as a means to supplement their energy resource base and through that, help improve their socio-economic well being [11].

Even though there is no clear-cut policy on dissemination of biogas plants in Ghana, according to the Strategic National Energy Plan (SNEP) for Ghana for the period 2006–2020, the government hopes to promote biogas-for-heating in institutional kitchens, laboratories, hospitals, boarding schools, barracks, etc. As part of its strategic targets the government hopes to achieve 1% penetration of biogas for cooking in hotels, restaurants and institutional kitchens by 2015 and 2% by 2020 [9]. Currently, a number of biogas service providers are involved in the construction of biogas plants in Ghana from 2001 to 2009 [10]. Some of these biogas plants have being constructed for schools, churches, hospitals and for private individuals.

2.2. *Types of biogas plants in Ghana*

The most common biogas plant designs disseminated in Ghana are either fixed-dome as shown in Fig. 1 or the floating-drum which are constructed using bricks. Floating-drum plants consist of an underground digester and a moving gasholder. The gasholder floats either directly on the fermentation slurry or in a water jacket of its own. The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored. The gas drum is prevented from tilting by a guide frame as shown in the Fig. 2 [14]. Most the floating-drum digesters are of the water-jacket type with a spherical digester