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Water Scrubbing: A Better Option for Biogas Purification for Effective Storage

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Abstract: Concerns over the environment and the rising costs for energy and wastewater treatment have caused a resurgence of interest in anaerobic treatment and subsequent use of the biogas produced during this treatment of organic wastes as fuel. Biogas from faecal and landfill wastes has become a potential renewable energy source for both domestic and commercial usage especially in Ghana where a 50MW capacity waste-to-power plant is undergoing construction. In addition, an average total capacity of about 95MW biogas plants is in operation in other parts of the country. Due to the presence of carbon dioxide (CO_2) and hydrogen sulphide (H_2S) in biogas, it has become extremely difficult to transport and store it effectively especially where it's produced in commercial quantities. Thus the need emerges for a unified approach for scrubbing, compression and subsequent storage of biogas for wider applications. This paper presents the developments in biogas purification and storage into steel propane and butane tanks (requiring a medium pressure of 1.05-1.97bar) for easy and cost effective transportation and utilization. The paper also presents water scrubbing as a better option for biogas purification in Ghana.

Key words: Water scrubbing · Purification · Storage · Anaerobic digestion

INTRODUCTION

Waste management in Ghana is gradually improving as most of the municipal wastes are being converted to various forms of energy including biogas. In developing countries like Ghana, biogas is mainly used as a low-cost fuel for cooking and as a source of fuel in gas engines to generate electricity in rural areas. Ghana currently has about nine (9) biogas plants (with a total of 21 digesters) which are operational at an average capacity of $45m^3$ per digester, corresponding to an average power generation of 0.27MWh at a cost of USD 2,812. [1] This is expected to increase to about 6.03MWh power generation per a digester in the year 2015. In addition to this, a waste-power plant (biogas plant) commissioned in Kumasi, one of the metropolitan cities in Ghana, is expected to consume about 1000 tonnes of solid waste per day generated at the Kumasi metropolis. This waste is expected to generate between 30-52MWh of electricity, which is about 30% the power requirement of the metropolis. [2] This clearly indicates that biogas production has a greater potential in Ghana thus the need to develop a cheaper and more efficient purification unit to help maintain the generators for a long time as the impurities biogas may cause corrosion of some parts of the generator. As regards to green fuel potential in Ghana, the biogas needs to be scrubbed to make it transportable from production point to homes for domestic usage. It is in this view that water scrubbing is proposed since water can be obtained cheaply and always in Ghana as other methods may not be appropriate.

Recent technologies to purify biogas having about 50-65% methane have been found to increase its caloric value yielding about 70-85% methane or more. Of all the methods investigated into, it was found out by a feasibility study on most biogas plants in Ghana that the water scrubbing technology is the best. This paper presents some outcome of the study.

Biogas refers to a gas, primarily of methane and carbon dioxide, produced by the anaerobic digestion or fermentation of biodegradable materials such as manure or sewage, municipal waste, energy crops etc in the absence of oxygen. The methane in biogas gives it the ability to be used as a fuel, the combustion of which

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releases energy. However, the proportion of methane to carbon dioxide in biogas depends on the composition of the substrate.

Biogas cannot be stored easily as it does not liquefy easily under pressure and at ambient temperature (-82.5°C and 47.5 bar respectively) [3]. But biogas being a potential fuel serving various purposes, a more efficient and cost effective method of purifying it has been investigated into. The calorific value of biogas produced in Ghana varies between 4,500-5,800 kcal/m^3. In terms of energy equivalent, 1.30-1.87m^3 and 1.4-2.1 m^3 of biogas with this calorific value corresponds to one liter of gasoline and diesel fuel respectively. [3]

Raw biogas contains impurities comprising about 30-45% CO_2 which specifically hinders is compression into cylinders; traces of H_2S and water vapour which facilitate corrosion in generator parts and other storage devices. Water scrubbing, however, is the absorption of CO_2 and H_2S in biogas using water at high pressure. Critical points of methane is recorded as 190.6 K (-82°C) and 46 bar (4.6 MPa). This means that methane will not liquefy at temperatures above-82 C, whatever the pressure implying that at any ambient temperature, methane is a gas. Liquid methane at atmospheric pressure would have a temperature of 111.5 K or-161.6 C thus a better way of storing it too has to be used.

Considering operational conditions in Ghana, water scrubbing, a method of biogas purification was found to be the simplest and most economical of all the other methods. This justification was done from a simple cost benefit analysis and environmental impact assessment carried out on the biogas plant at Appolonia in Ghana.

MATERIALS AND METHODS

Water Scrubbing Technology: Appolonia as Case Study

The biogas plant at Appolonia (a small community in the southern part of Ghana) constructed in 1991, has ten (10) digesters with a capacity of 50m^3 per digester. It generates about 125kW electricity (from about 1.1 tonne cow dung) which is fed to a local grid for domestic use in about twenty one (21) houses in the community. Since about 59.4% of the gas is used for cooking, there is the need to compress the gas to be stored in cylinders other than connecting underground pipes to all the houses which may increase the cost of plant operation. The biogas fed through the two generators is able to power almost all the street lights as well as domestic lights in the community. It was found out that the diesel-biogas system at Appolonia saves about 66% in diesel consumption.

Table 1: Summary of feasibility study on water scrubber design for Appolonia biogas plant

Design parameters	Specification
Plant capacity	300 m^3
Plant efficiency	70%
Biogas produced	210m^3/day
% of methane in biogas	55-65%
% of methane in scrubbed gas	75-95%
Calorific value of biogas	20MJ/m^3
Calorific value of scrubbed gas	28.7MJ/m^3
Total energy required per day	1082MJ
Total energy available from the biogas plant	4283.13MJ
Diameter of scrubber	300mm
Height of scrubber	9800mm
Number of ideal stages	18 stages
Pressure of biogas	1000kPa
Pressure of water used for scrubbing	1300kPa

A packed bed scrubber was designed for a feasibility study on the Appolonia biogas plant to absorb about 92% of the available CO_2 gas in the raw biogas. The raw biogas will be compressed at a pressure of 1.0 MPa so as to increase solubility of carbon dioxide in water. Water also at a pressure of 1.3MPa will be released to meet the incoming pressurized gas in the column in a counter current way. The process dissolves CO_2 as well as H_2S in water and the H_2S is collected at the bottom of the tower. The design results and other parameters are shown in Table 1 based on the assumption that six (6) digesters will be working at a time.

RESULTS AND DISCUSSION

Comparative Economic Analysis: Appolonia as a case study

Three common methods of purifying biogas i.e. absorption in water, absorption using chemicals, biological methods were considered in this study. Cost benefit analyses on the design of the scrubbing units were done based on the capacity of the biogas plant at the Appolonia and availability of water. Based on the above design parameters, the capital, annual operational and maintenance cost of water scrubber was compared to that of the chemical absorption and biological methods of purifying biogas. The results were based on the design parameters compared with their corresponding price of the packed bed absorber on the international market and the local manufacturers in Ghana. The results are represented in Table 2 and Fig. 1.

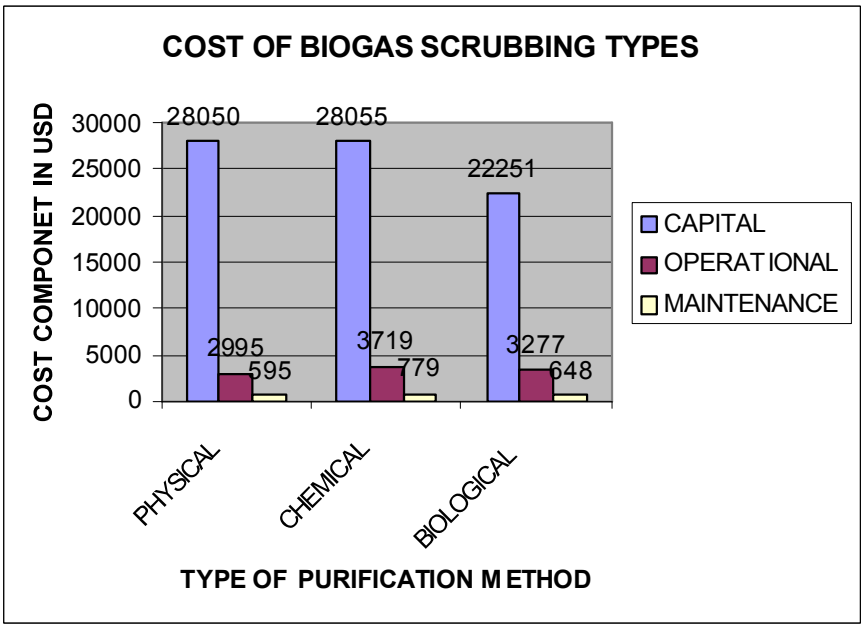

Fig. 1: Capital, Operational and maintenance cost of three biogas purification methods

Table 2: Comparative cost analysis of three types of biogas purification methods

Type of purification method	Cost of biogas purification unit, USD		
	Capital	Operational	Maintenance
Water scrubbing	28050	2995	595
Chemical absorption	28055	3719	779
Biological method	22251	3277	648

Comparative Environmental Impacts: It is revealed from previous studies that chemical absorption as a method of purifying biogas releases some dangerous gases into the environment themselves. This contributes so much to green house effect which violates the benefit of biogas. Water scrubbing is found to be eco-friendly compared to the other methods.

CONCLUSIONS

Biogas for cooking, electricity generation and sanitation control has proven to be technically feasible in Ghana. Due to its potential, the biogas needs to be purified for easy storage into cylinders and prolong the efficiency of generators used for electricity production. Out of the several methods of biogas enrichment, water scrubbing is found to be the most simple, low-cost and suitable method for enrichment of biogas in Appolonia, a rural community in Ghana. The proposed designed biogas water scrubber is able to remove 93% v/v of carbon dioxide present in raw biogas.

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