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Selectivity of Water Adsorbent Characteristic on Natural Zeolite in Cooling Application

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ABSTRACT

The natural resources from Indonesia that can be used as an adsorbent are natural zeolite which could adsorb water but less use in cooling application although it is in abundant amount. One of the cooling systems that use less energy is adsorption. The measurement considerations of adsorbent are surface are, pore size, Si/Al ratio, type of zeolite and hydrophilic characteristic. The material being tested in this research is natural zeolite from Yogyakarta and Cikembar, Indonesia. This research analyzes the characteristic of the adsorbent including the BET surface area, pore volume, structural or morphologies characterization, and element composition from each natural zeolite. The result of this study showed that the BET surface area and pore volume of natural zeolite from Yogyakarta are one third smaller than Cikembar, but it has more hydrophilic of Si/Al ratio. Whereas the result of selectivity study between the two prove that both zeolite has better selectivity in each area that can be improve with post treatment or modification.

1. Introduction

Indonesia stretch out between rings of fire and produce minerals including natural zeolite. There are more than 20 locations with more than 500.000.000 tons of natural zeolite were identify by Kusdarto [1]. The term of Zeolite created by Cronstedt from Greek to explain mineral which can adsorb water when it heated and originated from volcano rocks and the natural zeolite consist of Aluminium – Silica which its structure could filled with water and the cation can be replaced [2]. Due to its microporosity and relatively higher surface area, natural zeolite have been widely used as catalysts, separation media, ion exchanger and adsorbent [3]. Despite its wide applications of natural zeolite, it also has limitations due to (1) its properties that are not optimized by nature (2) some undesired impurity on its structure [4]. But, the surface area and acidity of natural zeolite could be modified easily. The activation and modification are the way to improve the impurity and crystallinity [5].

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Nowadays, high energy consumption synonymous with the commercial buildings, almost 50% of energy consumption is use for HVAC [6], which cause ozone depletion. Effort in renewable energy utilization [7] and energy conservation activities in all sectors need the worldwide energy policy where one of this is solar energy used for air-conditioning system [8,9]. Such a promising solution in alternative air-conditioning units that are derived from renewable energies right now [10,11]. Low-grade heat sources, such as solar energy or waste heat can be carried on for adsorption cooling system. The meaning of adsorption is a chemical or physical reaction process between a solid (adsorbent) and a gas (refrigerant). Physical reaction between the adsorbent and refrigerant occurred through the connections of Van der Waals force in wide spread use of adsorption chillers [12,13].

The natural zeolites from Indonesia are common for agriculture, livestock, fisheries, drying agent and some industries uses [14]. They rarely use as an adsorbent for cooling application. This research used two natural zeolites from two different areas where one of them usually use for dehydration of bioethanol [15] and the others for CO_2 capture [16]. The problems are investigating the best zeolite that suite for adsorption cooling application. This research aims to compare the characteristic of two adsorbent which are natural zeolite from Indonesia as water adsorbent for cooling application and then analyze the selectivity of each adsorbent.

2. Materials and Methodology

2.1 Materials

The first sample of natural zeolite ZB1 was taken from Yogyakarta province, Indonesia according to the research of Laksmono *et al.,* [17] and the second sample of natural zeolite ZE2 was obtained from PT. Katulistiwa Hijau Prima from Cikembar, Sukabumi, West Java province, Indonesia. Both zeolites were grinding into tiny size about 1 or 2 mm, then meshing by a micro-size screen to get very fine particles and measure their weight which ready to be use. Other material was the Aquadest bought from CV. Dwinika for activating the zeolites.

2.2 Method of Activation the Natural Zeolites

The activation of natural zeolite was performed by washing with Aquadest (1:3 w/v) under magnetic stirring for 3 hours. The type of machine used was IKA ® C-MAG HS7 at a rate of 2 Mot with room temperature and using the 1000 ml breaker glass. After 3 hours, take some hours to precipitate the solid phase and throw away the water also the first layer of the solid. The second layer was the clean natural zeolite which free from the impurity. Aerate the pure layers and weigh after it dried enough. The pure natural zeolite in solid phase was dried start from room temperature until 300°C for 3 hours using oven MEMMET UF 55. Weigh the natural zeolite again just after they were out from the oven to get the amount of water depreciation during the drying process. The goal of this physical activation was to throw away the molecule of water from the voids of natural zeolite and try to open the active site of natural zeolite.

2.3 Natural Zeolite's Characterization

There had been done three techniques to characterize the natural zeolite ZB1 and ZE2: Brunauer, Emmett and Teller Surface Area (BET) Analysis, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

2.3.1 Brunauer, Emmett and Teller surface area (BET) analysis

BET Analysis results some value such as BET surface area, pore volume, and pore size. These properties were very important to identify the porous of the natural zeolite especially in adsorption cooling application. More refrigerant like water was easy to adsorb by the adsorbent if there were much area of porosity. The sample of natural zeolite was measure by surface area and porosity analyzer from Micromeritics ASAP 2020 series in Chemistry Laboratory, Universitas Negeri Jakarta, Indonesia. The measurements of the adsorption isotherms of Nitrogen at 77°K became the base of the determination. The degassing sample take turn in 4 hours at 350°C. The BET equation in the relative pressure range of between 0.05 and 0.3, over 5 adsorption points to estimate the surface area. The t-plot Harkins and Jura equation is being calculated for micropore volume. Subtracting the micropore volume from the volume of liquid Nitrogen adsorbed at relative pressure of 0.990 being done to determine the corresponding mesopore volume. Non-local density functional theory for slit-like pore geometry was used to measure the pore size distribution.

2.3.2 Scanning Electron Microscopy (SEM) analysis

The Scanning Electron Microscopy Analysis to analyze characterization about the morphology of the adsorbent had been done by Oxford Instruments at PT. Gestrindo, Jakarta, Indonesia. The microstructure could be determined using the SEM Analysis [18, 19].

2.3.3 Transmission Electron Microscopy (TEM) analysis

Structural characterization or morphologies of natural zeolite was observe by conducting the Transmission Electron Microscopy (TEM) Analysis in Laboratory Transmission Electron Microscopy, ILRC Building, Universitas Indonesia using Microscope Tecnai 200 kV D2360 SuperTwin with 200 kV accelerating voltage, LaB6 gun type and FEI detector manufacturer.

3. Results

3.1 Surface Area and Pore Volume

The results of BET characterization such as BET Surface area and pore volume of each adsorbent, ar shown in Table 1. They could correspond to the mount of adsorbate which the adsorbent can adsorb it, according to the interface reaction when the adsorbate attached to the adsorbent surfaces. It shows that the natural zeolite from Cikembar (ZE2) has larger BET surface area and larger pore volume than the natural zeolite from Yogyakarta (ZB1), which means that greater surface area and pore volume so will be the more refrigerant (water) come into the natural zeolite pores.

Table 1
The values of BET characterization results

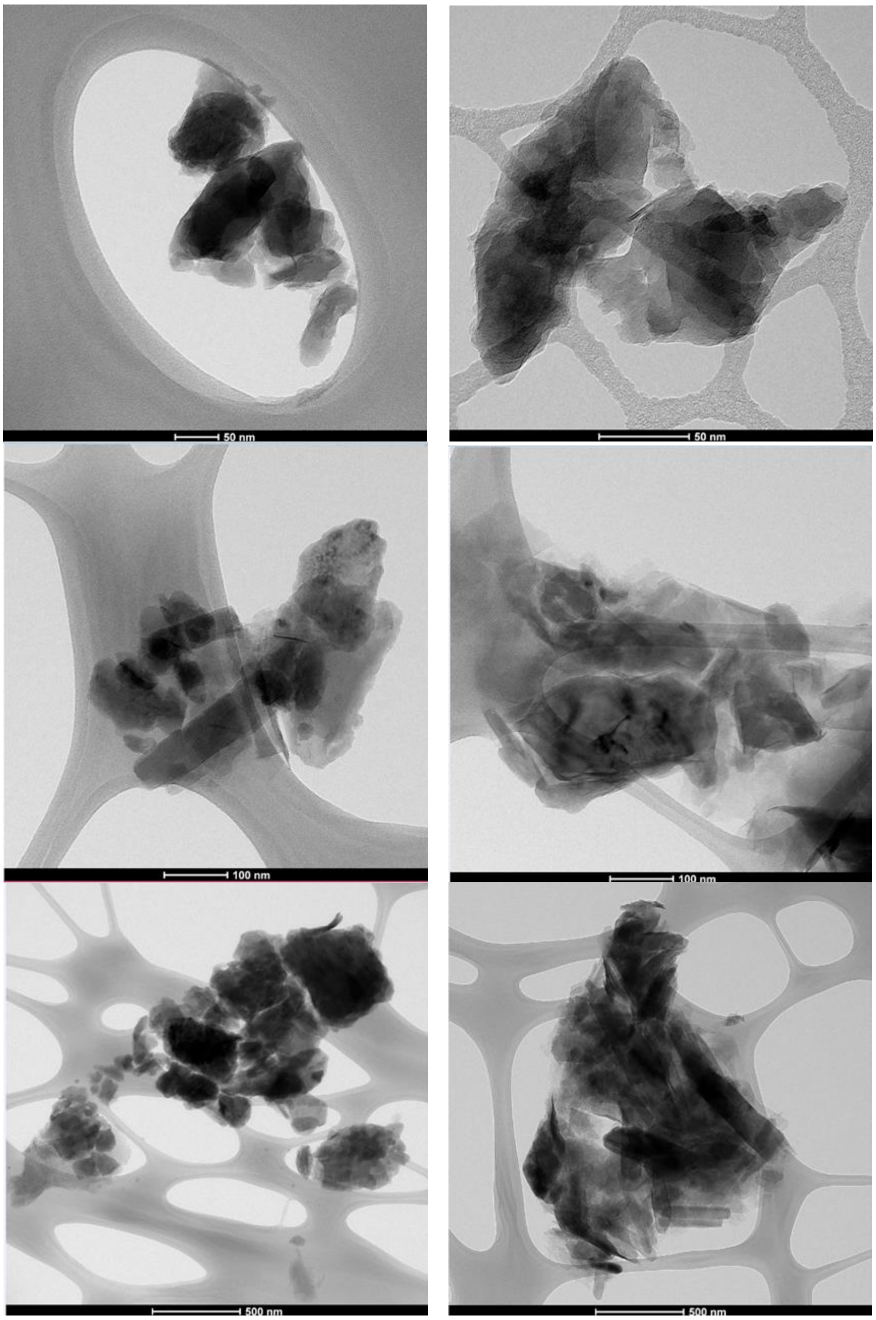
Measurements	ZB1	ZE2
BET Surface Area (m^2/g)	12.9068[17]	41.2870
Pore Volume (cm^3/g)	0.003780[17]	0.035138

Research about Zeolite Yogyakarta has been done by Wahono *et al.,* [20] used for bioethanol dehydration result in smaller BET surface area than our results. These limitations on BET surface area and pores size especially ZB1 can be overcome by modifications of the structure of natural zeolite.

Dealumination and desilication are commonly employed to change the properties of natural zeolite such as pore size [4,21,22].

3.2 Structural Characterization of Adsorbent

The morphologies or structural characterization of the adsorbent could display by the technique of Transmission Electron Microscopy (TEM). Figure 1 (a) are illustrate the bright field TEM images corresponding to natural zeolite from Yogyakarta and (b) from Cikembar, which the presence of different phases could be observed. They indicate that there is a presence of modernit (a) and clinoptilolite phase (b) and shows the cubic morphology of the material.



(a) (b)

Fig. 1. The morphology of (a) ZB1 and (b) ZE2 zeolite using TEM examination

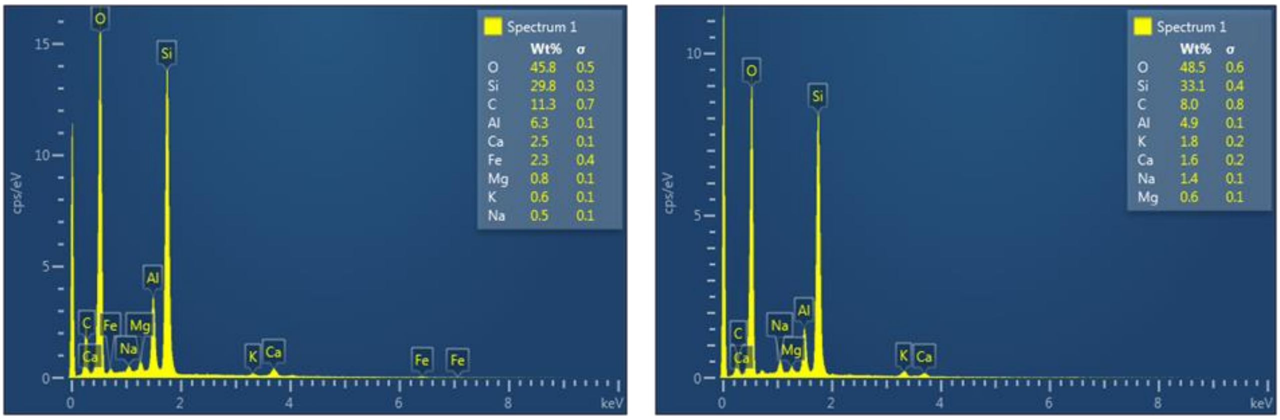
3.3 Surface Morphology and Element Composition of Natural Zeolite

The SEM element characterization result summarize for each natural zeolite is shown below in Table 2 and Figure 2, while the SEM visual result could be seen in Figure 3 which shows distinctive surface morphology of each adsorbent. The micrographs of both zeolites show many of the visible pores and SEM images the rough looking surface of zeolites. However, more impurities are shown in zeolite image. The image is consistent to the element reading of SEM in which confirms the existence of various impurities in zeolite. The element reading also shows that the ratio of Si/Al ratio for ZB1 is 4.69 and ZE2 is 6.47, thus considered that ZB1 is more hydrophilic than ZE2 although it has lower BET surface area.

Some post treatment to gain the hydrophilic Si/Al ration for ZE2 such as dealumination and desilication can also be used [3,9,13].

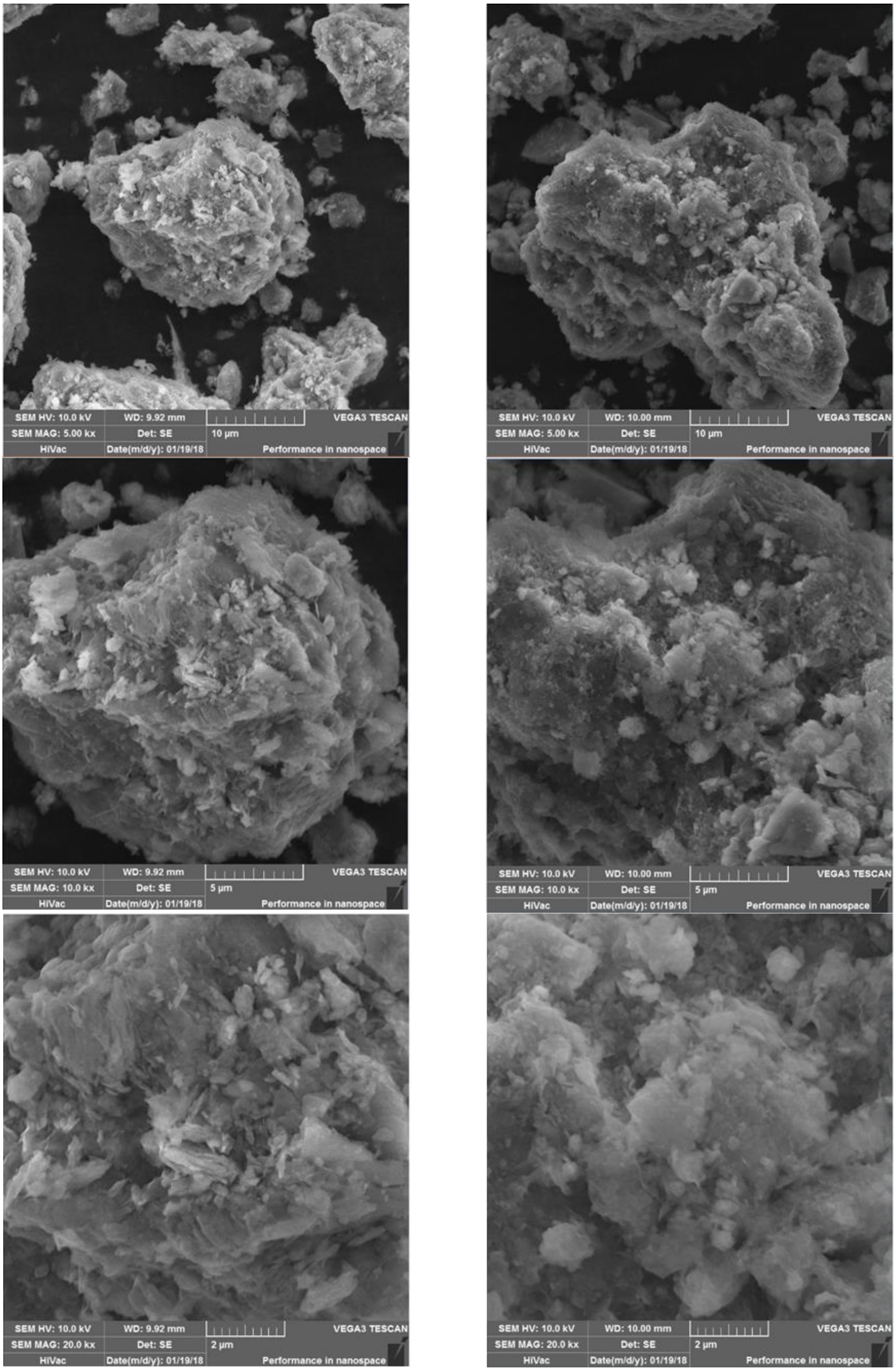
Table 2
Element reading by SEM result

		ZB1		ZE2	
Element	Standard Label	Wt%	Atomic %	Wt%	Atomic %
C	C Vit	11.29	17.82	8.02	12.77
O	SiO2	45.80	54.27	48.47	57.91
Na	Albite	0.53	0.44	1.35	1.12
Mg	MgO	0.82	0.64	0.62	0.49
Al	Al2O3	6.34	4.45	4.91	3.48
Si	SiO2	29.77	20.10	33.13	22.54
K	KBr	0.63	0.31	1.84	0.90
Ca	Wollastonite	2.52	1.19	1.65	0.78
Fe	Fe	2.30	0.78		
Total:		100.00	100.00	100.00	100.00



(a) (b)

Fig. 2. Spectrum of (a) ZB1 and (b) ZE2 zeolite from the results of SEM characterization



(a) (b)

Fig. 3. The results of SEM characterization of (a) ZB1 and (b) ZE2 zeolite

4. Conclusions

The data of characterization some natural zeolite that had been activated above show that both could be used as an adsorbent in cooling application. Next treatment of natural zeolite needed to achieve the best result as being adsorbent. Acidification treatment followed by calcination will be require for ZB1 to increase the BET surface area while Na-exchange treatment need by ZE2 to gain the optimal Si/Al ratio, strengthen by more data from Fourier Transform Infra Red (FTIR), Thermal Gravimetric Analysis (TGA) and X-Ray Fluorescence (XRF) characterization.

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References

[1] Kusdarto, Kusdarto. "Potency of zeolite in Indonesia." *Jurnal Zeolit Indonesia* 7, no. 2 (2008): 78-87.
[2] Gottardi, Glauco, and Ermanno Galli. *Natural zeolites*. Vol. 18. Springer Science & Business Media, 2012.
[3] Ming, Douglas W., and Janis L. Boettinger. "Zeolites in soil environments." *Reviews in mineralogy and geochemistry* 45, no. 1 (2001): 323-345.
[4] Weitkamp, Jens. "Zeolites and catalysis." *Solid State Ionics* 131, no. 1-2 (2000): 175-188.
[5] Lestari, Dewi Yuanita. "Kajian modifikasi dan karakterisasi zeolit alam dari berbagai negara." In *Prosiding Seminar Nasional Kimia dan Pendidikan Kimia*, pp. 1-6. 2010.
[6] Pérez-Lombard, Luis, José Ortiz, and Christine Pout. "A review on buildings energy consumption information." *Energy and buildings* 40, no. 3 (2008): 394-398.
[7] H. Lubis, "Renewable Energy of Rice Husk for Reducing Fossil Energy in Indonesia." *Journal of Advanced Research in Applied Sciences and Engineering Technology,* vol. 11, no. 1 (2018): 17-22.
[8] Ellabban, Omar, Haitham Abu-Rub, and Frede Blaabjerg. "Renewable energy resources: Current status, future prospects and their enabling technology." *Renewable and Sustainable Energy Reviews* 39 (2014): 748-764.
[9] Dincer, Ibrahim. "Renewable energy and sustainable development: a crucial review." *Renewable and sustainable energy reviews* 4, no. 2 (2000): 157-175.
[10] Fernandes, M. S., G. J. V. N. Brites, J. J. Costa, A. R. Gaspar, and V. A. F. Costa. "Review and future trends of solar adsorption refrigeration systems." *Renewable and Sustainable Energy Reviews* 39 (2014): 102-123.
[11] Gugulothu, Ravi, Naga Sarada Somanchi, Hima Bindu Banoth, and Kishan Banothu. "A review on solar powered air conditioning system." *Procedia Earth and Planetary Science* 11 (2015): 361-367.
[12] Choudhury, B., P. K. Chatterjee, and J. P. Sarkar. "Review paper on solar-powered air-conditioning through adsorption route." *Renewable and sustainable energy reviews* 14, no. 8 (2010): 2189-2195.
[13] Choudhury, Biplab, Bidyut Baran Saha, Pradip K. Chatterjee, and Jyoti Prakas Sarkar. "An overview of developments in adsorption refrigeration systems towards a sustainable way of cooling." *Applied Energy* 104 (2013): 554-567.
[14] Thamzil, L., and H. U. S. E. N. Zamroni. "Penggunaan Zeolit dalam Bidang Industri dan Lingkungan." *Jurnal Zeolit Indonesia* 1 (2010).
[15] Wahono, Satriyo Krido, Roni Maryana, and Diah Pratiwi. "Modification of Gunungkidul Natural Zeolite as Bioethanol Dehydrating Agents." *Energy Procedia* 65 (2015): 116-120.
[16] Adriany, Roza. "Pemanfaatan Zeolit Alam Termodifi kasi Kation Na+ untuk Penangkapan CO2." *Lembaran Publikasi Minyak dan Gas Bumi* 46, no. 3 (2012): 145-151.
[17] Laksmono, J. A., U. A. Pangesti, M. Sudibandriyo, A. Haryono, and A. H. Saputra. "Adsorption capacity study of ethanol-water mixture for zeolite, activated carbon, and polyvinyl alcohol." In *IOP Conference Series: Earth and Environmental Science*, vol. 105, no. 1, p. 012025. IOP Publishing, 2018.
[18] Muhamad, Ida Idayu, Nurul Shafinaz Md Katan, Shahrulzaman Shaharuddin, Dayang Norulfairuz, and Abang Zaidel. "Effects of Preparation Methods on the Properties of Pineapple Fibers." *Journal of Advanced Research Design* 4, no. 1 (2015): 1-8.
[19] M. S. Hajar, A. Supri, and A. Jalilah, "Effect of Poly (Ethylene Glycol) Diglycidyl Ether as Surface Modifier on Conductivity and Morphology of Carbon Black Filled Poly (Vinyl Chloride)/Poly (Ethylene Oxide) Conductive." *Journal of Advanced Research Design* 10, no. 1 (2015): 9-13.

[20] Wahono, Satriyo Krido, Anis Kristiani, Silvester Tursiloadi, and Haznan Abimanyu. "Characterization and utilization of gunungkidul natural zeolite for bioethanol dehydration." *Energy Procedia* 47 (2014): 263-267.

[21] Paixão, Viviana, Ana P. Carvalho, João Rocha, Auguste Fernandes, and Angela Martins. "Modification of MOR by desilication treatments: structural, textural and acidic characterization." *Microporous and Mesoporous Materials* 131, no. 1-3 (2010): 350-357.

[22] van Laak, Adri NC, Sophia L. Sagala, Jovana Zečević, Heiner Friedrich, Petra E. de Jongh, and Krijn P. de Jong. "Mesoporous mordenites obtained by sequential acid and alkaline treatments–Catalysts for cumene production with enhanced accessibility." *Journal of Catalysis* 276, no. 1 (2010): 170-180.