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Utilization of the Uncoated Steel Wool for the Removal of Hydrogen Sulfide from Biogas

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Abstract**—** Electricity generation in rural areas using biogas produced by anaerobic digestion of pig manure offers low cost and low emissions than any other energy sources. Biogas with its numerous benefits, however, contains hydrogen sulfide. Hydrogen sulfide (H_2S) gas is odorous, poisonous and corrosive that emits sulfur oxides upon combustion. It is an environmental hazard and can damage biogas engines. Most large systems use specialized biogas engines and are operating with some levels of hydrogen sulfide. To be economically feasible, smaller scale systems which are wide spread need inexpensive methods of removing hydrogen sulfide allowing more flexibility in engine choice for electricity generation.

This study investigated the effectiveness of a fixed bed of adsorbent from commercially available steel wool oxidized under atmospheric conditions for sixteen (16) weeks. Biogas mixture passed through the polyvinyl-chloride (PVC) columns with the steel wool. Iron oxide can be reused and the sulfur produced can either be released into the atmosphere or used as reagent in laboratories.

The fixed bed with iron oxide (regenerated steel wool) eliminated hydrogen sulfide with more than 95% efficiency. The adsorption oxidized hydrogen sulfide to elemental sulfur and sulfate reducing any spent steel wool disposal costs.

Keywords**—**Biogas, Hydrogen Sulfide, Regeneration, Steel Wool.

I. Introduction

FARMS raising animals on concentrated feedlots produce large quantities of manure that cannot be handled by the traditional practice of land spreading. Hence, disposal of farm animal wastes has become a serious problem to the farm owner and to the environment, among others.

Anaerobic digestion of animal wastes is an approach that can alleviate the problem. It reduces the capacity of the raw wastes to pollute the environments while producing a gas mixture that can be used as a source of energy.

Biogas can be defined as a fuel gas rich in methane produced through a biological route from a wide variety of substrate biomasses including animal wastes and plant residues. A typical biogas contains about 54 to 80% methane, 20 to 45% carbon dioxide and trace impurities including hydrogen sulfide [1].

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As a fuel, biogas can be used to run boilers, space heaters, cooking stove and stationary engines that can drive blowers, pumps or electricity generators. However, carbon dioxide, water vapor and hydrogen sulfide present in the biogas can cause some serious problems in the handling equipment. Hydrogen sulfide from poorly treated or untreated biogas in particular, can cause serious corrosion on the metal surfaces of handling equipment, burner and controls [2]. Table I shows the different hydrogen sulfide concentration standards in every application [3] - [7].

TABLE I
COMPOSITION OF DIFFERENT BIOGAS

Components	Household waste	Wastewater treatment plant sludge	Agricultural Waste	Waste of Food Industry
CH_4 % vol.	50 - 60	60 - 75	60 - 75	68
CO_2 % vol.	34 - 38	19 - 33	19 - 33	26
N_2 % vol.	0 - 5	0 - 1	0 - 1	-
O_2 % vol.	0 - 1	<0.5	<0.5	-
H_20 % vol.	6 (at 40^OC)	6 (at 40^OC)	6 (at 40^OC)	6 (at 40^OC)
Total % vol.	100	100	100	100
H_2S mg/m^3	100 - 900	1000 - 4000	3000 - 1000	400

Hydrogen sulfide (H_2S) is always found in the biogas. If the desired biogas is to be upgraded by reducing the hydrogen sulfide content, the biogas digester set up must have a system for its removal. Some of the desulfurizers for filtering the H_2S contaminant are available in the market, but they are costly, complicated and difficult to implement, especially in rural areas.

Hydrogen Sulfide (H_2S) is a pollutant gas that can be found as a contaminant in commercial gas. It is a smelly and deadly gas and very corrosive to certain type of metals. The disadvantages of H_2S contaminant have limited the application of biogas as fuel for internal combustion engine [8], [9], [10], and [11]. The recent life cycle assessment of biogas upgrading technologies [12] is criticized for ignoring the existence of the H_2S as impurities in the biogas and only focusing in removing its CO_2 content.

The result of combustion of the gas that contains H_2S is sulfur and sulfuric acid that is very corrosive to metals. The H_2S content that reach 200 ppm can cause death in 30 minutes. The safety and health standards give a maximum content of H_2S in the level of 20 ppm [9]. Other sources inform that the H_2S contaminant will reduce the lifetime of the plumbing system of an installation using biogas [8], [13].

The result formed after the combustion in which H_2S is involved will yield sulfur oxide that will corrode the metal component and cause the lubricant oil to become acidic. Therefore, to avoid the damage caused by H_2S, it must be eliminated or at least be reduced in the system [8], [13].

Hydrogen sulfide is a toxic gas that is rated as slightly less than cyanide, and more toxic than carbon monoxide [14].

Iron oxide (steel wool) as a component in a dry desulfurization system is effective in adsorbing and oxidizing hydrogen sulfide to elemental sulfur that can be safely released into the atmosphere [15].

The iron oxide can be regenerated at rates lower than the rates of scrubbing by forcing air through the iron sulfide formed during the scrubbing in the reactions [7], [16]:

$$2Fe_2S_{3(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)} + 6S \quad (1)$$

$$2Fe_2S_{3(s)} + 3O_{2(g)} + 6H_2O_{(l)} \rightarrow 4Fe(OH)_{3(s)} + 6S \quad (2)$$

The regenerated iron oxide can be reused. The iron oxide is normally changed once 75% of the scrubbing iron has been giving 3-5 cycles of use and regeneration [15].

As a continuation of our initial research [17], this study aims to establish the effectiveness of iron oxide as a low cost technology for removing hydrogen sulfide from biogas to minimize damage to gas handling equipment, to health of the users and operators of the system and on the environment.

II. Methodology

A. Biogas Plant

Fig. 1 shows the process behind the biogas production. First, load 6-8 kg of pig manure and 12 liters of water every day for 15 days; after 15 days, the biogas digester converted the pig manure into biogas by anaerobic digestion. The gas produced is stored in the gas holder before going to the hydrogen sulfide removal system.

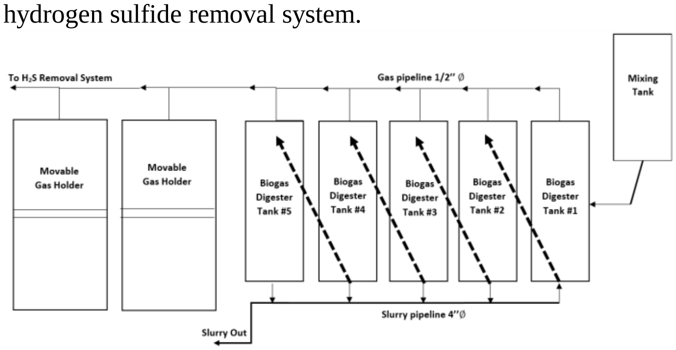

Fig. 1 Schematic Diagram of the Biogas Plant

B. Hydrogen Sulfide Removal System

As shown in the figure below, the biogas from the gas holder/tank passes through the inlet section on which mass flow, temperature, humidity and initial concentration of the hydrogen sulfide from the biogas is being measured. It passes through the 1st stage purifying chamber and passes through another until it reaches the last chamber. Upon exiting the respective chambers the concentration of the hydrogen sulfide is measured until it reaches the 3rd stage chamber. Then, at the exit port, the same parameters as the input are measured. The complete test rig for the removal of hydrogen sulfide is shown in Fig. 2 below.

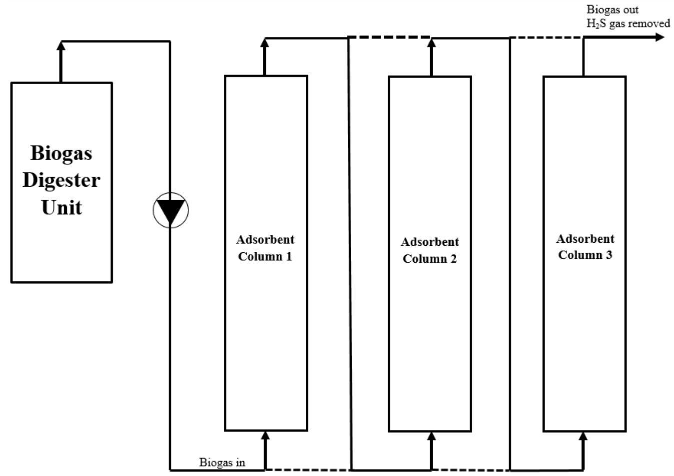

Fig. 2 Schematic Diagram of the H_2S Removal System

C. Regeneration of Steel Wool

The steel wools from the used adsorbent for the H_2S Removal System were taken out and aerated under atmospheric conditions for sixteen (16) weeks as shown in Fig. 3.

The experiment was started by selecting the used oxidized steel wools, since some of the iron sponge (steel wool) components were disintegrated during the previous cycle of usage process. The selected steel wools were then recycled and reused. The recycling of steel wools was done instead of immediately discarding them as wastes.

Fig. 3 The appearance of steel wool after oxidation for 16 weeks

Only the non-disintegrated steel wools were selected. The regeneration happened by simply exposing the steel wool to the atmosphere to yield Fe_2O_3 and also $Fe(OH)_3$. The appearance of the steel wool after the aeration process was black which is due to oxidation as shown in Fig. 3.

The regenerated used steel wool were then again assembled as a fixed bed desulfurization system as shown previously in Fig 2.

III. Results

The result of the experiment is presented in the Fig. 4. It indicates that the regenerated steel wool as an adsorbent performs as good as the new steel wool, i.e., almost 100% efficient and effective.

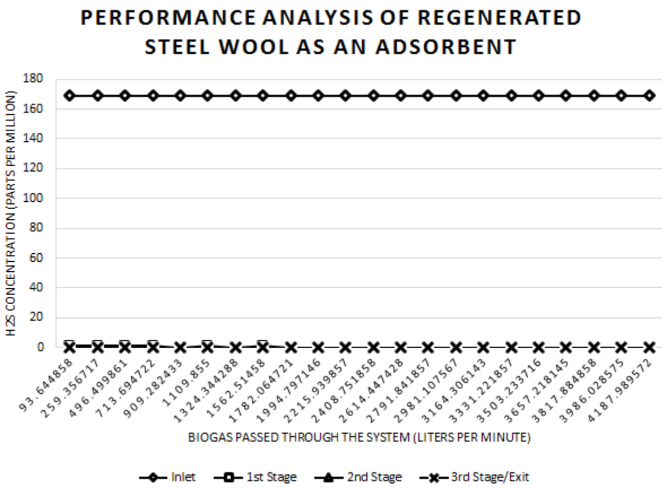

Fig. 3 Graph on the H_2S Inter-stage Concentration versus volume flow using regenerated steel wool as an adsorbent

IV. Conclusions

Based on the results of the experiment as shown, the following conclusions are derived.

1. The regenerated steel wool as an adsorbent for removing hydrogen sulfide from the biogas is effective, During the first stage outlet, recorded H_2S concentration of around zero (0) ppm is achieved.
2. For a given bed to diameter ratio of 6-7, flow rate of untreated biogas of around 3-4 liters per minute and mass of steel wool as an absorbent of about 1.9 kg, one (1) chamber or stage for removal of hydrogen sulfide in the system suffice from inlet H_2S concentration of higher than 150 ppm to an outlet H_2S concentration of zero (0) ppm with ± 0.1 ppm accuracy.
3. The experimental results show that the reduction of H_2S to almost zero parts per million is maintained even after 4.2 kg of gas passed through the system with the steel wool still intact.

V. Recommendations

This study showed that various parameters to be determined in order to understand more the removal of hydrogen sulfide from biogas using regeneration steel wool. The following are recommended for further studies:

1. More experiments should be conducted in determining the deterioration rate of the regenerated steel wool particularly the breakthrough curve.
2. Economic analysis with the utilization of the steel wool in the removal of hydrogen sulfide in a biogas will be determined.
3. Investigation on the dependency on the absorption capability of steel on surface area.

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