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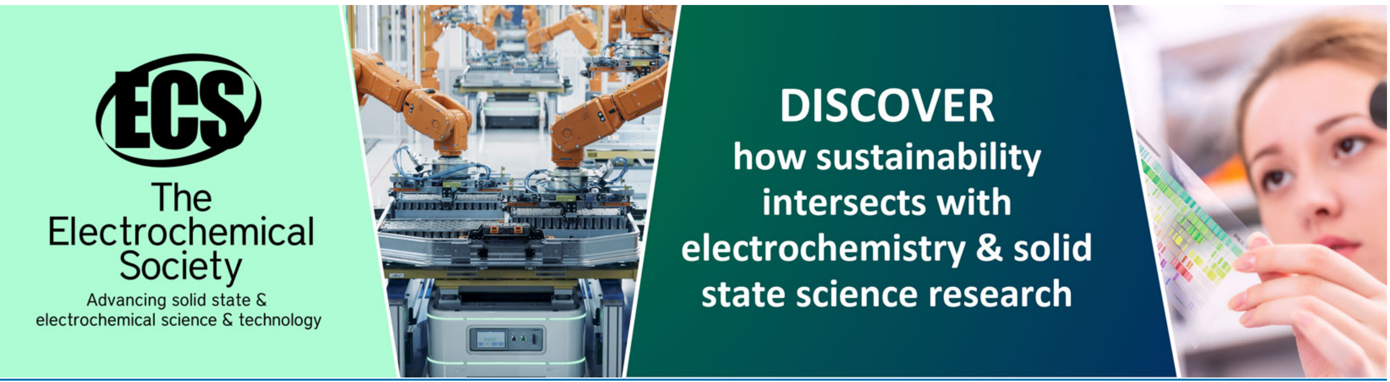

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Utilization of steel wool as removal media of hydrogen sulfide in biogas

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Abstract. In order to utilize biogas, hydrogen sulfide/H_2S impurities reduction is needed to maximize methane/CH_4 content. Although H_2S amount is relatively non-dominant, its presence can trigger corrosion, and is harmful to health and environment. Steel wool can be used as adsorption media to reduce H_2S content. This study was conducted to identify the characteristics of steel wool and H_2S concentration reduction efficiency. Biogas was flown to a PVC column (2 inches diameter) containing steel wool. The results showed that steel wool media contain active elements of Fe and Zn which are spread evenly on the media surface with a total amount of 97.5% mass. The concentration of H_2S at inflow ranged from 68 to 111 ppm with the outflow of 21.2-0 ppm, and the temperature in the system varied between 29-33 °C. Optimal H_2S removal efficiency reaches 97% in average, obtained at 100 cm column height and flow rate of 0.1 L/min. It can be concluded that the steel wool media has high content of active element and can reduce H_2S content in biogas at ambient temperature condition.

1. Introduction

As a form of coping with energy and solid waste problems in Indonesia, Anaerobic Digestion (AD) has been developed and implemented widely. When the AD process takes place, the formation of energy in the form of biogas occurs through three stages, namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis [1]. The biogas content is not only CH_4 but also contains CO_2, H_2O, and H_2S. Although the composition of hydrogen sulfide in biogas is relatively non-dominant, its presence can trigger corrosion. Burning biogas containing hydrogen sulfide will also emit sulfuric acid during its combustion process, and most importantly hydrogen sulfide is highly toxic and can pose serious health risks [2]. Thus, it is necessary to process the purification of biogas produced so that the corrosion and health risks decreased, so it can be utilized better.

There are various purification processes that can be done to remove impurities, such as water scrubbing system, chemical absorption, pressure swing adsorption (PSA), membrane, biofilter, and cryogenic separation [3]. In particular, the process of removing H_2S gas from biogas is very important before the installation of upgrading such as PSA. Various methods of removing H_2S include adsorption, absorption, membrane separation, biological processes, and claus process [2] [4] [5] [6]. One of the various methods available which has long been used is in the form of chemical adsorption using iron oxide [6] [7] [8].

The chemical reactions occurring in the process of iron oxide reducing hydrogen sulfide content are expressed in Equations (1) and (2) below [6].

$$Fe_2O_3 + 3\ H_2S \rightarrow Fe_2S_3 + 3\ H_2O \quad (1)$$

$$Fe_2S_3 + 3/2\ O_2 \rightarrow Fe_2O_3 + 3\ S \quad (2)$$

Therefore, this research uses iron oxide media in the column for the removal of H_2S from biogas. Iron oxide comes in various shapes/types and in this study used steel wool or iron sponge (iron fiber) that exist in everyday life as a form of iron oxide. This study identifies the characteristics of the steel wool that never been conducted before and its efficiency to reduce H_2S concentrations.

2. Methodology

The dependent variable of the research is the hydrogen sulfide concentration measured before and after biogas through the adsorption column which will be obtained the efficiency value of the removal. In this study, the biogas flows through the columns at ambient/room temperature. The first independent variable that the authors used in the study were the adsorption column height (50 cm, 75 cm, and 100 cm) with medium density to the adsorption column and the controlled flow rate was approximately 0.0943 g/cm^3 and 0.5 L/minute, respectively. Furthermore, after the optimum column height is obtained, the experiment is continued to optimize flow rate (1.5 L/min, 1.0 L/min, 0.5 L/min and 0.1 L/min) to be tested at density and columns height that are controlled equally. The method used in the measurement of H_2S gas in this study is by using SNI Method 19-7117.7-2005. In addition, this study also conducted characterization tests on adsorption media before and after use (media sample from optimum condition). Characterization test using SEM-EDS test methods. The series of research equipment is illustrated in figure 1.

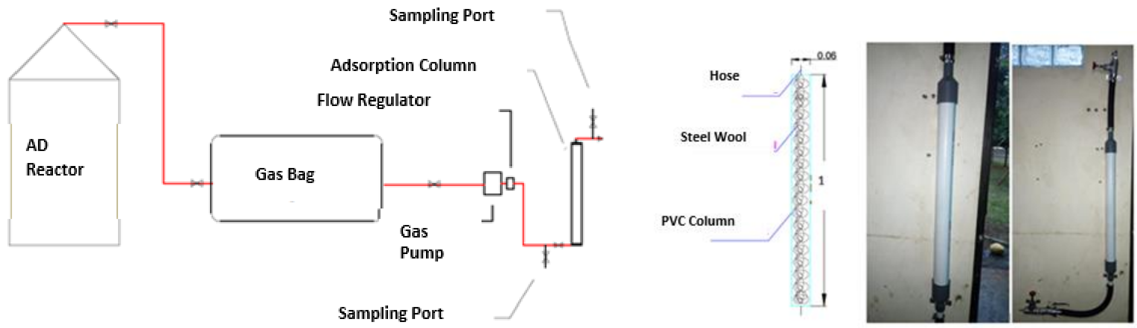

Figure 1. Series of adsorption columns.

3. Result and Discussion

The result of the experiment of column height variation can be seen in figure 2.

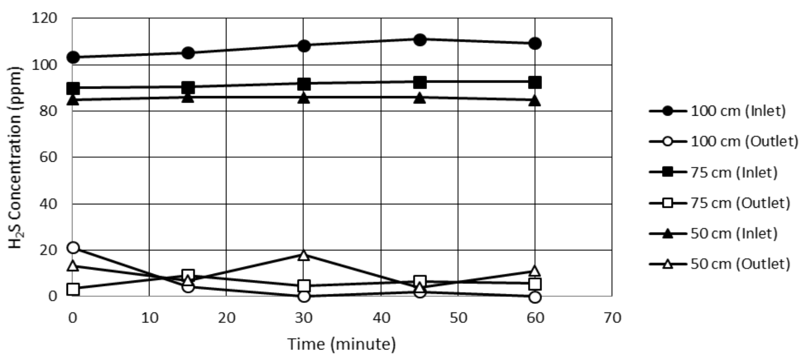

Figure 2. The result of the experiment of column height variation.

Based on the data obtained that as the height increases, efficiency of media/columns in reducing the concentration of H_2S gas is relatively bigger. As shown in figure 2, the average removal efficiency of H_2S at 50 cm column height reaches 88±6%, then reaches 94±2% at a height of 75 cm and becomes 95±9% at height of 100 cm.

However, ANOVA test results show the significance of 0.202 whose value is greater than 0.05indicating that the column height variations applied in the study of H_2S removal efficiency have no significant impact on H2S adsorption. Nevertheless, the height of 100 cm is applied in the next experiment of flow rate variation because 100% removal efficiency was observed. In addition, this is also based on the value of H_2S gas concentrations at outlets that have been below 10 ppm so as to be designated as stove fuel, even at this 100 cm height can reach natural gas standards under 4 ppm [5].

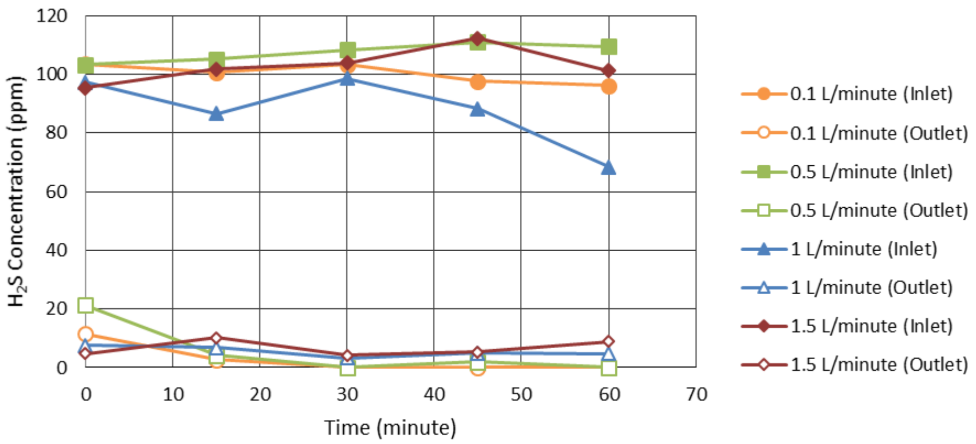

Figure 3. Relation of H_2S Concentration (inlet and outlet) to Time at Flow Rate 0.1 L / min; 0.5 L / min; 1 L / min; and 1.5 L / min.

The second set of experiment demonstrates that as the flow rate increases, the efficiency of media/columns in reducing the concentration of H_2S gas are relatively inversely proportional to the decrease in H_2S decreases with increasing flow rate. The average removal efficiency of H_2S at a flow rate of 0.1 L/min reached 97±5%, then reached 95±9% at a flow rate of 0.5 L/min, 94±2% at a flow rate of 1 L/min and became of 93±3% at a flow rate of 1.5 L/min.

ANOVA test of 0.662 (greater than 0.05) demonstrated that the variation of the flow rate applied to the study on H_2S removal efficiency has no significant difference. This is different compared to [9], that showed that the smallest flow rate variation resulted in the smallest impurity content (in research in the form of CO_2) in biogas due to biogas having longer contact time with the adsorption media. Although compared with [10], optimum removal of H_2S at 3.5 L/min flow rate (variations used 2.5, 3.5 and 5 L/min). Then when compared with [11], there is also a correspondence that the lower the flow rate the greater the H_2S is absorbed although only seen the effect of very small results.

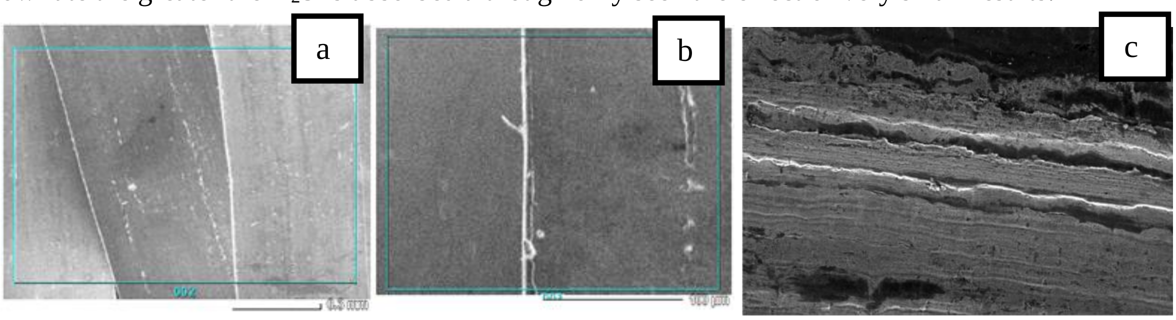

Figure 4. SEM Test Result of Media Before Used with Magnification (a) 100x; (b) 500x; and (c) 1000x.

Figure 4 shows the active area in the adsorption process located on the surface of the medium with a size of about 0.3 mm along the fiber of the adsorption medium. The surface of the media also looks relatively rough, uneven, and has a hollow pore as seen at 1000x magnification, with the illumination of a bright pattern indicating a higher elevation position than the dark one.

EDS media test results showed a large amount of iron (Fe) and Zinc (Zn) elements, respectively reaching 75.49% mass and 22.04% mass. These Fe and Zn elements are the principal active metal elements which can react with H_2S in biogas so that the amount is reduced. The distribution of these elements is even on the surface of the media as shown in figure 5. This illustrates that almost the entire surface of the media is comprised of active element.

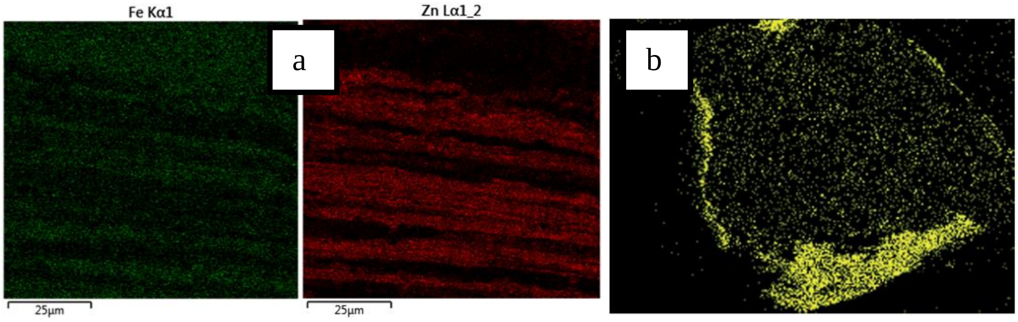

Figure 5. Active elements distribution on surface media : (a) *Steel Wool*; (b) Sulfatreat 410-HP®.

The relatively uniform distribution makes the steel wool media a potentially no lesser medium in the H_2S gas adsorption process when compared to existing commercial media such as Sulfatreat 410-HP® with the distribution of Fe elements as illustrated. With a thorough dissemination on the surface of the media, it illustrates that almost the entire surface of the media is enveloped by an active element.

From the test result, the amount of iron oxide reach 56%, theoretically (stoichiometry), of steel wool media can absorb H_2S with the amount equal to 64% of Fe_2O_3 available. However, there is 0.02% Pb as activator. Activators are elemental ingredients such as Platine, Gold, Silver, Copper, Cadmium, Nickel, Tanker, Mercury, Zinc and Cobalt with amounts of 0.125%-5% on commercial media such as Sulfatreat 410-HP® [4]. So, steel wool media contain fewer activators than the commercial media.

After the process of adsorption, the media used for the process is also tested analysis of SEM-EDS characteristics. Figure 6 is the result of SEM-EDS analysis of the media after the adsorption process. Based on the result of figure 6 there is a defect on the surface of the steel wool media after being used as an adsorption medium. The bright gradient of the image shows the elevation position of the higher surface than the dark portion, indicating the adsorbed material when compared to the medium before it is used with relatively homogeneous or uniform morphological adsorption.

Based on the test sample it is clear that there is a decrease of iron oxide compound which shows that there has been a reaction between H_2S and the compound so that its content in biogas decreases. This suggests that the Fe_2O_3 content decreases from 56.01% to 23.03%, obtained after flowing about 6 L of biogas through the column. This indicates that about 33% of Fe_2O_3 reacts with H_2S gas at the certain point of sample. The remaining Fe_2O_3 content in the media illustrates that the media still have the capacity to reduce H_2S gas further.

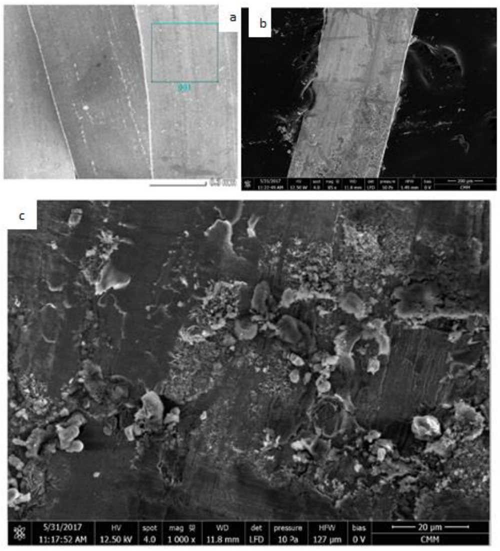

Figure 6. Morphology Test Results of Media : (a) Before Adsorption and (b&c) After Adsorption Process Using SEM (b) magnification 85x (c) 1000x magnification.

4. Conclusions

The active content in this steel wool (Fe and Zn) reaches a total of 97.5% mass with a uniform Fe distribution across the surface and a uniform Zn spread but there are some surfaces that do not contain Zn. The maximum removal efficiency of H_2S gas in Biogas reaches 100% (95% average) obtained at a height of 100 cm. Then 100% H_2S removal efficiency was also obtained at flow rate of 0.1 L/min with 100 cm column height (mean removal efficiency of H_2S was 97%).

5. Acknowledgment

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