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Research Paper

Analysis of Biogas Purification Reactor at Manggar Balikpapan Landfill

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Abstract

Biogas is a renewable and environmentally friendly energy source that can be produced from various organic wastes It's an alternative energy that can be developed in Indonesia. The main product of biogas is used for fuel and also for power generation. It should be noted that the gas produced as a result of the anaerobic digestion process contains not only methane, but also carbon dioxide, hydrogen sulfide, nitrogen, and impurities like hydrogen gas. These impurities gases must be treated by purification to separate a pure chemical component from a chemical component that is not used. This study uses a chemical absorption method with NaOH solution to determine the performance of the purification reactor on biogas located at the Manggar Final Disposal Site in Balikpapan with a variation of time ratio. The conclusion obtained that the biogas purification reactor at the Manggar Landfill functions properly and efficiently to reduce the impurities gases and the methane could be used as a substitute for LPG. This biogas purification reactor also should be tested further to optimize the performance of the reactor.

Keywords: *Biogas, Impurities Gases, Landfill, Manggar Balikpapan, Purification Reactor*

INTRODUCTION

Biogas is a renewable and environmentally friendly energy source that can be produced from various organic wastes. Biogas has many applications, such as cooking, heating, electricity generation, and transportation. However, biogas production and utilization face many challenges, such as feedstock availability, process optimization, gas quality, and economic feasibility. Biogas contains methane and carbon dioxide. Biogas is produced by an anaerobic bacterium that originates from organic matter in an anaerobic condition. This process works during the processing or fermentation stage, where most of the gas produced is methane and carbon monoxide, oxygen, hydrogen sulfide, hydrogen, and propane (Gustiar & Suwignyo., 2014).

Balikpapan City is one of the three administrative regions of the city in Kalimantan Province East with a population of 645,727 (BPS, 2022). Balikpapan is the city with the highest population density in East Kalimantan, which is 1,260 people/km^2. Nevertheless, Balikpapan City is known as one of the cities' pilots related to environmental issues and urban planning in Indonesia. One of the waste management pilots is the Manggar landfill (TPA Manggar) located in the East Balikpapan area. This site receives 467 tons of waste/day. The waste is 80% from Balikpapan city and 20% from other areas. This site is also equipped with a biogas capture plant which is used by the village community as an alternative fuel to replace LPG gas (DLH, 2019).

The main product of biogas plants is generally used as fuel for cooking, although with the development of technology began to be intended as fuel for power plants. The main product of biogas used as fuel is methane (CH_4). Nevertheless, the gas formed is not only CH_4 but also produced other gases such as CO_2, H_2S, N_2 and H_2 as known as impurities gases. These impurities can reduce the performance of the biogas to increase the use value of the biogas and benefit from more optimal biogas. However, the largest gas composition from biogas plants is CH_4: 55-70%, and CO_2 = 25-45% (Wu et al., 2017).

These impurities gases will not only interfere with the combustion process but also reduce

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the calorific value and will produce toxic, corrosive and odorous gases that are harmful to the environment. Hydrogen sulfide (H_2S) is a toxic and odorous gas and causes corrosion. If biogas contains this compound, it will cause harmful gas properties, the allowable concentration in ambient air is a maximum of 0.03 ppm (Harasimowicz *et al.*, 2007).

These impurities gases could be removed by purification. Purification is separating pure chemical components from unnecessary chemical components. The method we use is adsorption contained in the biogas purification process. The process of occurrence of a fluid flow event in contact with a solid so that the fluid changes composition (Zhao *et al.*, 2010).

In this study, biogas purification techniques were tried using a purification reactor that has been installed at the TPA Manggar landfill by observing a decrease in impurities gas in the gas outlet.

LITERATURE REVIEW

Biogas is a byproduct of fermentation technique that operates without free oxygen called anaerobic digestion (AD). The products of AD also carry impurities such as moisture, H_2S, ammonia, siloxane, and particulate matter. This process is chemically very complicated, involving many possible intermediate compounds and reactions (Heryadi & Chaiprasert, 2017).

The AD process is the breakdown of organic material by a microbial population that lives in an oxygen-free environment. When organic matter is decomposed in an anaerobic environment, the bacteria produce a mixture of methane and carbon dioxide gas. Anaerobic digestion treats waste by converting putrid organic materials to carbon dioxide and methane gas (Van et al., 2019).

Biogas is one of the alternative energy sources that can be developed in Indonesia. Gas from this biogas process comes from various kinds of organic waste such as biomass waste, human waste, and animal waste can be utilized into energy through the process of anaerobic digestion. This process presents an excellent opportunity to generate alternative energy and reduce reliance on fossil fuels (Achinas et al., 2017).

Methane production from a variety of biological wastes through anaerobic digestion technology is growing worldwide and is considered ideal in many ways because of its economic and environmental benefits. Furthermore, the benefits offered by the use of biogas over natural gas such as; 1) it is produced from renewable resources, 2) it reduces greenhouse gases in the atmosphere, 3) it is produced locally without any dependency on foreign oil or natural gas supplies, 4) it helps in reducing the pollution produced by the organic wastes, which account for most freshwater pollution, and, 5) it helps in retarding the waste management problems (Jeong et al., 2014; Heryadi & Chaiprasert, 2020).

Waste is waste material that has been disposed of and sourced from both the rest of human and natural activities that are not economically valuable. Waste has various forms in each phase of the material, namely in the form of solid, liquid, and gas. When based on its nature, waste is grouped into 2 types, namely organic waste (degradable) which originates from living things and is very easily decomposed, and waste (degradable) whose origin is from objects that are very difficult to decompose such as plastic bags, cans, rubber, and so on (Damanhuri et al., 2009).

Absorption is separation by absorbing a mixture of gases by contacting a liquid in which one component is absorbed while other components are not absorbed (Ardhiany, 2019). Adsorption is an event of attaching atoms or molecules of a substance to the surface of another substance due to an imbalance of forces on the surface (Anggriani, 2020). Based on the absorption process, absropsies are divided into two (Ardhiany, 2019): (a) Physical absorption, is an absorption in which the dissolved gas in solution is not accompanied by a chemical reaction. (b) Chemical absorption is an absorption where the gas dissolved in an absorbent solution is accompanied by a chemical reaction.

Table 1. General Biogas Composition

No	Gas	Chemical formula	Concentration %mol
1.	Methana (CH4)	CH4	50-75
2.	Karbon Dioksidaa (CO2)	CO2	25-50
3.	Nitrogen (N2)	N2	0-10
4.	Hydrogen (H2)	H2	0-1
5.	Hidrogen Sulfida (H2S)	O2	0-3
6.	Oksigen (O2)	H2S	0-0,5

Source: Suprianti (2018)

RESEARCH METHOD

The materials used in this research are biogas from Manggar Balikpapan landfill waste, water, and NaOH solution, with a 4% concentration and time variations of 60 minutes, 120 minutes, 180 minutes, and 240 minutes. The tools used are biogas purification reactors, 4 in 1 gas detectors (CO, O_2, and H_2S), CO_2 measuring instruments, gas manometers, and digital gas flow measurements.

FINDINGS AND DISCUSSION

Characteristics of Materials

The materials used in this study were biogas from waste in the Balikpapan Manggar landfill, water, and NaOH solution. The tools used are biogas purification reactors, litmus paper, 4 in 1 gas detector, CO_2 level measuring instruments, gas pressure meter, and digital gas flow meters.

The first reactor was a Water Scrubber. The function of using this water scrubber reactor is to remove the content contained in biogas, namely H_2S and CO_2, both gases are easily soluble in water compared to methane gas. The working principle of the Water Scrubber is to make contact between gas and liquid absorbent which is done in the opposite direction or the contact between gas and liquid absorbent with environmental temperature conditions. Biogas entering through the bottom of the column will be given absorbent liquid from the top of the column so that CO_2 and H_2S gas will be carried away with liquid absorbents. This method has the advantage of efficiency of >97% CH_4, and low CH_4 loss <2% but the disadvantage is that it requires a lot of water and can occur clogging (Suprianti, 2018).

The second reactor is the absorption column. In this second reactor using NaOH absorbents with a variation of 4% variation in contracting time of 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes.

The third reactor is zeolite filling, zeolite is used to remove the H_2S content in biogas. When biogas reacts with zeolite, H_2S will be adsopsied to the surface of the zeolite due to the structure of the large-porous zeolite.

The fourth reactor contains silica gel. This silica gel serves to absorb, dry and support catalysts so that it is used to prevent the formation of excessive moisture. Biogas will be adsorbed by the surface of silica gel so that biogas will be drier and moisture-free. After that, the results of this biogas purification will be seen by going to residents' homes to see the quality of the Manggar landfill biogas results with test equipment used 4in 1 gas detectors (CO, O_2 and H_2S).

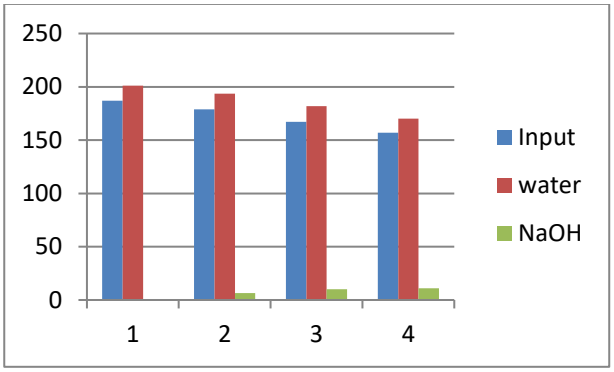

Figure 1. H_2S Concentration from biogas purification reactor

Figure 1 showed that the concentration of H_2S in the reactor in the first hour reaches the highest peak in the absorption column. Then in the next hour, it decreases by 4-7% every hour. This is due to an increase in flow rate and moisture in biogas and pressure drop. This pressure drop affects the quality of the biogas produced, namely the content of H_2S which is corrosive and reduces the calorific value of heat and gives a yellowish flame color.

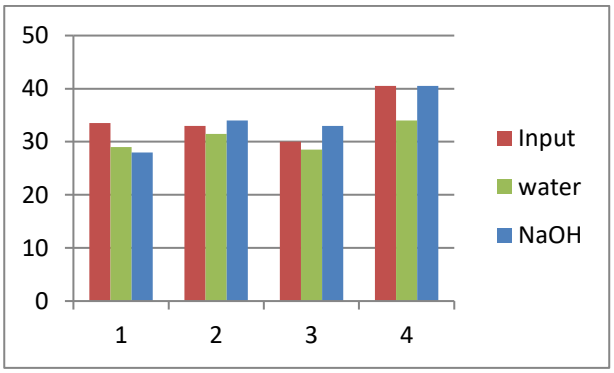

Figure 2. CO concentration from biogas purification reactor

Figure 2 showed the concentration of CO, in the first and second hour the CO content does not show a constant increase but in the next 4 hours, it has a significant increase of up to 97%. This is due to a decrease in the content of impurity gas in the reactor.

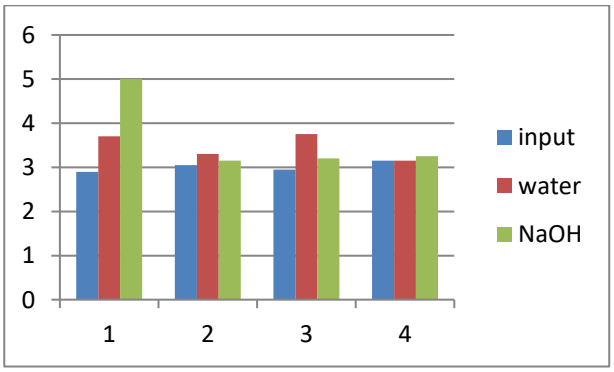

Figure 3. O_2 concentration from biogas purification reactor

Figure 3 revealed that the O_2 contained in the absorption reactor in the first hour contains a lot of O_2 gas, this is because a new reaction is formed between water and NaOH so that many O_2

content is found. Nevertheless, in the next 2-4 hours O_2 decreases very dramatically.

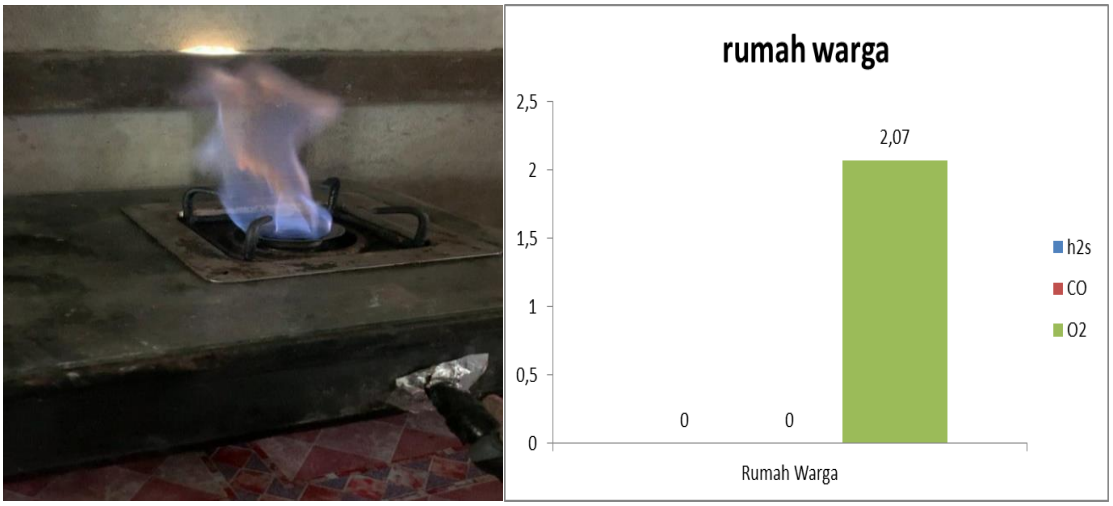

Figure 4. The colour test of the flame (left) concentration of H_2S, CO and O_2 (right) on the stove from the village.

After 4 hours of research on the reactor, biogas from residents' homes can be seen in the blue fire picture. The results showed no H_2S and CO content as shown at figure 4.

CONCLUSIONS

Waste from the Balikpapan Manggar landfill can be used as biogas by using water scrubbers, absorption columns, reactors with zeolite and reactors containing silica gel.

LIMITATION & FURTHER RESEARCH

From the results of the analysis, it can be concluded that this biogas purification reactor can function properly and efficiently as a substitute for LPG gas, but this biogas purification reactor must be tested further to optimize the performance of the reactor.

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