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Purification of Biogas by CO_2 Reduction in Biogas Using Potassium Hydroxide Solution (KOH) in a Packed Tower

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ABSTRACT
This research is about the absorption of carbon dioxide gas (CO2) in biogas processed from tapioca waste using a solution of potassium hydroxide (KOH) as absorbent. The purpose of this research was to determine the effect of gas flow rate and the flow rate of KOH solution to the absorption of CO2. The absorption reduces the CO2content in the biogas, and therefore the methane CH4 increases. As a result, the heating value of the CH4is alsoincreasing. The research was carried out by using chemical absorption,a packed tower with a diameter of 7.5 cm and 127 cm height. The flow rates ofthe KOH flow rate vary with 1, 2, and 3 liters/minute, and a variation of gas flow rate are 2, 3, 4, and 5 liters/minute. The concentration of KOH was 0.75 M and the contact time was 10 minutes. Analysis of gas samples of input and output gas was carried out using Gas Chromatography 2014-AT SHIMADZU Corp 08128. The results show that the greater the flow rate of gas, the lower the absorption of CO2. On the other hand, the higher the flow rate of the solvent, the higher thepercentage of absorbed CO2. The highest percentage of absorbed CO2 is at a gas flow rate of 2 liters/minute and 4 liters/minute with the percentage absorption of CO2of 95.98 and 97.623%respectively.

Keywords: *Biogas, Biogas Purification, Potassium Hydroxide, Packed Tower*

1. INTRODUCTION

Increased energy needs of the industrial world and the inability to meet those needs using limited energy sources such as fossil fuels will ultimately exacerbate the danger of a heating and energy crisis. Based on data from the Department of Energy and Mineral Resources states that the use of energy in Indonesia with petroleum, natural gas, and coal are 54%, 26.5%, and 14% of total energy use, respectively. In addition, oil, gas and coal reserves are only sufficient for the next 18 years, 61 years into the future, and 147 years into the future[1]. One solution to fulfil the needs of energy use is by looking for alternative energy sources such as biogas.

Biogas is an alternative fuel produced from the fermentation process of organic waste such as food scraps, animal waste, garbage, and food industry waste. The gas produced from the fermentation process is capable of producing gases such as $CH_4$of 50-70%, $CO_2$of 25-45%, and small amounts of H_2S and H_2O. Removal of impurities in the form of CO_2 to the purity of biogas is very important to the heating value produced because high CO_2 levels in biogas can reduce the heat value of biogas so that it can disrupt the combustion process.

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One method of reduction of the CO_2 content in biogas can be carried out by absorption. Absorption is a process of separation by contacting a mixture of gas with an absorbent liquid, which aims to remove one component of the gas. Gas absorption can be done physically, chemically, and biologically. However, in this study chemical absorption is carried out, where chemical absorption has the advantage of being able to accelerate the absorption rate and increase the capacity of the solvent to dissolve the dissolved components. Many absorbents that have been used in the CO2 absorption process include NaOH, KOH, K2CO3, monoethanolamine, diethanolamine, methyl diethanolamine, triethanolamine, and others [2].

KOH solution can be used as an absorbent to absorb CO2 content in biogas where KOH will bind CO2. The process of absorption of CO2 gas by KOH can be seen in the following reaction [3] :

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O \qquad (1)$$

The absorption is a chemical absorption which is accompanied by a direct chemical reaction between CO2 and KOH solution, where CO2 in the gas phase will be absorbed by the KOH solution in the liquid phase.

There are several factors that affect the absorption process, including gas and solvent flow rates. The flow rate affects the turbulence of the stream in the absorption column, contact time, and the pressure in the absorption column. Longer contact times cause fluids to contact and good react.

This study of the variable influence of gas flow rate in the process of absorption of CO2 gas in biogas has been conducted. The research conducted by Ningrum et al. (2017) about the effect of gas flow rate in the process of absorption of CO2 gas in biogas by using MDEA solution with solvent flow rate of 0.15 l/min and variable gas flow rate (1; 1.5; and 1.8 l/min) [4]. The result of her research shows the increase of percent of CO2 absorption up to the gas flow rate 1.5 l/min and then decreased in the gas flow rate of 1.8 l/min. In addition, the research by Suprianti (2016) indicating that the heating value of biogas after purification using a single column tends to increase with an increasing flow rate of gases. The higher CH4 content increase by using a flow rate of 3 l/min on a single column [5].

The good absorption also occurs when the absorbent flow rate is greater. Senja et al. (2016)mentions in her research that the greater the flow rate of the fluid used, then the value of the number of Reynold is the higher that causes the fluid stream is increasingly turbulent [6]. In the turbulent flow, molecules of fluid move to any direction that causes the particle's collision become larger. The larger the collision between molecules, then the greater CO2absorption will occur [7].

Referring to the research by Ningrum et al. (2017) which using small flow rate of absorbent, it needs advanced research [5]. Therefore, in this research, the variation of gas and liquid flow rate will be increased to determine the ratio of gas and liquid flow rate so the higher reduction of CO2 will be obtained.

2. MATERIALS AND METHODS

The material used in this study is biogas from tapioca waste in PD. Semangat Jaya, Bangun Sari, Negeri Katon, Pesawaran, Lampung. Absorbent was the solution of Potassium Hydroxide (KOH) with a fixed concentration of 10 litres of 0,75 M.

The flow rates of KOH varied in 1, 2, and 3 litres/minute and a variation of gas flow rates were 2, 3, 4, and 5 litres/minute. The initial biogas content was analysed by the gas chromatography to determine the content of the biogas before the absorption process. The composition of CH4 andCO2were 34,661% and 29,353% respectively.

The absorption process was carried out by flowing biogas into the absorbent in the absorption column through under packed tower, while the absorbent was fed from the top packed tower. The first run was carried out in the column with a gas flow rate of 2 l/min and 1 l/min of KOH. The contact time of biogas and KOH is 10 minutes. The biogas output from the absorption column was accommodated on the sample bag and analysed by the Gas Chromatography 2014-AT SHIMADZU Corp 08128. Then the experiment was carried out for different gas flow rates and different KOH flow rates.

3. RESULTS AND DISCUSSION

3.1. Effect of Gas Flow Rate on CO_2 Absorption

The effect of gas flow rate on CO2 absorption in biogas is shown in Figure 1 below:

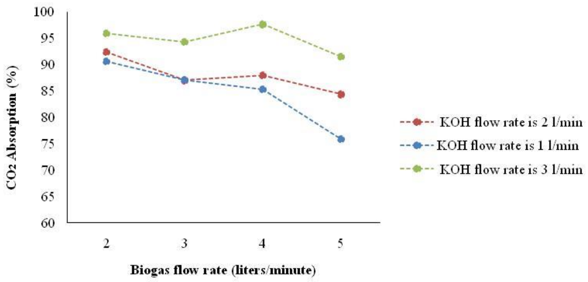

Figure 1 Effect of gas flow rate on the percentage of CO2 absorption

As shown in the figure, the percentage of CO2 absorption in the biogas decreases with an increase in the feed gas flow rates. This effect is due to increased turbulence in the absorber column so that the contact time between gas and liquid becomes shorter. Therefore, the increase of gas flow rate causes a reduction in the percentage of CO2 absorption. The highest percentage of CO2 absorption was 95.980% and 97.662% by using 2 and 4 l/min of gas flow rate and a solvent flow rate of 3 l/min. In this study, the shorter the contact time between gas and liquid may cause an increase of the mass transfer from gas to liquid. As a result, the percentage of CO2 absorption decreases [5]. This can occur because the contact time between gas and liquid decreased, which can limit the reaction of acid gas with an absorbent solution, so that reduces the performance of removing CO2 and H2S contained in biogas [8]. The increasing gas velocity reduces the thickness of the gas film and increases the level of turbulence, so the transfer of solute between the gas and the liquid phase increase [9,10].

Similar trends were also found by Aboudheir et al. (1998) [11]. He reported that an increaseinCO2 removal could be obtained by reducing the feed gas flow rate. It is coupled with research by Yu et al. (2008) also shown that increasing the gas flow rate causes a reduction in gas retention time [12]. Reduction of gas retention time, which causes concentration on the surface of the gas and liquid increases with increasing mass release. Although increasing the gas rate can reduce the thickness of gas boundary layer and increase gas mass transfer that can give benefits for removal CO2 levels. However, the residence time in the contactor will decrease so the removal efficiency of CO2 will be reduced at the same time.

3.2. Effect of KOH Flow Rate on CO_2 Absorption

The effect of KOH flow rate on the percentage of CO_2 absorption is shown in Figure 2 below :

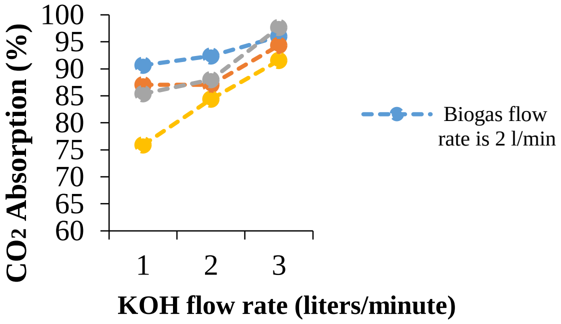

Figure 2 Effect of KOH flow rate on the percentage of CO2 absorption.

Figure 2 shows the effect of the KOH flow rate on the percentage of CO_2 absorption in the 3 l/min KOH flow rate with the percentage of absorption of 95.98, 94.318, 97.662, and 91.519% for different gas flow rates. In the figure, it appears that CO_2 absorption tends to increase with increasing solvent flow rates. With increasing solvent flow rates, the disturbance in the solution also increases so that the spread of CO_2 in the liquid becomes faster [11]. The increase of the KOH flowrate can strengthen the driving force from one phase to another. That driving force in the form of collisions between molecules containing a mixture of the liquid and gas phase with the addition of velocity of the liquid. Therefore, several collision between molecules causes the mass transfer between phases to increase. The higher the liquid flow rate, the higher the collision, which causes increasing the mass transfer between phases [7]. Similar trends were also found by Putri et al. that is the increasing of absorbent flow rate scan increases the Reynold numbers and fluid turbulence in the adsorption column, where the molecules in the fluid will move to all directions whichcauses the collision between particles will increase [13].Purba et al. (2018) also demonstrated the effect of absorbent flow rates on CO_2 absorption. In her study, it is explained that the absorption of CO_2 using NaOH solution increases with increasing absorbent flow rates due to the higher availability of absorbent for dissolving and reacting the CO_2 [14].

Based on research conducted by Ningrum et al. (2017) with the absorbent flow rate of 0.15 /min and 1 l/min of gas flow rate can reduce of CO_2 concentration from 40% to 17% [4], and then in this research by increasing of absorbent flow rate and gas flow rate can reduce CO_2 levels by 35%.This can be noted that increasing the flow rate has an important influence on the removal of CO_2.

3.3. Effect of KOH Flow Rate on CH_4 Levels

The effect of KOH flow rate on CH_4 levels shown in Figure 3 below :

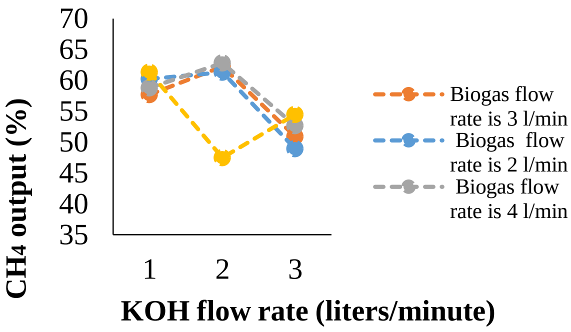

Figure 3 Effect of KOH flow rate on CH_4 levels

Figure 3 shows the correlation between the KOH flow rates in various gas feed flow rates and increasing CH_4 levels in biogas. The KOH flow rates and gas feed flow rates can reduce the CO_2 content in biogas, causing an increase in the CH_4 output content. The decrease of the CO_2 content automatically increases the CH_4 composition in the output gas. The heat value of biogas is expressed by how much content of CH4 in biogas. The higher the content of CH4, the greater the heat value in biogas [5].

The results obtained are varied with increasing the purity up to 32% from intialCH4 level. The best results in increasing the composition of CH4 in biogas were obtained with the gas flow rate of 4 litres/minute and the absorbent flow rate of KOH 2 litres/minute, which gives the CO2 absorption of 87,995%.

4. CONCLUSIONS

From the results and discussion, the conclusions are drawn as follows :

1. The highest CO2 absorption was obtained at the gas flow rate of 4 liters/minute with the highest solvent flow rate of 3 liters/minute gives the percentages of 97,662%.

2. The higher the gas flow rate will make the contact time between the gas and the liquid faster and causes the percentage of CO2 absorption to decrease.

3. The higher the solvent flow rates,the higher the percentage of CO2 absorption.

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