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Activated Carbon from Mulu Bebe Stem Waste for Methylene Blue (MB) Adsorption

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ABSTRACT

Methylene blue is a harmful synthetic dye waste component that poses a significant threat to the environment and human health if not disposed of properly. The best way to tackle this problem is by adsorption through activated carbon from Mulu Bebe banana stems, which are widely available in North Maluku. This agricultural waste can be used to produce activated carbon through pyrolysis at 500˚C for 30 minutes and activation using 0.5 M KOH solution for 24 hours. The activated carbon is then characterized using FTIR, SEM and XRD, which reveal the presence of various functional groups and pores. The XRD results indicate that the activated carbon structure tends to be amorphous. The adsorption analysis shows that the activated carbon from Mulu Bebe banana stems has a high adsorption capacity of 12.4 mg/g at the optimum condition of pH 7, contact time of 30 minutes, and initial concentration of 50 ppm. The Langmuir and Freundlich equations provide the best fit for the equilibrium adsorption data. By using activated carbon from Mulu Bebe banana stems, we can effectively reduce the amount of methylene blue waste in the environment and protect the ecosystem and human health.

Keywords: Activated carbon, Adsorption, Langmuir, Methylene blue, synthetic dye

ABSTRAK

Metilen biru adalah komponen limbah pewarna sintetis berbahaya yang dapat mengancam lingkungan dan kesehatan manusia jika tidak dibuang dengan benar. Cara terbaik untuk mengatasi masalah ini adalah dengan mengadsorpsi menggunakan karbon aktif dari batang pisang Mulu Bebe, yang tersedia melimpah di Maluku Utara. Limbah pertanian ini dapat digunakan untuk menghasilkan karbon aktif melalui pirolisis pada suhu 500˚C selama 30 menit dan aktivasi menggunakan larutan KOH 0,5 M selama 24 jam. Karbon aktif kemudian dikarakterisasi menggunakan FTIR, SEM, dan XRD, yang menunjukkan adanya berbagai grup fungsional dan pori-pori. Hasil XRD menunjukkan bahwa struktur karbon aktif cenderung amorf. Analisis adsorpsi menunjukkan bahwa karbon aktif dari batang pisang Mulu Bebe memiliki kapasitas adsorpsi tinggi sebesar 12,4 mg/g pada kondisi optimum pH 7, waktu kontak 30 menit, dan konsentrasi awal 50 ppm. Persamaan Langmuir dan Freundlich memberikan hasil yang paling cocok untuk data adsorpsi kesetimbangan. Dengan menggunakan karbon aktif dari batang pisang Mulu Bebe, kita dapat efektif mengurangi jumlah limbah metilena biru di lingkungan dan melindungi ekosistem serta kesehatan manusia.

Kata kunci: Karbon aktif, Adsorpsi, Langmuir, Metilen biru, Pewarna sintetis

INTRODUCTION

The problem of environmental pollution is a significant concern today, as it can have adverse effects on the survival of living beings. One of the major environmental pollution problems is water pollution, which can be caused by various factors, including synthetic dyes. Synthetic dyes are commonly used in industrial fields such as textiles, paper, cosmetics, pharmaceuticals, plastics, and food. The textile industry mainly uses methylene blue (MB) or Basic Blue 9 to dye cotton, wool, paper, hair, and other materials .(Han & Yun, 2007; Khan et al., 2020).

MB dyes can be problematic as they can produce organic dye waste, which is non-biodegradable due to the presence of a benzene group (Hassaan et al., 2017). If these compounds remain in the environment for an extended period, they can pose a serious threat to the ecosystem around the polluted waters and human health, potentially causing genetic, teratogenic, and carcinogenic mutations(Catanho et al., 2006).

To avoid the dangers of synthetic dyes, they must be processed before being discharged into waterways. The adsorption method is a commonly used technique to process artificial dye waste, as it is more accessible, effective, economical, and environmentally friendly(Chong & Tam, 2020; Yu et al., 2016). Adsorption is a process of absorbing a substance on the surface of another substance, and it is influenced by several factors, including the type of adsorbent, pH, and initial concentration of MB (Huang et al., 2014; Sahoo & Prelot, 2020; Zhao & Liu, 2008).

Activated carbon is one of the methods used to adsorb MB, as it has advantages such as a large surface area, high porosity, and many active groups. Activated carbon can be obtained from materials containing carbon sources such as cellulose, hemicellulose, lignin, and pectin found in coal, bamboo, wood, and agricultural waste. Using activated carbon from agricultural waste to overcome water pollution is auspicious because it is economical, widely available, and can increase the economic value of agricultural waste (Kaomierczak et al. 2013). Many researchers have reported the ability of activated carbon to act as an adsorbent for various pollutants in water. Activated carbon derived from organic sewage sludge has been proven effective in adsorbing mercury from water (Zhang et al., 2005). Furthermore, coconut shells have been reported to be highly effective as a material for producing activated carbon for hydrogen sulfide adsorption(Choo et al., 2013). In addition to these applications, activated carbon has demonstrated significant efficacy in removing heavy metals from water, such as Pb (II)(Huang et al., 2014), Arsenic (Mondal & Garg, 2017), and as well as various dyes.

Banana plants are one such agricultural waste that can be used to produce activated carbon. In North Maluku, where banana plants are found in abundance, the banana stem waste can be used as a source of active carbon. The banana stem consists of cellulose, which, when heated at high temperatures, loses the OH group, and carbon atoms remain in each corner. This imperfect arrangement of hexagonal rings in the cellulose structure allows spaces for adsorbates to enter the functional carbon structure.

METHODOLOGY

The study was conducted at the chemical education laboratory, FKIP, Khairun University. The sample preparation for Mulu Bebe Banana Stem involved cutting the stems into small cubes, which were left to dry under the sun for five days. The dried material was then heated in an oven at 110^{o} C for 4 hours and blended until smooth.

In terms of the synthesis of activated carbon, the modified procedure of (Manjuladevi et al., 2018) was strictly adhered to. The prepared banana stems were pyrolyzed using a furnace at 500 ^{0}C for 30 minutes until uniform-sized charcoal was obtained. This was then soaked in 0.5 M

KOH activator for 24 hours, washed with distilled water until the pH was neutral, and dried in an oven at 110^{o} C until it was completely dry.

As much as 25 mL of 10 ppm methylene blue solution was mixed with 0.1 gram of activated carbon for 30 minutes, then centrifuged, and the filtrate was analyzed using a UV-spectrophotometer. The adsorption processes were conducted by varying pH (3,5,7,9), contact time (10, 20, 30, 45 and 60 minutes), and then MB initial concentration (10 ppm, 30 ppm and 50 ppm).

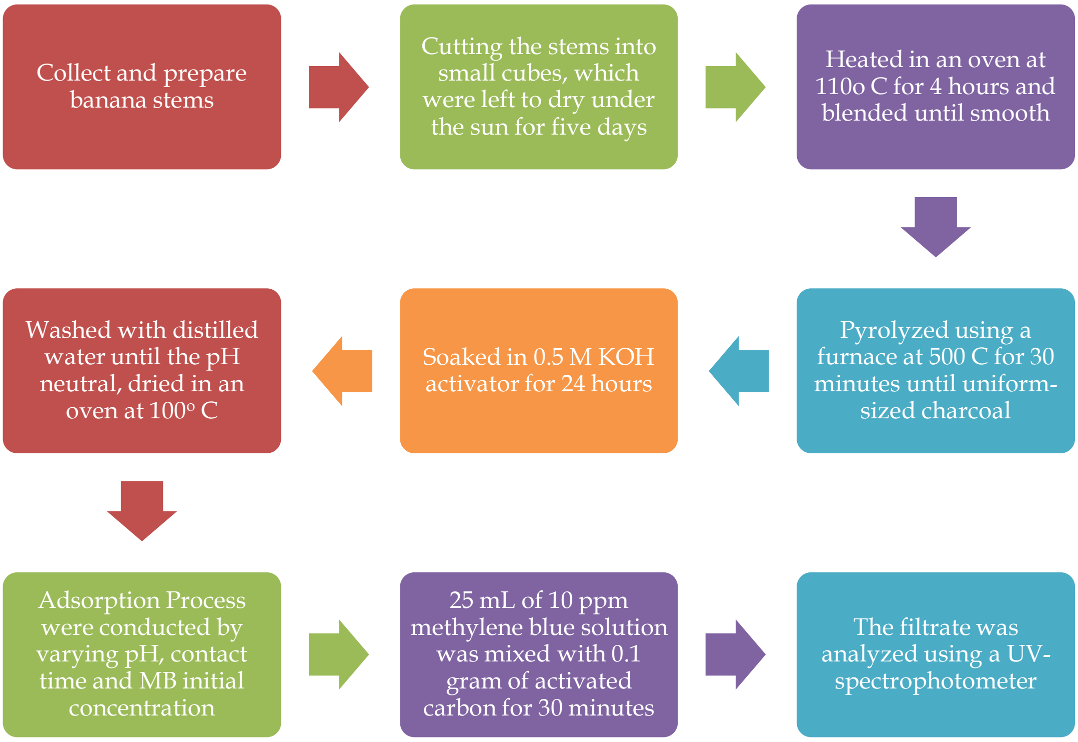

Figure. 1. Experiment design

RESULTS AND DISCUSSION

Activated carbon analysis using FTIR provides valuable information about the functional groups present in the active carbon. These functional groups are identified through absorption peaks, and they serve as unique characteristics of the activated carbon. The presence of the -OH (hydroxy) group can be determined by the absorption peak at wave number 3433.29 cm $^{-1}$. Additionally, the aliphatic CH bond can be identified at wave number 2962.66 cm $^{-1}$, and the presence of graphite is indicated by the absorption peak at wave number 1627.92 cm $^{-1}$, corresponding to the double carbon bond C=C. Other functional groups such as CH bending group, C O group, HC=O group, and CH 3 group can be identified at wave numbers 833.25 and 702.09 cm $^{-1}$; 2368.59 cm $^{-1}$; 2738.92 cm^{-1}; and 1404.18 cm^{-1}, respectively. However, further analysis needs to be carried out using XRD to identify the specific minerals in the Mulu Bebe banana stem activated carbon. The FTIR analysis is an essential step in understanding the characteristics of activated carbon and enables researchers to optimize the material for various applications.

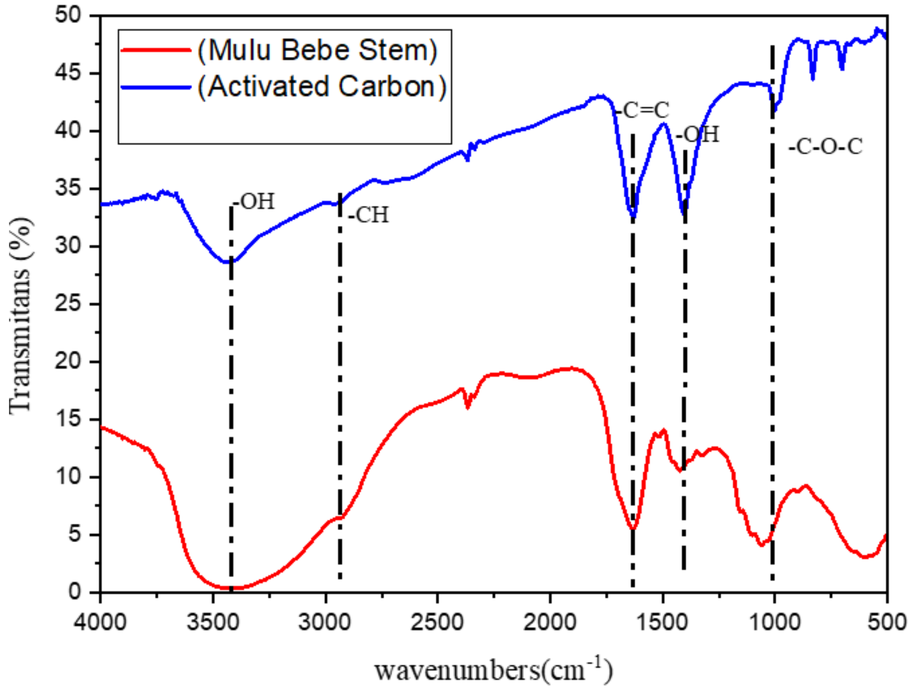

Figure 2. FTIR spectra of mulu bebe banana stem waste and activated carbon

Characterization of Activated Carbon with XRD

Characteristics of activated carbon for determining crystallite structure, determined by XRD diffractogram analysis. In Figure 4.3, it can be seen that the diffraction pattern of active carbon from Mulu Bebe banana stems shows that the active carbon structure tends to be amorphous with a heterogeneous surface as indicated by the widened diffraction peaks and irregular peaks produced at 2θ 7-30.

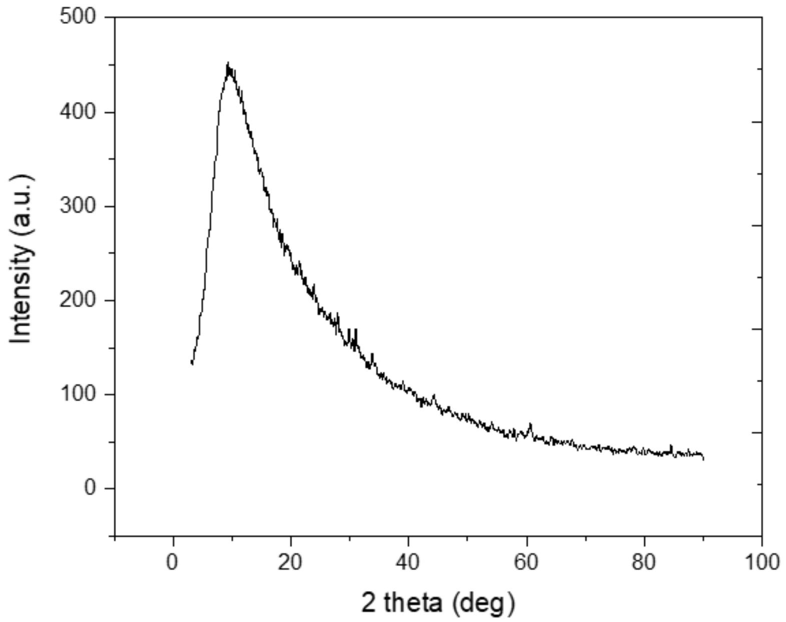

Figure 3. XRD diffractogram of mulu bebe banana stem activated carbon

Active Carbon Characterization using SEM

Scanning Electron Microscopy is an analytical instrument used to see the morphology or surface shape of activated carbon. Characterization of Mulu Bebe Banana Stem activated carbon was carried out at 500x magnification. The results of the Mulu Bebe banana stem activated carbon test using SEM indicated that there was a distribution of cavities called pores. This occurs due to the process of decomposing organic compounds in Mulu Bebe banana stems which is caused by the influence of the carbonation process and chemical activation using. The pores formed function as sites for adsorbate absorption (Al-Ghouti et al., 2019; Mulana et al., 2015; Yu et al., 2016).

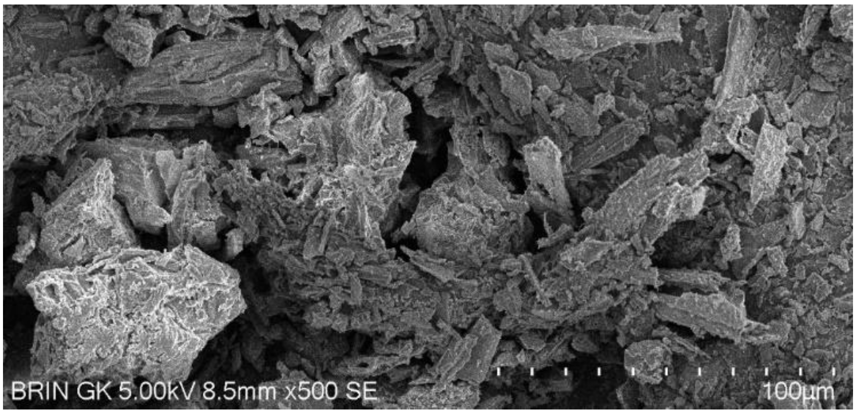

Figure 4. SEM image of banana stem activated carbon

Determination of Optimum pH

The pH conditions can determine the ionization level of the solution so that it can provide an idea of the charge on the surface of the activated carbon (Choo et al., 2013; Foo & Hameed, 2012; Mondal & Garg, 2017) . The results of the research show that in very acidic conditions (pH 3 and 5), the absorption efficiency of activated carbon tends to decrease and increase as the pH value increases up to pH 7. This is because in acidic conditions there are very many H + ions, making it possible for this to occur. The interaction between the hydrophilic groups on the surface of the active carbon and the H + ions in the MB solution results in the inhibition of the interaction process between the adsorbent and the adsorbate which is a cationic dye (Guerra et al., 2010; Yuan et al., 2019). At pH 9 there is a decrease in the adsorption efficiency. This is because due to the addition of the base, there is partial positive closure of the Nitrogen (N) ion in the MB by OH - ions from the base compound and the MB will interact with the Na + ions contained in the base so that it will form a salt. This is also in line with previous research, namely that the addition of alkali can reduce the levels of cellulose, hemicellulose and lignin which results in the interaction between activated carbon and MB being reduced, resulting in a decrease in the adsorption percentage (Jia et al., 2018).

Effect of Duration Contact

Figure 6. shows that with a contact time of 10 -30 minutes there is an increase in the percentage of adsorption efficiency and equilibrium occurs at the optimum contact time, namely 30 minutes with a % adsorption efficiency of 95.35%. This is because the longer the contact time, the more MB dye particles will collide with the active sites of the adsorbent, thereby allowing an increase in MB absorption into the activated carbon pores as the contact time increases and also at the beginning of the adsorption process the active carbon pores are still free from adsorbate

particles. The ability for adsorbate particles to be adsorbed in the pores of activated carbon is still very large because the active groups on the adsorbent have not interacted optimally.

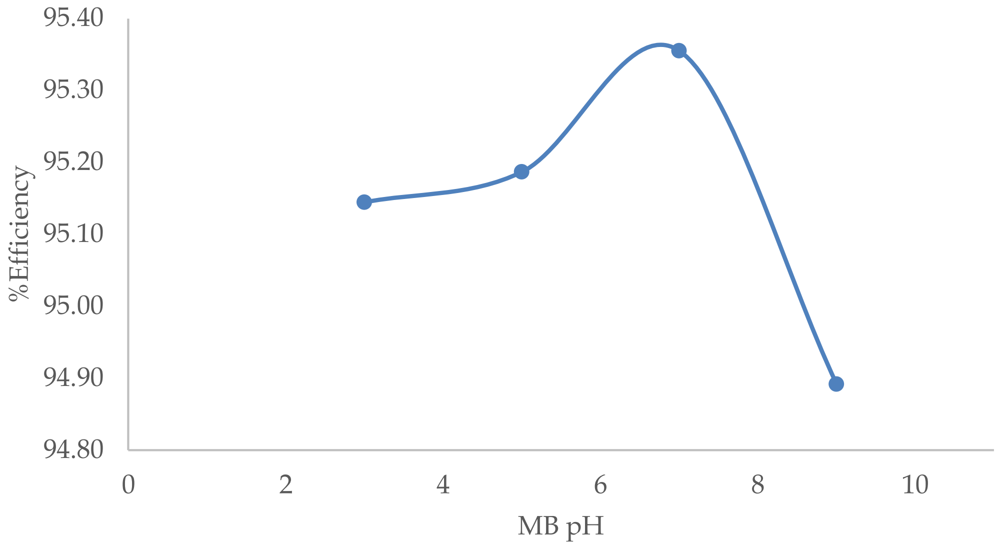

Figure 5. pH effect to MB adsorption trough activated carbon from mulu bebe banana stem

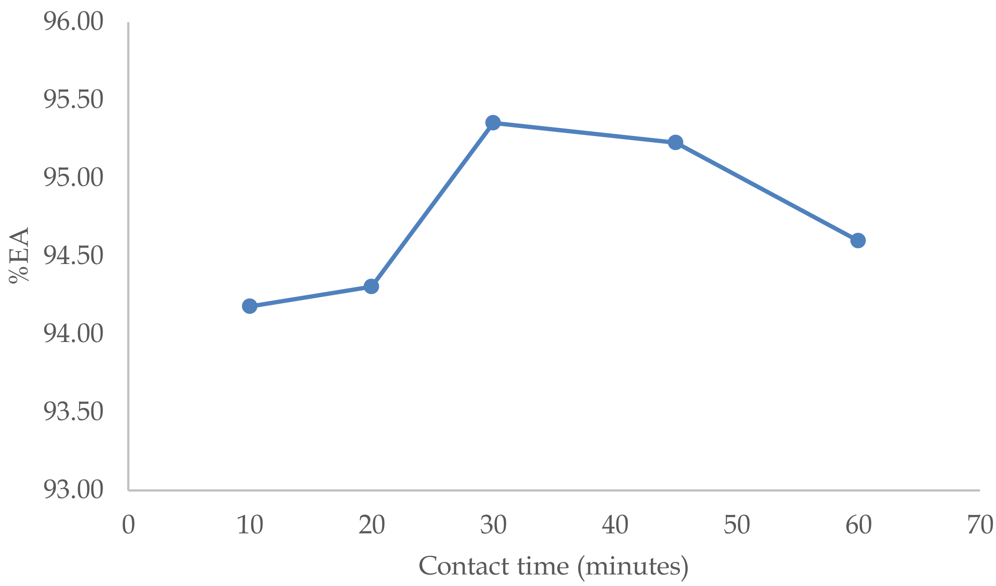

Figure 6. Duration contact in the adsorption process

At 45 to 60 minutes, there is a decrease in the percentage of adsorption; this is because the longer contact time between the adsorbent and the adsorbate allows the desorption process to occur, namely the process of releasing the dye in the adsorbent again after reaching the equilibrium process, namely at 30 minutes. In the equilibrium state of the carbon surface, the active site has experienced saturation so that the adsorption process cannot continue even though the contact time continues to increase.

Effect of Varying Initial MB Concentration on Adsorption Capacity

In Figure 7 it can be seen that when the initial concentration of MB dye was increased from 10 to 50 ppm, the adsorption capacity increased, namely from 2.38 mg/g to 12.4 mg/g. The increase in MB dye adsorption capacity was caused by the large number of MB particles growing with the adsorbent, causing the dye adsorbed in the activated carbon pores to increase as the MB concentration increased. This is also because the active sites on activated carbon have not yet experienced saturation so the adsorption process continues.

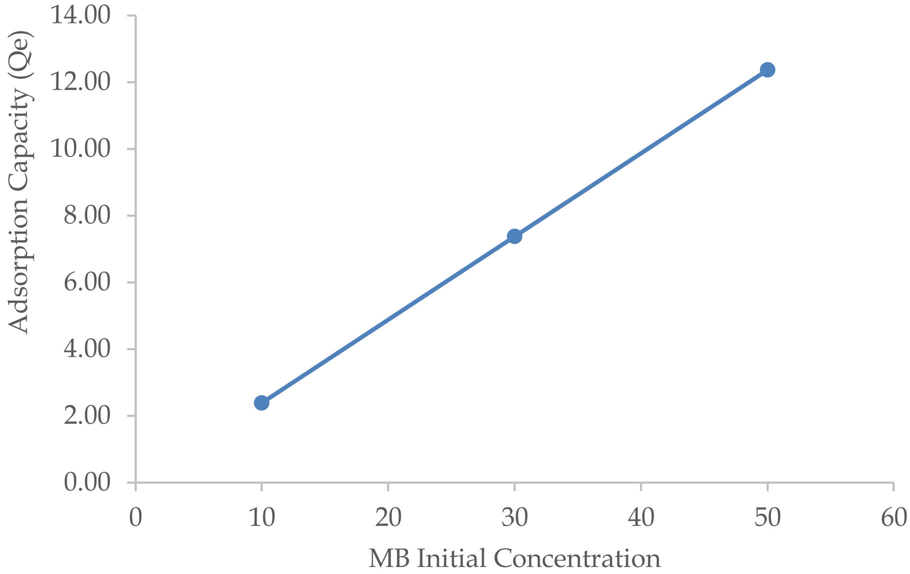

Figure 7. Effect of MB initial concentration trough adsorption capacity

Determination of Adsorption Isotherms

A high correlation coefficient (R^2) and are almost close to 1. The correlation coefficient for the Freundlich model namely R^2 = 0.9888 and the Langmuir equation model, namely R 2 = 0.9972. This shows that the adsorption process of activated carbon from Mulu Bebe banana stems on the MB solution is an adsorption that occurs physically and chemically. The adsorption that occurs physically assumes that the adsorption process occurs through the pores on the surface of the activated carbon and forms a multilayer layer. Where the bond formed between the adsorbent and the adsorbate occurs due to Van der Waals forces. Meanwhile, chemical adsorption occurs due to chemical bonds between the active groups on the surface of the activated carbon and the adsorbate.

CONCLUSION

By utilizing activated carbon derived from Mulu Bebe banana stems, we can significantly reduce the amount of methylene blue waste in the environment. This reduction in waste not only helps to protect aquatic ecosystems, preventing the disruption of aquatic life and maintaining biodiversity but also safeguards human health by ensuring cleaner water sources. The adsorption properties of activated carbon enable it to effectively remove methylene blue from wastewater, mitigating its toxic effects and promoting a healthier, more sustainable environment.

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