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The Effect of Excess Oxygen and Operating Temperature on Bioscrubber Performance in Reducing H2S Concentration in Biogas

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ABSTRACT*: Bioscrubber is a separator that can be used to reduce the concentration of hydrogen sulfide (H2S) in biogas. Problems that affect the performance of the bioscrubber include excess oxygen and temperatures that do not match the operating requirements, resulting in less than optimal performance of the bioscrubber in reducing the concentration of hydrogen sulfide (H2S). To minimize this problem, data analysis was carried out related to the need for excess oxygen and optimal operating temperature. In this study, direct data collection was carried out by taking biogas production data at the Sei Mangkei Biogas Power Plant (PLTBg) which was then processed data related to the need for excess oxygen and operating temperature in the H2S separation process. From the research conducted, it is known that the process of reducing H2S concentration using the bioscrubber at the Sei Mangkei PLTBg requires excess oxygen of 363.4% of the theoretical oxygen requirement and an operating temperature of 38oC to be able to reduce the H2S concentration by 97.5%.*

KEYWORDS*: biogas, bioscrubber, H2S, excess oxygen, temperature.*

INTRODUCTION

Biogas is one of the renewable energies that can be used as a fuel for power plants. Biogas is a renewable energy that comes from the decomposition of organic matter by anaerobic microorganisms. However, biological activity that occurs when microorganisms decompose organic matter in anaerobic conditions causes the formation of H2S gas in biogas, generally the H2S content formed reaches 50 - 5000 ppm (E.Dumont, 2015). High H2S content has a negative impact if used as a fuel for power plants, including reducing combustion efficiency, causing damage to the engine, accelerating oil degradation in *gas engines* and the formation of *sulfur dioxide* (SO2) which is a toxic pollutant that causes acid rain (Sylvie, 2019). Therefore, before being used as a fuel for power plants, it is necessary to reduce the H2S levels in biogas. Reducing H2S levels can be done by various methods such as *chemical scrubbers* , bioscrubbers and *wet scrubbers* .

The process of reducing H2S levels used in the biogas power plant industry at the Sei Mangkei PLTBg is a bioscrubber. Bioscrubber is a tool used for the process of reducing H2S concentration where the main factor of its effectiveness is based on the performance of sulfur-oxidizing microorganisms. The use of bioscrubber as a biogas purification method because it has several advantages, namely the cost of the biological method is more profitable, more

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environmentally friendly because the degradation results are in the form of harmless compounds and has an efficiency level of up to 99% (N. De Arespacochaga , F 2014). Based on these reasons, bioscrubber is a technology that is suitable for use in the biogas purification process. However, of course in its operation it is necessary to control several parameters such as temperature, pH, oxygen, water circulation, and so on. However, this study will discuss "The Effect of Excess Oxygen and Operating Temperature on Bioscrubber Performance in Reducing H2S Concentration $_{in}$ Biogas". Oxygen is one of the factors that affect the performance of bioscrubber in the biogas purification process, namely in the process of reducing the concentration of H2S $_{in}$ biogas, where the amount of oxygen will affect the amount of H2S $_{that}$ can be reduced and decomposed into sulfur compounds. In this process, oxygen is needed by microorganisms that play a role during the purification process, microorganisms in the purification process are sulfur oxidizing bacteria such as *thiobacillus* where this bacteria is one of the aerobic bacteria which means it also requires a certain amount of oxygen in the process of decomposing H2S $_{so}$ that with optimal oxygen, the role of bacteria in the process of reducing H2S $_{in}$ biogas is more optimal. Based on the results of the purification process in the industry, an excess amount of oxygen is needed to maximize the effectiveness of the bioscrubber for that, in the process of operating the bioscrubber, an optimal excess oxygen supply is needed so that the purification process is more effective.

In addition to being influenced by oxygen, bioscrubber performance is also influenced by operating temperature because it is known that microorganisms are living things whose activities, growth and reproduction are influenced by environmental conditions, one of which is temperature. By carrying out the purification process at the optimal temperature required, the efficiency of reducing H2S $_{in}$ the bioscrubber can be increased.

LITERATURE REVIEW

Bioscrubber

The biogas purification process can be done with various methods, one of which is using a bioscrubber. Bioscrubber is a separation tool with biological techniques, namely utilizing microorganisms in the biogas purification process, this tool is commonly used in the biogas purification process because it has several advantages such as easy to operate, cheaper costs and easy *maintenance* .

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a gas produced from the anaerobic process in the digester, so that the biogas produced has a concentration of H_2S < 2%. Although the percentage of H_2S in biogas is small, if measured at a concentration of parts per million (ppm) H_2S usually has a concentration of between 1000 - 2000 ppm, where this concentration has several negative impacts if not removed from the biogas content. As a fuel for power plants, biogas with high concentrations of H_2S can cause a decrease in combustion efficiency, cause damage to the gas engine due to its corrosive nature and can cause acid rain due to the formation of *sulfur dioxide* (SO_2) (Sylvie, 2019).

Oxygen

In the purification process using a bioscrubber, oxygen acts as an electron acceptor, namely when microorganisms oxidize H_2S . So that from this decomposition process, sulfur compounds are produced which are safer to be disposed of into the environment (Abimanyu, et al., 2022).

The oxygen required in the oxidation reaction of H_2S decomposition into sulfur compounds can be determined based on the reaction that occurs or what is called theoretical oxygen. However, in the field process, additional oxygen is usually required or what is called excess oxygen *where* this oxygen plays a role in maximizing the biogas purification process carried out, namely to ensure complete oxidation of H_2S so that with excess O_2 ensures that H_2S is oxidized into the desired sulfur compounds, supports the growth of microorganisms so that with excess H_2S ensures that microorganisms have enough O_2 to grow and function properly and maintain optimal pH because the oxidation process produces sulfuric acid and with the presence of excess O_2 will help neutralize the bioscrubber pH in the optimal range of 7-8.

Temperature

Temperature is a quantitative measure of the heat and cold of an object or environment. In the biogas purification process, temperature is an important parameter that needs to be controlled because the bioscrubber utilizes microorganisms for the absorption process of H_2S contained in biogas so that environmental conditions such as temperature will affect the performance of microorganisms in the biogas purification process. The bacteria that play a role in this purification process are mesophilic bacteria, which means that the operating temperature needs to be controlled in the mesophilic temperature range (20-45 ^{o}C). One of the temperature controls that can be done is by replacing POME water periodically based on the condition of the bioscrubber.

METHODOLOGY

The bioscrubber used in this study is a bioscrubber located at the Sei Mangkei PLTBg, where the bioscrubber uses HDPE filter media and functions as a tool to reduce the H2S levels of the biogas produced, namely having a concentration of 1200-1450 ppm.

The solution methods used in this research are:

1. Literature study

   Literature study is studying theories that are relevant to the problem being researched, either through books, journals, articles and other reliable sources.

2. Discussion method

   The discussion method is to conduct discussions with the supervising lecturer, field supervisor and workers at the Sei Mangkei PLTBg regarding the problems being researched.

3. Field study
   - Data collection of biogas input measured on the flowmeter and POME water *flowrate* used in the purification process in *the bioscrubber* .
   - *input* and *output* biogas composition concentration data obtained from measurement results using *a gas analyzer* .
   - Data collection of operating temperature on *the bioscrubber*, namely obtained from the measurement results of the installed *temperature gauge* .
4. Data analysis
   - Calculate the theoretical oxygen requirement and the amount of oxygen input based on the oxidation reaction that occurs, namely with a mole ratio of 2.

     $$O2\ teoritis = H2S\ input\ x\ rasio \ldots\ldots\ldots\ldots\ldots .(1)$$

     $$O2\ input = O2\ output + O2\ teoritis \ldots\ldots\ldots\ldots .(2)$$

   - Calculating H2S *removal* and H2S *removal* efficiency

     $$H2S\ removal = H2S\ input - H2S\ output \ldots..(3)$$

     $$RE\ H2S\ (\%) = \frac{\text{H2S removal}}{\text{H2S input}}\ x\ 100\% \ldots\ldots\ldots\ldots .(4)$$

   - Calculate the percentage of excess oxygen based on the oxygen output data obtained from measurements using *a gas analyzer* .

     $$Excess\ oxygen\ (\%) = \frac{O2\ output}{O2\ teoritis}\ x\ 100\% \ldots..(5)$$

   - Analyze the data obtained to determine the optimal *excess oxygen requirements in the process of reducing* H2S levels using *a bioscrubber* and determine the effect of

temperature on the resulting efficiency.

RESULTS AND DISCUSSION

Effect of Addition of Excess Oxygen on the Reduction of H_2S

The performance of the bioscrubber for the process of reducing H_2S in biogas depends on the ability of microorganisms to convert H_2S into sulfur compounds. One factor that will affect this process is the oxygen content in the purification process. From data collection at the Sei Mangkei PLTBg, it is known that the biogas production from the digester does not contain oxygen because the production process takes place anaerobically, so that the fulfillment of oxygen requirements to be able to degrade H_2S requires the addition of oxygen during the purification process in the bioscrubber. Theoretically, the amount of oxygen required can be determined based on the ratio of oxygen (O_2) to hydrogen sulfide (H_2S) which can be determined based on the following reaction:

$$H_2S + {}_2O_2 \rightarrow H_2SO_4$$

From this reaction, it is known that the amount of oxygen has a ratio of 2 to the concentration of H_2S. However, based on research conducted by Pau San-Valero (2019) , the purification process using bioscrubber often experiences blockages due to sludge buildup which results in decreased bioscrubber efficiency, this is indicated as a result of a lack of oxygen supply. Therefore, an excess oxygen supply is needed in the biogas purification process. The relationship between the percentage of excess oxygen and the amount of H2S reduction produced can be seen in the graph below, namely :

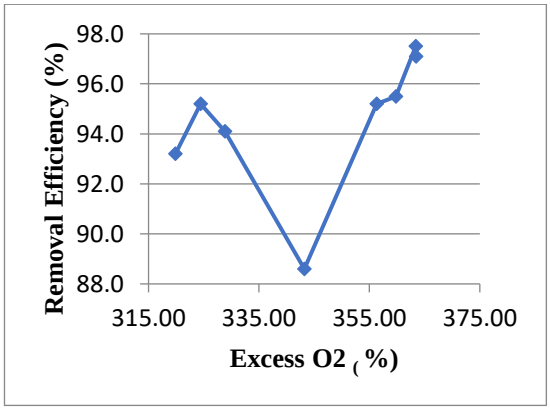

Figure 1. Effect of Excess Oxygen on H2S Removal

From the graph above, it can be seen that the higher the amount of excess oxygen , the higher the efficiency of H_2S that can be removed from the biogas content. From the data

obtained, the highest amount of H2S reduction is in the 2nd data, which is 97.5 % with an *excess oxygen percentage of* 363.40%. While in the 6th data, the percentage of *excess oxygen* is the smallest, which is 319.87% and a smaller reduction in H2S is obtained, which is 93.2%. Based on these results, it is known that low excess oxygen can cause a decrease in the performance of the bioscrubber in reacting H2S gas in biogas. This can happen because if the excess oxygen provided is low, it will affect the biogas purification process using a bioscrubber because it can inhibit the oxidation of H2S into sulfur and accelerate the growth of anaerobic microorganisms that can produce toxic compounds for H2S oxidizing microorganisms .

However, in the 7th data, the efficiency of H2S reduction decreased by 88.6% even though the excess O2 was quite high at 343.23%. This can happen because the purification process in the bioscrubber is also influenced by other factors such as temperature, where the temperature in this data is 34oC . In addition, it can also be caused because before taking this data, maintenance has been carried out on the bioscrubber, namely sludge disposal, which causes the efficiency of the bioscrubber to increase due to the reduced accumulation *of sludge* on *the packing media* . And in the 3rd data, there was also a decrease in efficiency to 97.1% even though the concentration of excess O2 was the highest. This could occur due to competition between O2 and H2S substrates to obtain the same enzyme on the surface of the microorganism so that when the concentration of O2 is high, the enzyme will be more bound to O2 and H2S cannot be oxidized optimally. In addition, microorganisms that are exposed to too much oxygen can be damaged or even die, which can reduce the effectiveness of the bioscrubber in reducing H2S levels in biogas (Choiron, 2014).

Based on the research that has been done, to improve the performance of the bioscrubber in the process of reducing H2S gas in biogas, it is necessary to add excess oxygen (excess O2) while still controlling the supply of injected oxygen. And in the biogas purification process carried out at the Sei Mangkei PLTBg, it was found that the optimal amount of excess oxygen to be added to the biogas purification process using a bioscrubber was 363.40 % .

Effect of Temperature on Biogas Purification Process

In the process of purifying H2S using bioscrubber, another factor that affects the performance of the bioscrubber is the operating temperature. As is known, the process of reducing the concentration of H2S in the bioscrubber is influenced by the activity of sulfur-oxidizing bacteria, where, to maintain the growth and performance of bacteria effectively, optimal

temperature control is required. Based on the data at the Sei Mangkei PLTBg, the relationship between temperature and the efficiency of reducing H_2S_{in} the bioscrubber is shown in the following graph:

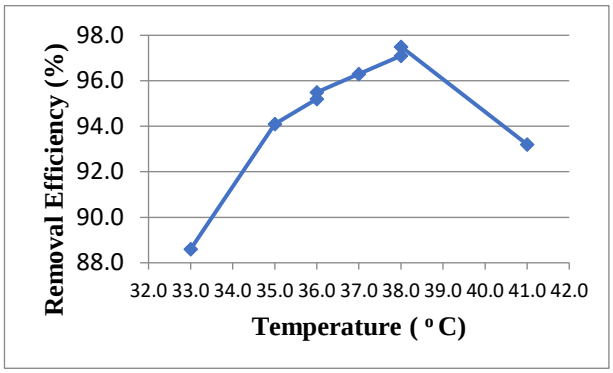

Figure 2. Effect of Temperature on Bioscrubber Efficiency

From the graph above, it can be seen that the increase in temperature tends to increase the efficiency of H2S reduction . From the data, it is known that the highest efficiency is in the 2nd data reaching 97.5% with a temperature of 38 ° C and the lowest efficiency is in the 7th data which is 88.6% with a temperature of 34 ° C and at a temperature of 41 ° C the bioscrubber efficiency decreases to 93.2%. This is in accordance with the research of Yonghua Yang (2012) which states that low temperatures can cause a decrease in microbial activity and cause a decrease in the solubility value of hydrogen sulfide along with a decrease in temperature. However, at temperatures that are too high can reduce the ability of microbes to degrade H_2S_{in} biogas where based on the results of his research that an increase in temperature that is too large can reduce efficiency from 97.4% to 40%.

From these results, it is known that temperature control in the bioscrubber purification process is an important factor to control, because in addition to weather factors, temperature changes can also be caused by microbial respiration. Therefore, in controlling the operating temperature in the bioscrubber, it is necessary to control the POME liquid flow rate because according to Mulyanto (2020), a flow rate that is too high can increase the operating temperature while a flow rate that is too low can reduce the effectiveness of the bioscrubber in reducing $H_2S_{concentration}$.

CONCLUSION

In recent years, there has been significant development in the biogas purification process, especially in reducing H2S concentration . The technology that is often used is bioscrubber,

where this technology has advantages including being environmentally friendly, low maintenance costs and easy to operate.

However, there are factors that need to be considered so that the operating process is maximized, including *the excess oxygen* added and the operating temperature. Based on research that has been conducted, the amount of optimal excess oxygen needed to reduce the concentration of $H2S_{to}$ the smallest H2S content is 363.40% and the optimal operating temperature in the bioscrubber to reduce the concentration $_{of}H2S_{is}$ $38\ ^{o}C$.

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