

Utilization of Activated Carbon/Magnesium(II) Composites in Decreasing Organic Materials

Pemanfaatan Komposit Karbon Aktif/Magnesium(II) Dalam Penurunan Kadar Bahan Organik

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Article History

Received: 11th February 2023; Revised: 08th August 2023; Accepted: 10th August 2023;

Available online: 22th August 2023; Published Regularly: June 2023

doi: [10.25273/cheesa.v6i1.15662.63-75](https://doi.org/10.25273/cheesa.v6i1.15662.63-75)

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Abstract

This study aimed to determine the characteristics, adsorption capacity, and isotherm of the adsorbent AC/Mg(II) composite in decreasing organic matter in peat water. Activated carbon was produced from empty fruit bunches of oil palm containing high levels of lignocellulose. Carbon was synthesized through the carbonization process and then activated with CH_3COONa . The activated sample was composited with magnesium nitrate hexahydrate through an in-situ method under alkaline conditions using NaOH. The adsorbent AC/Mg(II) composite that had been prepared was characterized using FTIR, showing the presence of Mg-O bonds at the absorption wave number of 403.12 cm^{-1} . The results showed that the moisture content of the adsorbent was lower compared to activated carbon, namely 1.30%. Furthermore, the best mass was 2 g AC/Mg(II) with an adsorption of 2.26 mg/g and an organic matter adsorption percentage of 14.41%. Furthermore, the optimum contact time was 15 minutes with an adsorption of 2.42 mg/g and a percentage of 17.15%. The mechanism occurring in the AC/Mg(II) composite with peat water organic matter followed the Langmuir isotherm equation, which formed a monolayer. The equation gave R^2 , adsorption capacity (Q_0), and adsorption constant (k) values of 0.9994, 0.2340 mg/g, and 0.0047, respectively.

Keywords: Activated carbon; fruit bunches; Magnesium(II); organic matter; peat water

Abstrak

Penelitian ini bertujuan untuk menentukan karakteristik adsorben AC/Mg(II) serta mengetahui kapasitas adsorpsi dan isoterm adsorpsi terhadap penurunan kadar bahan organik air gambut. Karbon aktif dipreparasi dari tandan kosong kelapa sawit (TKKS) yang merupakan limbah yang mengandung lignoselulosa tinggi sebagai sumber karbon. Karbon dibuat melalui proses karbonisasi kemudian diaktivasi dengan CH_3COONa . Karbon aktif dikompositkan dengan magnesium nitrat heksahidrat melalui teknik in-situ dalam suasana basa menggunakan NaOH. Adsorben komposit AC/Mg(II) yang telah dibuat dikarakterisasi menggunakan FTIR menunjukkan adanya ikatan Mg-O muncul pada serapan bilangan gelombang $403,12 \text{ cm}^{-1}$. Kadar air adsorben AC/Mg(II) lebih rendah dari karbon aktif yaitu 1,30%. Hasil penelitian menunjukkan massa adsorben terbaik adalah 2 g AC/Mg(II) dengan daya adsorpsi 2,26 mg/g dan persentase adsorpsi bahan organik sebesar 14,41%. Waktu kontak terbaik adalah 15 menit dengan daya adsorpsi 2,42 mg/g dan persentase adsorpsi bahan organik 17,15%. Mekanisme adsorpsi yang terjadi pada komposit AC/Mg(II) dengan bahan organik air gambut mengikuti persamaan isoterm adsorpsi Langmuir yang membentuk lapisan monolayer dengan nilai R^2 sebesar 0,9994, nilai kapasitas (Q_0) sebesar 0,2340 mg/g dan nilai konstanta adsorpsi (k) sebesar 0,0047.

Kata Kunci: air gambut; bahan organik; karbon aktif; Magnesium(II); tandan kosong kelapa sawit.

1. Introduction

Peat water is a type of surface water found in peatland areas and is characterized by its acidic nature (low pH), yellow to brown color, and high organic matter content. Furthermore, its primary organic components are humic and fulvic acids, which are primarily responsible for its properties. This resource can be treated to obtain clean water by reducing organic matter to meet the standard quality criteria. Several methods have gained widespread usage for the treatment process, including adsorption [1], membrane separation, and coagulation-flocculation [2]. Among these methods, adsorption holds a distinct preference due to its economic feasibility, ease of use, high efficiency, and ability to remove undesired compounds [3]. An extensively studied adsorbent is activated carbon derived from oil palm empty fruit bunches (EFB).

The high lignocellulose content within oil palm EFB offers a foundational resource for the production of activated carbon due to the presence of active functional groups, such as hydroxyl and carboxyl. These groups have been reported to serve as active sites for the binding of metals [4]. Despite this inherent potential, the adsorption capacity of the adsorbent is still suboptimal. This indicates that its combination with other nanoparticles is required to enhance the adsorption capability [5].

Several studies have reported the capacity of MgO nanoparticles to significantly decrease COD levels in tannery wastewater. In a previous study, the concentration dropped from an initial 2725.9 mg/L to 126.5 mg/L [6]. Furthermore, MgO exhibits the capacity to reduce the concentration of humic acid within a solution, with a maximum

efficiency of approximately 91% after a contact time of 20 minutes [7].

Ghalekhondabi et al. [8] have composited MgO with activated carbon to adsorb methylene blue organic compounds. The composite showed an impressive maximum adsorption efficiency and capacity of 97.5% and 642 mg/g, respectively. Chemical modifications have also been widely used to enhance the quality of activated carbon as an adsorbent for broader applications [9].

Activated carbon has showcased its utility in the removal of Fe(II) from peat water [10] and the reduction of organic matter [11]. The positive results obtained from the use of this adsorbent in adsorbing Fe(II) and organic matter formed the foundation for this current study to employ the Activated Carbon/Magnesium(II) (AC/Mg(II)). Activated carbon was combined with magnesium(II), where the positive charge of Mg interacted with the negative charge on the surface of the adsorbent. This interaction hinged on the connection between the hydroxyl groups on the activated carbon surface and magnesium, aiming to enhance the capacity and efficiency of organic matter adsorption in peat water.

The use of Mg offers the potential to greatly enhance the ability of the composite to adsorb organic matter due to the formation of complex compounds between organic molecules and the metal. Organic matter content reduction occurs through Mg complexation with organic substances within the pores of activated carbon. Organic compounds carrying a negative charge often bond with the positive charge of composites and vice versa [12]. Therefore, this study aimed to create activated carbon from EFB, which was activated using CH₃COONa. The

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matter was then composited with Mg(II) as an adsorbent for organic matter in peat water. CH₃COONa exhibited the best performance in activating EFB charcoal compared to ammonium chloride and ammonium sulfate [13]. The adsorbent produced was subjected to characterization using FTIR to identify functional groups or bonds formed within the AC/Mg(II) composite, with subsequent comparison to the results of activated carbon. This study examined the influence of adsorbent mass and contact time to determine the optimum capacity of carbon composite for organic matter in peat water using a batch system. Furthermore, the adsorption isotherm model occurring during the process was also determined.

2. Research Methods

2.1 Tools and Materials

The instruments used in the study included Shimadzu 820 IPC Fourier Transform Infra Red (FTIR) and Shimadzu 1280 UV-Vis (Ultra Violet-Visible) Spectrophotometer. Meanwhile, the matters were peat water, CH₃COONa (Merck), H₂C₂O₄, H₂SO₄ 98% (8 N), KMnO₄ (0,01 N), Mg(NO₃)₂.6H₂O (Merck), methylene blue (Merck), NaOH (Merck), and EFB.

2.2 Carbonization of EFB for Activated Carbon

The EFB samples were pulverized, washed with deionized water, and dried for six days under direct sunlight. Approximately 200 g of dried EFB were then placed in a crucible, transferred to a furnace at a temperature of 350 °C for 1 hour, and placed in a closed container. Furthermore, the percentage of water loss after the carbonization process was calculated. The carbonized sample was

then ground and sieved using a 100-mesh sieve to obtain a uniform particle size.

2.3 Carbon Activation

A total of 61.18 g of carbon was placed in a round-bottom flask equipped with a condenser and a magnetic stirrer. Subsequently, 250 mL of 1 N CH₃COONa solution was added to the flask, and the mixture was refluxed for 1 hour using a hotplate at approximately 120 °C. After the reaction mixture was cooled to room temperature, the solid was filtered and washed with deionized water [13]. The solid was then dried in an oven at 110 °C for 6 hours, leading to the production of activated carbon.

2.4 Preparation of AC/Mg(II) Composites

Magnesium oxide was composited with activated carbon in a 1:1 ratio. A total of 42 g of Mg(NO₃)₂.6H₂O was dissolved in 250 mL of deionized water and stirred. In the mixture, 15 mL of NaOH 2M and 42 g of activated carbon (obtained from procedure 2.3) were slowly added while stirring gently for 60 minutes. The suspension obtained was allowed to stand for 60 minutes and slowly decanted. Subsequently, the residue was dried in an oven for 24 hours at a temperature of 80 °C and calcined at 350 °C for 60 minutes.

2.5 Characterization of the AC/Mg(II) Composites

The characterization of activated carbon and composites was carried out by determining the moisture content, adsorption capacity, and functional groups using FTIR.

2.5.1 Determination of Functional Groups Using FTIR

Activated carbon and AC/Mg(II) composite samples were prepared, weigh-

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ing approximately 0.5 g, and then stored in containers. Furthermore, the samples were analyzed using an FTIR at Hasanuddin University, Makassar.

2.5.2 Determination of Moisture Content

A total of 1 g of activated carbon was weighed and placed in a porcelain crucible of known weight (sample weight was denoted as W_1). The porcelain crucible was then placed in an oven at 105 °C for 2 hours. After cooling in a desiccator, it was weighed until a constant weight was achieved (denoted as W_2). The calculation formula for determining the moisture content is presented in Equation 1.

$$\text{Moisture Content} = \frac{W_1 - W_2}{W_1 - W} \times 100\% \dots\dots(1)$$

W = Weight of crucible (g)

W_1 = Initial sample weight before oven drying (g)

W_2 = Sample weight after oven drying (g)

2.5.3 Methylene Blue Adsorption Test (SNI 06-3730-1995)

A Methylene Blue (MB) solution was prepared with a concentration of 10 ppm, and its absorbance was measured in a wavelength range of 500–700 nm using a UV-Vis spectrophotometer. A standard curve was then established based on the absorbance of standard MB solutions with concentrations of 0, 0.5, 1, 1.5, 2, 2.5, and 3 ppm at the maximum wavelength. Furthermore, a graph relating the absorbance to the concentration was plotted, and it was used to obtain the linear equation. Activated carbon and composites were tested for MB adsorption. The samples were combined with 25 mL of a 3 ppm MB solution and shaken using a shaker at 240 rpm for 15 minutes. The mixture was then filtered using Whatman No. 42 filter paper, and the filtrate was measured using a UV-Vis spectrophotometer at the maximum

wavelength to determine the final concentration. The amount of MB adsorbed was calculated using Equation 2.

$$MB = \frac{(C_{mb \text{ awal}} \times V_{mb}) - (C_{mb \text{ sisa}} \times V_{mb})}{W_{\text{Sample}}} \dots\dots\dots(2)$$

MB = Amount of adsorbed MB (mg/g)

$C_{mb \text{ initial}}$ = Initial MB concentration (ppm)

$C_{mb \text{ residual}}$ = Residual MB concentration (ppm)

V_{mb} = Volume of MB solution used (mL)

W_{sample} = Sample weight (g)

After calculating the adsorbed MB concentration, the surface area of activated carbon and AC/Mg(II) was determined using equation 3.

$$S = \frac{Q_t \times N \times A}{M_r} \dots\dots\dots(3)$$

S = Surface area of activated carbon and AC/Mg(II) (mg/g)

Q_t = Weight of adsorbed substance (mg/g)

N = Avogadro's number ($6,022 \times 10^{23} \text{ mol}^{-1}$)

A = Area covered by 1 molecule of the sample ($197 \times 10^{-20} \text{ m}^2$)

M_r = Relative molecular mass of MB (320,5 g/mol)

2.6 Determination of Organic Matter Content in Peat Water Using Permanganometry Method

A total of 100 mL of the sample was placed into an Erlenmeyer flask, and three boiling stones were added. A few drops of 0.01 N KMnO_4 were added to the sample until a pink color appeared. Subsequently, 5 mL of 8 N H_2SO_4 was added, and the mixture was heated on an electric heater at a temperature of 105 °C \pm 2 °C. The process was continued with the addition of 10 mL of 0.01 N KMnO_4 standard solution, followed by boiling for 10 minutes. A total of 10 mL of 0.01 $\text{H}_2\text{C}_2\text{O}_4$ solution was added and the mixture was titrated with 0.01 N KMnO_4 0,01 N solution until a pink color appeared. The

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volume of KMnO₄ used was recorded and if the value exceeded 7 mL, the test was repeated by diluting the sample. The procedure was repeated twice (duplicate), and the equivalent value of permanganate could be determined using Equation 4.

$$KMnO_4 = \frac{[(10-1)b - (10 \times c)] \times 31,6 \times 1000}{d} \dots\dots\dots(4)$$

- a = Volume of KMnO₄ 0,01 N required during titration
- b = Actual normality of KMnO₄
- c = Normality of H₂C₂O₄
- d = Volume of the sample

2.7 Determination of the Relationship Between Peat Water Absorbance and Permanganate Number

The relationship between peat water absorbance and the permanganate number was determined by creating a calibration curve between both parameters. The association was initially established by determining the permanganate number of peat water with dilution variations of 30-fold, 40-fold, 50-fold, 60-fold, and 70-fold. Subsequently, the absorbance was measured with the same dilution variations at a wavelength of 254 nm using a UV-Vis spectrophotometer. A linear equation was derived based on the curve depicting the relationship between peat water absorbance and the permanganate number. This equation was then used to determine peat water's organic matter content before and after adsorption.

2.8 Application of AC/Mg(II) Composites as an Adsorbent

2.8.1 Determination of Optimal Adsorbent Mass for AC/Mg(II) Composites

A total of 4 Erlenmeyer flasks were each filled with 100 mL of peat water. Furthermore, different variations of adsorbent mass, namely 0.5 g, 1.0 g, 2.0 g,

and 3.0 g, were added to each flask. The mixtures were stirred using a shaker at a speed of 150 rpm for 60 minutes and left undisturbed for 1 hour [14]. The solutions were filtered, and the organic matter content of peat water was determined using a UV-Vis spectrophotometer at a wavelength of 254 nm and measured for the permanganate number.

2.8.2 Determination of Optimal Contact Time

In this process, 5 Erlenmeyer flasks were each filled with 100 mL of peat water. The optimal adsorbent mass of 2 g was added to each flask, and stirring was carried out using a shaker at a speed of 150 rpm with varying contact times of 10, 15, 30, 45, and 60 minutes. The mixtures were then left undisturbed for 1 hour, followed by filtration. Subsequently, the organic matter content of peat water was determined using a UV-Vis spectrophotometer at a wavelength of 254 nm and measured for the permanganate number.

2.9 Determination of Adsorption Isotherms

The obtained data were analyzed using the Langmuir and Freundlich adsorption isotherm equations. The Langmuir isotherm determination used Equation 5, while the Freundlich isotherm used Equation 6.

$$\frac{Q_e}{C_e} = kQ_0 - kQ_e \dots\dots\dots(5)$$

- C_e = Equilibrium concentration of adsorbate (mg/L)
- Q_e = Total of adsorbate on adsorbent at equilibrium (mg/g)
- Q₀ = Adsorption capacity (mg/g)
- k = Langmuir isotherm constant

$$\text{Log } Q_e = \text{Log } kF + \frac{1}{n} \log C_e \dots\dots(6)$$

- kF = Freundlich isotherm constant
- n = Intensity of adsorption

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Langmuir and Freundlich Isotherm Models explain the formation of monolayer and multilayer adsorption, respectively. The determination of the equilibrium model for Langmuir and Freundlich isotherms was based on the coefficient of determination (R^2), with the highest value indicating the preferred model.

3. Results and Discussion

3.1 Oil Palm EFB Carbonization

The carbonization process of EFB was carried out in several steps. The first phases involved preparation, including size reduction, retting, water soaking, and drying. Size reduction was performed manually, followed by a retting process to separate the fiber portions since EFB was a collection of intertwined fibers. Approximately 3.10 kg of EFB fibers were soaked in hot water to remove impurities and extract any remaining oil. This was to ensure that it did not hinder the heat during the carbonization process. The EFB fibers were then drained to separate water and oil. Sun-drying was performed to eliminate any remaining moisture in the samples and reduce the raw matter's volume [15]. Furthermore, the drying process aimed to facilitate carbonization and reduce the volume of the raw matter.

The carbonization process was carried out using a furnace at 350 °C for 1 hour. At temperatures between 300 °C and 400 °C, the process was considered primary pyrolysis, which yielded charcoal, various gases, and H_2O . This was due to the decomposition of wood components, such as hemicellulose, cellulose, and lignin present in EFB, leading to complete carbonization.

The yield of carbonized EFB was 204.69 g, but it was reduced to 62.21 g

after grinding, and only 50.01 g passed through the 100-mesh sieve. The carbon yield obtained from EFB was 74.01% of the original sample, accounting for the loss of 25.99%. Carbon obtained from the furnace process was then ground and sieved using a 100-mesh sieve to produce particles of uniform size and increase the contact surface area, thereby enhancing the adsorbent's ability to absorb adsorbates.

3.2 Activation of EFB Carbon

This study employed chemical activation using CH_3COONa as the activator. The aqueous CH_3COOH species from CH_3COONa salt interacted with the decomposition products generated during the carbonization process on the surface of the EFB charcoal. A 250 mL acetic acid solution was used to soak the carbon. Furthermore, the activation was aided by heating to accelerate penetration [16].

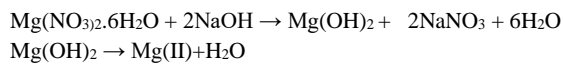
The activation process gave a yield of 97.99% or 58.94 g of the product. The process led to both physical and chemical changes in carbon. Carbon's color became slightly darker, with a smoother texture, decreased mass, and opened pores. These changes increased the surface area and affected its adsorption properties. Based on the obtained yield results, the content of compounds or impurities lost was 2.01%. The low content of non-carbon compounds or impurities lost was because the compounds that reacted with the activator had been completely consumed and transformed into soluble minerals [17].

3.3 AC/Mg(II) Composites

The production of AC/Mg(II) composite was carried out using a solution of Magnesium Nitrate Hexahydrate ($Mg(NO_3)_2 \cdot 6H_2O$) as a precursor along with the addition of NaOH. The

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Mg(NO₃)₂·6H₂O solution mixture with NaOH base solution formed a Mg(OH)₂ sol. The Mg(OH)₂ obtained was then composited within the structure of activated carbon. Furthermore, the calcination process was conducted to transform Mg(OH)₂ into MgO based on the reaction below [18]:



The calcination process was carried out using a furnace at 500°C for 2 hours. However, the use of high temperatures and a sufficiently long duration led to the formation of ash by composite. Consequently, the temperature of the process was adjusted to 350°C. The formation of ash was because activated carbon used in composites was derived from EFB, which were soft matter and could not be calcined at high temperatures.

The ideal condition for the formation of MgO was a temperature range of 500 – 700 °C for 1–2 hours [19,20]. Based on these results, it could not be concluded that composite matter contained MgO. However, from the characterization results,

it could be inferred that Mg(II) was composited within activated carbon. Magnesium was incorporated into activated carbon through the hydroxyl groups of Mg(OH)₂ on the surface of activated carbon.

3.4 Characterization of Activated Carbon and AC/Mg(II) Composites

3.4.1 FTIR Characterization

Activated Carbon and AC/Mg(II) composites were characterized using FTIR to identify functional groups and bonds present in the adsorbents. Figure 1 (red line) showed the FTIR results of EFB-activated carbon. It was observed that in the process of producing activated carbon, absorptions occurred at wavenumbers 3419.79 cm⁻¹, 2924.09 cm⁻¹, 1705.07 cm⁻¹, 1604.77 cm⁻¹, 1379.10 cm⁻¹, and 1246.02 cm⁻¹. Each of these wavenumbers represented vibrations, namely stretching of –OH, CH₃, and CH₂, C=O stretching, C=C vibration in the hexagonal carbon structure, bending vibration of C-H, and C-O functional groups related to ethers and esters.

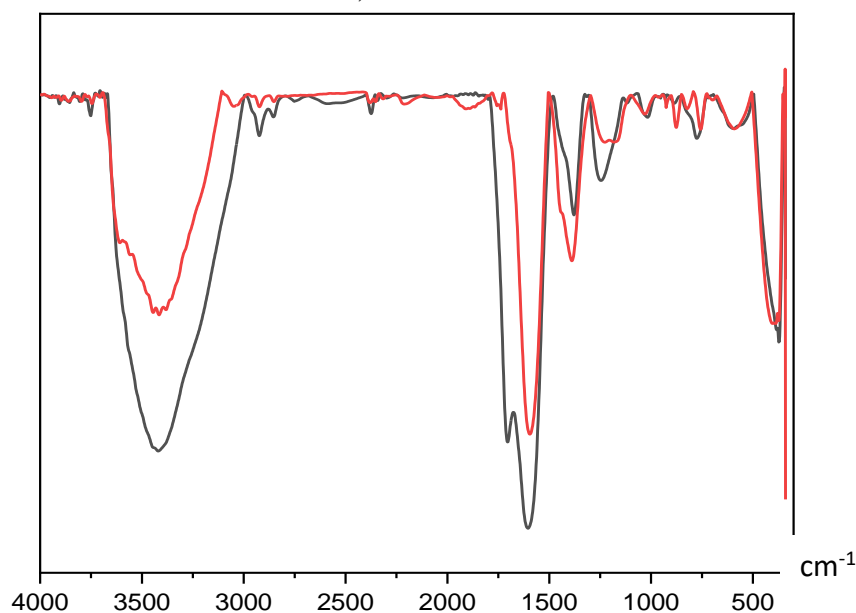


Figure 1. FTIR spectra of EFB activated carbon and AC/Mg(II) composites

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The black line indicated the FTIR results for the production of the AC/Mg(II) composite. Absorptions were observed at wavenumber 3415.93 cm^{-1} , indicating –OH stretching vibrations. An absorption at wavenumber 1595.13 cm^{-1} indicated the presence of aromatic C=C bonds in the activated carbon structure. According to Khaleel et al. [19], the wavenumber 1566 cm^{-1} signified the stretching vibration of the Mg-OH bond. The decrease in wavenumbers between activated carbon and composite in this study suggested the presence of formed Mg(II). The wavenumber 1388.75 cm^{-1} indicated the bending vibration of C-H, while 1226.73 cm^{-1} and 1182.36 cm^{-1} showed C-O vibrations. Another bond present in the AC/Mg(II) composites was seen at wavenumber 403.12 cm^{-1} , indicating Mg-O vibrations from MgO. Khaleel et al. [19] reported the presence of Mg-O vibrations in the wavenumber range of 400 cm^{-1} to 480 cm^{-1} . Moreover, Nga et al. [18] stated that this phenomenon was also found at wavenumber 409 cm^{-1} . The shift in wavenumbers from activated carbon to AC/Mg(II) composites towards smaller values is due to the interaction of magnesium with oxide, leading to the formation of magnesium bonds. The intensity of the Mg-O vibration absorption indicated the presence of Mg(II) on activated carbon surface.

3.4.2 Moisture Content

The results from Table 1 showed that activated carbon and AC/Mg(II) composites had a moisture content of 8.29% and 1.30%, respectively. These values were consistent with the SNI 06-3730-1995 standard, which is specify a maximum of $< 15\%$. The composite process reduced the adsorbent's moisture

content due to the release of water molecules or hydration during the heating process. The lower values indicated that less residual water covered the activated carbon pores. Consequently, the pores of activated carbon became larger, leading to an increase in the surface area.

3.4.3 Methylene Blue Adsorption Test

Figure 2 showed that the adsorption capacity of activated carbon for MB was 383.657 mg/g with an adsorption efficiency of 52.70%. In comparison, the adsorption capacity of the AC/Mg(II) composites was 682.286 mg/g , with an adsorption efficiency of 92.80%. These results were consistent with Ghalekhondabi et al. [8] who stated that the AC/MgO composite could adsorb MB with a maximum efficiency and adsorption capacity of 97.50% and 642 mg/g , respectively. Furthermore, the characterization results of the adsorption capacity of activated carbon and composite for methylene blue met the SNI 06-3730-1995 standard, which required a minimum of 120 mg/g [18].

Table 1. Moisture content results for activated carbon and AC/Mg(II) composites

Sample	Moisture content %
Activated Carbon	8.29 %
AC/Mg Composites	1.30 %

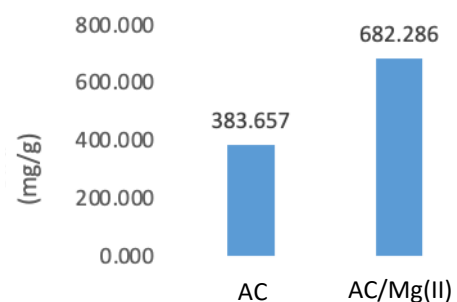


Figure 2. Methylene blue adsorption test

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Another result obtained from the MB adsorption test was the specific surface area of activated carbon and AC/Mg(II). This parameter was determined based on the adsorption capacities of activated carbon and AC/Mg(II) for the MB compound, with values of 1420.38 m²/g and 2524.43 m²/g, respectively. The specific surface area of the adsorbent significantly affected its adsorption capacity. This indicated that the larger the specific surface area of the adsorbent, the greater its adsorption capability.

3.5 Application of AC/Mg(II) Composites as Organic Matter Adsorbent

3.5.1 Relationship between Absorbance and Permanganate Number

Based on Figure 3, a relationship between the absorbance of peat water and its permanganate value was obtained with the linear equation $y = 0.0132x - 0.2023$ with R² value of 0.9755. This equation could be used to determine the reduction in organic matter content in peat water after the adsorption process using AC/Mg(II) composite. Furthermore, the permanganate number indicated the amount of organic matter present in peat water. The higher the absorbance and permanganate number, the higher organic matter content in the sample. The relationship between absorbance and permanganate number in peat water is presented in Figure 3.

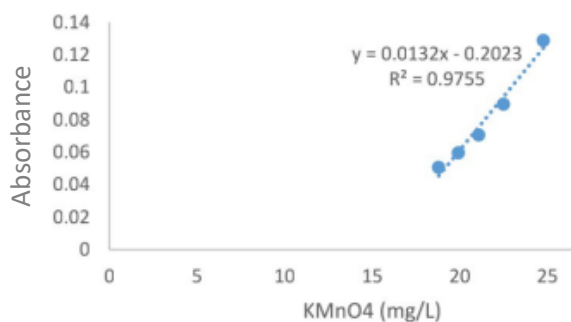


Figure 3. Relationship between permanganate number and adsorption

3.5.2 Determination of Optimum Mass of AC/Mg(II) Composites

The optimal mass was determined to ascertain the required quantity of adsorbent for adsorbing organic matter in peat water. Based on Figure 4, it was evident that the percentage of adsorption increased with the use of adsorbent masses ranging from 0.5 g to 2 g. However, at 3 g, the adsorption percentage decreased to 11.61%. This indicated that there had been a buildup of adsorbent particles, limiting the spread of organic substances, leading to reduced adsorption onto the adsorbent surface. The reduction in organic matters content in peat water after adsorption was determined based on the percentage decrease in permanganate number. The use of AC/Mg(II) composites could reduce the percentage of permanganate by 14.41%, from the initial value of 283.28 mg/L to 242.45 mg/L.

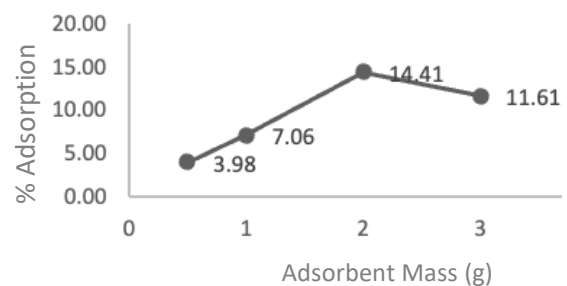


Figure 4. Relationship between adsorbent mass and % adsorption effectiveness

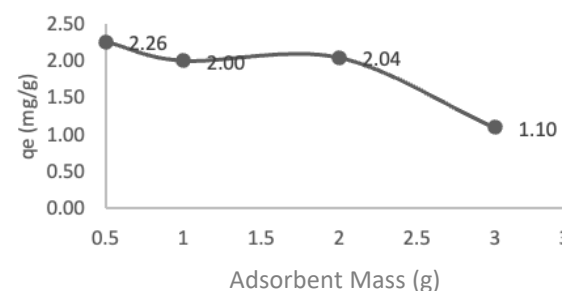


Figure 5. Relationship between mass and adsorption capacity

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Figure 5 illustrated the effect of varying the mass of the AC/Mg(II) composites adsorbent on the adsorption capacity. Furthermore, adsorption capacity indicated the amount of adsorbate adsorbed per unit mass of adsorbent, and its magnitude was influenced by mass. This parameter decreased due to the addition of more adsorbent, which led to an increase in the active sites in the solution. The results showed that the adsorption time and solution concentration remained constant. This led to the need for a longer time to reach equilibrium due to the overlapping of adsorbent particles or stacking at the bottom of the container. This accumulation of particles limited the dispersion of organic matter, causing a decrease in the adsorption of organic substances onto the adsorbent surface.

3.5.3 Determination of the Optimum Contact Time for Organic Matter Adsorption

Various contact times were employed, including 10, 15, 30, 45, and 60 minutes, using the optimum mass of 2 g for composite. The optimum contact time was determined to ascertain the duration required for composites to achieve maximum adsorption of organic matter.

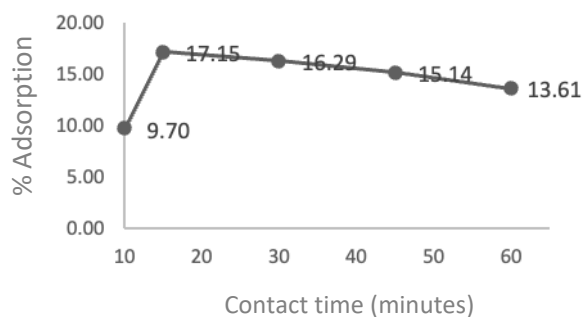


Figure 6. Relationship between contact time and % adsorption effectiveness

Figure 6 illustrated the amount of organic matter adsorbed by AC/Mg(II) at various contact times. Based on these results, the optimum contact time for reducing organic matter in peat water was 15 minutes.

Figure 7 illustrated the effect of varying the time for AC/Mg(II) composite at 10, 15, 30, 45, and 60 minutes, which yielded adsorption capacity values of 1.3712 mg/g, 2.42 mg/g, 2.30 mg/g, 2.14 mg/g, and 1.92 mg/g, respectively. Rahmayani et al. [20] stated that the longer the contact time used, the more frequently the adsorbent particles collided with the adsorbate, leading to increased adsorption. However, this indicated that the linearity was lower compared to the results obtained. Contact times beyond 15 minutes, such as 30, 45, and 60 minutes, showed a decrease in the percentage of organic matter absorbance in peat water, indicating the occurrence of desorption. This phenomenon often occurred when the adsorbent surface became saturated in the adsorption process. In the saturation state, the adsorption rate declined because the adsorbent had reached its maximum interaction capacity [21].

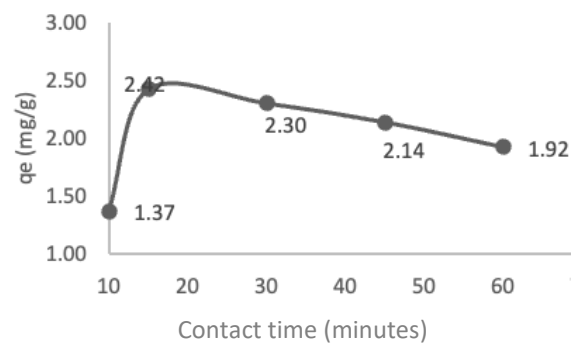


Figure 7. Relationship contact time and adsorption capacity

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3.6 Determination of the Adsorption Isotherm Model

The determination of adsorption isotherm models was conducted to understand the adsorption mechanism. The shape of the Langmuir and Freundlich isotherm curves is presented in Figures 8 and 9, respectively.

Based on Figures 8 and 9, the adsorption isotherm model in this study followed the Langmuir isotherm with a linear equation $y = 0.0047x - 0.0011$ and an R-squared value of 0.9994. The constant value (k) was the slope of the linear equation, which was 0.0047. Furthermore, the adsorption process of organic matter from peat water using AC/Mg(II) adsorbent derived from EFB followed the Langmuir isotherm equation. This indicated the presence of chemical adsorption that formed a single layer (monolayer). Based on the Langmuir isotherm equation $y = 0.0047x - 0.0011$, the adsorption capacity value was 0.2340 mg/g. The results obtained in this study did not meet the standard for clean water quality, namely 10 mg/L. However, the adsorption results were good, as they effectively reduced the organic content

from 283.28 mg/L to 234.29 mg/L. The high organic content also affected the adsorption capacity of the adsorbent. This indicated that the bonds between the groups present in the adsorbent and organic matter weakened, allowing some groups with stronger bonding to remain attached to the adsorbent.

4. Conclusion

In conclusion, the characteristics of the AC/Mg(II) adsorbent derived from EFB included a black color with a slight white appearance, and a lower moisture content of 1.298% compared to activated carbon. Moreover, the presence of Mg-O bonds was analyzed using FTIR instrumentation, leading to an absorption band at a wavenumber of 403.12 cm⁻¹. The adsorption capacity of AC/Mg(II) for peat water was 2.42 mg/g, with an adsorption percentage of 17.15%. The results showed that the adsorption mechanism followed the Langmuir isotherm equation, forming a monolayer with R-squared, adsorption capacity (Q₀), and adsorption constant (k) values of 0.9994, 0.2340 mg/g, and 0.0047, respectively.

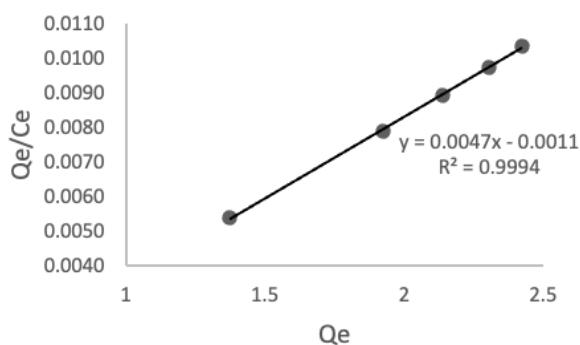


Figure 8. Langmuir adsorption isotherm curve

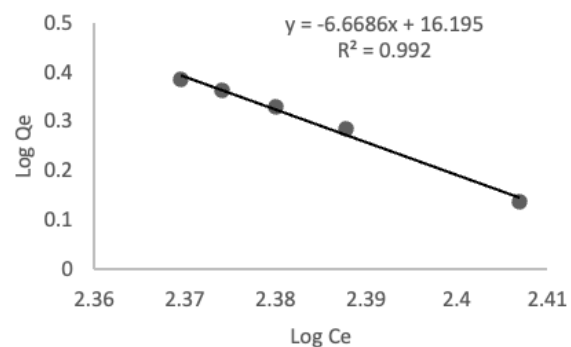


Figure 9. Freundlich adsorption isotherm curve

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