Capturing CO_2 from Biogas by MEA (Monoethanolamine) using Packed Bed Scrubber

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ABSTRAK
Biogas adalah salah satu sumber energi terbarukan yang dapat dimanfaatkan sebagai pengganti energi fosil. Biogas sebagian besar mengandung metan (CH_4) dan karbon dioksida (CO_2). Kandungan CO_2 pada biogas mengurangi efisiensi pada proses pembakaran dan dapat menyebabkan korosi pada komponen-komponen logam yang kontak langsung dengan biogas. Pemurnian biogas dengan absorpsi merupakan suatu cara untuk menurunkan kadar CO_2 yang terkandung, dan meningkatkan kandungan CH_4 pada biogas sehingga biogas yang dihasilkan dapat digunakan sebagai bahan bakar. Penelitian ini ditujukkan untuk mempelajari pengaruh konsentrasi monoethanolamine (MEA) dan laju alir absorben terhadap penurunan kadar CO_2 yang terkandung dalam biogas. Proses absorpsi CO_2 dilakukan pada scrubber tipe *spray tower*, s*crubber* yang digunakan pada penelitian ini berbahan akrilik dengan diameter 64 mm, panjang *scrubber* 750 mm, tinggi packing pada *scrubber* 500 mm dan dengan kapasitas 1.5 m^3. Laju alir biogas yang digunakan 26 L/menit dengan variasi laju alir larutan MEA sebesar 0,5, 1 dan 1,5 L/menit dan variasi konsentrasi larutan MEA sebesar 1, 3, 5, dan 7M. Hasil penelitian menunjukkan pada laju alir larutan MEA 1,5 L/menit dengan konsentrasi larutan MEA 7M dapat menurunkan CO_2 dari 8,53% menjadi 0,10%, dan dapat meningkatkan kandungan metana (CH_4) dari 69,24% menjadi 81,20%.

Kata kunci: absorpsi; biogas; MEA; *packed bed scrubber*; pemurnian biogas

ABSTRACT
Biogas is a renewable energy source that can be used as a substitute for fossil energy. Biogas mostly contains methane (CH_4) and carbon dioxide (CO_2). The content CO_2 in biogas reduces the efficiency of the combustion process and cause corrosion in metal components when direct contact with biogas. Biogas purification using absorption method can reduce levels of CO_2 contained and increase levels of CH_4 then the biogas produced can be used as fuel. This research study the effect of monoethanolamine (MEA) concentration and absorbent flow rate on the reduction of CO_2 contained in biogas. CO_2 absorption process is carried out by a spray tower type scrubber. It consisted of an acrylic absorption column (64 mm in diameter, 750 mm in height, 500 mm in packing height and 1.5 m^3 in capacity). Biogas flow rate used is 26 L/min with variation of the flow rate of MEA 0.5, 1, and 1,5 L/min and concentration of MEA solution 1, 3, 5, and 7M. The results showed that the flow rate of MEA 1.5 L/min with a concentration of 7M MEA solution can reduce CO_2 from 8.53% to 0.10% and can increase the methane (CH_4) load from 69.24% to 81.20%.

Keywords: absorption; biogas; biogas purification; MEA; packed bed scrubber

1. INTRODUCTION
Fossil energy consumption in Indonesia is increasing every year. Energy reserves are running low, it is feared that fossil energy sources in Indonesia will soon run out (there needs to be an effort to overcome the energy scarcity that will be faced by Indonesia).

Therefore, to overcome the problem of global energy needs that continue to increase, efforts are needed to utilize alternative sources, namely through efforts to utilize agricultural, plantation or forest product residues and household organic waste in the form of biomass. Today biomass has become the

most popular energy source in every region of the world [1]. Biomass has great potential to become one of the alternative energy sources in the future [2]. Biomass energy sources have very potential in Indonesia, including biodiesel and biogas. Biodiesel is an alternative fuel sourced from plants and animal fats, Crude Palm Oil (CPO), waste cooking oil, and algae plants, while it is predicted that biodiesel consumption in Indonesia in 2025 will increase to 6.9 million kiloliters [3-6]

Biogas is one of a variety of new renewable energy that is continuously being developed at this time. Biogas is a mixture of flammable gases that comes from the anaerobic digestion process. Compounds contained in biogas include CH_4, CO_2 and other compounds in small amounts [7]. The biogas produced can be directly used as fuel for biogas stoves, but biogas without purification is still high in CO_2 content, it needs to be purified in the biogas produced to be used as fuel.

Biogas which is formed from the organic waste fermentation process does not have a gas content that is 100% flammable. Biogas products consist of CH_4 55-65%, CO_2 35-45%, nitrogen (N_2) 0-0.3%, hydrogen (H_2) 1-5%, H_2S 0-3 %, oxygen (O_2) 0.1-0.5%, and water vapor. all of these elements that play a role in determining the quality of biogas namely methane and carbon dioxide [8-9].

To increase the utilization of biogas as renewable energy, it is necessary to carry out the stages of refining methane. Biogas purification techniques can be carried out by the absorption method, which is the separation of a particular gas from a mixture of gases by transferring mass into a liquid that has a different solvent selectivity from the gas to be separated. Various kinds of biogas purification methods include physical absorption, chemical absorption, absorption separation with membranes, cyrogenic and chemical conversion into other compounds [10]. There is also to capture CO_2 with various solvents such as ammonia, tetrahydrofuran, monoethanolamine and

tetra-n-butyl ammonium bromide [11-12].

The purity of CO_2 and H_2S content in biogas is very important for the machine because it affects the heating value and the life of the device that uses biogas. Carbon dioxide is an inhibitor of the rate of combustion chemical reactions in the engine [13]. CO_2 compounds reduce the heating value of combustion, it is necessary to eliminate or reduce this CO_2 content. Pure CH_4 has a calorific value of 9100 kcal/m^3 at 15.5°C and 1 atmosphere, while the caloric value of biogas combustion is around 4800–6900 Kcal/m^3 [14].

In the biogas production process, the biogas products produced contain H_2S ranging from 100-10000 ppm, the H_2S content depends on the type of biomass and organic material it contains [15]. H_2S has been identified as a compound that causes corrosion in machining components. Using biogas that contains H_2S will produces sulphur and sulfuric acid which are corrosive to various types of metals. H_2S content of 200 ppm if inhaled by humans for 30 minutes can cause death. The maximum permit for H_2S for safety and health standards is 20 ppm [16]. When H_2S contained in biogas burns, H_2S will turn into sulfur oxides (SO_X) which will cause corrosion on metal components and make engine lubricating oils acidic. To reduce the damage caused by H_2S, the H_2S compound must be removed or reduced to the tolerance level [17].

Various methods for removing CO_2 and H_2S content such as physical adsorption, catalyst conversion [18]. Between NaOH solution, ethylene glycol, MEA and DEA, MEA solution has the highest efficiency in the absorption of CO_2 and H_2S [19]. Amine solution which is used as an absorber of CO_2 and H_2S in biogas in the scrubber, has a very high selectivity in terms of absorption of CO_2 and H_2S [20]. MEA is an amine solution that is best used as an absorption process, this is because MEA has the highest ability to absorb CO_2 compared to diethanolamine (DEA) and methyl diethanolamine (MDEA) [21]. The concentration of MEA as a solution to bind CO_2 needs to be considered because

it can improve the quality of purified biogas [22-24].

The design of a packed bed scrubber is very important. The size column and packing size affect the process of purification. Previous researchers have done various modifications to the size of the purification column by using MEA solution as an absorber. Scrubber with a diameter of 70 mm, height of 1000 mm with the the rasch ring, using 1M MEA solution. The result of this study CO_2 removal efficiency reaches 73% [23]. Furthermore, scrubber size 600 mm in height and 30 mm in diameter with the the rasch ring packing. The result of this study CO_2 removal efficiency reaches 65% [22].

Next research with size column 780 mm in height and 120 mm in diameter using MEA solution as an absorber increased the CH_4 content from 70% to 92% and decreased the CO_2 content from 30% to 5% in the biogas by purification [25].

In this study the the packed bed scrubber is made of an acrylic absorption column (64 mm in diameter, 750 mm in height, 500 mm in packing height and $1.5m^3$ in capacity).

2. METHODS

In this study began with a literature study on the process of making biogas and the process of purification of biogas, then the preparation of materials for the manufacture of packed bed scrubbers, during the process of making tools, made biogas with raw materials cow dung and water 1: 2. The making of biogas uses a fixed dome type biodigester with a capacity of 500 liters found in the State Polytechnic of Sriwijaya Laboratory.

Biogas purification process requires a tool to reduce CO_2 content, various methods and tools used in biogas purification, one of which is by using a packed bed scrubber tool. Figure 1 is a picture of a packed bed scrubber tool used in this study, this tool is equipped with a temperature sensor to see the temperature changes that occur during the purification process, and is equipped with a biogas pump that functions so that the gas

flow rate that enters during the purification process is constant.

This unit have dimension: 416 x450 x 1.170 mm, with scrubber diameter 64 mm and length 500 mm, in the scrubber have rasch ring packing with dimension 10 mm in height, 5 mm in diameter. This unit equipped with biogas pump (flow rate 26 L/min) and solution pump.

Biogas produced from fixed dome type biodigesters, biogas was analyzed for the composition of biogas at 5-day intervals, on days 5, 10, 15, 20, 25, and 30, then purification was carried out on the biogas produced using monoethanolamine.

In this research used MEA of loba chemie brand with 99% concentration. The process of purification CO_2 by varying the concentration of MEA (1M, 3M, 5M, 7M) and varying the flow rate (0.5 L/min 1 L/min and 1.5 L/min). The biogas from digester collect using 30 L biogas bag, after that the biogas in 30 L is purified then stored in 2 L biogas bag.

Biogas analysis was carried out in the PT Pupuk Sriwijaya Palembang laboratory using Shimadzu GC-2014 gas chromatograph. The Shimadzu GC-2014 is a highly versatile gas chromatograph system. The GC unit is ideal for both routine analysis like in chemicals analysis. Biogas in sample bag injected into the Shimadzu GC-2014, the result of data analysis from this GC is using concentration of the biogas.

3. RESULTS AND DISCUSSION

Biogas production is carried out at a biogas installation in the State Polytechnic of Sriwijaya (Renewable Energy Laboratory), the digester used can be seen in Figure 1 and the packed bed scrubber used in this study can be seen in Figure 2.

Figure 1. fixed dome Biodigester [26]
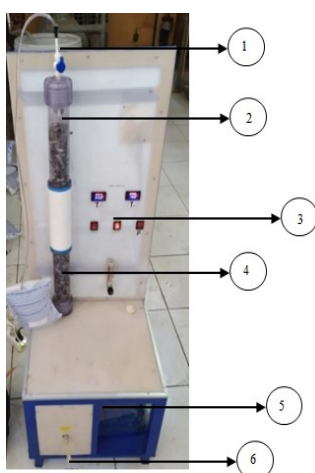
Figure 2. Packed bed scrubber. (1) Biogas output, (2) Scruber, (3) Control panel, (4) Packing, (5) Solution tank, (6). Biogas input.

The biogas produced is stored in a 30 L bag, then the biogas is connected to the biogas input to the absorber for absorption by the output of a 2 L biogas sample bag. The biogas purification results used MEA solution before and after purification on packed bed scrubber in Table 1 and Table 2.

3.1 ANALYSIS RESULT BEFORE AND AFTER PURIFICATION

Observation data were obtained by analyzing biogas samples at PT Pupuk Sriwijaya Palembang. The purpose of the analysis is to determine the content of CH_4, CO_2, O_2 and N_2 contained in biogas. Following are the results of the analysis of biogas composition before being purified.

Biogas analysis before purification is conducted at intervals of 5 days, the point is to find out the optimum biogas content condition. On the 5th day the digester did not produce biogas, entering the 10th day the biogas was formed but the methane content was still low. Result data analysis biogas composition before purification 5 days interval in Table 1.

Entering the 15th day the composition began to increase CH_4 44.42%, CO_2 1.64%, O_2 16.96% and N_2 35.28%.

Table 1. Biogas composition before purification from biodigester production in 5-30 days

Biodigester production time (days)	Biogas Composition (%)			
	CH_4	CO_2	O_2	N_2
5	0	0	0	0
10	19.18	0.93	19.54	58.80
15	44.42	1.64	16.96	35.28
20	60.27	3.05	14.27	20.61
25	71.18	8.53	6.65	12.28
30	62.04	14.64	3.27	18.28

On the 20th day and the 25th day the CH_4 content continued to increase with an optimal composition on the 25th day showing that the CH_4 content reached 71.18%, CO_2 8.53% O_2 content decreased to 6.65% and N_2 also decreased to 12.28%.

Day 30 there was a decrease in biogas production, the results of biogas composition analysis on day 30 decreased compared to day 25th CH_4 62.04%, CO_2 14.64%, O_2 3.27% and N_2 18.28%. Therefore, researchers purified using biogas which was produced on the 25th day as a gas for the purification process, because the optimum methane content was found on the 25th day, 71.18% with CO_2 content of 8.53%.

Purification procces is to reduce CO_2 content in biogas, decreasing CO_2 content in biogas, the methane content will increase. Data from analysis of biogas content after purification in Table 2.

Table 2. Biogas composition after purification by MEA using packed bed scrubber

MEA Flow Rate (L/min)	MEA Concentration (M)	Biogas Composition (%)			
		CH_4	CO_2	O_2	N_2
0.5		72.64	0.68	7.65	17.10
1	1	73.52	0.66	7.36	16.56
1.5		73.74	0.64	7.52	16.13
0.5		75.77	0.42	6.52	15.42
1	3	76.04	0.39	6.77	15.37
1.5		76.23	0.36	6.53	15.28
0.5		77.30	0.29	6.57	14.20
1	5	77.41	0.21	6.34	14.53
1.5		78.04	0.17	6.80	13.54
0.5		79.07	0.15	6.80	11.55
1	7	80.24	0.13	6.41	11.78
1.5		81.20	0.10	6.89	11.01

3.2 ANALYSIS RESULT CO_2 AND CH_4 AFTER PURIFICATION

Figure 3 is data that has been processed into a graph of the effect of flow rate and concentration of MEA to CO_2 reduction after purification.
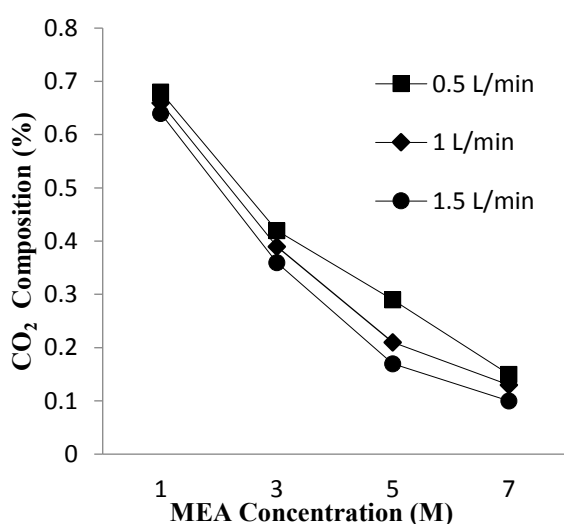

Figure 3. CO_2 reduction after purification using MEA at flow rate of 0.5, 1, 1.5 L/min

The results of biogas analysis after purification showed very significant results at a MEA flow rate of 0.5 L/min with a concentration of 1M MEA able to reduce CO_2 from 8.53% to 0.68% (Figure 3). Increasing the flow rate and concentration of MEA makes the CO_2 content decreases. This is due to the greater absorbent flow rate that will make an increase in the interfacial area of packing in the column. This is in line with research conducted by W. Kamopas et al. [25] which examined the effect of flow rate and concentration of MEA on gas purification. From his research proved that the rate of solution and the higher concentration of MEA that enters the scrubber can reduce CO_2. Furthermore, along with a decrease in CO_2 content in biogas, an increase in CH_4 content in biogas, the effect of the flow rate and the concentration of MEA on CH_4 can be seen in Figure 4.

In Figure 4, increasing the flow rate and the concentration of MEA make CH_4 contend inscrease. Concentration in biogas has increased from 71.18 to 81.20%. CH_4 has one carbon in each chain can produce more environmentally friendly combustion than long carbon chain fuels. This is due to the amount of CO_2 produced during the

combustion of short or fewer carbon chain fuels.
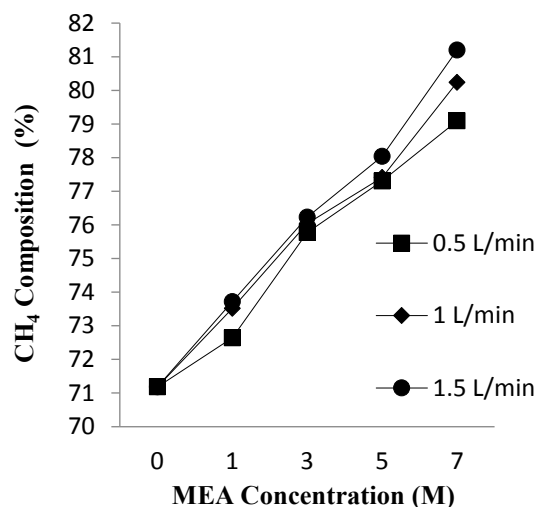
Figure 4. Effect of the MEA solution flow rate of 0.5, 1, 1.5 L/min on CH_4

4. CONCLUSIONS

The results of the study using MEA solution with Packed Bed Scrubber showed that the higher the flow rate of the solution and the higher the concentration of the solution would increase the absorption of CO_2 and increase the CH_4 content. The optimum results obtained at a solution flow rate of 1.5 L/min with a 7 M MEA concentration obtained a decrease in CO_2 content from 8.53% to 0.1%, while the CH_4 content from 71.18% to 81.20%, in this study obtained the best percentage reduction in CO_2 8.52% and in CH_4 increase 10.02%. The parameters carried out in this study are expected to be a reference for optimizing biogas purification.

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