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Effectiveness of Natural Zeolite Mass Variation for Turmeric Solution Adsorption Process

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ABSTRACT

The purpose of this study was to observe the effectiveness of adsorption process in turmeric solution with different zeolite masses. The method used was to highlight the solution with flashlight which was then measured using a lux meter. To support this research, we used a solution of turmeric with zeolite with mass variations ranging from and tested 3 times with a lux meter. The results obtained indicated that there are differences in the adsorption rate of turmeric solution with zeolite mass from 1 to 2,5 grams. This difference occurred because of the difference in the mass of the zeolite between which adsorbed the turmeric solution. The lux meter showed different results in each test and the water clarity level was different for each added mass variation. In addition, the compatibility of the experimental results with the isotherm adsorption model shows the adsorption mechanism that occurred. Thus, the difference in mass has an impact on use on a larger scale as needed. This research is expected to provide new knowledge for the community about the benefits of zeolite for water purification process in daily life.

ABSTRAK

Tujuan dari penelitian ini adalah untuk mengetahui efektivitas proses adsorpsi dalam larutan kunyit dengan massa zeolit yang berbeda. Metode yang digunakan adalah dengan menyorot larutan dengan senter yang kemudian diukur menggunakan lux meter. Untuk mendukung penelitian ini digunakan larutan kunyit dengan zeolit dengan variasi massa mulai dari 1; 1,5; 2; sampai 2,5 gram dan diuji 3 kali dengan lux meter. Hasil yang diperoleh menunjukkan bahwa terdapat perbedaan laju adsorpsi larutan kunyit dengan massa zeolit dari 1 sampai 2,5 gram. Perbedaan ini terjadi karena adanya perbedaan massa antara zeolit yang mengadsorbsi larutan kunyit. Lux meter menunjukkan hasil yang berbeda pada setiap pengujian dan tingkat kejernihan air berbeda untuk setiap variasi massa yang ditambahkan. Selain itu, kesesuaian hasil percobaan dengan model adsorpsi isoterm menunjukkan mekanisme adsorpsi yang terjadi. Dengan demikian, perbedaan massa berdampak pada penggunaan dalam skala yang lebih besar sesuai kebutuhan. Penelitian ini diharapkan dapat memberikan pengetahuan baru bagi masyarakat tentang manfaat zeolit untuk proses penjernihan air dalam kehidupan sehari-hari.

Introduction

Adsorption is the absorption of a substance (molecule or ion) on the surface of the adsorbent. The way adsorption works is described as a process when molecules that are initially present in solution, physically attach to the surface of the adsorbent substance [1]. The illustration of adsorption process is described in Figure 1. Adsorption can occur in the solid-liquid, solid-gas or gas-liquid interfaces. The molecule that is bound to the interface is called the adsorbate, while the surface that absorbs the adsorbate molecules is called the adsorbent. In adsorption, the interaction between the adsorbent and the adsorbate only occurs on the surface of the adsorbent [1]

The solids commonly used in the adsorption process are zeolites. Zeolite is a hydrated aluminosilicate compound consisting of SiO4 and AlO4 tetrahydrate bonds linked by oxygen atoms to form a framework [2]. Zeolite is also often referred to as 'molecular sieve' or 'molecular mesh' (molecular sieve) because zeolites have molecular-sized pores so that they are able to separate/filter molecules of a certain size. Zeolite is one of the alternative adsorbents that has high adsorption ability because it has many pores and has a high cation exchange capacity and can be applied in a wide temperature range so it is very suitable to be used as an adsorbent [2]. In this study, the adsorbate used was a turmeric solution.

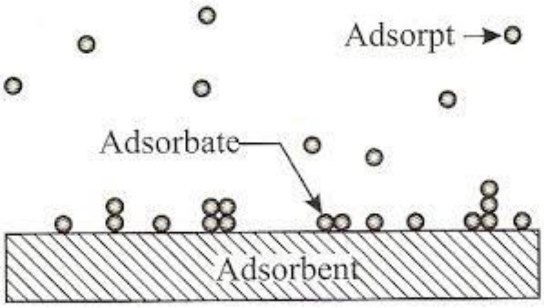

Figure 1. Illustration of the adsorption process.

Several studies have been conducted and are shown in table 1. Broadly speaking, on average, these studies have disadvantages:

(i) Expensive materials
(ii) Use of hazardous chemicals
(iii) Benefits to society are limited

Table 1. Comparison of Experiments

No	Researcher	Topic/Material	Excess	Deficiency	No Ref
1	Said, Muhammad	Activation of Natural Zeolite as an Adsorbent in Iodine Solution Adsorption	Materials are easy to get	The benefits for the community are still quite limited	[3]
2	History, Beautiful	ADSORPTION OF METHYLENE BLUE COLORING USING ALANG ALANG (Imperata cylindrica) ACTIVATED SULPHIC ACID	The object of research focuses on cleaning the environment polluted by textile waste.	Using hazardous chemicals, namely sulfuric acid.	[4]
3	Kurniasari, Laeli	ACTIVATION OF NATURAL ZEOLITE AS ADSORBENT IN LOW TEMPERATURE DRYER	Use of easily available materials Research focuses on improving food quality.	Use of some hazardous materials Use of very specific tools	[5]
4	Agustiningtyas, Zurida	Optimization of Pb(II) Ion Adsorption Using Ditizon Modified Natural Zeolite	The object of research focuses on cleaning the	The use of chemicals that tend to be	[6]

			environment from pollutants	expensive	
5	Sudarni, Sudarni	ACTIVATION OF ZEOLITE AND ACTIVE CARBON TO REDUCE WATER HARDNESS IN SAPIRIAK VILLAGE, MAKASSAR CITY	The object of research focuses on cleaning waste in the water The benefits for the community are very broad	Less efficient	[7]
6	Arita, Susila	SPENT ACID WASTE PURIFICATION WITH ADSORPTION PROCESS USING ZEOLITE AND BENTONITE	The object of research focuses on cleaning acid waste to reduce pollution	The object of research is dangerous and requires special attention	[8]
7	Sanjaya, USA	Study of Pb Adsorption Kinetics Using Activated Charcoal	Research is relevant to today's era where cleaning the environment from pollutants is very much needed Easy to get materials		[9]
8	Ma'rifat, Ma'rifat	SYNTHESIS OF ZEOLITE FROM COAL BASE ASH AND ITS APPLICATION AS ADSORBENT OF METAL MERCURY (II)	Research focuses on cleaning up hazardous mercury waste	Requires very specific equipment The object of research requires special attention	[10]
9	Emelda, Lisanti	Utilization of Activated Natural Zeolite for Adsorption of Chrome Metal (Cr3+)	Chromium metal adsorption studies are rare	The tools used are specific and unaffordable	[11]
10	Intercession, Fahmi	Kinetics of Nitrate and Phosphate Anion Adsorption on Natural Zeolite Modified Surfactant Hexadesiltrimethylammonium Chloride	High efficiency	The use of materials that are very specific and hard to come by. Benefits for the community are limited	[12]

From these data, there is no research on the Observation of the Adsorption Process of Turmeric Solution with Natural Zeolite with Varied Mass. Therefore, the purpose of this study was to determine the ability of the adsorption process to turmeric solution with zeolite of various masses. From the results of this study, we hope it can provide insight to the community about zeolite effectiveness to purify ground water in daily life.

Materials and Methods

The materials used were zeolite sand (natural zeolite, Indonesia) and turmeric powder (Desaku turmeric powder, PT. Motasa, Indonesia). This experiment used a zeolite with a size of 2 mm with a mass variation of 1; 1.5; 2; and 2.5 grams and a solution of 100; 35; 25; 12,5; and 6,25 ppm of turmeric concentration. The tools used were cardboard, flashlight, 100 mL box-shaped water bottle, a small box to store the bottle to be tested, and a lux meter application that can be installed on a cellphone as illustrated in Figure 2.

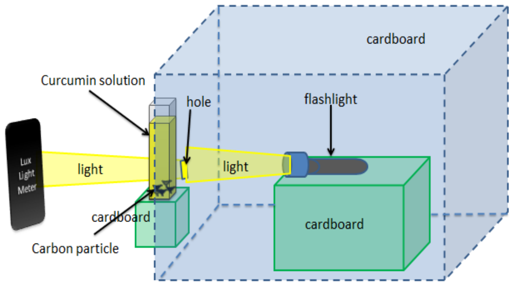

Figure 2. Turmeric Adsorption Test Kit

Adsorption experiments were carried out by mixing a solvent, in this case water, with 100 percent pure turmeric powder to get 100 mL of 100 ppm turmeric solution. The use of 100% pure turmeric is very important to prevent contamination due to impurities. A total of 100 mL of 100 ppm turmeric solution that has been made was then diluted to 35; 25; 12,5; and 6,25 ppm with volume of 100 mL each.

Turmeric solution was measured first using a lux meter before being mixed with zeolite. The four diluted turmeric solutions were mixed with zeolite with a mass variation of 1; 1.5; 2; and 2,5 grams. One hour after the solution was mixed with zeolite, measurements were made again using a lux meter.

The test was carried out in the darkest possible place to prevent measurement errors due to the influence of outside light. The measurement results were then compared between zeolites with a mass of 1 gram, 1.5 grams, 2 grams and 2.5 grams. The results from the lux meter are then converted to absorbance using the Lambert-Beer law.

$$A = \varepsilon bC$$

A = absorption

e = molar adsorptivity

b = length between light and solution

c = concentration (ppm, mg/L)

Or by converting Transmittance (lux) to Absorbance

$$A = -logT\%$$

$$A = -log\frac{I}{I_0}$$

T= Transmittance (lux)

I= Transmittance after passing through the solution

I_0= Transmittance before passing through the solution

The absorbance results are then applied into each adsorption isotherm model according to the required parameters. To match the experimental data with the adsorption isotherm model, Table 2 shows the plotting characteristics and parameters of each model.

Table 2. Isotherms Equations

Isotherm Type	Linier Equation	Plotting	Parameter
Langmuir	$\frac{1}{Qe} = \frac{1}{QmaxK_L}\frac{1}{Ce} + \frac{1}{Qmax}$	$^1/_{C_e}\ vs\ ^1/_{Q_e}$	• $\frac{1}{Q_{max}} = intercept$ • $Qmax = \frac{1}{intercept}$ • $K_L = \frac{1}{Q_{max} \times slope}$
Freundlich	$\ln Q_e = \ln k_f + \frac{1}{n}\ln C_e$	$lnC_e vs\ lnQ_e$	• $lnK_F = intercept$ • $K_F = e^{slope}$ • $\frac{1}{n_F} = slope$ • $n_F = \frac{1}{slope}$
Temkin	$q_e = B_T \ln A_T + B_T \ln Ce$	$lnC_e vs\ Q_e$	• $B = slope$ • $lnA_T = \frac{intercept}{B_T}$ • $B_T = \frac{RT}{B}$
Dubinin-Radushkevich	$\ln q_e = \ln q_s - (\beta \varepsilon^2)$	$\varepsilon^2 vs\ lnQ_e$	• $\beta = K_{DR} = slope$ • $E = \frac{1}{\sqrt{2 \times K_{DR}}}$
Flory Huggins	$log\frac{\theta}{C_e} = logK_{FH} + n\log(1-\theta)$	$\log\left(\frac{\theta}{C_0}\right)$ vs $log(1-\theta)$	• $n_{FH} = slope$ • $log\ k_{FH} =$ intercept • $K_{FH} = 10^{intercept}$ • $\Delta G^{\circ} = RT\ln(k_{FH})$ • $\theta = 1 - (\frac{C_e}{C_0})$
Fowler-Guggenheim	$ln\left(\frac{C_e(1-\theta)}{\theta}\right) - \frac{\theta}{1-\theta} = -lnK_{FG} + \frac{2W\theta}{RT}$	θ vs $ln\left[\frac{C_e(1-\theta)}{\theta}\right]$	• $W = slope$ • $-lnK_{FG} =$ intercept • $K_{FG} = e^{-intercept}$ • $\alpha\ (slope) = \frac{2W\theta}{RT}$ • $W = \frac{RT\alpha}{2\theta}$ • $\theta = 1 - (\frac{C_e}{C_0})$
Hill-Deboer	$ln\left[\frac{C_e(1-\theta)}{\theta}\right] - \frac{\theta}{1-\theta} = -lnK_1 - \frac{K_2\theta}{RT}$	θ vs $ln\left[\frac{C_e(1-\theta)}{\theta}\right] - \frac{\theta}{1-\theta}$	• $-lnk_1 =$ intercept • $\alpha\ (slope) = \frac{k_2\theta}{RT}$ • $k_2 = \frac{RT\alpha}{\theta}$ • $\theta = 1 - (\frac{C_e}{C_0})$
Jovanovic	$lnq_e = lnq_{max} - K_J C_e$	$C_e vs\ lnQ_e$	• $K_J = slope$ • $lnQ_{max} =$ intercept • $Q_{max} = e^{intercept}$
Harkin-Jura	$\frac{1}{q_e^2} = \frac{B}{A} - \left(\frac{1}{A}\right)logC_e$	$logC_e\ vs\ \frac{1}{q_e^2}$	• $A_H = \frac{1}{Slope}$ • $\frac{B_H}{A_H} = intercept$
Halsey	$lnQ_e = \frac{1}{n_H}lnK_H - \frac{1}{n_H}lnC_e$	$lnC_e vs\ lnQ_e$	• $\frac{1}{n_H} = slope$ • $\frac{1}{slope} = n_H$ • $lnK_H =$ intercept • $K_H = e^{intercept}$

Result and Discussion

After the transmittance determination with lux meter, the results found that every mass variation added to the solution gave different readings. The difference stated that some of the turmeric was adsorbed by the zeolites. Zeolite adsorbed the turmeric molecules to its surfaces, thus the concentration of the turmeric was reduced.

All the readings then converted to the absorbance to get the final concentrations showed in table 3.

Table 3. Final Concentration Reading for 35 ppm samples

Zeolite mass (gram)	Initial Concentration (ppm)	Final Concentration (ppm)
1	35,5027	33.0159
1,5		31.2866
2		29.6292
2,5		26.3168

The results showed that more zeolite added, more surface area of zeolite was larger. Mass variation of 2,5 grams zeolites added provided much larger adsorption than 1 gram zeolites added. Therefore, the final concentration decreased in a large manner.

After the absorbance results was ready, all the result then applied into 10 adsorption isotherm model.

1. Langmuir

Langmuir adsorption isotherm is used to describe the equilibrium between adsorbate and adsorbent system, where the adsorbate adsorption is limited to one molecular layer at or before a relative pressure of unity is reached. $R^2>0.70$ indicates the presence of monolayer adsorbate on adsorbent surface. The results applied to Langmuir model shown in figure 3.

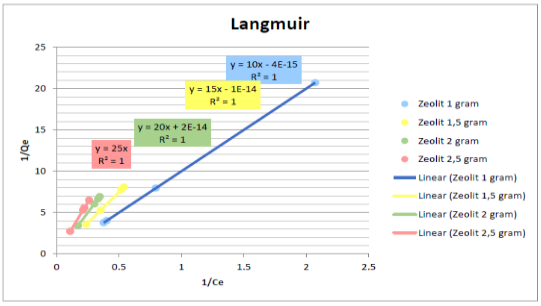

Figure 3. Langmuir adsorption isotherm model

Plotting results show each regression or R2 shows results above 0.70. The regression shows that the Langmuir model fits the experimental data. Thus, Langmuir model highly represent adsorpsion mechanism based on the experiment.

2. Freundlich

Freundlich isotherm defines a physical form of adsorption in which the adsorption takes place in several layers with weak connections (multilayer). $R^2>0.70$ indicates multilayer adsorption. The results applied to Freundlich model shown in figure 4.

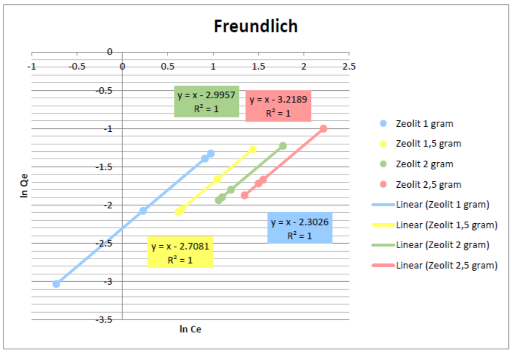

Figure 4. Freundlich adsorption isotherm model

3. Temkin

Temkin isotherm is based on three assumptions: the adsorption heat decreases linearly as surface adsorbent coverage increases, the adsorption process assumes a uniform binding energy distribution on the adsorbent surface, and the adsorption interaction involves the interaction between adsorbate and adsorbent. $R^2>0.70$ indicates uniform distribution adsorbate to adsorbent surface. The results applied to Temkin model shown in figure 5.

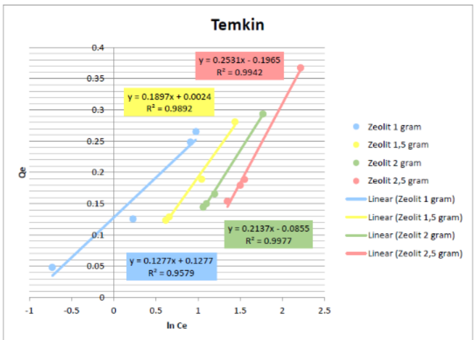

Figure 5. Temkin adsorption isotherm model

4. Dubinin-Radushkevich

Dubinin-Radushkevich *isotherm based on* adsorption process on an adsorbent with a pore structure or adsorbent with a heterogeneous surface, which expresses the adsorption free energy. Micropore volume filling is the basis f*or its adsorption mechanism.* R^2>0.70 indicates micropore size is exist in adsorbent surface. The results applied to Dubinin-Radushkevich model shown in figure 6.

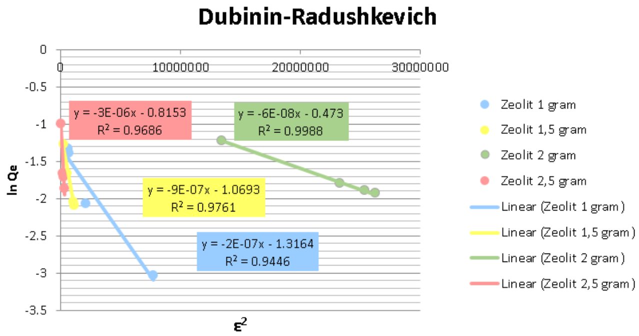

Figure 6. Dubinin-Radushkevich adsorption isotherm model

5. Flory-Huggins

The degree of surface covering of the adsorbate on the adsorbent is taken into consideration by the Flory-Huggins isotherm. This isotherm also presupposes that the adsorption proc*ess takes place on its own.* R^2 > 0.70 indicates the existence of monolayer on the surface of adsorbent. The results applied to Flory-Huggins model shown in figure 7.

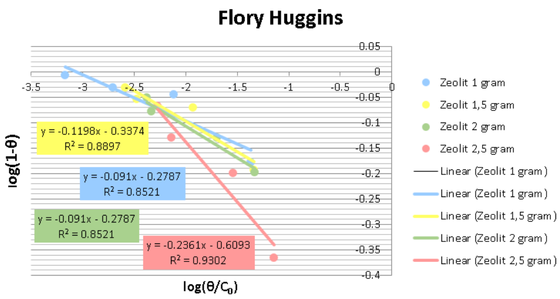

Figure 7. Flory-Huggins adsorption isotherm model

6. Fowler-Guggenheim

Fowler-Guggenheim isotherm shows that at a collection of isolated locations, there is a lateral interaction with weak interactions between adsorbed *species at surrounding sites.* R^2>0.70 indicates the existence of monolayer on the surface of adsorbent. The results applied to Fowler-Guggenheim model shown in figure 8.

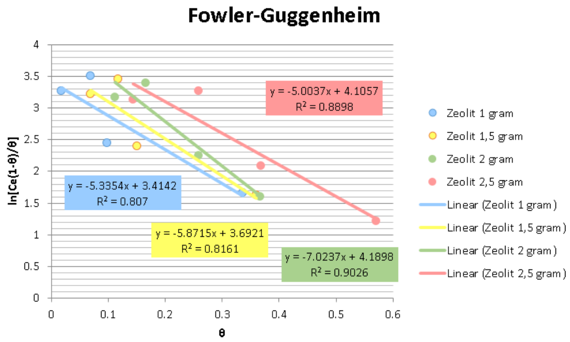

Figure 8. Fowler-Guggenheim adsorption isotherm model

7. Hill-Deboer

Hill-Deboer isotherm describes mobile adsorption and bilateral interactions *between adsorbed molecules. R*^{2}> 0.70 indicates the existence of monolayer on the surface of adsorbent. The results applied to Hill-Deboer model shown in figure 9.

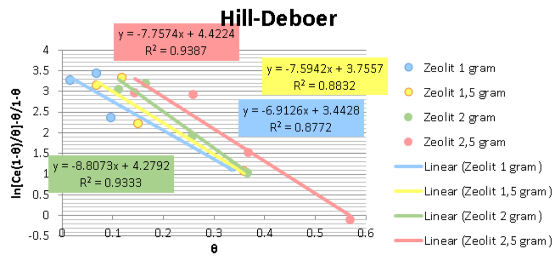

Figure 9. Hill-Deboer adsorption isotherm model

8. Jovanovic

Jovanovic isotherm is based on the Langmuir model's assumptions, but it does not allow for any mechanical contact between the adsorbate and the adsorbent. R2 > 0.70 indicates the existence of monolayer on the surface of adsorbent. The results applied to Jovanovic model shown in figure 10.

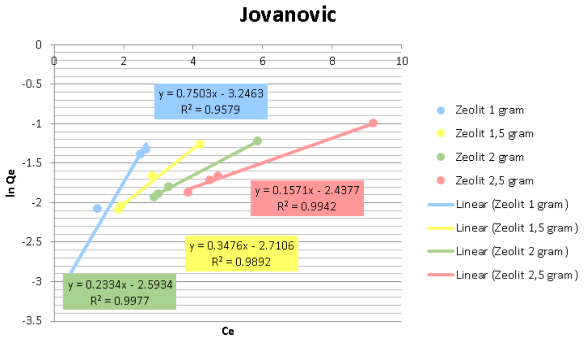

Figure 10. Jovanovic adsorption isotherm model

10. Harkin-Jura

Harkin-Jura model specifies that $R^2 > 0.70$ indicates the existence of multilayer on *the surface of adsorbent and* $R^2 < 0.70$ indicates the existence of monolayer on the surface of adsorbent. The results applied to Harkin-Jura model shown in figure 11.

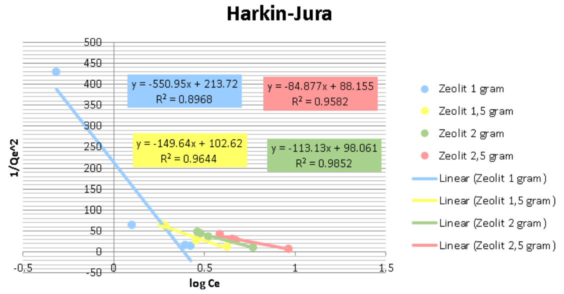

Figure 11. Harkin-Jura adsorption isotherm model

All of those models showed that every mass variation has their own adsorption coefficient of determination (R^2) used to determine the compability of adsorption isothermic model with the experiment data.

Ranging from 1 to 2,5 grams zeolite, the study found based on the average of all R^2 of mass variation respectively. Mass variation of 2,5 grams zeolite provided the most stable and effective adsorption system. Therefore, the mass variation proved that the more zeolite added, the larger surface area of the zeolite combined, thus more adsorption happened.

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Conclusion

This study aims to demonstrate the adrsorption process of turmeric solution using zeolite of various masses with fixed size. The measurement results were compared between zeolites with a mass of 1; 1,5; 2; and 2,5 grams. It was found that the addition of zeolite to the turmeric solution affects the clarity of the solution and increases the amount of light intensity, but must be in a certain ratio. The more zeolites were added; the clearer solution was. The results then plotted to the isotherm adsorption model including Langmuir, Freundlich, Temkin, Dubinin-Radushkevich, Flory Huggins, Fowler-Guggenheim, Hill-Deboer, Jovanovic, Harkin-Jura, and Halsey.Based on the results of plotting and the suitability of the isotherm adsorption model. Most of the model best fits the experimental data obtained.

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