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THE EFFECT OF VARIATION OF ZEOLITE AS ADSORBENT MEDIUM AND ADSOPTION PRESSURE TOWARD THE QUALITY OF OXYGEN PRODUCED FROM PRESSURE SWING ADSORPTION (PSA)

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One of the most important element in human life is oxygen. To produce good quality of oxygen, a purification process is needed. Pressure Swing Adsorption with the adsobent of zeolite is the most comon method used for oxygen purification. This study aimed to find out media variation of of zeolite as adsorbent medium and adsoption pressure toward oxygen quality produced from PSA. Variation of adsrobent medium used were 13X zeolite and combination of 13X zeolite and Bayah zeolite (zeolite 13X+ZAB). The study result shows that the use of 13X zeolite and 13X+ZAB zeolite can significanly increase the quality of oxygen in PSA compare to without using zeolite. The use of 13X zeolite produce higher quality of oxygen, this is because 13X zeolit is a zeolite which has high ability to adsorb nitrogen and 13X zeolite has high surface area. The higher the adsorbent surface area the more adsorbat was adsrobed so that 13X zeolite will adsorb niotrogen. Meanwhile the addition of Bayah natural zeolite into 13x zeolite (13X zeolite +ZAB) is to overcome the problem of the vapor releasing which can hinder the performance of PSA in certain period of time, so that it is needed one media of adsorbent of natural zeolite which can adsorb liquid produced from this PSA.
The effect of pressure variation toward oxigen quality produced from PSA is that the higher the pressure applied the faster the process of lowering the quality of oxygen would be, this is because the adsorben was more saturated. The pressure highly affect the adsorbability occur in PSA colomn.

Keywords: *Adsorption, Zeolite, PSA, Oxygen, Pressure.*

1. INTRODUCTION

Oxygen is one of important element in human life because it is a necessity for human, moreover in the middle of Covid-19 pandemic, the demand of good quality of oxygen increase as the solution in combating Covid-19 such as oxygen terapy recommended for many cases of Covid-19 with severe condition. To produce good quality of oxygen, a purification process is needed. Nowadays, there are many methods used in oxygen purification such as chemical reaction, criogenic method and adsorption method. Adsorption method is the most frequently used because this method is simple and cheap to be applied by using zeolite as the adsorbent.

Pores structure in zeolite can be used to separate different gases based on their size [1]. Zeolite as mineral consists of hydrated alumino cristal containing cation alkali or earth alkali in 3-D frame [2]. In addition, zeolite is also a mineral with very small porous which has size of 3-10 Å. Zeolite material has been widely used in various application for instance as catalyst, adsorbend, ion exchanger, and several other function which can give benefit [3] because of the surface area of zeolite micropores, the oxygen

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concentrator using Pressure Swing Adsorption (PSA) can adsorb nitrogen from air and release oxygen under the condition of high pressure. Consentrator can be regenerated by lowering the pressure to relarse nitrogent adsorbed [4]. Zeolite, based on the production process is classified as two major types those are natural zeolite and syntetic zeolite [5]. In indonesia natural zeolite is found in huge amount in several places such us Sumatra, Borneo, Sulawesi and Java [6], from which natural zeolite of Bayah is originated. Bayah is one region in Banten. In the other hand, the demand of ready to use - sintetic zeolite in Indonesia is still imported [7]. Natural zeolite in indonesia has been widely used, so that it is needed as the source of silica which can be used as syntetic zeoloite [8].

A substance called 13X Zeolite is a synthetic zeolite that is commonly used as an adsorbent used by oxygen-producing apparatus with technology of Pressure Swing Adsorption (PSA) because this zeolite has a high ability to adsorb nitrogen. The nitrogen adsorption capacity of 13X zeolite higher than the similar synthetic zeolite, namely zeolite 5A [9]. Then in the utilization of Pressure Swing Adsorption (PSA) technology by comparing 2 synthetic zeolite adsorption media, namely zeolite 13X and zeolite 5A, it is obtained that the purification quality of 13X zeolite as adsorption medium is better than that of zeolite 5A [10]. Pressure Swing Adsorption (PSA) using zeolite 5A is able to produce oxygen purity of 76.9% with adsorption pressure of 4 Bar [11].

Meanwhile, natural zeolite in previous studies can also be used as an adsorbent medium, although it was not as good as synthetic zeolite [12]. The adsorption ability of natural zeolite under activation with a size of 37 µm with the weight of 3 g was able to purify and reduce CO levels as 4.47% for 20 minutes [13]. Lampung natural zeolite can adsorb N2 selectively and increase the percentage of oxygen in the air up to 0.2% [14]. Natural zeolite was modified into CaO-zeolite by ion exchange process with lime solution (Ca(OH)2) with Ca concentrations of 0.682%, 0.849% and 1.244%. The adsorption test showed that there was a limitation of Ca content so that CaO-zeolite was more selective in adsorption of nitrogen. CaO-zeolite with Ca content of >1.125% adsorbed nitrogen more selectively than oxygen [15].

Adsorption technology is well known to have benefits in various applications, such as adsorption refrigeration cycles [16], dryers and gas separators or purifiers. Pressure Swing Adsorption (PSA) is a technology that can be used as a gas separator and purifier [17], including capturing CO2 [18] and nitrogen. The rules in designing the Pressure Swing Adsorption (PSA) include the selection of adsorbent, particle size, layer size, layer configuration, cleaning volume, pressure equalization and vacuum swing adsorption [19]. In addition, the flow rate, swing amplitude and swing period also have a great effect on the variation of the surface wave of falling film, and thus affect the heat and mass transfer performance on the adsorption performance of the adsorption apparatus or technology [20]. Pressure/Vacuum Swing Adsorption (PVSA) with an evacuation step of (-0.82 barg) and adsorption column of 3 cm diameter and 20 cm in length with nanosize zeolite adsorption media was able to produce 90% oxygen concentration [4]. Pressure Swing Adsorption (PSA) contains a pile of adsorbents that function to absorb CO2 contained in the raw biogas and PSA will be used in 2 columns that operate alternately so as to allow continuous processing. The design of the biogas upgrading process system using PSA includes the stages of determining the base design, drafting the conceptual design, and calculating the PSA column design [21].

In this study, the analysis was carried out using single bed type Pressure Swing Adsorption (PSA) which is different from previous studies with the consideration of its simpler construction so that it is portable and can be used by anyone and anywhere. The adsorbent media used was varied those are 13X synthetic zeolite and Bayah natural zeolite. Based on previous research 13X zeolite was a good synthetic zeolite used to improve oxygen quality by adsorbing nitrogen. However, the constraint of using the PSA is that the release of liquid vapor can inhibit the function of the PSA for a certain period of time, Bayah natural zeolite adsorbent medium was needed which can absorb the liquid produced by the PSA device. In addition Bayah natural zeolite is also a type of zeolite that is easier to obtain in Bayah area, Banten Province and also has a more affordable price compared to 13X synthetic zeolite. So it is expected to get a combination of zeolite adsorbent media variants that can improve the quality or purity of oxygen while remaining safe for PSA which has more affordable price and is easy to obtain. The analysis of pressure variations aims to obtain the phenomenon of how the effect of increasing adsorption pressure on the quality of oxygen produced by Pressure Swing Adsorption (PSA).

2. METHOD AND MATERIAL

In this study the method used was the experimental method. By using an oxygen production apparatus with a single bed type Pressure swing adsorption (PSA) system. Pressure swing adsorption (PSA) is one of the technologies used to separate several types of gas from a gas mixture according to the type of molecular

characteristics and affinity of the adsorbent material, the adsorbents used were 13X synthetic zeolite and bayah natural zeolite.

In this study, tests were carried out with variations in adsorption pressure (10 Psi, 20 Psi, 30 Psi, and 40 Psi) on PSA to produce oxygen with a high level of purity, by conducting experiments on the optimal pressure used to produce higher quality of oxygen. The apparatus and materials used in this study were as follows:

1. Single bed type of pressure swing adsorption (PSA).

Pressure swing adsorption (PSA) used in this study was single bed type for a zeolite capacity of 2 – 2.5 kg, the valve mechanism was conducted manually so it did not need to use automatic control system components, it used an electric power source and did not require accumulator components, and used 1 tube of O_2 so that it was simpler.

2. Furnace.

In this study, a furnace was used to calcinate the zeolite which would be used as adsorbent. The temperature used in the calcination process was 300 ^oC for 60 minutes.

3. 13X Zeolit

The zeolite used in this research is 13X zeolite because 13X zeolite is the most commonly used synthetic zeolite for oxygen purification process because of the good selectivity of nitrogen to oxygen adsorption [9].

4. Bayah Natural Zeolite

Bayah natural zeolite is a type of natural zeolite found in Bayah sub-district, Banten Province. Bayah's natural zeolite serves to absorb the the liquid produced as a result of the Pressure swing adsorption (PSA) process. At the same time, it is also a solution to obtain variations in the combination of synthetic zeolite and natural zeolite as adsorbent medium that can produce high quality oxygen, yet it is easy to obtain and has a more affordable prices.

3. RESULT AND DISCUSSION

Based on the existing theory, the pore structure in zeolite can be used to separate gases which are different in size. Same as other silica minerals, zeolite is a porous mineral. If there are several molecules entering the zeolite micro pore system, the molecules can be adsorbed based on the polarity or molecular interaction with the zeolite [22]. So that the research will find out the effect of variations in adsorbs media and also pressure on the quality of the oxygen produced.

Table 1: Testing data

TIME (s)	PRESSURE (Psi)	PURITY OF O_2 (%)		
		ZEOLITE 13X	13X ZEOLITE +ZAB	WITHOUT ZEOLITE
20	20	82	71	21
40		78	68	
60		76	67	
20	30	79	68	
40		76	66	
60		74	65	
20	40	76	65	
40		72	63	
60		71	61	
Air temperature = 30^{o}C Air humidity = 65%				

The time based on the length of data retrieval. For data retrieval at a pressure of 20 psi, the time was 0-20 seconds and the purity was recorded, it was continued at the time range of 21-40 seconds and the purity was also recorded, as well as 60 seconds. The pressure given into the adsorbent tube and when data collection is maintained in a stable condition.

Table 1 is the test data for the level of oxygen purity or oxygen concentration, O2 (%) on a variation of 13X synthetic zeolite as adsorbent medium (13X zeolite) and a combination of 13X synthetic zeolite + Bayah natural zeolite (13X zeolite + ZAB) and without adsorbent (without zeolite) , with variations in

adsorption pressure of 20 Psi, 30 Psi and 40 Psi and the data collection time was 20 seconds, 40 seconds and 60 seconds. Without using adsorbent, the oxygen concentration produced was 21% for all pressure variations and test time variations. Meanwhile, when using adsorbent media, the oxygen concentration will increase depending on the adsorbent medium and its pressure.

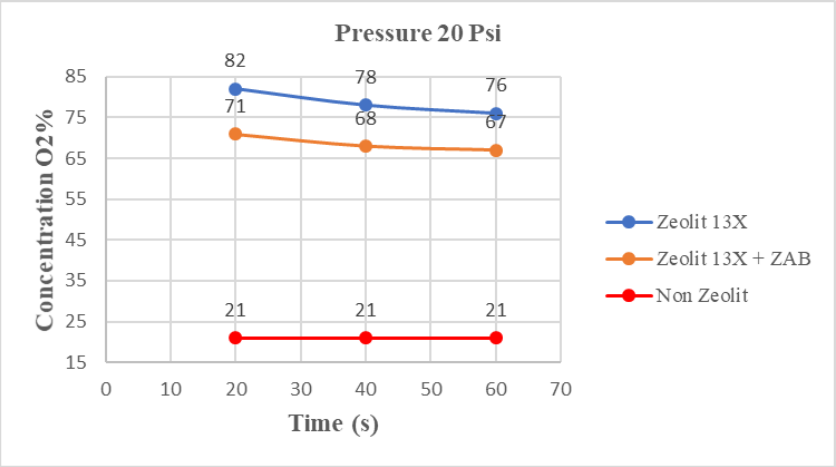

Figure 5. Graph of oxygen purity at the pressure of 20 Psi

Figure 5 is a graph of the operating data collection of the pressure swing adsorption (PSA) at a pressure of 20 Psi, the results obtained are:

At the time of 20 seconds with the pressure of 20 Psi the PSA apparatus produced an oxygen concentration of 82% by using Zeolite 13X, while at the using a combination of 13X Zeolite + ZAB produced oxygen concentration of 71%. At the time of 40 seconds with a pressure of 20 Psi PSA produced oxygen concentration of 78% by using 13X Zeolite, while using a combination of 13X Zeolite + ZAB produced oxygen concentration of 68%. At the time of 60 seconds with a pressure of 20 Psi the PSA produced an oxygen concentration of 76% by using 13X Zeolite, while at the using a combination of 13X Zeolite + ZAB produced oxygen concentration of 67%.

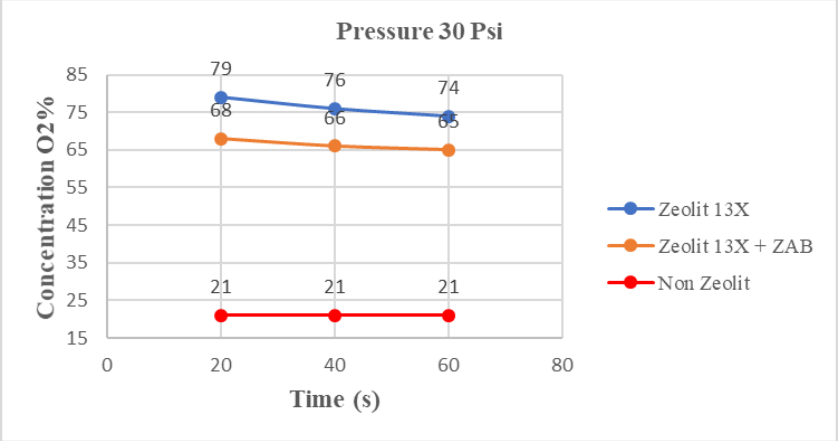

Figure 6. Graph of oxygen purity at the pressure of 30 Psi

Figure 6 is the operating data collection of the pressure swing adsorption (PSA) apparatus at the pressure of 30 Psi, the results obtained are:

At the time of 20 seconds with a pressure of 30 Psi, PSA produced oxygen concentration of 79% by using 13X Zeolite, while at the using of combination of 13X Zeolite + ZAB produced oxygen concentration of 68%. At the time of 40 seconds with a pressure of 30 Psi, PSA produced oxygen concentration of 76% by using 13X Zeolite, while at the using of combination of 13X Zeolite + ZAB produced oxygen concenteation of 66%. At the time of 60 seconds with a pressure of 30 Psi, PSA produced oxygen concentration of 74% by using 13X Zeolite, while using a combination of 13X Zeolite + ZAB produced oxygen concentration of 65%.

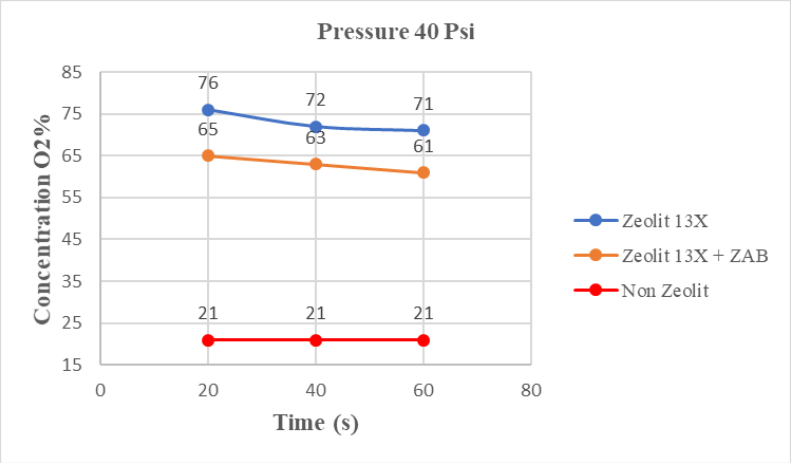

Figure 7. Graph of oxygen purity at the pressure of 40 Psi

Figure 7 is the operating data collection of the pressure swing adsorption (PSA) at the pressure of 40 Psi, it is known that:

At the time of 20 seconds with a pressure of 40 Psi, pressure swing adsorption (PSA) produced oxygen concentration of 76% by using 13X Zeolite, while at the using of combination of 13X Zeolite + ZAB produced oxygen concentration of 65%. At the time of 40 seconds with a pressure of 40 Psi, PSA produced oxygen concentration of 72% by using Zeolite 13X, while at the using of combination of 13X Zeolite + ZAB produced oxygen concentration of 63%. At the time of 60 seconds with a pressure of 40 Psi, PSA produced oxygen concentration of 71% by using 13X Zeolite, while at the using of combination of 13X Zeolite + ZAB produces oxygen concentration of 61%.

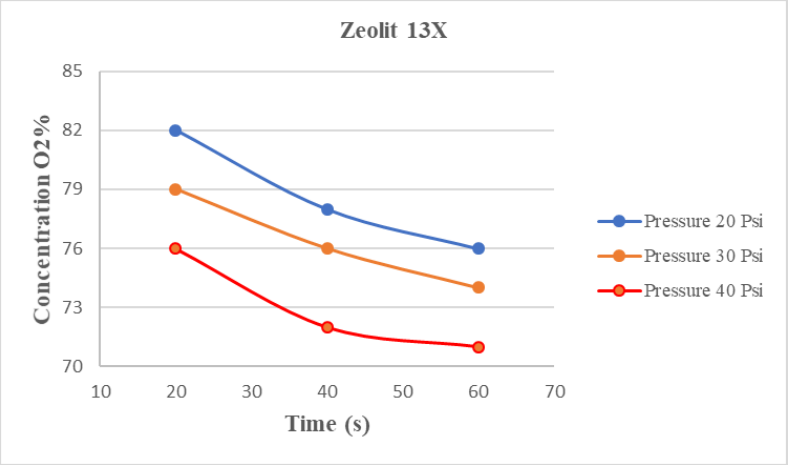

Figure 8. Graph of the effect of pressure on oxygen purity with 13X zeolite

Based on the graph in Figure 8, it can be concluded that the most optimum pressure in producing high level of oxygen purity using 13X zeolite was at the pressure of 20 Psi, which produced oxygen concentration of 82%, then the oxygen level decreases as the increasing pressure. This was because the zeolite will work optimally in adsorption of nitrogen at a pressure of 20 Psi and the zeolite was not saturated so that the purity of oxygen obtained will be high. So that the higher the adsorption pressure above 20 Psi, the oxygen level will decrease because the adsorbent (Zeolite 13X) will be more saturated and affect the nitrogen adsorption power so that the oxygen purity will be lower as the lower pressure applied.

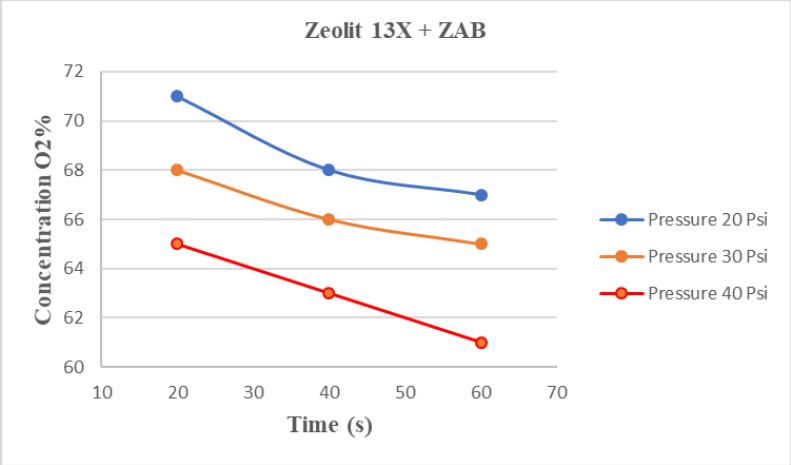

Figure 9. Graph of the effect of pressure on oxygen purity with 13X zeolite + ZAB

Figure 9 shows that oxygen purity produced using a combination of 13X zeolite and Bayah natural zeolite (ZAB) resulted in a different oxygen concentration comparet o the result by using 13X zeolite. The highest oxygen level was at the pressure of 20 Psi at 71%. In addition, the higher the adsorption pressure above 20 Psi, the lower the oxygen concentration would be because the adsorbent will be more saturated and affect the nitrogen adsorption power so that the oxygen purity will be lower as the lower pressure applied. Therefore, the optimal pressure used to produce high oxygen concentration by using a combination of 13X zeolite + Bayah natural zeolite was at the pressure of 20 Psi.

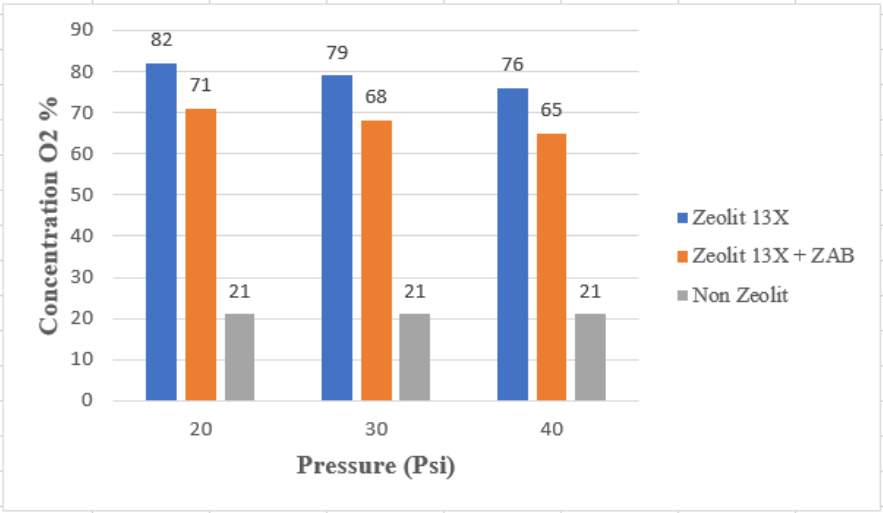

Figure 10. Comparison of the purity of 13X zeolite, 13X zeolite + ZAB and without zeolite

Figure 10 is a comparison graph of oxygen purity based on variations in zeolite as adsorbent medium and variations in adsorption pressure. From the graph in Figure 10 it shows that using zeolite as adsorbent medium, both 13X zeolite and 13X zeolite + Alam Bayah zeolite (ZAB), can significantly improve the quality of the air produced in Pressure Swing Adsorption (PSA), in which the best improvement was at the pressure of 20 Psi, which increased by 61% for 13X zeolite as adsorbent medium compared to the process without using zeolite as adsorbent medium and increased by 50% for 13X zeolite +ZAB as adsorbent medium compared to the process without using zeolite as adsorbent medium. Then at the pressure of 30 Psi, the use of 13X zeolite as adsorbent medium can improve air quality by 58% and by 47% for the use of 13X+ZAB zeolite as adsorbent medium compared to the process without using zeolite as adsorbent medium. While at a pressure of 40 Psi, the use of 13X zeolite as adsorbent medium can improve air quality by 55% and by 44% for the use of 13X zeolite +ZAB as adsorbent medium compare to the process without using zeolite as adsorbent medium.

The effect of pressure variations on the production of oxygen was that the oxygen concentration decreased more rapidly. The significance of the decrease in the level of oxygen gas produced was affected by the higher pressure. This higher pressure is inversely proportional to the level of oxygen produced. The greater the pressure applied, the lower the oxygen concentration would be, this was because the adsorbent would be more saturated. This pressure greatly affects the adsorption ability of the adsorbent that occurs in the pressure swing adsorption (PSA) column.

During the adsorption process, gas will enter the cavity of the 13X zeolite and 13X+ZAB zeolite, so that the longer the contact time the more compound deposited into the pores of the adsorbent until saturation occurs. The adsorbent cannot adsorb nitrogen and will release nitrogen due to the pores of the adsorbent was fully filled, so that when these conditions occur, the nitrogen that was not absorbed will be dispersed into oxygen. At high pressures the 13X zeolite will adsorb faster so that the adsorbent will saturate faster than the Pressure swing adsorption (PSA) operating at lower pressures. Therefore, by using adsorption at high pressure, the oxygen concentration will be decreased proportionally to the contact time.

The purity of oxygen produced using only 13X zeolite produced a higher oxygen purity than that of the mixture of 13X zeolite and Bayah natural zeolite (zeolite 13X+ZAB), this was because 13X zeolite is a zeolite that has a high ability to adsorb nitrogen. and the surface area of 13X zeolite is higher, the higher the surface area of the adsorbent, the greater the amount of adsorbate that can be absorbed so that the 13X zeolite will adsorb more nitrogen.

However, the use of a combination of adsorbents with 13X zeolite and Bayah natural zeolite (13X+ZAB zeolite) can also significantly improve the quality of oxygen produced in Pressure Swing Adsorption (PSA), in which the oxygen concentration is 70% at the pressure of 20 Psi, compared to the process without using zeolite as adsorbent medium, which was 20% oxygen at a pressure of 20 Psi. The value of increasing the quality of oxygen concentration on the use of adsorbents combination of 13X zeolite and Bayah natural zeolite (13X+ZAB) was not far from the process using 13X zeolite as adsorbent medium, which was 82% at the pressure of 20 Psi. The use of a pressure swing adsorption (PSA) has a problem, the release of liquid vapor that can inhibit the function of the PSA for a certain period of time, so that natural zeolite as adsorbent medium was needed that can absorb the liquid produced by the PSA, so that a combination of natural zeolite was needed in the use adsorbent media on PSA and Bayah natural zeolite is a type of zeolite that was easier to obtain in the Bayah area of Banten Province and also at a more affordable price than 13X synthetic zeolite as adsorbent medium.

The results showed that the use of 13X zeolite adsorbent media produced the best oxygen quality, this was in accordance with the results of previous studies conducted by Shokroo et al [9]and also Mofarahi et al [10], namely the nitrogen adsorption capacity of 13X zeolite was the best, more than other similar synthetic zeolites. In this study, using a combination of adsorbents with 13X zeolite and natural zeolite Bayah (13X+ZAB zeolite) can also significantly improve the quality of oxygen produced in the Pressure Swing Adsorption (PSA). The use of a pressure swing adsorption (PSA) has a problem, in which the release of liquid vapor that can inhibit the function of the PSA device for a certain period of time, so a natural zeolite adsorbent media is needed that can absorb the liquid produced by the PSA device, so a combination of natural zeolite is needed in the use adsorbent media on PSA and Bayah natural zeolite. is a type of zeolite that is easier to obtain in the Bayah area of Banten Province and also a more affordable price than if only using 13X synthetic zeolite as adsorbent.

4. CONCLUSION

The use of 13X zeolite and the combination 13X zeolite and Bayah natural zeolite (zeolite 13X+ZAB) as adsorbent medium could significantly improve the quality of oxygen in pressure swing adsorption (PSA) compared to the process without using zeolite adsorbent media. The use of 13X zeolite as adsorbent medium produces higher oxygen quality, this was because 13X zeolite is a zeolite which has a high ability to adsorb nitrogen and has higher surface area, the higher the adsorbent surface area, the more. the amount of adsorbate that can be adsorbed so that the 13X zeolite will adsorb more nitrogen. While the addition of natural zeolite Bayah into zeolite 13X (13X+ZAB zeolite) is to overcome the problem of the release of liquid vapor that can inhibit the function of the PSA for a certain period of time, so we need a natural zeolite as adsorbent medium that can adsorb the liquid produced by PSA. In addition natural zeolite Bayah is a type of zeolite that is easier to obtain in the Bayah area of Banten Province and also at a more affordable price.

The effect of pressure variations on the quality of the oxygen produced in the pressure swing adsorption (PSA) is that the greater the pressure applied, the lower oxygen concentration would be produced, this was because the adsorbent will be more saturated. This pressure greatly affects the adsorption power of

the adsorbent that occurs in the pressure swing adsorption (PSA) column.

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