

Biogas Purification by CO₂ Reduction in Bubble Column Using Ca(OH)₂ and NaOH

E Purba^{1,*}, C N Yogia¹, P D R Sari¹

¹Department of Chemical Engineering, Universitas Lampung, Jl. S. Brodjonegoro No.1, Bandar Lampung, Indonesia

*Corresponding author. Email: elida.purba@eng.unila.ac.id

ABSTRACT

This study is about biogas purification process by reducing the CO₂ content in order to increase the heating value of biogas by using Ca(OH)₂ and NaOH solution as the absorbent in a bubble column. The purpose of this study is to determine the effect of the sparger hole diameter and the height of Ca(OH)₂ and NaOH solutions in the column. The bubble column is made from acrylic with diameter of (2.5; 3.0; and 4.0 in) and the height of column is 100 cm. The column is equipped with a sparger with a variety of hole diameter about 1 and 2 mm. The sparger is placed at the bottom of the column. The volume of solution for each run is same (2 liters) but the height of solvent is followed the diameter of the columns. Therefore, the height of the solutions is 63, 44, and 25 cm. The flow rate of the biogas is 1 liter/min, which was fed from the bottom of the column. Both output and input in each run sample were analyzed by Gas Chromatography 2014 AT (SHIMADZU Corp 08128). The results show that the higher the absorbent in the bubble column, the higher the percentage of CO₂ absorption and the CH₄ contain. The absorption of the CO₂ is varied using Ca(OH)₂ and using NaOH. The absorption using Ca(OH)₂ and NaOH are 70.18 and 90.66% respectively. The CH₄ content also increases using Ca(OH)₂ and NaOH up to 66.84 and 87.755% respectively.

Keywords: CO₂ reduction, Absorption, Bubble Column, Absorbent Height, Sparger Hole Diameter

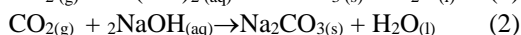
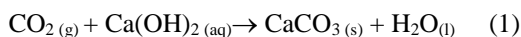
1. INTRODUCTION

Biogas is one of the non-fossil fuels which can be used as an alternative bioenergy. Biogas is obtained from a fermentation process of biomass containing carbohydrates by using a microorganisms [4]. Biogas consists of methane of 50 - 70%, carbon dioxide of 25 - 45%, and small amounts of hydrogen, nitrogen, and hydrogen sulfide [9].

The carbon dioxide (CO₂) content can reduce the heating value of biogas in a combustion system. The hydrogen sulfide (H₂S) causes corrosive in construction material [3]. For this reason, an effort to increase the heating value of biogas by reducing the CO₂ content becomes a concern for research.

One of the methods to reduce CO₂ content in biogas is the absorption process by chemical absorption. The CO₂ is removed by contacting the biogas into a liquid solvent where one or more gas components will be absorbed by the liquid [1]. Chemical absorption method is preferred because it is more economic. This is because the absorbent can be regenerated [7]. Absorbents for reducing the CO₂ are Ca(OH)₂ and NaOH solutions.

The process of CO₂ gas absorption by Ca(OH)₂ and by NaOH are shown in reaction (1) and (2) respectively.



The chemical reaction is irreversible, where CO₂ in the gas phase will be absorbed by the absorbent solution in the liquid phase. When the gas approaches liquid interphase, CO₂ gas will dissolve and react immediately with absorbent [8].

The chemical absorption process can be carried out in a bubble column. A bubble column is a two-phase column, equipped with a gas distributor as a sparger at the bottom of the column. The gas-phase fluid is dispersed through the sparger, so that gas bubbles are formed, which then move through the liquid phase fluid inside the column. When the bubbles rise to the top through absorbent, the gas is dispersed into the liquid phase in the form of small bubbles resulting in a large contact area. Mass transfer occurs during bubble formation and also when bubbles rise to the surface.

In this study, biogas purification was investigated by using Ca(OH)₂ and NaOH in the bubble column, by varying the sparger hole diameter and the height of the

absorbent solution. The height of the solution was varied but keeping the volume of the absorbent constant throughout the process. Therefore, the diameter of the column was varied then the level of the absorbent is varied as a consequence. The aim is to determine the optimum height of the absorbent and hole diameter of sparger on reducing the CO_2 .

2. MATERIALS AND METHODS

The main equipment used in this study is the acrylic bubble column. The diameter of the absorption column varies, they are 2.5, 3.0, and 4.0 in, and the height of column is 100 cm. The volume of the absorbent is constant of 2 liters solution, so the height of the absorbent in the absorption column adjusts accordingly. As a result, the heights of absorbent were 25, 44, and 63 cm. The column is equipped with a sparger with a variety of hole diameter 1 and 2 mm. Supporting equipments are biogas input and output sample bags, gas

flowmeter, aerator, and Gas Chromatography 2014 AT (SHIMADZU Corp 08128) for gas analysis.

The biogas was produced from cow dung in Kediri, Gadingrejo, Pringsewu, Lampung. The absorbent were the solution of $\text{Ca}(\text{OH})_2$ and NaOH with a constant concentration of 2 liters of 2.5 M. The initial biogas content and the product after absorption process were analyzed by using the gas chromatography. Initially, the composition of biogas i.e CH_4 and CO_2 were 50,642 and 48,978% respectively. The absorption process was carried out by flowing the biogas through the sparger in the absorption column with the flow rate of 1 liter/min. The first run was carried out in the column with a diameter of 2.5 inch and 1 mm hole diameter of the sparger. The biogas output was analyzed by the gas chromatography. Then, the experiment was carried out in the different columns and different hole diameter of sparger.

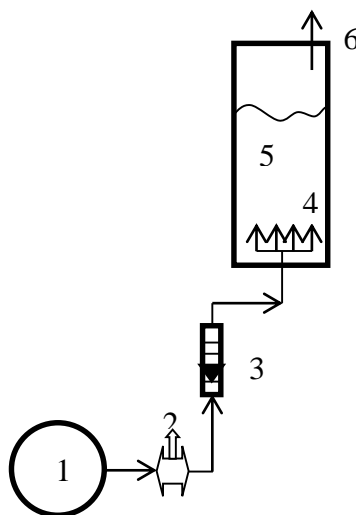


Figure 1 The scematic of absorption column. 1- Biogas input, 2- Aerator, 3- Flowmeter, 4- Sparger, 5- Absorbent solution, 6- Biogas output

3. RESULTS AND DISCUSSION

3.1. The Effect of Absorbent Height on CO_2 Absorption and CH_4

Figure 2 shows the effect of absorbent height on the CO_2 absorption using 2 different absorbent

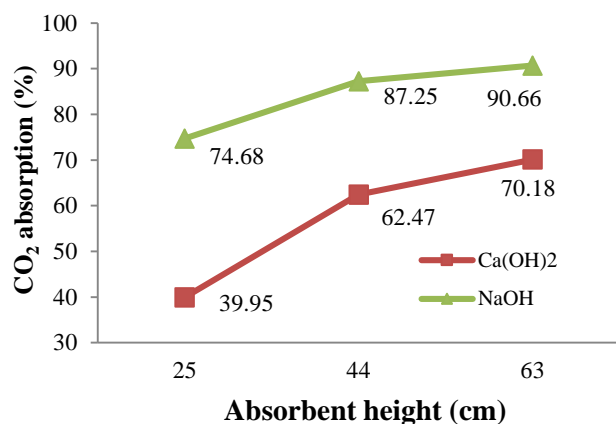


Figure 2 The effect of absorbent height on the CO₂ absorption

As shown in the Figure 2, the higher the absorbent, the percentage of CO₂ absorption continues to increase to 70.18% with Ca(OH)₂ and 90.66% with NaOH. Meanwhile, at a lower absorbent height, the percentage of CO₂ absorption only reached 39.95% and 74.68%. The percentage of CO₂ absorption in the biogas purification process increases with increasing absorbent height. This is because of the higher the absorbent in the bubble column the longer the contact time in the column. When the two fluids are in the longer contact time, the gas diffused into the absorbent will increase, and the mass transfer rate will be even greater, resulting in more CO₂ content absorbed.

The result is supported by the study by Apriandi *et al.*, 2013, the research aims to get the maximum CO₂ absorption results in biogas by the manometer column absorption technique, using Ca(OH)₂. The results obtained in their research are CO₂ contained in biogas decreased by 29.34%, and the CH₄ increased by 29.14%.

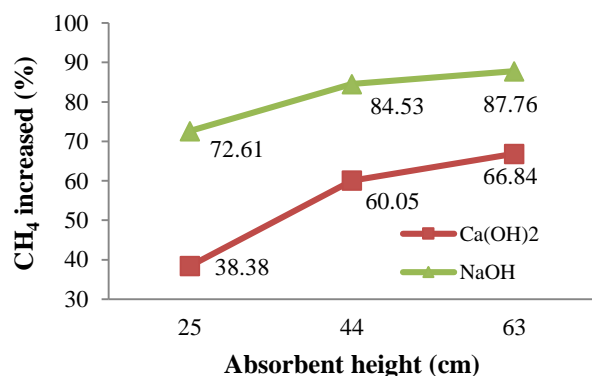


Figure 3 The effect of absorbent height on the CH₄ increased

Figure 3 shows the effect of absorbent height on the percentage of CH₄ with two different solvent. The reduction of the CO₂ content causes an increase of CH₄ content. It can be seen in Figure 3 that the CH₄ content continues to increase up to 66.84% with Ca(OH)₂ and up to 87.76% with NaOH with the height of the bubble column of 63 cm. In the same run, it can be seen in Figure 2 that the percentage of CO₂ absorbed also continues to increase up to 70.18% with Ca(OH)₂ and 90.66% with NaOH.

3.2. The Effect of Sparger Hole Diameter on CO₂ Absorption and CH₄

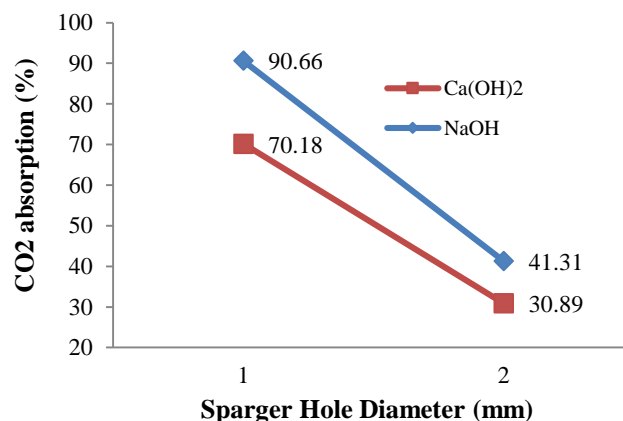


Figure 4 The effect of sparger hole diameter on CO₂ Absorption

As shown in Figure 4, the smaller the diameter of the sparger hole, the percentage of CO₂ absorption reaches 70.18% with Ca(OH)₂ and 90.660% with NaOH. Meanwhile, in the larger sparger hole diameter the percentage of CO₂ absorption only reaches 30.89% with Ca(OH)₂ and 41.31% with NaOH. The percentage of CO₂ absorption decreases with increasing sparger hole diameter.

Biogas which is fed from the sparger, will form a flow of bubbles that will rise towards the absorbent surface. The size of these bubbles will affect the results of the absorption process. The smaller the bubble causes the contact area between biogas and absorbent to increase. The wider contact area will increase the chance of the gas to diffuse into the absorbent, so the absorption rate will also be greater, and CO₂ content absorbed will also increase.

The results obtained are supported by previous study Navisa J, 2014, which conducted research on the effect of nozzle diameter and flow rate on the rate of oxygen transfer in the aeration process of salt-

containing water. From this study it can be concluded that the best aeration process is in the treatment with the smallest nozzle size of 0.7 mm. The resulting bubble of 1.45 mm requires more time to reach the surface, increasing the residence time of each bubble in water, and encouraging a better rate of oxygen transfer.

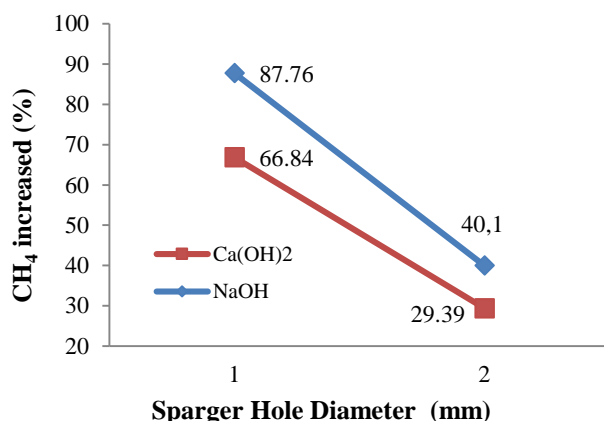


Figure 5 The effect of sparger hole diameter on the CH₄ increased

Reduced of CO₂ content will increase the CH₄ content. This can be seen in Figure 5, which shows the effect of the sparger hole diameter on the increase in CH₄, where when the sparger hole diameter is 1 mm, the highest percentage of CH₄ increase is 66.84% with Ca(OH)₂ and 87.76% with NaOH. Figure 5 shows that the bigger the diameter of the sparger hole in the bubble column results in decreasing the CH₄ content.

According to observations during the study, a sparger hole diameter of 1 mm produce bubbles on average by 0.5 cm, while for sparger hole diameter of 2 mm produce bubbles on average by 1.5 cm. The smaller the diameter of the sparger hole, the smaller the diameter of the bubble produced, resulting in a wider contact area between biogas and absorbent solution. This will increase the chance of the gas to diffuse into the absorbent, so that the CO₂ content absorbed will increase and produce more CH₄.

4. CONCLUSION

The absorption of CO₂ increases with increasing absorbent height in the column due to a longer contact time of biogas in the absorption column. The smaller the diameter of the sparger hole, the smaller the diameter of the bubble, resulting in a larger contact area between biogas and absorbent. Sparger hole diameter of 1 mm produces bubbles on average by 0.5 cm. While, the sparger hole diameter of 2 mm produce bubbles on average by 1.5 cm. The absorption of CO₂ by NaOH is

greater when compared with Ca(OH)₂. CO₂ is absorbed by Ca(OH)₂ up to 70.178%, and CH₄ increases up to 66.843%, while with NaOH the most optimum CO₂ absorption reaches 90.660%, and CH₄ increased up to 87.755% with solution height of 63 cm and the smallest sparger hole diameter 1 mm.

REFERENCES

- [1] Altway A, Kusnaryo, and Wijaya R P. 2008. *Analisa Transfer Massa Disertai Reaksi Kimia Pada Absorpsi CO₂ dengan Larutan Potasium Karbonat dalam Packed Column*. Jurusan Teknik Kimia, Fakultas Teknologi Industri, ITS.
- [2] Apriandi N, Kusuma IGB W, Widiyarta IM. 2013. *Pemurnian Biogas Terhadap Gas Pengotor Karbondioksida (CO₂) dengan Teknik Absorpsi Kolom Manometer (Manometry Column)* (Jurnal Logic)
- [3] Dienullah M, Tira H S, and Padang Y A. 2017. *Pemurnian Biogas dengan Sistem Berlapis Menggunakan Fe₂O₃ Zeolit Sintetik dan Zeolit Alam*. Jurusan Teknik Mesin, Fakultas Teknik, Universitas Mataram. Nusa Tenggara Barat.
- [4] Harahap F 1980 *Teknologi Gas Bio*. ITB Press. Bandung.
- [5] Navisa J. 2014. *Effect of Bubble Size on Aeration Process*. Asian Network for Scientific Research. India.
- [6] Javed K H, Mahmud T, and Purba E. 2010. *The CO₂ Capture on a High-Intensity Vortex Spray Scrubber*. Institute of Particle and Science Engineering, School of Process, Environmental and Materials Engineering, The University of Leeds, Leeds LS2 9JT, UK.
- [7] Kamopas and Kiatsiriroat. 2011. *Biogas Purification by Uniform Bubble Flow in Ethanolamine Solution. The Second TSME International Conference on Mechanical Engineering*. Krabi.
- [8] Kumoro, Andri, and Hadiyanto, 2004. *Absorpsi Karbondioksida dengan Larutan Soda Api dalam Kolom Unggun Tetap*. Forum Teknik Jilid 24.
- [9] Nadliriyah N and Triwikantoro. 2014. *Pemurnian Produk Biogas dengan Metode Absorpsi Menggunakan Larutan Ca(OH)₂*. Jurusan Fisika, FMIPA, Institut Teknologi Sepuluh Nopember (ITS). Surabaya.

- [10] Purba E, Mahmud T, and Javed K H . 2006. *Enhancement of Mass Transfer in a Spray Tower Using Swirling Gas Flow*. *Jurnal International Chemical Engineering Research and Design*, Volume 84, Issue 6, Hal 448-446.
- [11] Purba E. 2016. *Absorption of CO₂ from Modified Flue Gases of Power Generation Tarahan Chemically Using NaOH and Na₂CO₃ and Biologically Using Microalgae*. The Department of Chemical Engineering, Faculty of Engineering, University of Lampung.