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Design and Construction of Portable Oxygen Concentrator using Pressure Swing Adsorption Technology

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A B S T R A C T

Oxygen is used in various chemical processes and medical purposes around the world. During the COVID-19 pandemic, the need for medical oxygen has increased sharply in all hospitals in the world. In the current work, we designed an oxygen concentrator by using the Pressure Swing Adsorption (PSA) technology. Efficient operation of the PSA process is required to utilize the adsorbent capacity as much as possible and reduce the processing power requirements. The effect of feed gas temperature, cycle time, and pressure were investigated. The research is expected to provide suitable operating conditions to develop a better PSA process using zeolite Na-X.

A R T I C L E I N F O

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1. INTRODUCTION

Oxygen is one of the essential ingredients to support life on earth (Towe, 1988). Oxygen is abundantly available in gaseous form in our atmosphere at a concentration of about 21% (Kirschner *et al*., 2000). Today the need for oxygen in purer form has increased rapidly with the emergence of a variety of new manufacturing processes and the need for medical applications. The use of pure oxygen in the industrial world is found in industries that produce steel, chemicals, petrochemicals, glass, ceramics, paper, and the recovery of non-ferrous metals. The application of pure oxygen in medical applications, especially surgery, outpatient care, and Chronic Obstructive Pulmonary Disease (COPD) patients to help patients breathe (Branson, 2018). The use of zeolite as an adsorption medium can help increase energy use efficiency, increase process efficiency, increase processing rate, improve product quality, and reduce the environmental impact of the oxygen purification process.

This paper examines the effectiveness of the use of Natural Bayah zeolite and Na-X zeolite on the efficiency of the PSA process using an adsorption column design that has high efficiency by utilizing heat exchange from adsorption and desorption reactions. Detailed information for the apparatus is shown in our previous studies (Bahari *et al*., 2023).

2. METHODS

Detailed experimental apparatus is explained in our previous study (Bahari *et al*., 2023). This study is to evaluate several variations. Detailed information is explained in each chapter in the results and discussion section.

3. RESULTS AND DISCUSSION

3.1. Timing and Stages of Column Operations

The cycle of PSA is presented in **Figure 1**. The process was done into 6 steps. We used 2 columns.

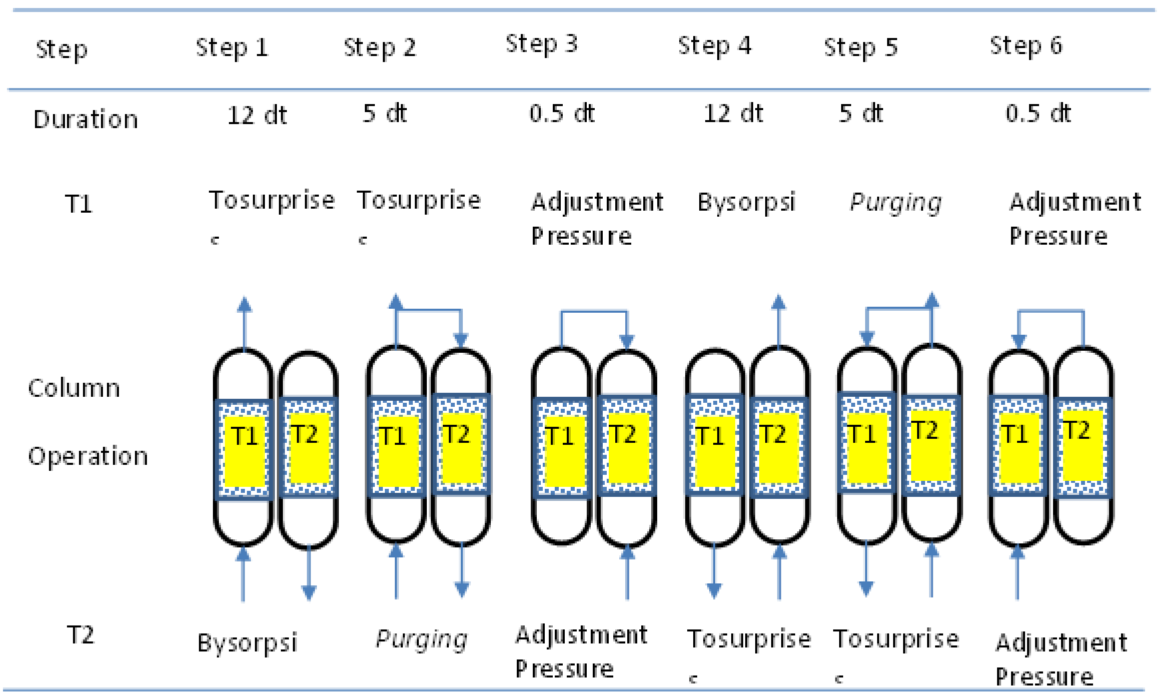

Figure 1. Timing and stages of column operations.

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3.2. Analysis of Oxygen

One of the tools available in the market to measure oxygen levels is the Oxygen Concentration Tester CY-12C Content Meter (Detector CY12C O Content 2. Portable). Variations of the experiment will be performed with several variables as shown in **Table 1**.

Table 1. Experiment variables.

No	Experiment variables	Unit	Parameter			
1	The flow rate of air in the column	L/min	40	50	60	
2	Column inlet air temperature	°C	Ambien	10	15	20
3	Column inlet air pressure	kg/cm^2.G	1	2	3	4
4	Direction of economic inflows		CoCurrent	Countercurrent		
5	Operating Time of column	Second	10	12	15	30
6	Column Regeneration Time	Second	5	8	10	12

3.3. The Results of Experiments Under Various Conditions

For the initial stage, the oxygen concentration gauge (oxygen analyzer) is calibrated by setting the oxygen hail display equivalent to 21.0%. Then, the oxygen analyzer tool is placed in the oxygen output of the product. Thus, an oxygen concentration is obtained. The value taken is the value with the highest concentration of oxygen in the measurement range. Detailed data is shown in **Figure 2**.

From **Figure 2**, the oxygen concentrator of the scattered unit can produce high concentrations of oxygen and in operating time the concentration will decrease due to the mixing of Nitrogen released from the pores of the zeolite. We divided into 3 zones:

(i) Oxygen Rich Zone is when Nitrogen gas is bound to the zeolite pore so that what will pass through the zeolite is oxygen gas and a little nitrogen gas

(ii) Zonek balances Oxygen gas and nitrogen gas where part of the nitrogen gas is not bound in the pore of the zeolite pore and is carried away to the oxygen gas.

(iii) The nitrogen release gas zone is where nitrogen gas can be bound again in the zeolite pore so that nitrogen gas will be carried entirely into the oxygen gas path.

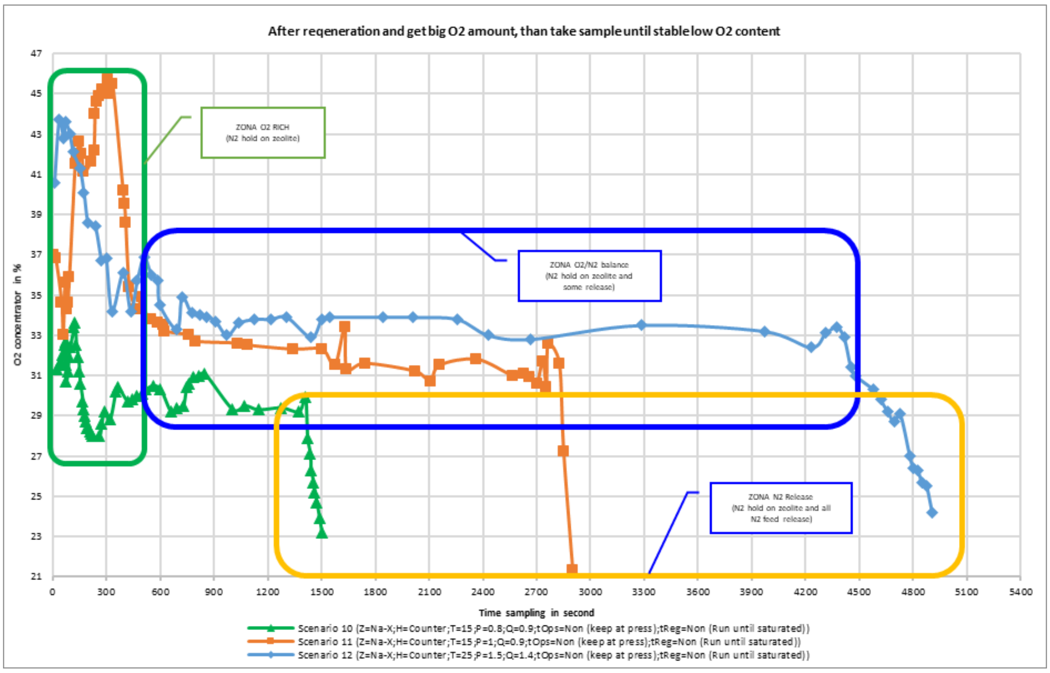

Figure 2. Oxygen condition concentration until saturated.

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3.4. Effect of Pressure Operation

In **Figure 3**, the operating conditions of a column with an entry pressure of about 1.5 kg/cm^2.G will produce oxygen concentrations ranging from 30 – 45% purity. This is because at this pressure more nitrogen gas is adsorbed into the pores of the zeolite. Thus, the air that is missing from the resin will be more oxygen gas as evidenced by the high concentration of oxygen. This is because the pores of zeolite hold more bound nitrogen gas. Thus, the output of gas in the form of oxygen gas concentration will increase. The same is true at lower pressures as indicated by **Figures 4** and **5**. The smaller the operating pressure, the lower the purity of the oxygen produced and accommodated into the storage tube. From simulations carried out with a theoretical approach and mathematical calculations, results were also obtained in accordance with the experiment directly in the designed concentrator (Bahari *et al.*, 2023).

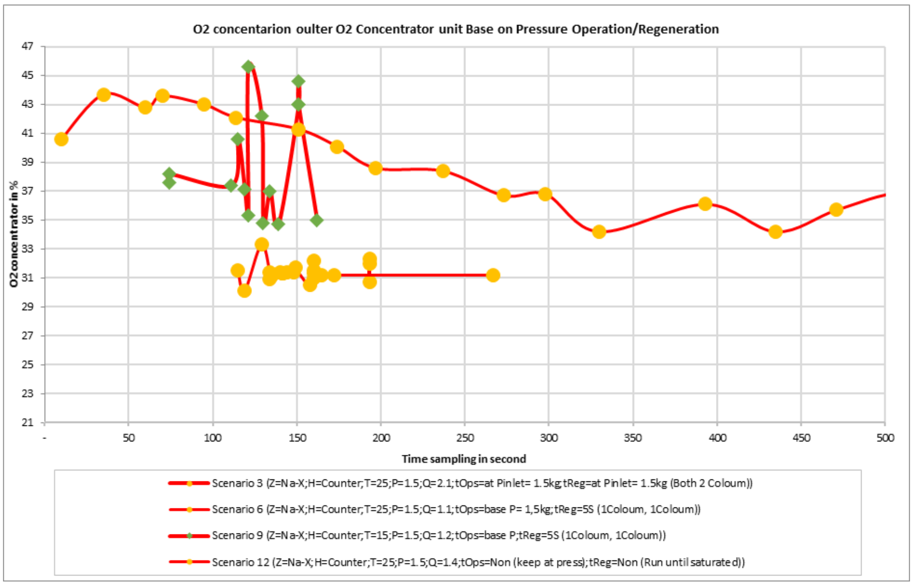

Figure 3. oxygen condition concentration at operating conditions of pressure column 1.5 kg/cm^2.G.

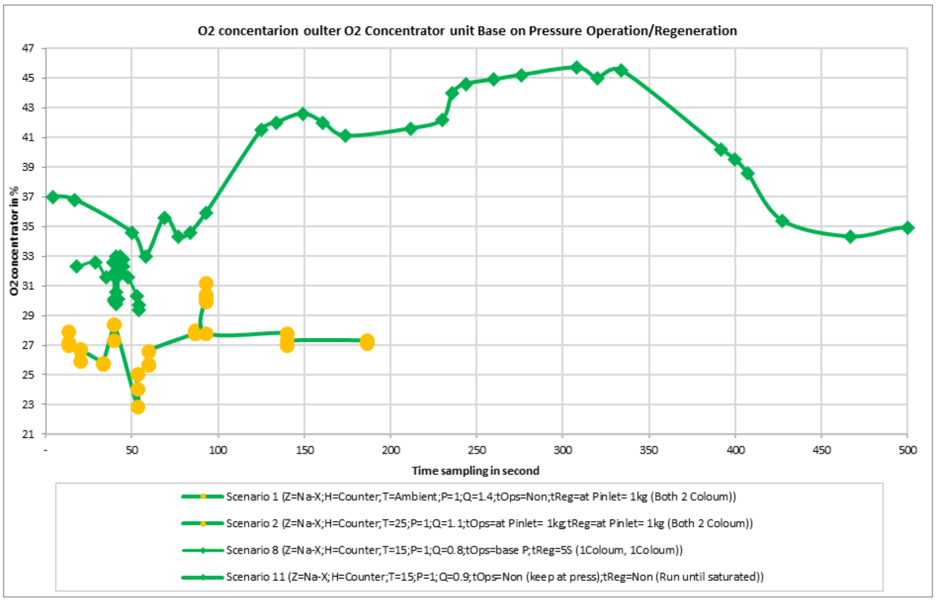

Figure 4. oxygen condition concentration at operating conditions of pressure column 1 kg/cm2.G.

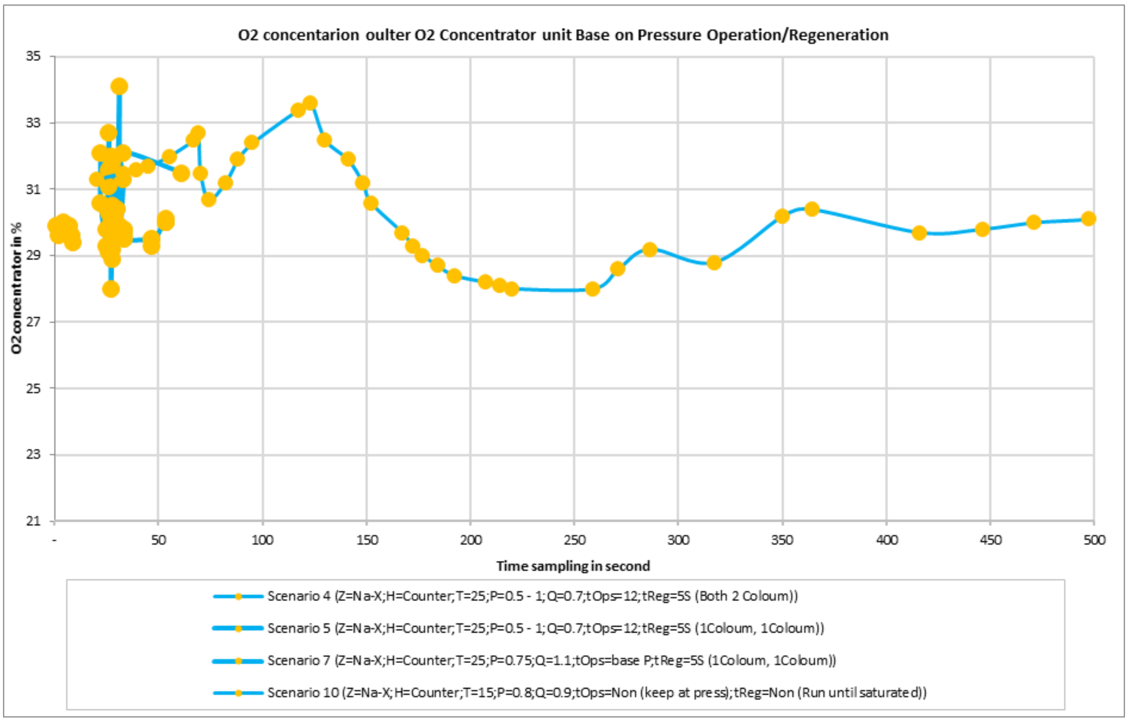

Figure 5. oxygen condition concentration at operating conditions column pressure 0.75 kg/cm^2.G.

Figure 6 shows the suitability of the results, although the precision operation is carried out below from the simulation. At this time the researcher does not run column operations above 1.5 kg because of the risk of leakage or the column will break.

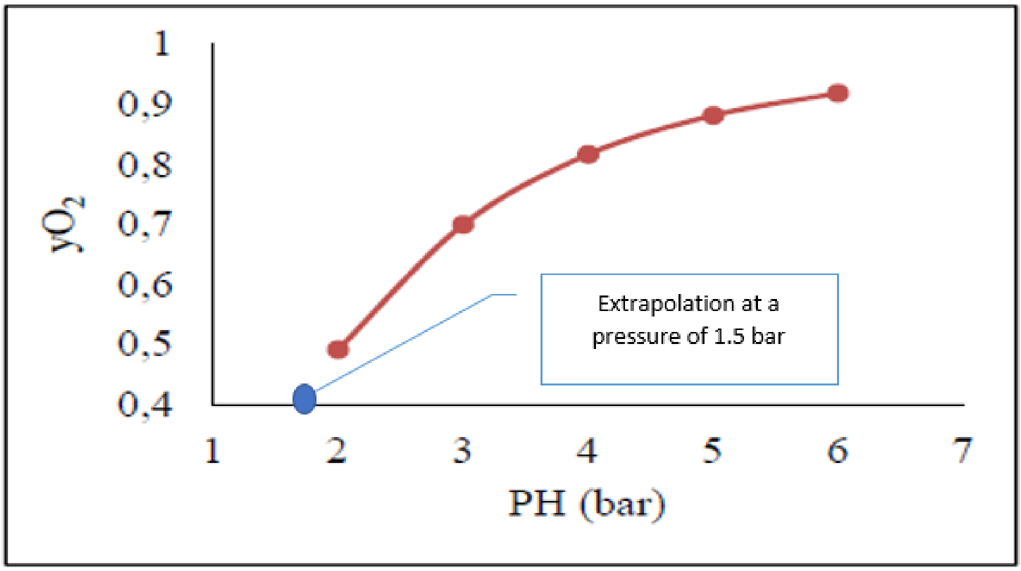

Figure 6. Oxygen condition concentrations from simulations at various pressures.

3.5. Effect Temperature

Figures 7 and **8** show the influence of the temperature of the air entering the column containing zeolite. At lower temperatures will get a higher concentration of oxygen. This can be indicated by air temperature data using cooling using ice or without using ice. In designing this oxygen concentrator, it has been designed. Thus, the reaction temperature that occurs during adsorption can be used to raise or lower the zeolite temperature. The efficiency of the

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adsorption process in zeolite media will be more optimal. In addition, the adsorption column design also uses HE (heat exchanger) from the outside of the column which also helps the cooling process and heating the incoming air. Thus, efficiency also increases.

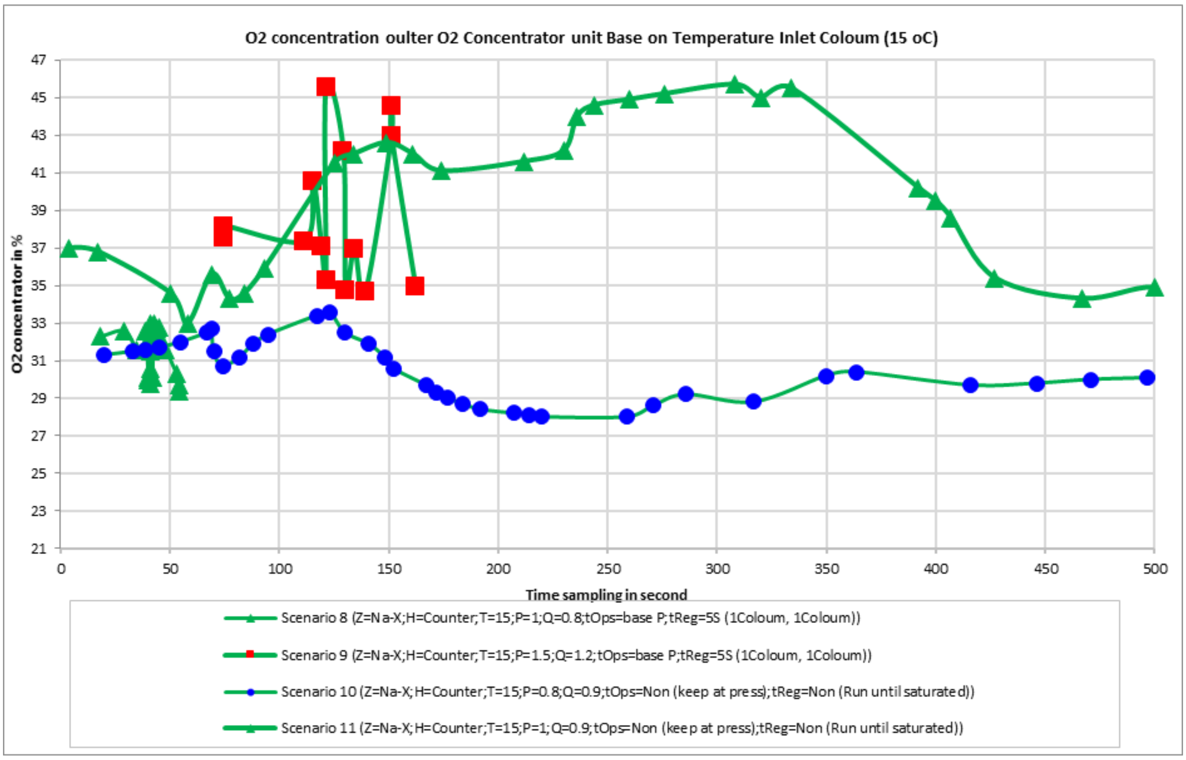

Figure 7. oxygen condition concentration at operating conditions of 15 °C temperature column.

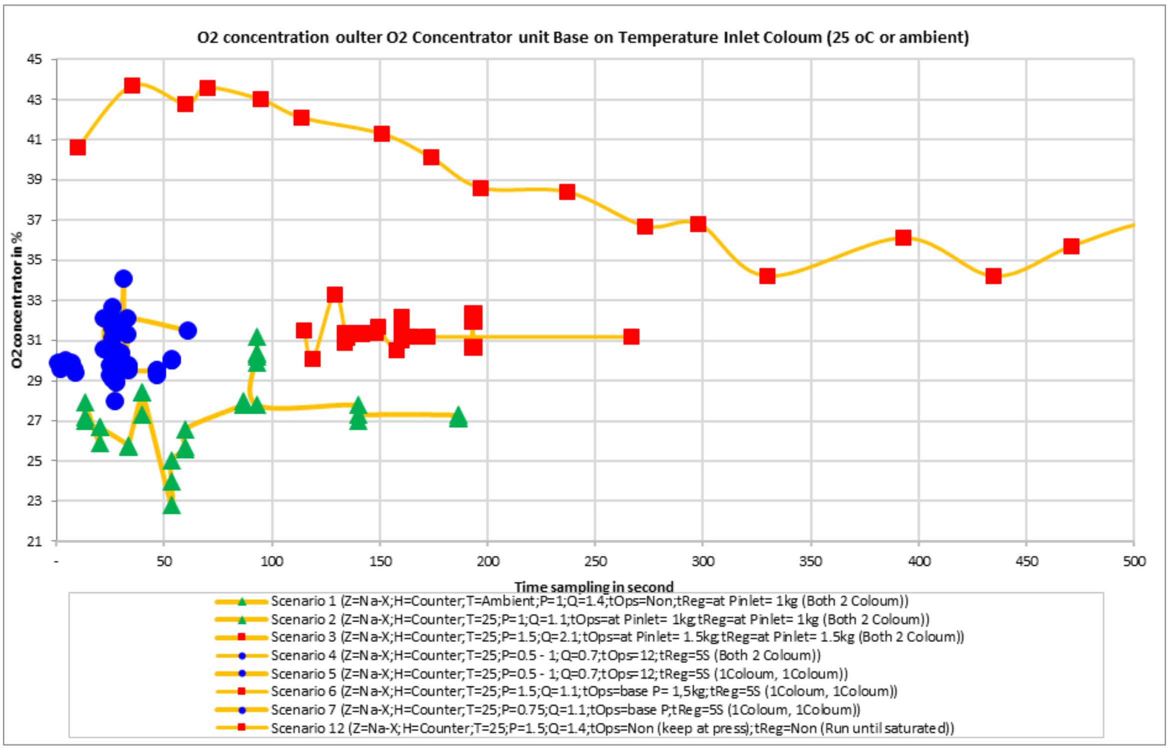

Figure 8. oxygen condition concentration at operating conditions of 25 °C/ambient temperature column.

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3.6. Regeneration Scenario

Another experiment was carried out by varying the way the column was regenerated. Regeneration column operations are performed one by one from the two columns by alternating or simultaneously between the two columns. This variation can be identified in **Figures 9** and **10**. From the curves, the regeneration method with one column then continued with the other column to produce a higher concentration of oxygen.

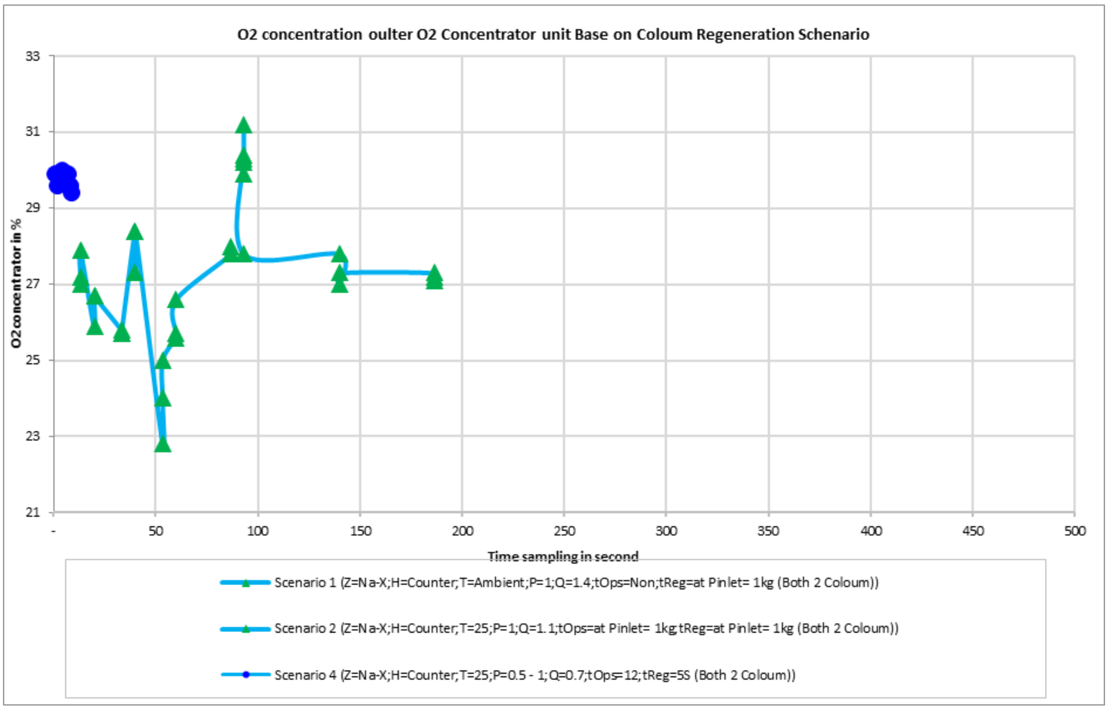

Figure 9. oxygen condition concentrates on the operation condition of the concurrent rewrite column of two columns

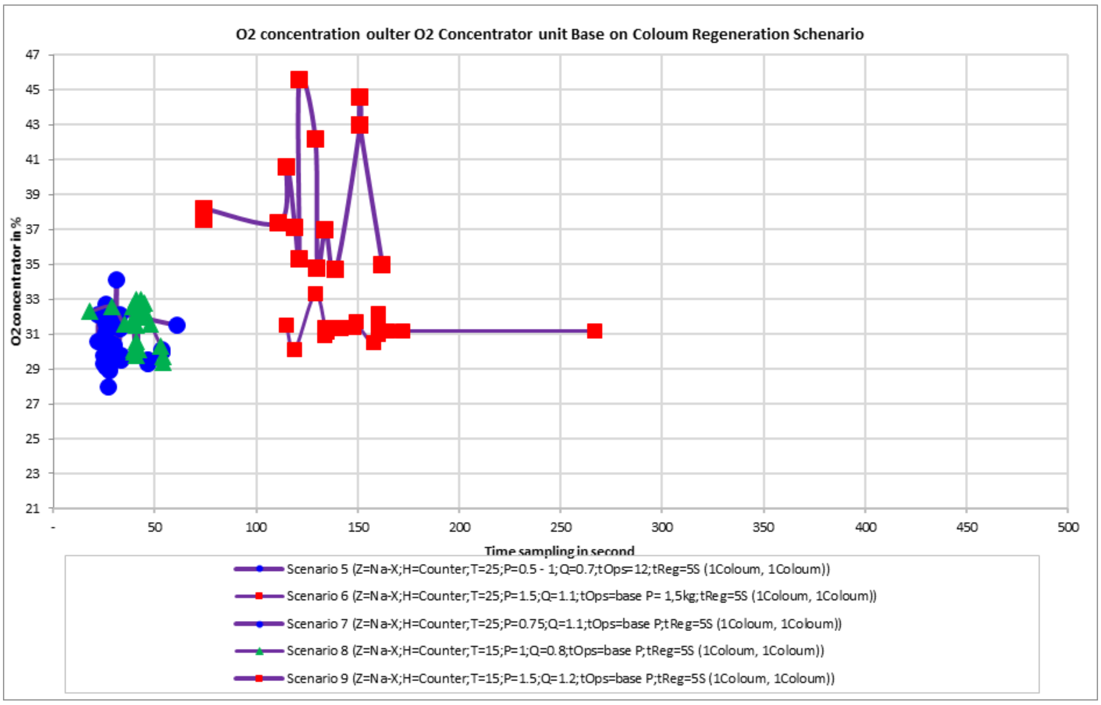

Figure 10. The oxygen condition concentrates on the operating conditions of one column regenerating one column followed by another column.

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3.7. Range Pressure Effect

From **Figure 11**, the greater the column operation pressure, the oxygen content that comes out of the oxygen concentrator will increase, this is because the efficiency of zeolite in nitrogen gas binding is greater. At the time of regeneration, the amount of nitrogen gas wasted by pressure swing will also increase so that the concentration of oxygen gas after regeneration will increase sharply.

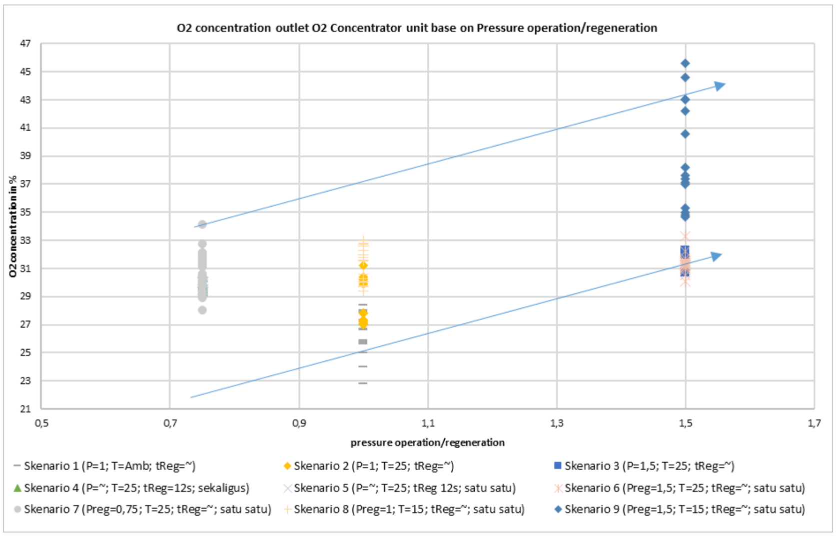

Figure 11. Oxygen condition concentration at various pressure range conditions.

4. CONCLUSION

Our design can produce oxygen concentration with concentration until 40% as oxygen concentration. This equipment must test another variable for a complete image of the oxygen concentration operation parameter and get a good target result until 93% oxygen concentration.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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