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Effect of Adsorbent Mass and Contact Time on the Removal of Iron (Fe) Metal Ions from Palm Kernel Shells using an Adsorption Column

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ABSTRACT

Palm kernel shell is a waste produced by industrial processing. Its utilization is still widely open as a purification of water, oil, juice, and other uses. This study aims to utilize palm kernel shells as activated carbon for the removal of the Fe metal adsorption process following the isothermal model. The methods used include carbonization, activation, and characterization tests. For the sorption process using carbon mass variations 262; 264; 266; 268; 270; 272; 274; 276 and 278 grams and contact time variations of 15; 20; 25; 30; 35; 40; 45; 50; 55 and 60 minutes. The results of Fe metal removal were analyzed by AAS to obtain an absorption efficiency of 97% at a mass of 278 grams and 89.6% at an optimum time of 25 minutes. The Langmuir isotherm equation obtained adsorption capacity of 0.0139 mg/g and 0.064 mg/g and Freundlich of 92.89 mg/g and 3605.7 mg/g.

Keywords: *Adsorption, Activated Carbon, Heavy Metals, Isotherm Model*

1. INTRODUCTION

In recent years, with rapid industrialization, more and more environmental pollution has occurred. The amount of waste and synthetic chemicals in the aquatic environment is increasing. One of them is heavy metal pollution which can affect living organisms[1]. Heavy metal ions can be separated from water by various methods such as ion exchange, precipitation, coagulation, biosorption, and adsorption [2]. Materials commonly used as adsorbents include activated carbon, zeolite, silica gel, bentonite, and alumina [3].

However, the material commonly used today is activated carbon, where activated carbon is a microcrystalline adsorbent with a porous structure designed to increase internal porosity [4]. One of the adsorbents used is palm kernel shell. Palm kernel shell is a waste obtained after palm kernel processing [5]. This large amount of waste can be used in various applications [6]. This waste can be used as an adsorbent in reducing heavy metal levels using the adsorption method.

In the adsorption mechanism, activated carbon is a commonly used adsorbent for heavy metal removal [7]. The metal removal process can be carried out when the solution containing dissolved particles tends to come into contact with adsorbents with high pore structures[8].

In previous studies, Fe (II) and Ni (II) metals were removed by pyrolysis at 500-800ºC with a concentration of 1 M HCl. So the absorption obtained on Fe^{2+} metal was 83% for 120 minutes and Ni^{2+} was 67% for 150 minutes [9]. In research [10], Fe and Mn levels were removed by carbonization at 600ºC for 5 hours and activated with NaOH and 30% HCl for 24 hours. So the absorption capacity of activated carbon with NaOH is Fe 1.49 ppm and Mn 0.059 ppm with a mass of 20 g and the absorption capacity of activated carbon with HCl is Fe 0.82 ppm and Mn 0.051 ppm with a mass of 10 g. Based on previous research, this research aims to make the absorption capacity in the removal of Fe metal by activated carbon higher by utilizing palm shells as the raw material used.

2. MATERIAL AND METHODS

2.1 Tools and Materials

In this study, tools such as a set of adsorption tools, analytical balance, siever, oven, furnace, porcelain cup, the crucible, Scanning Electron Microscope (SEM), Fourier Transform Infrared Spectroscopy (FT-IR), Atomic Adsorption Spectrophotometry (AAS) were used. The materials used are palm shells, hydrochloric acid (HCl), distilled water, and river water.

2.2 Preparation of Activated Carbon

Palm kernel shells are dried in the sun, then cut into pieces and weighed using an analytical balance before being put into a jug. Put into the furnace at 500ºC for 2 hours. The results of carbonization are crushed and sieved with a size of approximately 10 mesh.

2.3 Chemical Activation

The adsorbent was chemically activated by adding 2 M and 3 M HCl solutions to 500 ml of distilled water for 24 hours. The results of the bath were rinsed using distilled water until it reached a neutral pH. Dry at 110ºC for 1 hour and proceed to test the characteristics of activated carbon from palm kernel shells.

2.4 Fe Metal Ion Sorption Process with Activated Carbon

The effect of optimum mass variation of activated carbon on Fe metal ions was carried out by weighing the adsorbent as much as 262; 264; 266; 268; 270; 272; 274; 276 and 278 grams. After that, the adsorbents were put into the adsorption column in turn. Set the flow rate at 25 mL/minute for 30 minutes. The results obtained were put into a bottle for Fe metal analysis using AAS.

The effect of variation of contact time of Fe metal ions with activated carbon was carried out by weighing 226 grams of adsorbent. After that, the adsorbent was put into the adsorption column and set at a speed of 25 mL/minute for 15; 20; 25; 30; 35; 40; 45; 50; 55, and 60 minutes, respectively. The results obtained were put into a bottle for Fe metal analysis using AAS.

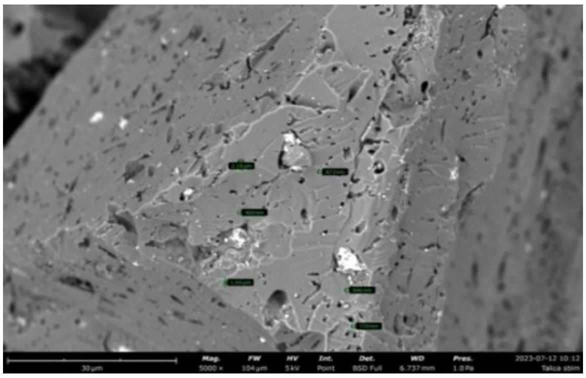
3. RESULTS AND DISCUSSIONS

3.1 Characteristics of Activated Carbon

Activated carbon that has been activated, carried out a characteristic test by SNI 06-3703-1995 to see the quality of activated carbon. The moisture content of activated carbon obtained was 12.7% and 13.4%. High and low water content is also influenced by temperature and activator concentration. The activator concentration increases, the pore area will increase and the adsorption capacity will increase. The fly content was found to be 22.3% and 22.1%. The fly content can decrease due to the increase in carbonization temperature and activator concentration. This occurs due to incomplete decomposition of non-carbon compounds during activation. When the temperature and time of carbonization increase, the amount of vaporized substances increases and causes the fly matter to decrease [11]. Ash content was found to be 2.43% and 2.25%. Ash content greatly affects the quality of activated carbon. The more oxides, the higher the ash content produced, and vice versa. This can cause clogged pores so that the surface area is reduced [12]. The bound carbon content was found to be 80.13% and 80.15%. This shows that activated carbon from palm kernel shells is almost perfectly carbonized. The high and low carbon content, besides being influenced by the activator concentration, is also influenced by the high and low levels of ash and fly matter [13].

3.2 Surface Morphology Analysis of Activated Carbon

SEM aims to determine the morphological characteristics of the adsorbent surface. The results obtained are shown in Figure 1.



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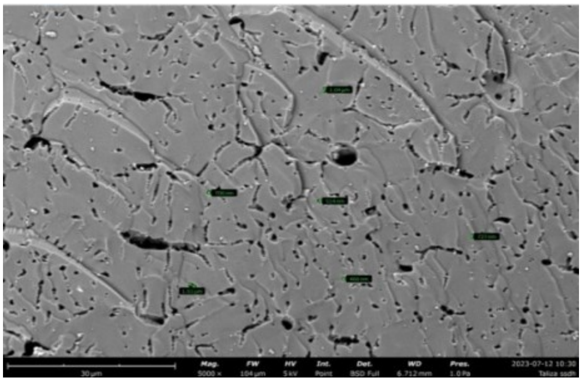

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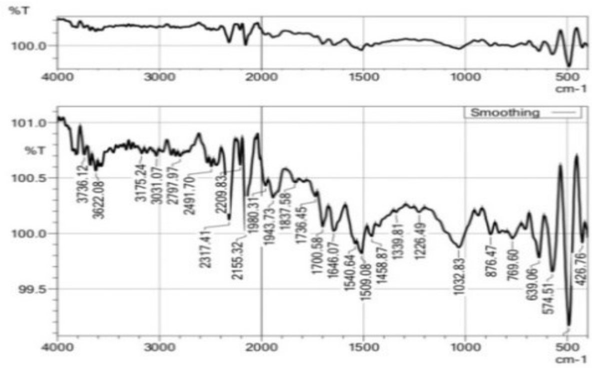
Figure 1. SEM Test Results of Activated Carbon (a) Before Activation and (b) After Activation

Comparison of the SEM results of activated carbon before activation has a larger surface area, seen at 5000X magnification shows a small diameter size of 1.69 µm and a large diameter of 873 µm, while the results of activated carbon after activation show a small diameter size of 1.04 µm and a large diameter of 706 µm. In this case, the activation process is thought to reduce the size of the pores due to the presence of activating substances that stick to the surface to form active ends, and the active ends absorb more substances that are absorbed so that the resulting size is smaller than before the activation process.

3.3 Analysis of Activated Carbon Functional Groups

FT-IR testing aims to obtain the functional groups of activated carbon which can be seen from the wavelengths produced. The results obtained are shown in Figure 2.



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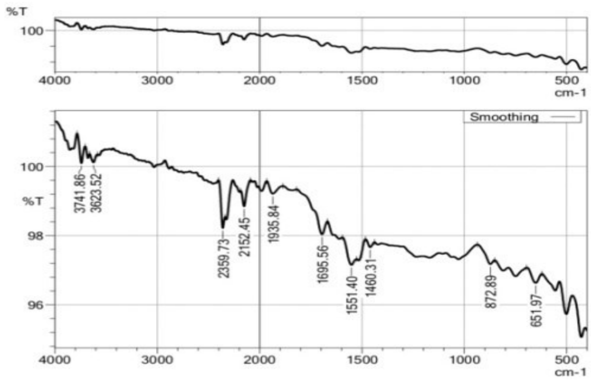


(b)

Figure 2. FT-IR Test Results of Activated Carbon (a) Before Activation and (b) After Activation

The test results showed that the spectrum produced 6 absorption bands that were read. The results identified were at waves 500-4000 cm^{-1}[14]. It can be seen in both figures, that there is a displacement of waves caused by the addition of activators. Strong peaks at 690-900 cm^{-1} and 1340-1470 cm^{-1} are in the C-H alkene group. The 1500-1600 wave absorption peaks at the C=C group of the aromatic ring which means a typical compound of activated carbon. Compared to 1610-1690 cm^{-1} indicates the C=C group with vibration. The aromatic C=O group is at 1750-1950 cm^{-1}, the alkyne C≡C group is at 2100-2260 cm^{-1}, at 3590-3650 cm^{-1}in the double O=H group and 3730-3585 cm^{-1}in the double O-H group 1.

3.4 Determining the Optimum Mass of Fe Metal Ion Absorption

Figure 3 shows that activated carbon can adsorb Fe metal ions, seen at a mass of 278 grams, where the effectiveness of adsorption is 97%. Determination of the effectiveness of Fe metal adsorption by activated carbon from palm kernel shells can be seen in Figure 3. Based on theory, the increase in the number of adsorbents is equivalent to the increase in the number of particles and surface area, as a result, the binding amount and efficiency of metal ions increase [15].

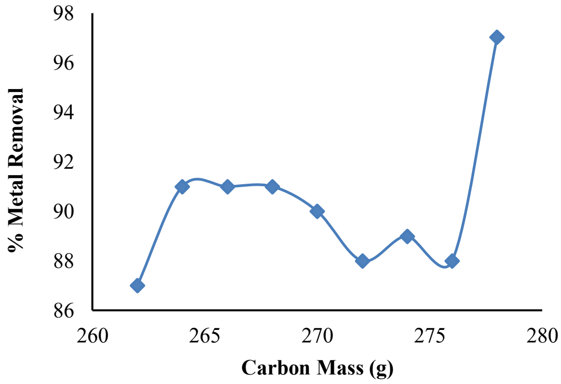


Figure 3. Effect of Carbon Mass on % Metal Removal

The effect of the amount of adsorbent becomes a reference parameter to determine the adsorbent capacity of the initial concentration added [16]. Looking at the graph above indicates that activated carbon from palm shells can reduce Fe metal levels. The percentage increase is due to the increase in adsorbent mass, so the adsorption capacity is greater and the ability to contact metals is higher, thus making many metal ions adsorbed.

3.5 Determining the Optimum Time for Fe Metal Ion Absorption

Seen in Figure 4 states that activated carbon can adsorb Fe metal ions by 89.6% for 25 minutes, but in the next minute there is a decrease, so it can be concluded that the absorption that occurs is not optimal. The effectiveness of Fe metal adsorption in determining the optimum contact time is shown in Figure 4.

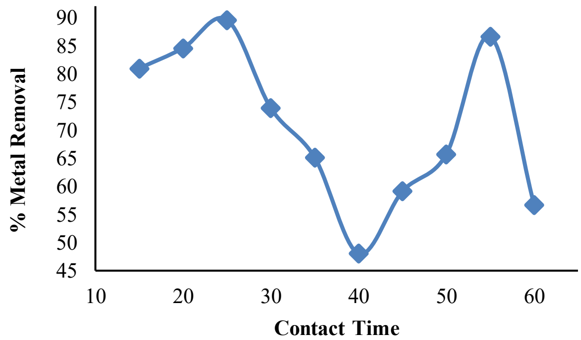
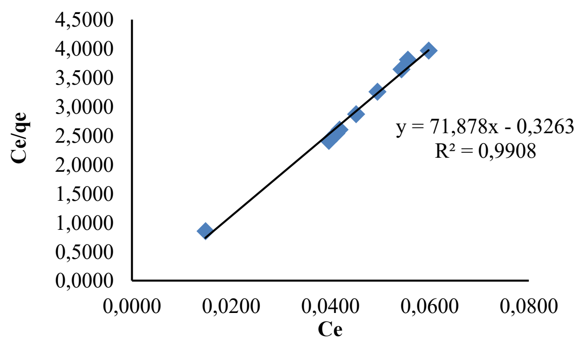


Figure 4. Effect of Adsorption Contact Time on % Metal Removal

Theoretically, the length of contact time of activated carbon makes more metals absorbed. In addition, with increasing adsorption speed, the smaller the particle size [17] so that in the 25th minute the optimal time is reached. This happens because the reaction works quickly.

In the 30th minute, there was a decrease, which is estimated to be at the saturation point. Where the absorption conditions are too long, the bound metal ions will be released again or desorption will occur.

Based on the results of the study when it has reached optimal conditions, the contact time does not bind the adsorption optimally. This happens because the situation is saturated so that it reaches the equilibrium point.



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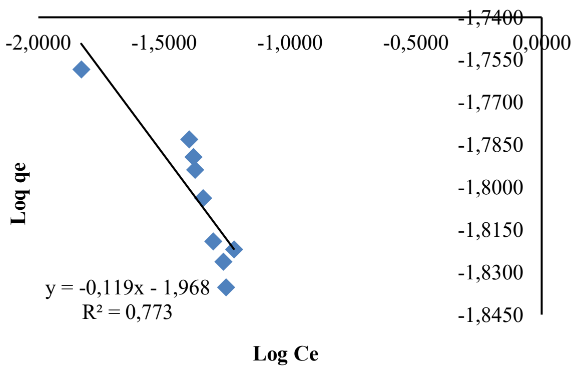
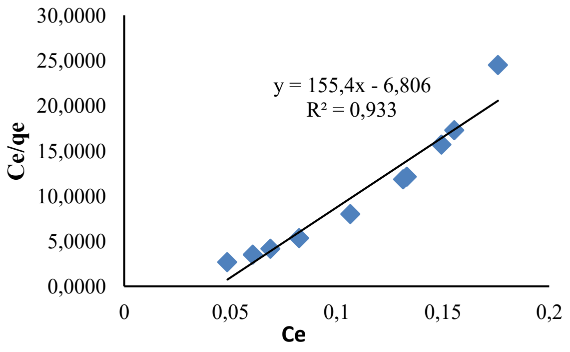


(b)

Figure 5. (a) Langmuir Isotherm and (b) Freundlich Isotherm in the Fe Metal Ion Sorption in Carbon Mass Variation

In addition, the adsorption process can be influenced by factors such as isotherm models, such as Freundlich and Langmuir. Adsorption capacity can be calculated from the slope obtained in the known linear equation. The curve between Log qe and Loq Ce shows the Freundlich isotherm, while the curve between Ce/qe and Ce shows Langmuir [18]. For further explanation, see Figure 5 and Figure 6.



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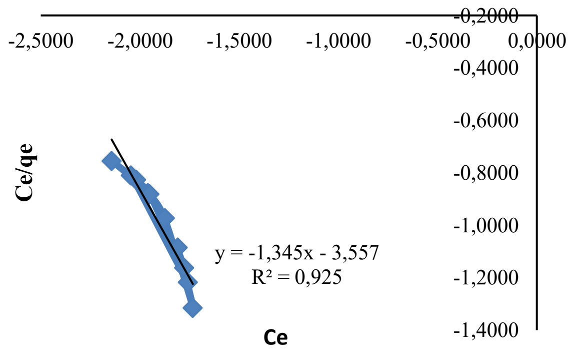

(b)

Figure 6. (a) Langmuir Isotherm and (b) Freundlich Isotherm in the Fe Metal Ion Sorption at Variation of Contact Time

In the Langmuir adsorption equation, the equations y = 71.87x - 0.326 with R^2 = 0.990 and y = 155.4x - 6.806 with R^2 = 0.933 were obtained. This equation model states that the adsorption of palm kernel shell-activated carbon on Fe metal ions is homogeneous or only one keli surface coating occurs. While in the Freundlich adsorption equation the equation y = 0.119x - 1.968 with R^2 = 0.773 and y = 1.345x - 3.557 with R^2 = 0.925. The Freundlich equation model states that there is more in the surface layer and the sides are heterogeneous, so there are differences in bond energy on each side [19]. The calculation results show the maximum adsorption power is 46.344 mg/g and 1333.52 mg/g.

4. CONCLUSIONS

Activated carbon from palm kernel shells can absorb Fe metal at an optimum mass of 140 grams with an adsorption effectiveness of 97% and an optimum contact time of 25 minutes with an adsorption effectiveness of 90%. The adsorption capacity in the Langmuir equation is 0.0276 mg/g and 0.0128 mg/g, while Freundlich is 46.344 mg/g and 1333.52 mg/g.

The use of HCl activator concentration does not determine how much it affects the characteristics of activated carbon. This is because the value is not much different (fluctuating). However, it can be seen from the results of SEM and FT-IR analysis.

REFERENCES

[1] R. R. Karri and J. N. Sahu, "Process optimization and adsorption modeling using activated carbon derived from palm oil kernel shell for Zn (II) disposal from the aqueous environment using differential evolution embedded neural network," *J. Mol. Liq.*, vol. 265, no. 1, pp. 592–602, 2018, doi: 10.1016/j.molliq.2018.06.040.

[2] A. Khamwichit, W. Dechapanya, and W. Dechapanya, "Adsorption Kinetics and Isotherms of Binary Metal Ion Aqueous Solution Using Untreated Venus Shell," *Heliyon*, vol. 8, no. 6, p. e09610, 2022, doi: 10.1016/j.heliyon.2022.e09610.

[3] V. Nejadshafiee and M. R. Islami, "Adsorption Capacity of Heavy Metal Ions Using Sultone-Modified Magnetic Activated Carbon as a Bio-Adsorbent," Mater. Sci. Eng. C, vol. 101, no. 3, pp. 42–52, 2019, doi: 10.1016/j.msec.2019.03.081.

[4] Hisbullah, S. Kana, Nabila, and M. Faisal, "Characterization of Physically and Chemically Activated Carbon Derived From Palm Kernel Shells," *Int. J. GEOMATE*, vol. 23, no. 97, pp. 203–210, 2022, doi: 10.21660/2022.97.7554.

[5] E. Baffour-Awuah, S. A. Akinlabi, T. C. Jen, S. Hassan, I. P. Okokpujie, and F. Ishola, "Characteristics of Palm Kernel Shell and Palm Kernel Shell-Polymer Composites: A Review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1107, no. 1, p. 012090, 2021, doi: 10.1088/1757-899x/1107/1/012090.

[6] I. Uchegbulam, E. O. Momoh, and S. A. Agan, "Potentials of Palm Kernel Shell Derivatives: a Critical Review on Waste Recovery for Environmental Sustainability," *Clean. Mater.*, vol. 6, p. 100154, 2022, doi: 10.1016/j.clema.2022.100154.

[7] T. M. Asnawi, H. Husin, A. Adisalamun, W. Rinaldi, M. Zaki, and F. Hasfita, "Activated Carbons from Palm Kernels Shells Prepared by Physical and Chemical Activation for Copper Removal from Aqueous Solution," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 543, no. 1, 2019, doi: 10.1088/1757-899X/543/1/012096.

[8] V. V. Dev, K. K. Nair, G. Baburaj, and K. A. Krishnan, "Pushing The Boundaries of Heavy Metal Adsorption: A Commentary on Strategies to Improve Adsorption Efficiency and Modulate Process Mechanisms," *Colloids Interface Sci. Commun.*, vol. 49, p. 100626, 2022, doi: 10.1016/j.colcom.2022.100626.

[9] G. O. Chie-Amadi, "Kinetics and Isotherm of Heavy Metal Adsorption on Activated Nigerian Coconut Shell and Corn Cob," *NEWVIEWS Eng. Technol.*, 2021.

[10] E. Eprie, K. Bungas, and A. Abudarin, "Pemanfaatan Arang Cangkang Sawit Teraktivasi NaOH dan HCl dalam Menurunkan Kadar Fe, Mn dan Zat Warna pada Air Gambut," *J. Environ. Manag.*, vol. 3, no. 2, pp. 146–152, 2022, doi: 10.37304/jem.v3i2.5506.

[11] A. Nurrahman, E. Permana, D. R. Gusti, and I. Lestari, "Pengaruh Konsentrasi Aktivator Terhadap Kualitas Karbon Aktif dari Batubara Lignit," *J. Daur Lingkung.*, vol. 4, no. 2, p. 44, 2021, doi: 10.33087/daurling.v4i2.86.

[12] S. Oko, Mustafa, A. Kurniawan, and E. S. B. Palulun, "Pengaruh Suhu dan Konsentrasi Aktivator HCl terhadap Karakteristik Karbon Aktif dari Ampas Kopi," *Metana Media Komun. Rekayasa Proses dan Teknol. Tepat Guna*, vol. 17, no. 1, pp. 15–21, 2021.

[13] R. Dewi, A. Azhari, and I. Nofriadi, "Aktivasi Karbon Dari Kulit Pinang Dengan Menggunakan Aktivator Kimia Koh," *J. Teknol. Kim. Unimal*, vol. 9, no. 2, p. 12, 2021, doi: 10.29103/jtku.v9i2.3351.

[14] D. M. Hafidoh, "Dari Bambu Menggunakan Aktivator HCl Sebagai Adsorben Timbal (Pb)," *Univ. Islam Negeri Maulana Malik Ibrahim Malang*, 2021.

[15] S. R. Y. Reyra, Anilza Silvi, Syarfi Daud, "Pengaruh Massa dan Ukuran Partikel Adsorben Daun Nanas Terhadap Efisiensi Penyisihan Fe Pada Air Gambut," *Jom FTEKNIK*, vol. 4, no. 02, 2017.

[16] R. P. Anjani and T. Koestiari, "Penentuan Massa dan Waktu Kontak Optimum Adsorpsi Karbon Granular Sebagai Adsorben Logam Berat Pb(II) Dengan Pesaing Ion Na+," *UNESA J. Chem.*, vol. 3, no. 3, pp. 159–163, 2014.

[17] S. H. S. Hasmalina Nasution, Mayudendi, "Penentuan Waktu Kontak dan pH Optimum Penyerapan Zat Warna Direct Yellow Menggunakan Abu Terbang (Fly Ash) Batubara," *Semirata 2015*, vol. 0, no. 0, pp. 747–756, 2016, [Online]. Available: http://jurnal.untan.ac.id/index.php/semirata2015/article/view/14296

[18] I. Wahyuni and R. Fathoni, "Production of Activated Carbon from Palm Oil Shells with Variation of Activation Time," *J. Chemurg.*, vol. 3, no. 1, p. 11, 2019.