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Studies of the water adsorption on Lampung's natural zeolite of Indonesia for cooling application

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Abstract. Part of minerals that originally formed from volcanic rock and ash layers reacting further with alkaline groundwater is called natural zeolite, where its sources are not always available in all countries. Indonesia is located in the ring of fire which have a huge sources of zeolite, one of the area is Lampung, South Sumatra. Natural zeolite has been considered as one of potential heat adsorbent medium which can contribute to the energy consumption and reduce air pollution in the using of cooling application. The characteristic of this Lampung natural zeolite such as adsorption kinetics, adsorption water uptake, and adsorption capacity were test with ASAP 2020 system. Sorption kinetics by this experiment of zeolite samples were carried out in a constant temperature and humidity chamber. The chamber can supply constant air condition with deviations of ±0.5 °C for temperature and ±3% for relative humidity. The data based on rate of adsorption and the defined working condition was set as 20°C and 70% RH. Pore volume is a significant parameter for determining the limitation of water uptake, which can describe the saturated condition of zeolite. Sorption isotherm models used to describe sorption phenomena are commonly deduced from the Polanyi potential theory were investigated. The water adsorption quantity increased with the increase of relative pressure. To sum up, this pure zeolite has a less heat and mass transfer performance so its need to be activated before using in cooling application to get their great potential and by being coated in a desiccant heat exchanger systems.

1. Introduction

The use of natural zeolite from Indonesia as an adsorbent for cooling application can be a huge alternative energy resources for energy conservation and environmentally protection. Natural zeolites are scattered in several regions in Indonesia on more than twenty places in Indonesia among others in Sumatra, Java and East Nusa Tenggara because it's spread on the land near the volcanic mountains [1] with lots of mordenit and klinoptilolit type [2]. More research show that a lot of it using for other needs.

Nowadays, widely utilization of natural zeolite in Indonesia have been applied in agriculture, livestock, fisheries and some industries [3]. However, there is a research about natural zeolite in Indonesia as a adsorber in CO2 capture modified with Na+ to achieve the higher of adsorption capacity was conducted [4]. Besides, the research of chromium (VI) waste adsorption by zeolite has done by isotherm adsorption method to determine maximum capacity of zeolite to chromium (VI) waste [5]. Subsequent work by [6] and [6] show about conversion of palm oil into bio gasoline using Ni/ZA or natural zeolite catalyst and Cr/ZA catalyst on the conversion reaction of waste cooking oil into liquid fuel. In addition, the dehydration process on the bioethanol purification using natural zeolite result the purity more than 99% but has lower yield and much ethanol can be absorbed by natural zeolite from Gunung Kidul which could be seen from the addition of adsorbent weight by

20% [7] and [8] also as a molecular sieve [9]. This kind of natural zeolite used for the phase purification of methane in biogas which can be converted into electrical energy was doing by [10]. In medical science it can be used as a raw material of antiseptic [11]. Another field by hydrocracking of waste tires has been done too [12].

Thus, there is limited study about the use of natural zeolite from Indonesia using for cooling application. In this paper, an Indonesian natural zeolite from Lampung were under testing and some key parameters were studied. First about the sorption kinetics and then the sorption isotherms data were measured and investigated.

2. Methodology / experimental

The material used in this paper mainly included natural zeolite from Lampung, Indonesia. This source being selected because the sufficient value of total surface area, total pores volume and relatively small pores distance which can result high pore density and adsorbing rate [13].

2.1. Measurement of sorption kinetics

Sorption kinetics of the samples were being tested in humidity chamber and a constant temperature with the reference of natural zeolite. This humidity chamber could deliver constant air condition by the temperature deviations of ±0.5°C and relative humidity deviation of ±3%. The setup temperature and humidity of defined working condition were 20°C and 70%RH respectively. The samples were dried in the oven by the temperature of 100°C as for pretreatment. Recorded the weights of the samples at setting intervals by an electronic balance, the accuracy was 0.001 g.

2.2. Measurement of sorption isotherms

The samples were carried out in an improved Accelerated Surface Area and Porosimetry System (ASAP 2020) system at 20°C to get their water sorption isotherms data. This system apply the principle of static volumetric technique to acquire nitrogen adsorption/desorption isotherms at temperature -196°C. The error from this experimental of the ASAP apparatus is particularly caused by pressure and temperature transducers. The fidelity of pressure transducer is about 0.1% while temperature is ±0.02°C.

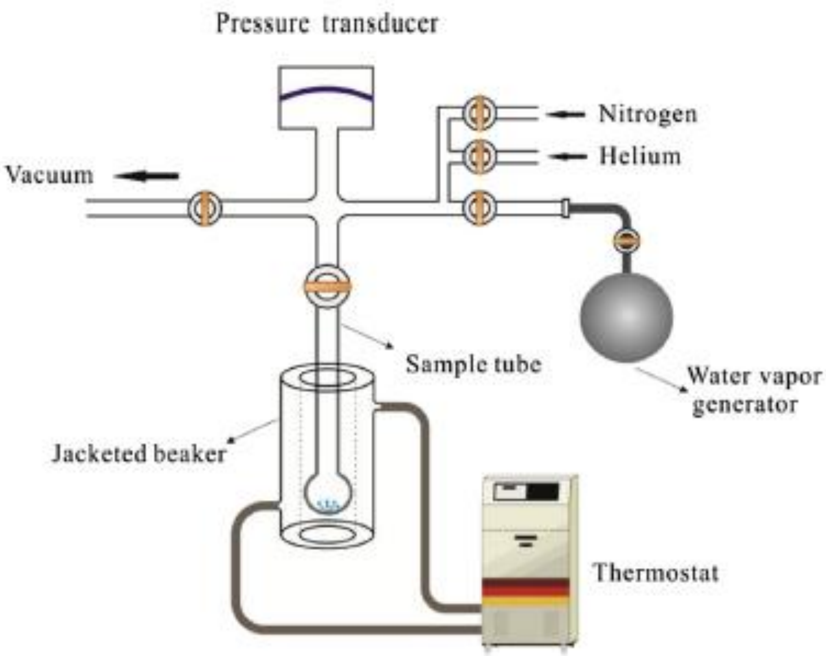

Figure 1. The schematic diagram of the improved ASAP 2020 system [14]

Fig. 1 represent the schematic diagram of the improved ASAP 2020 system. There are many items such as a jacketed beaker, a water vapor generator and a thermostatic water bath in that ASAP 2020 apparatus. The jacketed beaker and the thermostatic bath are integrated together to control the temperature of the sample tube with the accuracy of the thermostat is ±0.05°C. By utilizing the improved ASAP 2020 machine, sensitive water sorption isotherms can be examined and sorption temperature of a test sample can also be exactly managed.

3. Results and discussion

3.1. Sorption kinetics

The natural zeolite's dynamic sorption amounts on water vapor were find out in a thermo-humidistat chamber under the test condition of temperature 20°C and 70%RH. The water sorption quantity was indicated as per water uptake on per unit mass of natural zeolite (i.e. g g^{-1}).

As represented in Fig. 2, for all the composition of relative humidity, the dynamic water sorption increases harshly at the initial stage of sorption. Then it grows gradually until the sorption equilibrium is obtained. Contrast with the lowest relative humidity, the highest relative humidity not only produced higher dynamic sorption quantities, but also had faster sorption rates.

The reason for this is that water sorption by higher relative humidity having more physical sorption. The released sorption heat influenced the time needed to reach sorption equilibrium.

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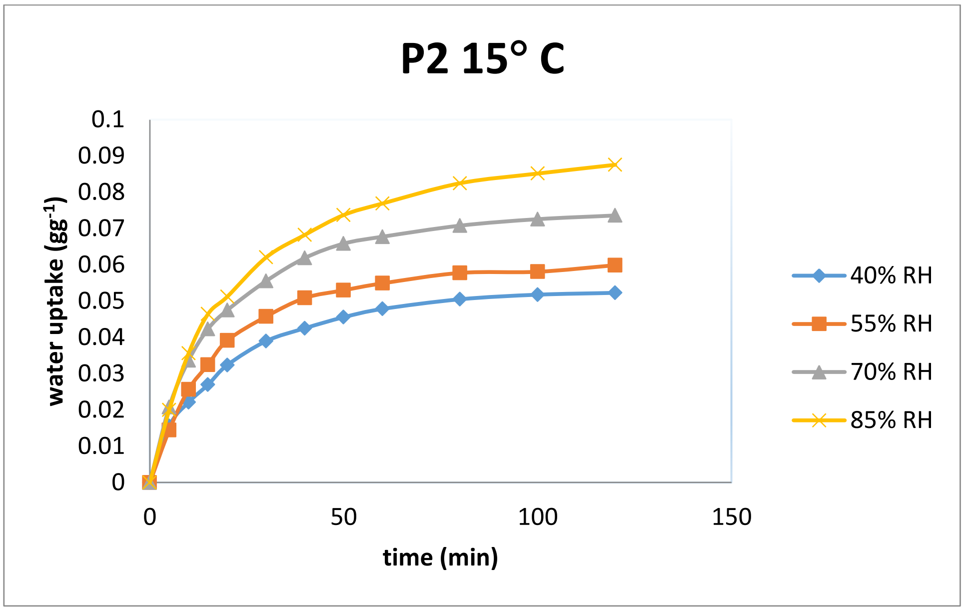

Figure 2. Water sorption kinetic curves of natural zeolite from Lampung, Indonesia at 15°C with different relative humidity

3.2. Sorption isotherms

The water sorption isotherms behavior of natural zeolite were conducted by an improved ASAP 2020 system at 20°C. The isotherms were provided in Fig. 3. It can be noticed that, water sorption capacity of Lampung's natural zeolite fluently grew with the enhanced of relative pressure.

With the increase of relative pressure, the more liquid absorption process occurred. Sorption isotherm models to describe sorption phenomena are commonly sum up from the Polanyi potential theory:

$$\varepsilon = -RTln\left(\frac{P}{Po}\right) \quad \text{(1)}$$

where,
ε is sorption potential (kJ kg^{-1}),
T is the sorption temperature (K),
P is the vapor pressure (Pa),
Po is the saturated vapor pressure at sorption temperature T (Pa).

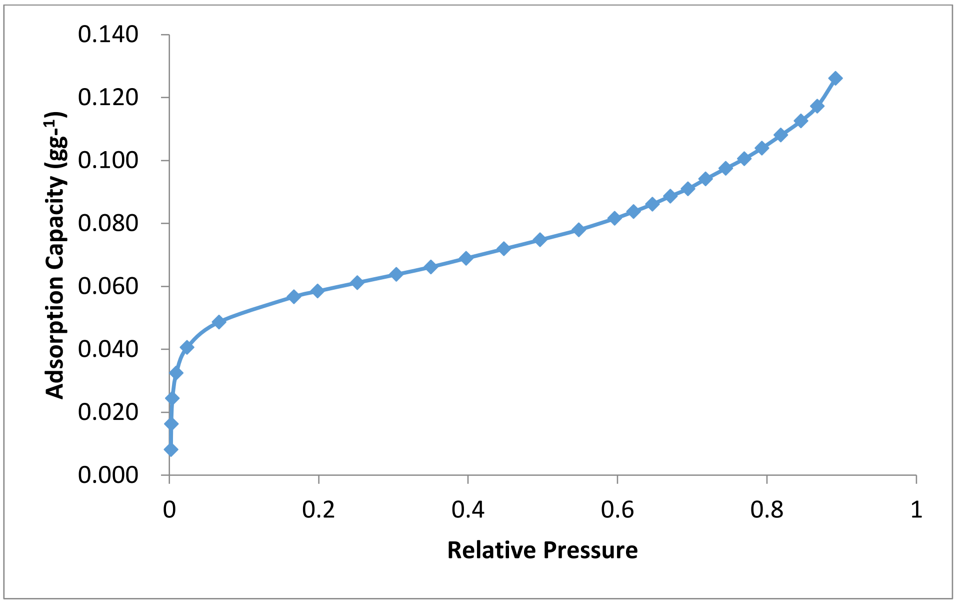

Figure 3. Water sorption isotherms of Lampung's natural zeolite at 20°C by an ASAP 2020 apparatus.

By using the sorption potential, pressure and temperature can be merge into a single parameter. The correlation curves which represent the relation between adsorbed water and sorption potential can be achieved, as shown in Fig. 4.

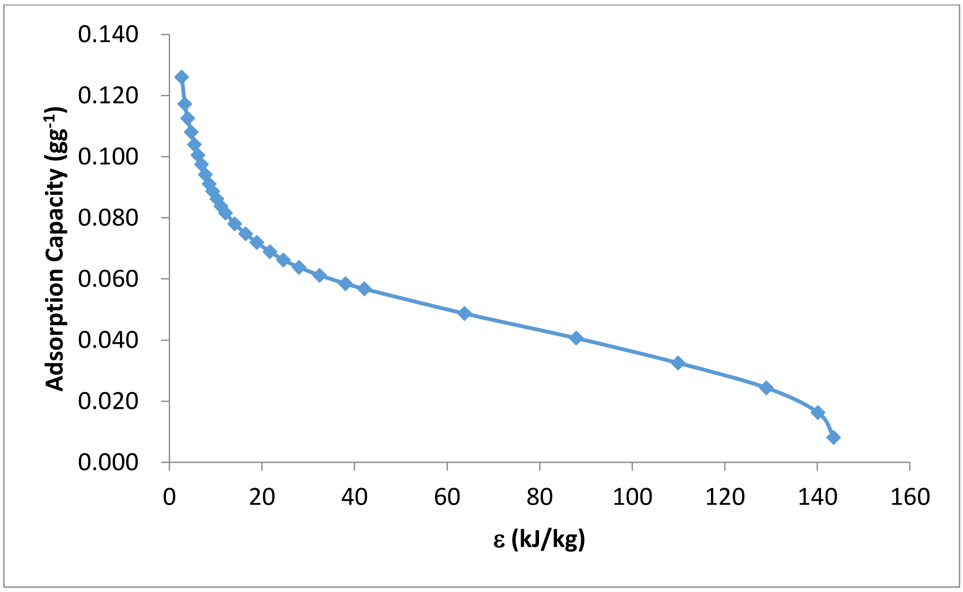

Figure 4. Correlation curves between adsorbed water and sorption potential of Lampung's natural zeolite.

4. Conclusion

Investigation on sorption kinetics (i.e. dynamic sorption quantity and rate coefficient) indicated that Lampung's natural zeolite having denote higher dynamic sorption quantities and faster sorption rates.

Sorption isotherms were acquired by an improved ASAP 2020 system to explore water sorption behavior of Lampung's natural zeolite and the experimental data had good agreement with calculated data.

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