Evaluation of Jordanian Natural Zeolite for Air Separation into Oxygen and Nitrogen

Asem Mohammad AL Jarrah

Tafila Technical University, 66110 Tafila, Jordan, PO BOX 179.
asem[at]ttu.edu.jo

Abstract: ***A fixed bed adsorption apparatus was used to evaluate Jordanian natural zeolite for air separation into oxygen and nitrogen. The adsorption was tested at different pressures and sizes of zeolite. The results show that at a pressure of 7.9 atm Jordanian natural zeolite is comparable to commercial Zeolite 5A. Around 7.9 atm, the saturation capacity of zeolite was found to be 0.25g N2/g zeolite.***

Keywords: Jordanian natural zeolite, Air Separation, Adsorption, Pressure Swing Adsorption

1. Introduction

Air separation into oxygen and nitrogen is an important field in industry. Oxygen is needed in hospitals, metal welding and cutting (oxyacetylene), steel making and a lot of other applications. Three main methods are existed for air separation [Shreve's, 1984]: Cryogenic air distillation, Adsorption/ Pressure swing adsorption, and membrane separation. Cryogenic distillation is used when large amount and high purity of oxygen is needed such as in steel making. Pressure swing adsorption technique is used for low to moderate scale oxygen production as in the units used for producing oxygen cylinder for hospitals or gas welding/cutting. Membrane separation is very expensive and not yet fully developed and commercialized.

Air separation by pressure swing adsorption is widely spread and improved in the last years [Ibrahim 2015]. A commercial compact unit of pressure swing adsorption are available in the markets with accepted cost. Zeolite, activated carbon, or silica gel are the most used packing materials for adsorption in these units. Zeolite is the predominant using material among the three materials because its saturation capacity is high [Santos et.al. 2007]. As predicted from the work done by [Sebastian et.al., 1997] the saturation adsorption capacity of pure zeolite mineral is 0.2g N2/g zeolite at around 5 atm.

Jordan contains large amount of natural zeolite in different locations as shown in Figure 1 and it has been used for several applications [1].The objective of this work was to evaluate Jordanian natural zeolite located in Jabal Aritayn for air separation into oxygen and nitrogen using fixed bed adsorption technique.

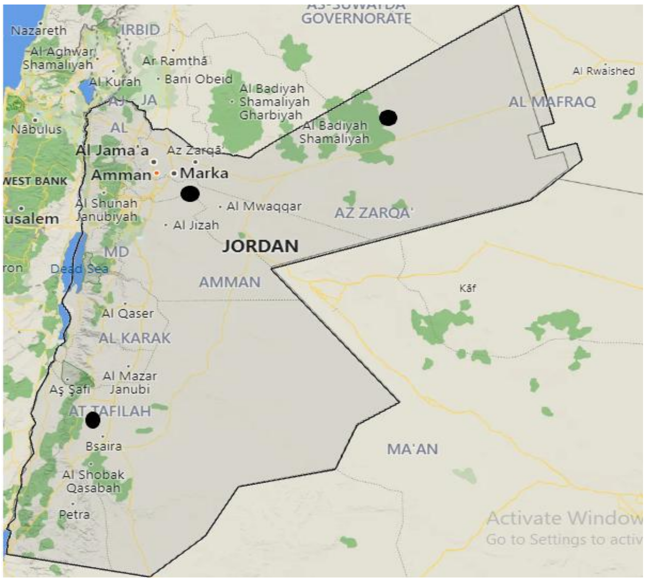

Figure 1: Potential Location of Jordanian Zeolite. [AL Dwairi- et, al. 2007]

2. Experiment

Several samples of naturally occurring zeolite were collected from Jabal Aritayn located in Mafraq area 32° 04' 44 Longitude (N) 36° 51' 23 (E). The samples were well mixed in a solid mixer to make a homogenous mixture then crushed by jaw crusher followed by milling on a ball mill. The average chemical composition of the zeolite is shown in Table 1.

Table 1: Composition of natural zeolite taken fromJabal Aritayn [AL Dwairi- et, al. 2014].

Constituent	SiO_2	Na_2O	Fe_2O_3	MgO	Al_2O_3	K_2O	CaO	MnO	TiO_2	P_2O_3	LOI
Composition wt. %	42.20	3.13	13.37	9.40	12.64	1.49	9.35	0.18	2.32	0.62	3.39

The experimental setup used for this work are shown in Figure 2.Fresh air is compressed into storage tank and then filtered to remove any moisture and impurities from the air. The air is then compressed to the required pressure by a second compressor (compressor2) before it enters the adsorption bed. The flow rate of air is controlled by valve V3. The concentration of O2 at the exit is measured by oxygen meter (Type: Lutron DO-5510HA). The operating pressure of the fixed bed can be achieved by closing valve V3 until the pressure build up to the required pressure and then the valve is opened to pass the required flow rate. The pressure is measured by pressure gauge mounted at the exit of the bed and the flow rate is measured by a rotameter.

Licensed Under Creative Commons Attribution CC BY

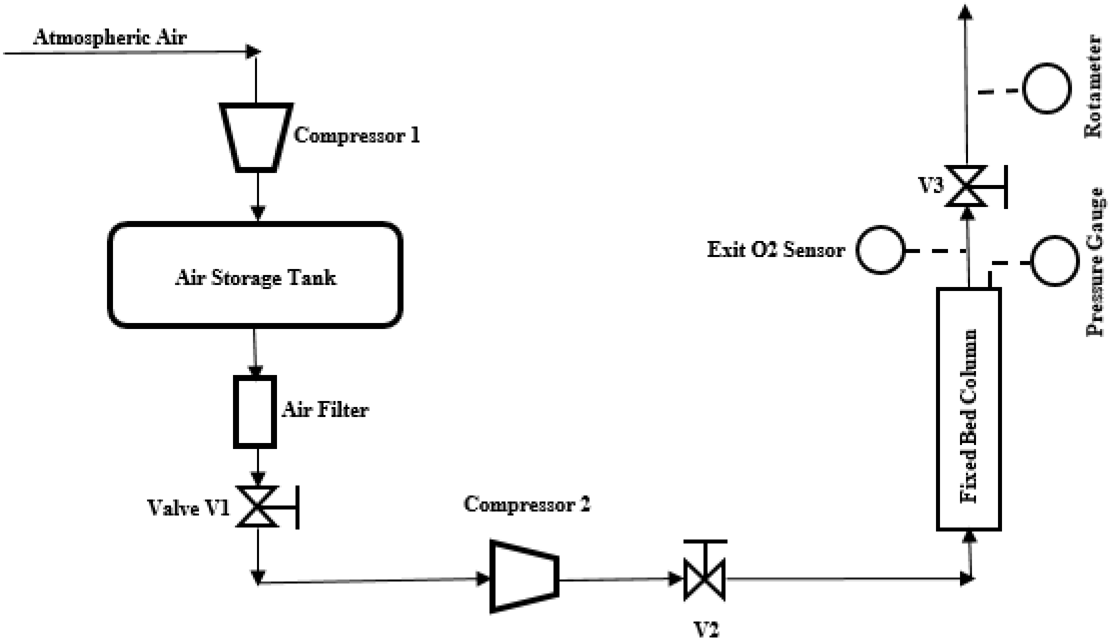

Figure 2: Experimental Setup

3. Results and Discussion

The obtained results are shown in Figures3-5 using Jabal Aritaynnatural zeolite for air separation into oxygen and nitrogen where nitrogen is absorbed into zeolite in the fixed bed. Pressures from 1-10 atm and zeolite sizes of 14/20, 35/48 and 200/pan were used.

The exit concentration of O2 versus time at zeolite size of 35/48 for different pressures are shown in Figure 3. It can be seen from this figure that for pressures approximately up to 7.9 atm no adsorption occurs and the adsorption of N2 starts to at a pressure around 7.9 atm. As the pressure increased the adsorption is increased up to 10 atm and further increasing in pressure results in low increase in adsorption. Therefore, pressure about 9atmis the most appropriate pressure for adsorption using Jabal Aritayn natural zeolite for air separation.

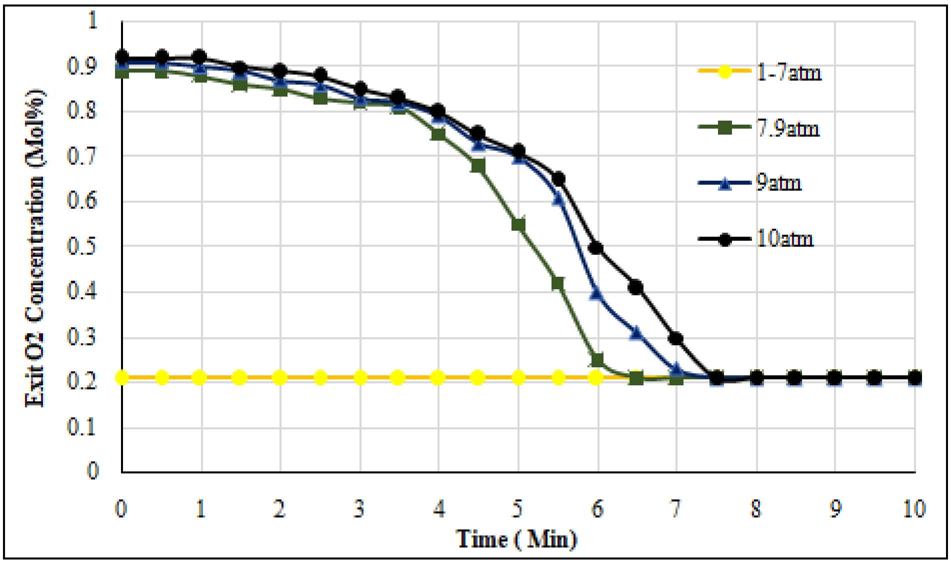

Figure 3: Exit concentration of oxygen as a function of time at deferent pressures for size of 35/48.

The effect of zeolite particles sizes are shown in figure 4.This figure shows that as the particles size decreases the adsorption is increases. This is because as the particles size decreased, the surface area increased, and therefore, more sites for adsorption are created.

Licensed Under Creative Commons Attribution CC BY

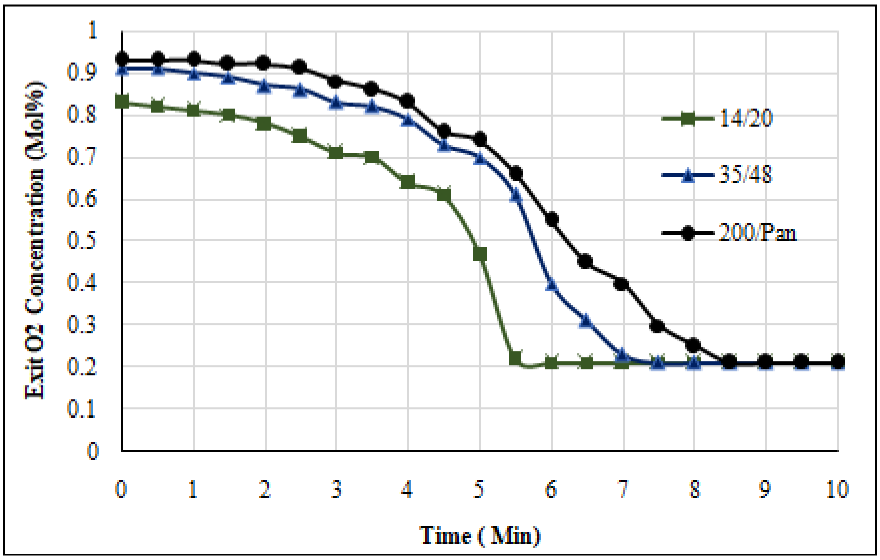

Figure 4: Exit concentration as a function oftime for different zeolite sizes atpressure of 5atm.

Figure 5 shows the adsorption capacity of Jabal Aritayn natural zeolite versus pressure. The total amount of N2 gas adsorbed is [Warren et.al. 1993].

$$W_{sat} = \frac{QM}{w} \int_0^{t_e} (C_e - C_i)dt \quad (1)$$

Where, W_{sat} is the amount of zeolite adsorped, Q is the flow rate, C_i is the concentration of O2 at the inlet on molar basis, M is the molecular weight of oxygen, and w is the amount of zeolite. The integration in equation 1 is the area above the curve of concentration ofO2 versus time. The results obtained in Figure 5indicate that no adsorption occurs below 7.9atm. The adsorption starts to occur at about7.9atm and increased more with pressure up to 10atm. For pressures greater than 10atm, $W_{sat}$is very weakly increase with pressure.

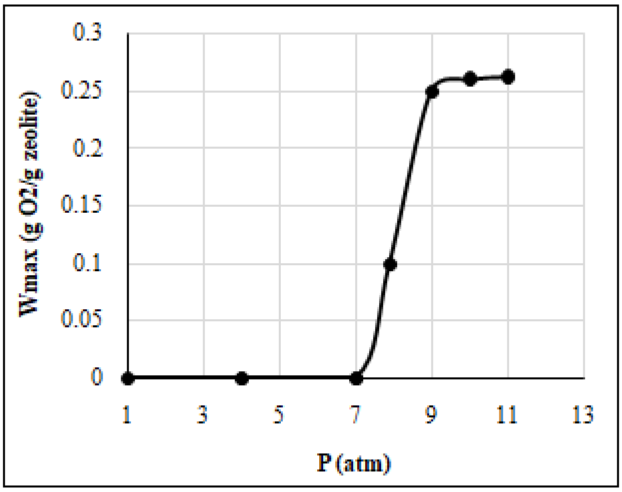

Figure 5: Adsorption capacity of nitrogen versus pressure at mesh size of 35/48 for Jabal Aritayn zeolite.

4. Conclusion

The results of this work shows that Jordanian natural zeolites are equivalent to commercial zeolite grade 5A for air separation into oxygen and nitrogen. For pressure less than 7.9atm, no separation occurs, and the adsorption starts at about 7.9atm.For a pressure around 9 atm which is the suggested operating pressure for Jabal Aritayn zeolite, the adsorption capacity is around 0.26 g N2/ g zeolite compared to zeolite grade 5A of 0.2 g N2/ g zeolite at a pressure of 5atm.

References

[1] AL Dwairi R. A., 2007. Characterization of the Jordanian zeolitic tuff and its potential use in Khirbet Es-Samra wastewater treatment plant. Ph.D. Thesis, University of Jordan, Amman, Jordan.

[2] Al Dwairi, R. A., Ibrahim, K. M. and Khoury H. N. (2014): Potential use of faujasite-phillipsite and phillipsite-chabazite tuff in purification of treated effluent from domestic wastewater treatment plants, Environmental Earth Sciences, 71:5071-5078.

[3] Barry C., John T.F.1998. Adsorption Technology and Design. First Edition, 1998.

[4] Dwairi, I. M., 1987, A chemical study of the palagonitic tuffs of the Aritain area of Jordan, with special reference to nature, origin, and industrial potential of the associated zeolite deposits. PhD thesis, Hull Univ., UK.

[5] Gregg S. J., Kenneth S.W., 1982, Adsorption, Surface Area, & Porosity, Academic Press; 2nd edition.

[6] Ibrahim H., 2015,Oxygen Separation from Air Using Zeolite Type 5A, International Journal of Scientific & Engineering Research, Volume 6, Issue 5, ISSN 2229-5518.

[7] Ibrahim, K., 1996, Geology, mineralogy, chemistry, origin, and uses of the zeolites associated with Quaternary tuffs of Northeast Jordan. PhD thesis, University of London, UK.

[8] Rege S.U., Yang R.T., 1997, Limits for Air Separation by Adsorption with LiX Zeolite, Ind. Eng. Chem. Res., 36, 5358- 5365.

[9] Reyad A.D., Hany K., Khalil I., 2010, Occurrence and Properties of Jordanian Zeolites and Zeolitic Tuff: Jordanian Zeolitic Tuff.

[10] Richard I. M., 1996, Principles of Adsorption and Reaction on Solid Surfaces, 1st Edition.

[11] Ronald A. M., 2018, Properties of natural zeolites.

Licensed Under Creative Commons Attribution CC BY

[12] Santos J.C., Cruz P., Regala T., Magalhaes F.D., and Mendes A., 2007, High- Purity Oxygen Production by Pressure Swing Adsorption, IndEngchem 46, pp 591-599, (2007).
[13] Sebastian D., Hiroki M., Hiroyuki S., Jiro K.,1997,Adsorption Capacity Prediction on Zeolite 5A, Research Gate Publications.
[14] Austin G.T., 1984, Shreve's Chemical Process Industries Handbook, 5th Edition. McGraw Hill.
[15] Sircar S., 1988, Air Fractionation by Adsorption, Separation Science &Technology, 23(14 & 15).
[16] Warren L.M., Julian C. S., Peter H., 1993, Unit Operations of Chemical Engineering, Fith Edition, McGraw-Hill Publications.
[17] Wong T.W., 2009, Handbook of Zeolites: Structure, Properties and Applications.

Licensed Under Creative Commons Attribution CC BY