Analysis of the Effect of Grain Size on the Characteristics of Zeolite as Adsorbents

Susilawati[1,2], M. N. Nasrusddin[1], Y. A. Sihombing[1,2], Bonar Ferdiansyah[1] and Sri Ningsih Y. Pakpahan[1]

[1]*Physics Department, Faculty of Mathematic and Natural Science, UniversitasSumatera Utara, Medan, Indonesia*
[2]*Pusat Unggulan Inovasi Green Chitosan dan Material Maju Universitas Sumatera Utara*

Keywords: Pahae Natural Zeolite, Adsorbents, Grain Size.

Abstract: Zeolite is a material that has been widely used for various applications, and its availability in natureis also abundant. Applications of zeolite materials are widely studied including adsorbents. The performance of zeolites as adsorbents is influenced by the particle size. The purpose of this study was to determine the grain size towards the zeolite characteristics as an adsorbent. Samples were taken from Pahae, North Tapanuli Regency. Zeolites were sieved with 200 mesh, 325 mesh, and 400 mesh sizes. Then, the physical properties of samples were characterized such as density, water adsorption, and Particle Size Analyzer (PSA) test. The test results showed that the finer the grain size274.6 nm, the porosity81.90%, and water adsorption98.29% increased. However, after the fineness of the grain reached 400 mesh, the porosity and water adsorption values decreased.

1 INTRODUCTION

Zeolite is a hydrated porous alumina silicate crystal mineral that has a three-dimensional skeletal structure formed from tetrahedral [SiO4]4- and [AlO4]5-. The two tetrahedral are connected by oxygen atoms producing an open and hollow three-dimensional structure in which metal atoms are filled with usually alkali or alkaline earth metals and freely moving water molecules (Breck, 1974; Cheetham, 1992; Scott et al., 2003).

Zeolite is a material that has been widely used in various applications and its availability in nature is also abundant. Applicationsof zeolite materials that are widely studied include adsorbents, ion exchanger, and catalysts. Zeolite is most used as an adsorbent because it has a three-dimensional skeletal structure with a cavity in it and a large surface area.

Wahono et al. (2014), made zeolite-based adsorbents using natural zeolite in Gunungkidul with a size of 100 mesh for bioethanol purification (Wahono et al., 2014). Natural zeolites were activated by Chemistry (HCl) and Physics (Calcination 400°C) and compared with non-activated natural zeolites and synthetic zeolites. The results showed that natural zeolite activation had the ability to purify bioethanol the same as synthetic zeolite, but the results were lower. Mudjijono et al. (2015), modified the natural zeolite of Gunungkidul as a bioethanol dehydration agent with a size of 100 mesh. Modifications were conducted with variations, namely non-activation, chemical activation, chemical activationand calcination, chemical activation zeolite and treatment with ammonium nitrite, chemical activation and treatment with ammonium nitrite and calcination. The results showed that the best result of bioethanol dehydration agent was zeolite with chemical activation (Mudjijono et al., 2015). Nasution et al. (2015), made zeolite-based water vapor filters by varying the size of zeolites (60 mesh and 200 mesh) and the types of zeolite (natural zeolites of Pahae and natural zeolites of Cikalong). The results showed that the natural zeolite filter of Pahae with a size of 200 mesh had optimum water vapor adsorption and was suitable as an adsorbent (Nasution et al., 2015). In this study, the size variations of zeolite were made with 3 variations namely 200 mesh, 325 mesh, and 400 mesh, which aimed to determine the effect of grain size variations on the characteristics of zeolites as adsorbents.

Susilawati, ., Nasruddin, M., Sihombing, Y., Ferdiansyah, B. and Pakpahan, S.
Analysis of the Effect of Grain Size on the Characteristics of Zeolite as Adsorbents.
DOI: 10.5220/0010163300002775
In *Proceedings of the 1st International MIPAnet Conference on Science and Mathematics (IMC-SciMath 2019)*, pages 308-313
ISBN: 978-989-758-556-2

2 RESEARCH AND METHODS

Zeolite samples were taken from Pahae Julu District, North Tapanuli. Zeolite in the form of chunks was crushed and sieved with a size of 200 mesh, 325 mesh, and 400 mesh. Characterization of zeolite samples includes physical properties (porosity and water adsorption) and grain size analysis using Particle Size Analyzer (PSA).

2.1 Porosity

Porosity is defined as the ratio between the amount of pore volume (volume of empty space) in solids and the total volume of solids. The porosity was calculated from the pore volume divided by the total volume. The equation of porosity is:

$$\%porosity = \left(\frac{m_b - m_k}{\rho_{water} \times V_t}\right) \times 100\% \qquad (1)$$

When; m_b= wet mass (Kg) and m_k= dry mass (Kg).

2.2 Water Adsorption

Water adsorption in each sample can be done by weighing the dry mass and wet mass of the sample. Dry mass is the mass when the sample is dry, while the wet mass is obtained after the sample has been immersed for 24 hours at room temperature. The equation of water adsorption is:

$$\%water\ adsorption = \left(\frac{m_b - m_k}{m_k}\right) \times 100\% \qquad (2)$$

When m_b= wet mass (Kg) and m_k = dry mass (Kg).

Characterization of grain size analysis used the Particle Size Analyzer (PSA). PSA measurement is based on the principle of the dynamic light scattering (DLC) method which is the best technique for particle size measurement (Galuh & Rahmi, 2014; Prasmita, 2012). The method of particle counting contained in the PSA tool consisted of three methods, namely the pade-laplace method, statistical method and cumulants method (Muchtar et al., 2015).

3 RESULT AND DISCUSSION

3.1 Porosity

Porosity of zeolite with size variations of 200 mesh, 325 mesh, and 400 mesh is shown in Figure 1.

Figure 1 shows that zeolite size variations affect the porosity value. The minimum porosity was found at a size of 200 mesh with a porosity value of 49.58%, while the maximum porosity was found at 325 mesh with a porosity value of 81.90%. Zeolite is a material mostly composed of oxygen, silica, carbon, and aluminium, where oxygen is the largest constituent element. Thus, zeolites have cavities or pores that can adsorb water. In addition, the grain size also affects the porosity value. The finer thegrain size of a zeolite, the greater the porosity value. However, in 400-mesh zeolite, the porosity value decreased which means that the ability of zeolite to be used as an adsorbent became lower. According to SNI 13-7168-2006, the porosity value will increase if the size of the zeolite becomes smoother. However, if thegrain size is too, it will result in a limited cavity structure so that porosity becomes reduced (SNI 13-7168-2006, 2006). Therefore, 325-mesh zeolite had a more optimum porosity value than 400-meshzeolite.

3.2 Water Adsorption

The water adsorption of zeolite with size variations of 200 mesh, 325 mesh, and 400 mesh is shown in Figure 2.

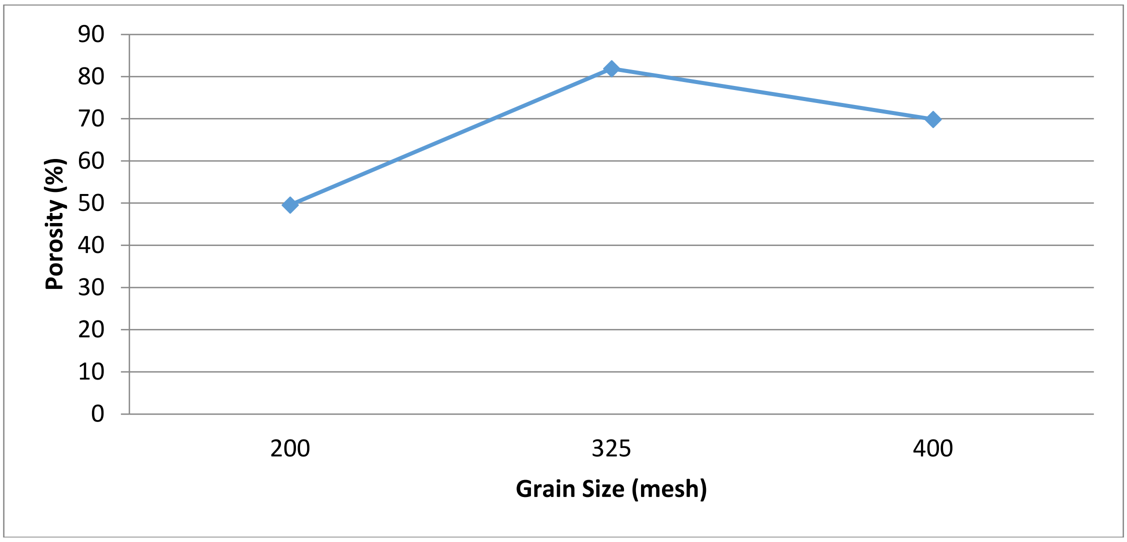


Figure 1: The relationship between porosity and variations in the grain size of zeolite.

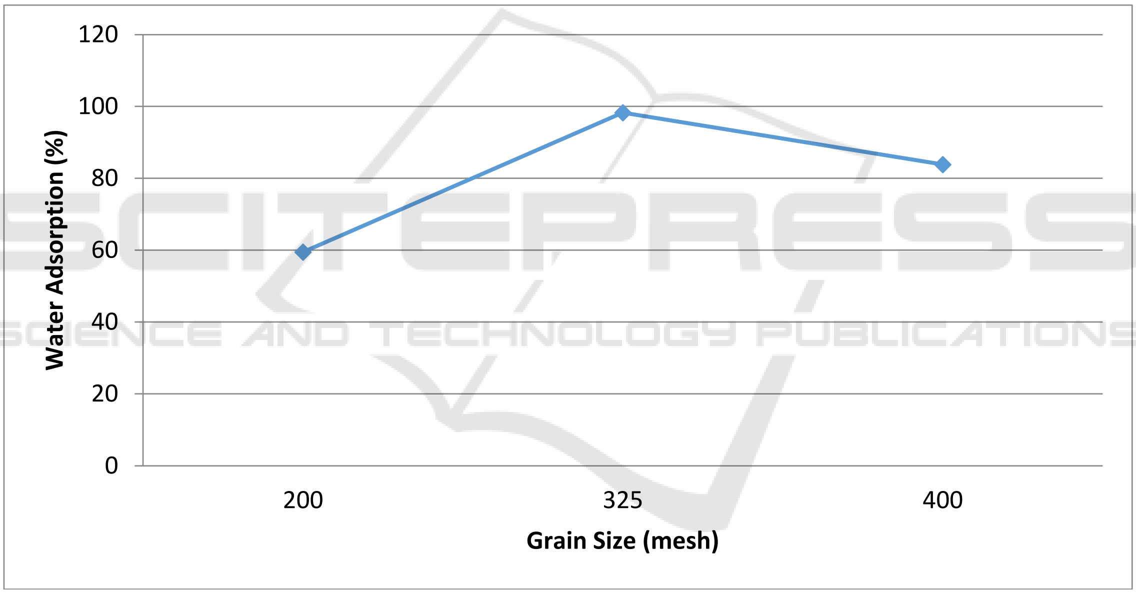


Figure 2: The relationship between water adsorption and variations in the grain size of zeolite.

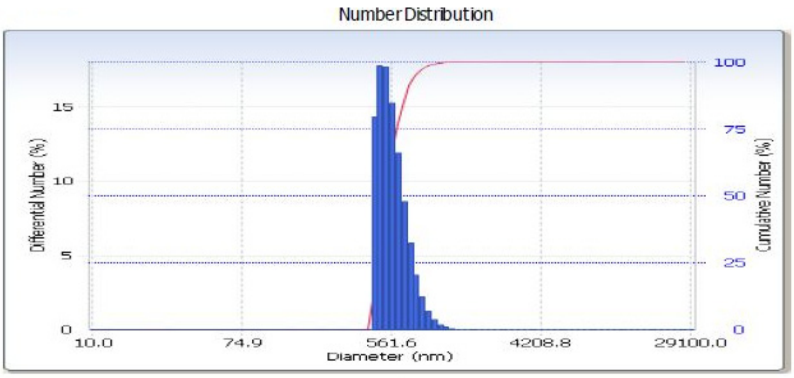
Figure 2 shows that the size variations of zeolite affect the water adsorption value. Based on the test results, the minimum water adsorption was 59.50% in 200-mesh size, while the maximum water adsorption was 98.29% in 325-mesh size. The water adsorption value was directly proportional to the porosity value, where the greater the pore or cavity of zeolite, the higher the value of water adsorption. However, the 400-mesh zeolite had a smaller water adsorption value compared to the 325-mesh zeolite because the particle size is one of the factors that can affect the capacity and rate of water adsorption of zeolite to certain adsorbates. The particle size of zeolite will affect the selectivity of zeolites to which molecules will enter the zeolite cavity and which will be rejected. The finer the particle size, the more selective the adsorption process will be.

3.3 Particle Size Analyzer (PSA)

The PSA characterization to determine the grain size of zeolites with 200 mesh, 325 mesh, and 400 mesh size variations is shown in Figure 3.

Figure 3 is the PSA test results showing the diameter of zeolite. The 200-mesh zeolite had an average diameter of 569.9 nm, the 325-mesh zeolite had an average diameter of 274.6 nm, and the 400-mesh zeolite had an average diameter of 381.8 nm. The relationship between diameter and variations in the grain size of zeolite resulted from the PSA test can be seen in Figure 4.

Figure 4 shows the finer the size of the zeolite, the smaller the diameter of zeolite. However, the 400-mesh zeolite had a larger diameter than 325 mesh. The smaller the diameter of the zeolite, the separation process using the nature of zeolite will be more selective (Wulandari & Priyono, 2014). This is in accordance with the optimum porosity and water adsorption value in the 325-mesh zeolite.



Distribution Results (Contin)

Peak	Diameter (nm)	Std. Dev.
1	569.9	119.8
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
Average	569.9	119.8
Residual :	2.020e-002	(O.K)

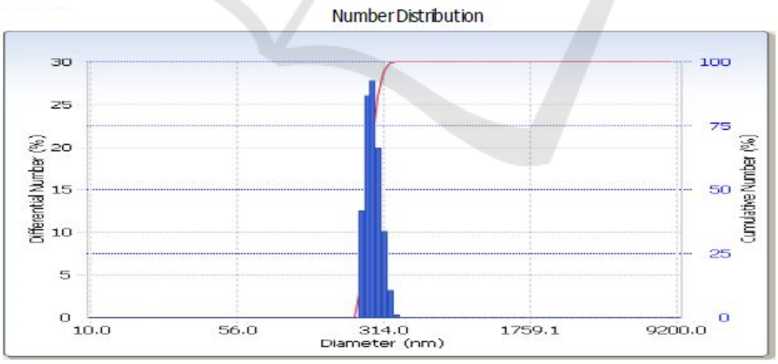
Cumulants Results

Diameter	(d)	: 1183.8	(nm)
Polydispersity Index	(P.I.)	: 0.465	
Diffusion Const.	(D)	: 3.689e-009	(cm²/sec)

Measurement Condition

Temperature	: 25.0	(°C)
Diluent Name	: WATER	
Refractive Index	: 1.3300	
Viscosity	: 1.0000	(cP)
Scattering Intensity	: 11621	(cps)

a. 200 mesh.



Distribution Results (Contin)

Peak	Diameter (nm)	Std. Dev.
1	274.6	25.2
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
Average	274.6	25.2
Residual :	4.198e-002	(O.K)

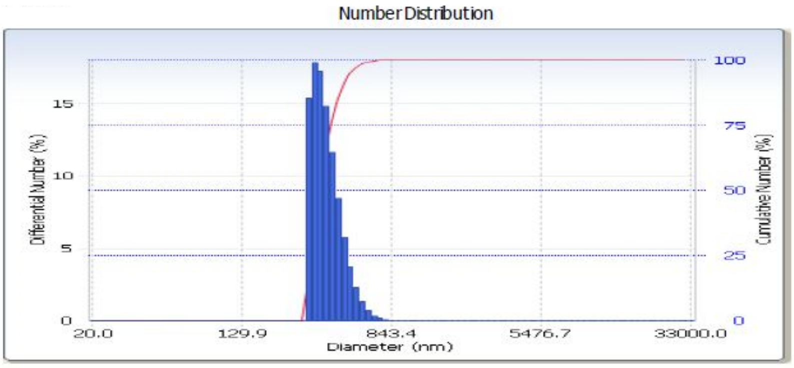
Cumulants Results

Diameter	(d)	: 527.1	(nm)
Polydispersity Index	(P.I.)	: 0.232	
Diffusion Const.	(D)	: 9.360e-009	(cm²/sec)

Measurement Condition

Temperature	: 25.0	(°C)
Diluent Name	: WATER	
Refractive Index	: 1.3328	
Viscosity	: 0.8852	(cP)
Scattering Intensity	: 15148	(cps)

b.325 mesh.



Distribution Results (Contin)

Peak	Diameter (nm)	Std. Dev.
1	374.4	73.6
2	17.313.1	2.889.5
3	0.0	0.0
4	0.0	0.0
5	0.0	0.0
Average	381.8	366.8
Residual :	2.583e-002	(O.K)

Cumulants Results

Diameter	(d)	: 1300.3	(nm)
Polydispersity Index	(P.I.)	: 0.495	
Diffusion Const.	(D)	: 3.783e-009	(cm²/sec)

Measurement Condition

Temperature	: 25.0	(°C)
Diluent Name	: WATER	
Refractive Index	: 1.3328	
Viscosity	: 0.8878	(cP)
Scattering Intensity	: 10777	(cps)

c.400 mesh.

Figure 3: PSA test results for zeolite in a size of(a) 200 mesh (b) 325 mesh, and (c) 400 mesh.

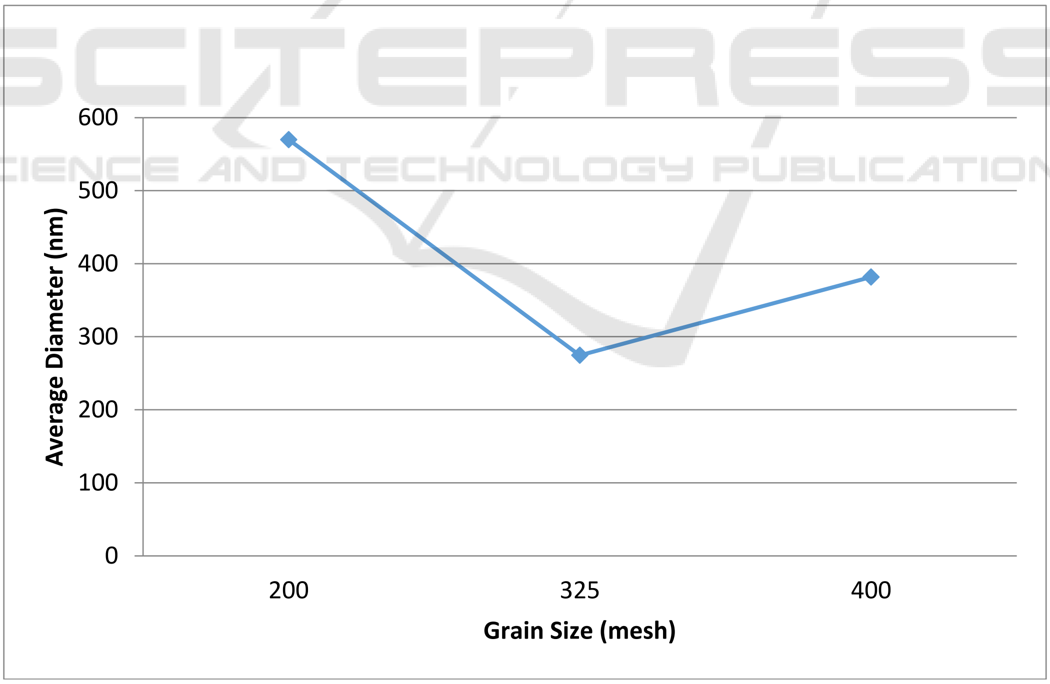


Figure 4: The relationship between diameter of zeolite and variations in the grain size.

4 CONCLUSIONS

The study results prove that the grain influences the characteristics of zeolite as an adsorbent. The 325-mesh zeolite had optimum porosity and water adsorption values compared to the 200-mesh zeolite and 400-mesh zeolite. These results are consistent with the Particle Size Analyzer (PSA) test results which showed that the 325-mesh zeolite had the smallest diameter compared tothe 200-mesh zeolite and the 400-mesh zeolite.

ACKNOWLEDGEMENTS

The authors are very grateful to Universitas Sumatera Utara for its funding throughout TALENTA research program 2019 with given contract numbers 4167/UN5.1.R/PPM/2019 on 01 April 2019.

REFERENCES

Breck, D. W. (1974). *Zeolites Molecular Sieves: Structure, Chemistry, and Use*. John Wiley & Sons Inc.

Cheetham, A. K. (1992). *Solid State Compound*. Oxford university press.

Galuh, S., & Rahmi, D. (2014). Pembuatan nanopartikel dengan metoda high speed homogenization. *Jurnal Litbang Industri*, *3*(2), 67–131.

Muchtar, H., Anova, I. T., & Yeni, G. (2015). Pengaruh Kecepatan Pengadukan dan Kehalusan Gambir Serta Variasi Komposisi Terhadap Beberapa Sifat Fisika dalam Pembuatan Tinta Cetak. *Jurnal Litbang Industri*, *5*(2), 131-139.

Mudjijono, H., Wahono, S. K., Maryana, R., & Pratiwi, D. (2015). Modification of Gunungkidul Natural Zeolite as Bioethanol Dehydrating Agents. *Energy Procedia*, *65*, 116–120. https://doi.org/10.1016/j.egypro.2015.01.042

Nasution, T. I., Zebua, F., Nainggolan, H., & Nainggolan, I. (2015). Manufacture of Water Vapour Filter Based on Natural Pahae Zeolite Used for Hydrogen Fueled Motor Cycle. *Applied Mechanics and Materials*, *754–755*, 789–793. https://doi.org/10.4028/www.scientific.net/AMM.754-755.789

Prasmita, K. (2012). *Studi pendahuluan penentuan distribusi ukuran nanopartikel logam Menggunakan mikroelektroda*. Universitas Indonesia.

Scott, E. K., Reuter, J. E., & Luo, L. (2003). BRIEF COMMUNICATION Small GTPase Cdc42 Is Required for Multiple Aspects of Dendritic Morphogenesis. *Journal of Neuroscience*, *23*(8), 3118–3123. https://doi.org/https://doi.org/10.1523/JNEUROSCI.23-08-03118.2003

SNI 13-7168-2006. (2006). *Syarat mutu zeolit sebagai bahan pembenah tanah pertanian*. StandarNasional Indonesia.

Wahono, S. K., Mudjijono, H., Kristiani, A., Tursiloadi, S., & Abimanyu, H. (2014). Characterization and Utilization of Gunungkidul Natural Zeolite for Bioethanol Dehydration. *Energy Procedia*, *47*, 263–267. https://doi.org/10.1016/j.egypro.2014.01.223

Wulandari, R., & Priyono, C. (2014). Pengaruh Ukuran Partikel Zeolit Terhadap PeningkatanKadar Bioetanol. *Indonsian Journal on Medical Science*, *1*(2).