UNIVERSITI
MALAYSIA
KELANTAN

FYP FBKT

Effect of Adsorbent Dosage, Initial Concentration and Contact Time on Methylene Blue Dye Removal using Bamboo-derived Activated Carbon

Nor Aina Natasha Binti Abu Bakar
J20A0542

A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Bioindustrial Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY
UMK

2024

DECLARATION

I hereby declare that this thesis entitled "Effect of Adsorbent Dosage, Initial Concentration and Contact Time on Methylene Blue Dye Removal using Bamboo-derived Activated Carbon", matric number J20a0542 is the result of my own research except as cited in the references.

Signature : ______________________
Student's Name : ______________________
Date : ______________________

Approved by:

Signature : ______________________
Supervisor's Name : ______________________

Stamp : ______________________
Date : ______________________

ACKNOWLEDGEMENT

First and foremost, I want to express my gratitude to God for His favours during my research. I also appreciate God for His protection and guidance during my studies. I also appreciate Him for providing me with the mental power to conduct this study successfully.

I would like to express my heartfelt gratitude to Dr. Wan Hasnidah Binti Mohammad, my supervisor, and Dr. Sitti Fatimah Binti Mhd Ramlee, my co-supervisor, for their invaluable advice, moral support, and encouragement during my study. I am so grateful for the empathy, love, and kindness. Without their assistance, this research would not have been conducted effectively.

My thanks also go to Universiti Malaysia Kelantan (UMK) for providing me with the necessary resources, such as lab space and other resources, to accomplish my research. I am grateful to the lab assistants that support me in my study.

I had wanted to express my heartfelt appreciation to my dear parents, Mr Abu Bakar Bin Yunus, and Mrs. Zuraiivi Binti Kamarudin, for their love, prayers, and blessings. I am grateful to my family members for understanding me and assisting me in completing my studies.

Finally, I would like to express my gratitude to my friend, Nurul Izzah Binti Nordin for her unwavering support system throughout this arduous journey.

Kesan Dos Penyerap, Kepekatan Awal dan Masa Hubungan pada Penyingkiran Pewarna Biru Metilena menggunakan karbon diaktifkan yang berasal dari buluh

ABSTRAK

Kajian ini meneliti kecekapan penyingkiran pewarna Methylene Blue (MB) menggunakan karbon teraktif daripada buluh, meneroka faktor-faktor penting seperti dos penyerap, kepekatan pewarna awal, dan masa sentuhan. Sifat unik karbon teraktif daripada buluh memainkan peranan utama sebagai penyerap utama. Melalui eksperimen sistematik, dos penyerap optimum adalah 4g, mengambil kira titik kejenuhan untuk penyingkiran yang kos-efektif. Kepekatan pewarna awal yang lebih rendah iaitu 50 mg/L berkorelasi positif dengan peningkatan kecekapan penyingkiran. Masa optimum untuk menyerap pewarna Methylene Blue (MB) adalah 6 jam. Selepas penyerapan, keterlibatan kumpulan fungsi disahkan oleh perubahan puncak regangan N-H dari 3343.58 cm^{-1} kepada 3336.22 cm^{-1}, menunjukkan perubahan pengikatan selepas interaksi dengan pewarna MB. Secara keseluruhan, kajian ini memberikan panduan penting untuk pembangunan strategi penapisan air yang efisien dan mampan.

Kata kunci: Karbon Teraktif Daripada Buluh, Pewarna, Metilena Biru, Parameter, Peratusan Penyingkiran, Transformasi Fourier Inframerah (FTIR)

Effect of Adsorbent Dosage, Initial Concentration and Contact Time on Methylene Blue Dye Removal using Bamboo-derived Activated Carbon

ABSTRACT

This study delves into the efficiency of Methylene Blue (MB) dye removal using bamboo-derived activated carbon, exploring key factors such as adsorbent dosage, initial dye concentration, and contact time. The unique properties of bamboo-derived activated carbon play a central role as the primary adsorbent. Through systematic experimentation, optimal adsorbent dosages are 4g, considering saturation points for cost-effective removal. Lower initial dye concentrations which were 50 mg/L positively correlate with enhanced removal efficiency. The optimum time to absorb the Methylene Blue (MB) dye is 6 hours. After adsorption, functional group involvement was confirmed by shift in the N-H stretching peak from 3343.58 cm^{-1} to 3336.22 cm^{-1}, suggesting binding alterations following interaction with MB dye. In summary, this research provides crucial guidance for the development of efficient and sustainable water purification strategies.

Keyword: Bamboo-derived activated carbon, Methylene Blue Dye, Parameter, Removal percentage, Fourier Transform Infrared (FTIR).

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Dyes play a significant role in various sectors, including textiles, paper, food, cosmetics, pharmaceuticals, plastics, and coatings (Ardila-Leal et al., 2021). In the textile industry, dyes are used extensively to colour fabrics and garments, adding vibrancy and variety to clothing and home textiles. Printing and paper industries utilize dyes to create vivid colours and high-quality images in newspapers, magazines, books, and packaging materials. In the food industry, dyes are employed to enhance the visual appeal of products such as candies, soft drinks, baked goods, and processed foods. Cosmetics and personal care products, including hair dyes and nail polishes, rely on dyes to offer a diverse range of shades and colours.

Dyes are also used in pharmaceuticals for tablet and capsule colouring, as demonstrated in the study by Maheshwari et al. (2021). Additionally, dyes find applications in plastics, coatings, and paints to add colour and improve the aesthetic appeal of the finished products. However, it is important to be mindful of the environmental impact of dyes, particularly in wastewater. Improper disposal of dye-containing wastewater can lead to pollution and harm ecosystems. Therefore, proper management and treatment of dye wastewater are crucial to mitigate environmental consequences. They can create environmental issues such as eutrophication and aquatic life poisoning.

Activated carbon, a porous substance used to remove colours from wastewater and has a high surface area, a large volume of micropores. The specific surface area of activated carbon may exceed 3000 m^2/g, making it particularly efficient in removing inorganic contaminants like heavy metals from water (Gan & Yong, 2021). It is made of many materials, including bamboo and an essential part of the filter material used to remove dangerous substances from exhaust gases for the treatment of wastewater. The efficiency of dye removal using activated carbon depends on various factors, including the operating conditions. Due to its various applications and the fact that many nations are requiring activated carbon to comply with environmental regulations, the market for this product will only grow.

Bamboo has a large pore capacity and a high surface area, making it an excellent dye adsorbent. Bamboo is a rapidly growing and long-lasting plant of the Poaceae grass family. It has a high strength-to-weight ratio and is made up of cellulose, hemicellulose, and lignin. Cellulose accounts for up to 50% of the dry weight of bamboo stems, with hemicellulose accounting for the remaining 20-25%. Lignin functions as a binder and accounts for approximately 20% of the dry weight (Divya et al., 2020). Furthermore, bamboo contains trace amounts of extractives such as phenols, flavonoids, and terpenoids, which help to explain its antibacterial and antioxidant effects.

The cellulose and hemicellulose components of bamboo can be utilized to create activated carbon, which can effectively adsorb and remove dyes from wastewater. The activated carbon derived from bamboo has a high surface area and porosity, making it an ideal adsorbent for removing various types of dyes from industrial effluents. The presence of small amounts of extractives in bamboo, such as phenols, flavonoids, and terpenoids, may also contribute to its ability to remove dyes through chemical interactions or oxidation processes (Liu et al., 2020).

1.2 Problem statement

Dyeing is a prominent industrial process that generates substantial volumes of wastewater. This wastewater is frequently laden with dyes, which can pose significant environmental challenges. One of the key concerns is eutrophication, a phenomenon where the excessive nutrients from dyes promote the rapid growth of algae and other aquatic plants (Sharma et al.,2021). This excessive growth disrupts the natural balance of ecosystems, depleting oxygen levels and negatively impacting aquatic life.

Furthermore, the presence of dyes in wastewater can also lead to aquatic life poisoning. Many dyes contain toxic compounds that can be harmful to various organisms in water bodies.

These toxic substances can accumulate in the tissues of aquatic organisms, leading to physiological and reproductive issues. Moreover, when consumed by humans, these contaminated organisms can pose risks to human health.

Addressing the environmental issues caused by dyes in wastewater requires effective treatment and management strategies. Implementing proper wastewater treatment processes can help remove or minimize the concentration of dyes and their associated toxic components, mitigating the potential impacts on aquatic ecosystems and human health. Activated carbon is a promising material for the removal of dyes from wastewater. However, the efficiency of dye removal by activated carbon depends on a few operational parameters, such as the type of dye, the concentration of the dye, the pH of the solution, and the contact time between the dye and the activated carbon. Methylene blue (MB) is a water-soluble dye that is used in a variety of industries, including textile, paper, and printing. It is also used in medicine as a topical antiseptic. However, MB is also a potential environmental pollutant. It can enter the environment through wastewater from these industries, as well as from runoff from agricultural fields where it is used as a fungicide. MB is toxic to aquatic organisms and can cause problems in the food chain.

1.3 Objectives.

The objectives for this study are:

- To study the effect of the operational parameters on Methylene Blue dye removal using bamboo-derived activated carbon.
- To investigate the removal percentage (%) of Methylene Blue dye using bamboo-derived activated carbon.
- To characterise the Bamboo-derived Activated Carbon using Fourier-Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and Brunauer-Emmett-Teller (BET) analysis.

1.4 Scope of study

The purpose of this research is to study the effect of the operational parameters which are adsorbent dosage (g), initial dye concentration (mg/L) and contact time (min) on the removal of Methylene Blue dye using bamboo-derived activated carbon. This study is focus on the removal percentage (%) of Methylene Blue dye using bamboo-derived activated carbon. Additionally, the research aims to characterize the bamboo-derived activated carbon through various analytical techniques such as Fourier-Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and Brunauer-Emmett-Teller (BET) analysis.

1.5 Significance of study

Activated carbon, especially the bamboo-derived activated carbon, has been widely used as an effective adsorbent material for the removal of dyes from wastewater due to its high adsorption capacity and low cost. However, the efficiency of the adsorption process can be influenced by various operational parameters, such as contact time, pH, initial dye concentration, and temperature. This study can help improve how dyes removed from wastewater treatment. By using more effective and efficient methods, we can reduce the harm to the environment caused by releasing coloured wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Bamboo

Bamboo is a large grass that is native to tropical and subtropical regions. It is a member of the grass family *Poaceae* which also includes wheat, rice, corn and is the fastest-growing plant in the world. Bamboo can grow up to 30 centimeters (1 foot) per day and can reach heights of over 40 meters (130 feet). Bamboo is a versatile plant that has many uses, including construction, furniture, food, textiles, and perennial plant, which means that it lives for more than two years. Bamboo also can be grown without the use of pesticides or herbicides. Bamboo is also a carbon-neutral plant, which means that it does not release greenhouse gases into the atmosphere (Divya et al., 2020). Figure 2.1 shows the bamboo plant.

Figure 2 1: Bamboo plant.

(Source: Bernama, 2021)

Bamboo grows from a rhizome, which is an underground stem. The rhizome sends up new shoots, which grow into culms, or stems, enabling bamboo to propagate and form extensive clumps (Britannica et al,2023). The culms are the main structural elements of bamboo trees, often referred to as bamboo stalks or canes. They are the tall, hollow, and segmented stems that grow from the ground and can be used for a variety of purposes.

Nodes are the joints or points of attachment on the bamboo culms. They are usually slightly thicker and more solid than the internodes.

For internodes, it is the sections between the nodes on bamboo culms. They are typically hollow and contribute to the overall flexibility and lightness of bamboo. Bamboo trees have an extensive root system that provides stability and absorbs water and nutrients from the soil. The roots anchor the plant and help it to thrive in various environments. These components work together to support the growth and functionality of bamboo trees, making them versatile and valuable plants. Figure 2.2 shows the anatomy of the bamboo.

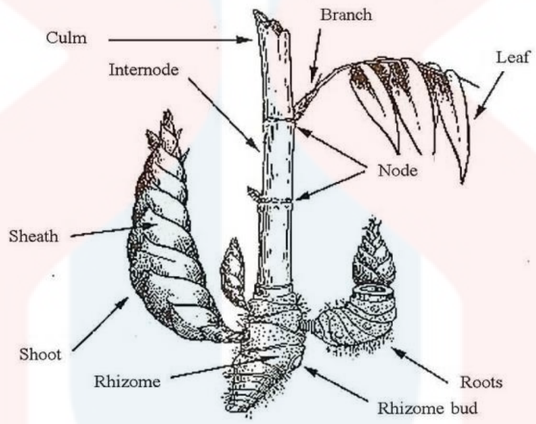


Figure 2 2: Anatomy of bamboo

(Source: Bamboo Stem Anatomy, 2018)

Bamboo is known for its high strength-to-weight ratio and is composed of cellulose, hemicellulose, and lignin. Cellulose is the main component and accounts for up to 50% of the dry weight of the bamboo stem, followed by hemicellulose, which makes up 20-25%. Lignin acts as a binder and comprises approximately 20% of the dry weight. In addition, bamboo contains small quantities of extractives such as phenols, flavonoids, and terpenoids, which contribute to its antibacterial and antioxidant properties (Yang et al., 2021).

The cellulose and hemicellulose components of bamboo can be utilized to create activated carbon, which can effectively adsorb and remove dyes from wastewater. The activated carbon derived from bamboo has a high surface area and porosity, making it an ideal adsorbent for removing various types of dyes from industrial effluents.

2.2 Activated Carbon

Activated carbon (AC), commonly known as activated charcoal, is a porous black solid material characterized by its large specific surface area, well distributed pore sizes, and heightened surface reactivity. Each microcrystal has a size of about 1–3 nm and a thickness of approximately 1–1.3 nm (Yuan Gao et al, 2020). Figure 2.3 shows the activated carbon.

Figure 2 3: Activated carbon.

(Source: Aletihad Minerals, 2024)

The production involves two main methods: physical activation and chemical activation. In the context of water purification, activated carbon exhibits significant promise for adsorbing heavy metals, owing to its expansive surface area, microporous characteristics, and the intricate chemical composition of its external surface (Asif Ahmad et al.,2019). In recent times, activated carbon available in the market (commercialized activated carbon or CAC) is being used more extensively worldwide.

2.2.1 Physical activation

Activated carbon, a versatile adsorbent widely used in water treatment, air purification, and industrial processes, can be produced through physical activation. This method involves the transformation of carbonaceous raw materials, such as coconut shells or wood, into a porous structure without the use of chemical agents. The process encompasses carbonization, activation using steam or carbon dioxide in a controlled furnace, cooling, washing to remove impurities, and final drying and sizing. Physical activation results in activated carbon with distinct properties compared to chemically activated counterparts, making it suitable for specific applications. The selection of raw materials, activation agents, and optimization of process parameters allow for tailoring the final product to meet diverse industrial needs. The choice between physical and chemical activation depends on factors like cost, raw material availability, and the desired characteristics for the intended application (Udyani & Purwaningsih, 2021).

2.2.2 Chemical activation

The production of activated carbon through chemical activation is a process that involves converting carbon-rich raw materials into a highly porous material with an extensive surface area suitable for adsorption applications. This method employs activating agents, such as phosphoric acid or potassium hydroxide, to create pores within the carbon structure. The general process includes carbonization, impregnation with activating agents, drying, activation through controlled heating, washing, optional acid treatment, and final drying and sizing. Each step is crucial in determining the properties of the activated carbon, making it effective for specific applications (Udyani & Purwaningsih, 2021). The choice of raw material and activating agent, as well as the optimization of process parameters, allows to produce tailored activated carbon products with desired characteristics for diverse industrial uses, including water treatment, air purification, and various industrial processes.

2.3 Dye

Dyes are colourful substances used to add colour to textiles, leather, paper, and other materials. Nowadays, most dyes are made from coal tar and petrochemicals. Dyes can be modified easily, allowing for the creation of new colours and types. When dyes are applied to materials, they bond with the fibres in a way that makes them resistant to removal by solvents. Some dyes, called fibre-reactive dyes, form a strong bond with the fibres through a chemical reaction. Other dyes require the use of a mordant, which is an inorganic substance that helps the dye attach to the material by forming an insoluble salt. According to a study conduct by Pavithra et al (2019), dyes can have harmful effects when their wastewater is released into the environment. This wastewater is often highly coloured, can cause changes in pH levels, has high chemical oxygen demand (COD), and can be toxic to bacteria.

2.3.1 Classification of Dyes

Dyes can be categorized as readymade dyes or ingrain dyes. Readymade dyes can further be categorized as water-soluble dyes (direct, acid, reactive, basic) and water-insoluble dyes (vat, sulphur, disperse). Ingrain dyes require chemical reactions or specific conditions to develop their colour and include azoic colours, oxidation colours, and mineral colours. On the other hand, most dyes used in the textile industry have also been categorised based on their chemical structure, including azo, nitro, indigo, and nitroso colours. Table 1.1 shows the usage, properties, and potential environmental impact for each dye.

Table 2 1: The usage, properties, and potential environmental impact for each dye.

(Source: Kaur, 2019)

Type of Dye	Usage	Properties	Potential Environmental Impact
Azo Dyes	Textiles, cosmetics, printing, food	Contains azo (-N=N-) functional groups, bright colours.	Some may be toxic, carcinogenic, or mutagenic
Nitro Dyes	Textiles, inks, paints	Contains nitro (-NO2) functional groups, good lightfastness	Can persist in the environment, potential toxicity
Indigo Dyes	Denim production, textiles	Derived from Indigofera tinctoria, good colour fastness.	Relatively non-toxic, process may have other environmental impacts
Nitroso Dyes	Textiles, paper, leather	Contains nitroso (-N=O) functional groups	Potential toxicity, impact on aquatic organisms

2.3.2 Azo Dyes

Azo dyes are synthetic organic compounds that are widely used in various industries, including textile, food, and cosmetics. They are characterized by the presence of one or more azo (-N=N-) functional groups, which give them bright and vivid colours. Azo dyes are important because they provide an inexpensive and efficient means of dyeing various materials. Based on the research by Benkhaya et al (2020), it can be concluded that azo dyes, which are commonly used in textiles and other industries, have the potential to enter the aquatic environment and contaminate the aquatic habitat. This suggests that there is a risk of environmental pollution and potential adverse effects on aquatic organisms due to the presence of azo dyes. Further investigation and implementation of appropriate management strategies may be necessary to mitigate the impact of these dyes on aquatic ecosystems.

2.3.3 Nitro dyes

Nitro dyes are synthetic dyes that have one or more nitro groups ($-NO_2$) attached to an aromatic ring. These nitro groups serve as the chromophore, which gives the dye its colour. Nitro dyes are colourful compounds that can make materials like textiles, plastics, and food appear bright yellow, orange, or red. In addition to their industrial applications, nitro dyes are utilized in biological staining techniques due to their ability to bind to specific proteins and nucleic acids.

The study conducted by Patra et al (2020) investigated the adsorption of nitro dyes from aqueous solutions using activated carbon as an adsorbent. They found that activated carbon is highly effective in adsorbing nitro dyes, leading to a significant reduction in their concentration in water. The study concluded that activated carbon offers favourable adsorption characteristics for the efficient removal of nitro dyes from aqueous solutions. These findings contribute to the development of sustainable strategies for treating water contaminated with nitro dyes.

2.3.4 Indigo Dyes

Indigo dye, derived from the plant Indigofera tinctoria, is renowned for its deep blue color and has been utilized in textile dyeing for centuries. However, its persistence and potential environmental harm underscore the importance of removing it from wastewater. Various methods, including adsorption, photocatalysis, and biological treatment, have been explored for this purpose.

One study by Garg et al. (2019) focused on adsorption techniques for indigo dye removal. The researchers investigated the efficacy of different adsorbents, including activated carbon, clay minerals, and agricultural waste materials, in removing indigo dye from aqueous solutions. Their findings revealed that activated carbon displayed high adsorption capacity and exceptional removal efficiency for indigo dye.

2.3.5 Nitroso dyes

Nitroso dyes are synthetic organic compounds that contain a nitroso functional group (NO) attached to an organic chromophore. They are widely used in industries such as textiles, printing, and plastics for their vibrant colours and excellent lightfastness. The presence of the nitroso group gives these dyes their distinct hues, ranging from yellow to red. Nitroso dyes are soluble in organic solvents, making them suitable for various dyeing processes. They also exhibit pH sensitivity, allowing them to be used as indicators for measuring acidity or alkalinity. However, environmental concerns are raised by the use of nitroso dyes due to their potential toxicity and persistence. Efforts are being made to develop eco-friendly alternatives and sustainable dyeing methods to mitigate these issues. Overall, versatility in coloration is offered by nitroso dyes, but careful consideration for their environmental impact is required.

2.4 Methylene blue dye

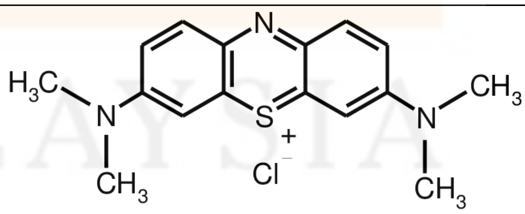
Methylene blue (MB) dye, is a cationic basic dye, mainly used for dyeing cotton and silk. MB effect can cause vomiting, nausea, hypertension and methemoglobinemia. One advantage of using MB is that it does not change its properties when exposed to different temperatures or pH levels. Additionally, MB has a strong ability to stick to solids, which makes it useful for investigating adsorption processes (Oladoye et al., 2022). Figure 2.4 shows a picture of methylene blue (MB) dyes.

Figure 2 4: Methylene Blue Dye

The methylene blue (MB) dye has a positive charge, which is shared by the nitrogen and sulphur atoms within the molecule. This distribution of positive charge allows MB to interact with negatively charged surfaces, such as solid adsorbents, through electrostatic interactions. The property of MB dye is shown in Table 2.2.

Table 2 2: Properties of Methylene Blue (MB)

(Source: Dev & Singh, 2019)

Chemical structure	
Category	Cationic dye
Charge	Positive (+)
Molecular formula	$C_{16}H_{18}N_3SCL.3H_2O$
Molecular weight	319.85 g/mol
Wavelength	665 nm

2.5 Adsorption

Adsorption is a process where molecules or ions from a liquid or gas adhere to the surface of a solid material. It occurs due to attractive forces between the adsorbent (solid material) and the adsorbate (molecules or ions) (Ren & Zhang, 2019). The adsorbent surface acts as a site for the adsorbate to bind, forming a thin layer of molecules or ions on its surface.

During the adsorption process, the adsorbate is typically attracted to the adsorbent surface through various types of interactions, such as van der Waals forces, hydrogen bonding, or electrostatic interactions. These attractive forces allow the adsorbate to stick to the surface and remain bound (Akter et al., 2021). Figure 2.5 shows the general mechanism of the adsorption process and table 1.3 shows the mechanism involve in adsorption.

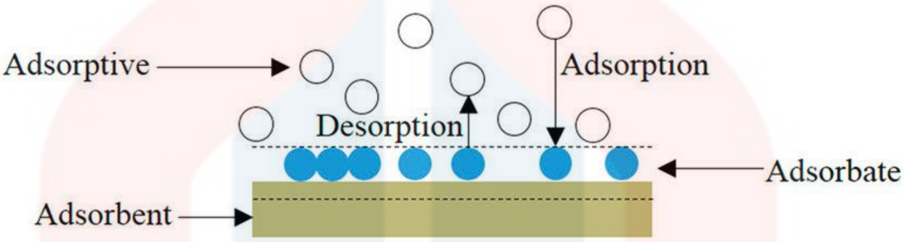


Figure 2 5: The general mechanism of the adsorption process.

(Source: Ameri, 2020)

Table 2 3: The mechanism involves in adsorption.

(Source: Kamble et al., 2020)

Mechanism	Physical Adsorption	Chemical Adsorption
Other Names	Physisorption, Van der Waals adsorption	Chemisorption
Bonding Forces	Weak intermolecular forces (Van der Waals, London dispersion).	Strong chemical bonds (covalent, ionic).
Reversibility	Reversible.	Irreversible.
Specificity	Non-specific.	Specific

2.5.1 Adsorption as basis dye removal.

Dye removal has evolved from a mere technical necessity to a paramount obligation in the contemporary landscape marked by a plethora of pollutants impacting water quality. The imperative of removing dye materials is deeply entrenched in the broader mission of safeguarding the environment and human health, a mission that has gained urgency with the increasing presence of pollutants in water sources. In the current era, water quality faces an onslaught of pollution from diverse sources, amplifying the importance of removing dye materials. Even trace amounts of dyes can increase visibility and undesirability, negatively impacting aquatic ecosystems (Teo et al., 2022). The necessity for dye removal is highlighted by the disproportionate aesthetic impact they have in water bodies compared to their concentration. This underscores the importance of developing effective and efficient removal techniques.

Techniques for dye removal can be broadly classified into physical, chemical, and biological methods. Each category presents its own set of challenges and advantages. In the realm of biological techniques, the degradation process emerges as a major challenge. The efficacy of degradation is contingent upon various physical properties, including dye concentration, class, pH, salinity, and the potential toxicity of end products. Employing different microbial strains under anaerobic conditions has been explored as a viable approach for decolorizing azo dyes, albeit with considerations of cost, environmental impact, and sludge production (Teo et al., 2022). Adsorption, encompassing both physical and chemical aspects, stands out as a pivotal technique in the removal of dyes. This method proves to be economically feasible, environmentally friendly, and capable of generating less sludge. The versatility of adsorption lies in its adaptability to various adsorbents, particularly agricultural and industrial waste, making it a cost-effective and efficient solution. Parameters such as particle size, contact time, adsorbent dosage, pH, and initial dye concentration exert influence on the efficacy of the dye removal process.

Among the myriad techniques available, adsorption emerges as the most applicable and pragmatic choice due to its economic viability and environmental friendliness. Utilizing readily available materials like agricultural and industrial waste streamlines the process, making it not only cost-effective but also contributing to waste management and repurposing. The utilization of agricultural and industrial waste as adsorbents exemplifies the practicality of adsorption in dye removal. These materials, typically discarded, are repurposed as effective adsorbents, thereby contributing to a sustainable and circular economy. The success of this approach relies on meticulous consideration of factors such as particle size, contact time, adsorbent dosage, pH, and initial dye concentration (Ahmad et al., 2023).

The imperative for dye removal transcends mere technical requirements, aligning with the broader goals of environmental conservation and safeguarding human well-being. Adsorption, with its economic feasibility and environmental friendliness, emerges as a powerful and applicable technique in this endeavour. The judicious utilization of agricultural and industrial waste further underscores the sustainable and holistic nature of adsorption in the removal of dyes from wastewater.

2.6 Factor Affecting the Adsorption

The process of removing dyes through adsorption is influenced by several factors. These factors include the particle size of the adsorbent, the quantity of adsorbent utilized, the initial concentration of the dye, the duration of contact between the adsorbent and the dye, and the pH of the solution. Regarding contact time, the rate of dye removal increases with prolonged contact between the adsorbent and the dye until reaching a certain threshold. At equilibrium, the adsorption process indicates a balance between dye adsorption and dye remaining in the solution. The amount of dye adsorbed at equilibrium indicates the maximum capacity of the adsorbent under the given conditions. The duration of contact between the adsorbent and dye is a crucial factor influencing the efficiency of dye removal (Rápó et al., 2021).

Increasing the amount of adsorbent typically leads to a higher percentage of dye removal. The adsorbent capacity to adsorb the dye is directly linked to the quantity of adsorbent utilized, as a greater dosage provides more adsorption sites on the adsorbent surface. Particle size also plays a crucial role. Smaller particles of the adsorbent exhibit a higher percentage of dye removal due to their larger surface area, facilitating more effective adsorption of the dye molecules.

Additionally, the pH of the solution can impact dye adsorption by influencing the surface charge of the adsorbent material and the degree of ionization of the dye molecules (Rápó et al., 2021). For example, cationic dyes demonstrate enhanced adsorption at higher pH levels, whereas anionic dyes exhibit higher removal percentages at lower pH levels. Lastly, the initial concentration of the dye affects the percentage of dye removal. Higher initial dye concentrations result in a greater loading capacity of the adsorbent because of the increased driving force for mass transfer.

2.7 Fourier Transform Infrared Spectroscopy (FTIR)

With the advancement of Fourier transform infrared (FTIR) spectroscopy, it has become a more prominent tool for quantitative analysis of complex mixtures, as well as the study of surface and interfacial phenomena. Fourier Transform Infrared Spectroscopy (FTIR) is a powerful analytical technique used to identify and analyse the chemical composition of a sample. It also provides valuable information about the molecular structure of substances by measuring the interaction of infrared radiation with the sample. The sample can be in form of a solid, liquid or gas and may be applied as a film, a drop or solution in a transmission cell (van Haaren et al., 2023).

FTIR works by shining a beam or infrared light through the sample and measuring the light that is absorbed or transmitted. The resulting data is then analysed using a Fourier transform to produce an infrared spectrum, which can be used to identify the chemical compounds present in the sample The following figure 2.6 shows a FTIR spectrometer.

Figure 2 6: FTIR spectrometer

2.8 UV-vis Spectrophotometer.

UV-vis spectrophotometer involves in the measurement and analysis of numerical data to determine the concentration or intensity of a substance in a sample. It relies on the principles of light interaction with the sample and calibration using known standards. This technique provides accurate and precise quantitative data for various applications in fields such as chemistry, biology, and environmental science. The process starts with a light source that emits a wide spectrum of light, usually in the visible or UV range. The emitted light is then directed through a monochromator, which separates the light into different wavelengths.

The transmitted or absorbed light is then detected by a photodetector, which measures the intensity of the light. A calibration curve is established using standard solutions with known concentrations of the compound. During the actual analysis, the absorbance or intensity of the sample is measured and compared to the calibration curve. This allows for the determination of the concentration of the compound in the sample (Shi et al., 2020). Figure 2.7 below shows a UV-Vis spectrophotometer.

Figure 2 7: UV-vis Spectrophotometer.

(Source: Edinburgh Instruments)

2.9 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) is a tool through which the invisible worlds of microspace and nanospace can be observed. It is a sophisticated imaging technique utilized for examining the surface morphology of materials with exceptional detail. A focused beam of electrons is employed to scan the sample surface, generating signals that are then translated into high-resolution images. SEM analysis involves the application of a beam of electrons with high energy, typically ranging between 100 and 30,000 electron volts (Abdullah et al., 2019).

The electron beam causes signals like secondary electrons (SE) and backscattered electrons (BSE) when it interacts with the atoms in the sample. SEs offer topographic pictures with great resolution, but BSEs facilitate elemental analysis. But if a negative voltage is provided to the collector screen, only BSE will be collected. Most SEMs have spots smaller than 10 nm, and the signals needed to create a picture are produced by electrons that are gathered from the final lens interacting with the specimen and penetrating to a depth of 1 μm (Abdullah et al., 2019).

In the context of bamboo-derived activated carbon, SEM plays a pivotal role in analysing its surface features. It helps in understanding the pore structure, surface texture, and overall morphology, providing crucial insights for optimizing its performance as an adsorbent. SEM is a powerful tool for visualizing surface characteristics, contributing to advancements in materials science and various scientific fields, particularly in enhancing our understanding of bamboo-derived activated carbon for effective utilization in adsorption applications. Figure 2.8 shows a Scanning Electron Microscopy (SEM).

Figure 2 8: Scanning Electron Microscopy (SEM)

(Source: UTM Faculty of Science)

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

The raw materials that were used in this experiment is bamboo (*Gigantochloa albociliata)* obtain in Selangor. The chemicals that were used are Methylene Blue dye obtain from faculty, distilled water, and phosphoric acid (H_3PO_4).

3.2 Apparatus and Equipment

The apparatus was used for this study are beaker (250 mL), aluminium foil, conical flask, measuring cylinder, spatula, crucible with lid, cuvette, airtight zip bag, filter papers and scott bottle. The equipment used in this study are oven, grinder, furnace, sieve, UV-Vis spectrophotometer, analytical balance, Fourier-Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM) and Brunauer-Emmett-Teller (BET).

3.3 Methods

3.3.1 Preparation of Bamboo-derived Activated Carbon

The bamboo raw was collected and washed thoroughly under tap water and was rinse using distilled water to make sure all dust, dirt or any unwanted matters remove from bamboo raw. Then, the bamboo was placed under the sun for 24 hours to dry. This was done to remove moisture from the bamboo. After that, the bamboo was oven-dry set at 70°C and left there for 24 hours. The purpose of this was to speed up the drying process and ensure that any remaining moisture were eliminated from the bamboo. After the dying process, the bamboo was cut into small pieces and then was grinded using a grinder machine. After that, the bamboo was carbonized using the furnace under high temperature of 500°C for 4 hours. Bamboo biochar was impregnated with phosphoric acid (H_3PO_4). The impregnated biochar is then heated at 600 °C. It creates pores and enhances the material adsorption properties. The bamboo activated carbon was stored in the airtight zipper bag and were sieved to get the particle size of 150 µm.

3.3.2 Preparation of Methylene Blue (MB) stock solution

1 g of methylene blue dye powder were weighed and dissolved in 1000 mL of distilled water to produced 1000 mg/L standard solution. The stock solution of MB dye was stored in a 1000 mL scott bottle in a dark place to prevent the dye from degrading due to exposure to light (Kuantari et al.,2018).

3.3.3 Preparation of Calibration Curve

The stock solution of methylene blue was prepared first by diluting at concentration of 0.5 mg/L, 2 mg/L, 4 mg/L, 8 mg/L and 10 mg/L from the standard MB solution using dilution method according to Equation 3.1

$$M_1V_1 = M_2V_2 \qquad \text{Equation 3.1}$$

Where M_1 is initial molarity, V_1 is initial volume, M_2 is final molarity, V_2 is final volume.

Subsequently, all solutions of methylene blue at varying concentrations were analyzed using a UV-Vis spectrometer at a wavelength of 665 nm (Alsubaie et al., 2021). Finally, absorbance readings were recorded to construct the calibration curve, which was then utilized to determine the final concentration of methylene blue.

3.4 Batch Adsorption Studies

Batch adsorption studies were conducted using Bamboo-derived Activated Carbon as the adsorbent for removing Methylene Blue (MB) dye. The parameters manipulated in this study included adsorbent dosage, initial dye concentration, and contact time. The adsorbent dosage ranged from 0.5 g to 4 g, while the initial concentration of the dye varied from 50 mg/L to 250 mg/L. Additionally, the range of contact time spanned from 30 minutes to 24 hours.

3.4.1 Effect of Adsorbent dosage

The study investigated the effect of adsorbent dosages set at 0.5 g, 1 g, 2 g, 3 g, and 4 g. Each dosage of the adsorbent was mixed with 100 mL of methylene blue solution. The agitation speed was maintained at 150 rpm, while the temperature was kept constant at 30°C. Following the designated contact time, the bamboo activated carbon was separated from the solution via filtration, and the filtrate was transferred to a cuvette. Subsequently, the cuvette was inserted into the UV-Vis spectrophotometer, where the absorbance reading was measured at a wavelength of 665 nm. The study was conducted following the approach outlined in Alsubaie et al. (2021), with minor adjustments tailored to the specific requirements of this investigation.

3.4.2 Effect of Initial Dye Concentration

The parameter was started from the working solution by mixing with 100 mL volume for each initial dye concentration at 50 mg/L,100 mg/L, 150 mg/L, 200 mg/L and 250 mg/L with the desired adsorbent dosage and contact time .The methodology outlined in Alsubaie et al. (2021) was used as a reference for conducting the experiment, with slight modifications made to suit the specific requirements of this study. After the end of the contact time, the solution was separated through filtration and the filtered solution was placed into the cuvette. The cuvette was inserted into the UV-Vis spectrophotometer at a wavelength of 665 nm to determine the absorbance reading.

3.4.3 Effect of Contact Time

The samples were filtered for thirty minutes, an hour, four hours, six hours, and twenty-four hours to examine the impact of contact time. The ideal adsorbent dose and starting dye concentration were used in this experiment, which was carried out based on earlier research. At the start of the experiment, the adsorbent and adsorbate combination were agitated, and the solution was filtered. To measure absorbance, the filtered solution was put into a cuvette. The methodology utilised in this study was adapted somewhat to meet the unique needs of the investigation, based on the strategy outlined by Alsubaie et al. (2021).

3.5 Analytical method using spectrophotometer.

The absorbance of Methylene Blue (MB) dye was assessed using a UV-Vis Spectrophotometer, with measurements taken at a wavelength of 665 nm. This wavelength was consistently employed throughout the experiment to establish the standard calibration curve and to determine the absorbance reading of the MB dye solution following the adsorption process (Cheng et al., 2013). The concentration of MB dye was calculated using linear standard curve equation. The removal percentage of MB dye were obtained according to the equation 3.2

$$\text{Removal Percentage of MB dye (\%)} = \frac{(C_i - C_f)}{C_i} \times 100 \qquad \text{Equation 3.2}$$

Where C_i is the initial concentration of MB dye (in mg/L) before the treatment and C_f is the final concentration of MB dye (in mg/L) after the treatment.

The adsorption capacity, q_e was calculated using Equation 3.3

$$\text{Adsorption capacity, } q_e = \frac{(C_i - C_f)}{m} \times V \qquad \text{Equation 3.3}$$

Where q_e represents the adsorption capacity (mg/g), C_i is the initial concentration of MB dye (in mg/L) before the treatment, C_f is the final concentration of MB dye (in mg/L) after the treatment, V is the volume (mL) of the solution and m is the mass (g) of the adsorbent.

3.6 Characterisation of Bamboo-derived Activated Carbon.

3.6.1 Fourier-Transform Infrared Spectroscopy (FTIR)

Fourier-Transform Infrared Spectroscopy (FTIR) analysis involves irradiating a sample with infrared light and measuring the absorption and transmission of the light at different frequencies (Liu et al., 2021). The importance of FTIR lies in identifying the functional groups of bamboo-derived activated carbon. FTIR analysis was conducted on 0.2 g of bamboo activated carbon and the bamboo powder after the adsorption process to observe its functional group properties.

3.6.2 Scanning Electron Microscope (SEM)

Scanning Electron Microscope (SEM) analysis was conducted to examine the morphology of bamboo structures, following the methodology outlined by Ragab et al. (2019). Specifically, 0.2 g of bamboo powder and bamboo powder after the adsorption process were analysed using a Jeol JSM-IT100 SEM instrument. The analysis involved observing the samples at five different magnification scales which is x200, x300, x400, x500 and x600, allowing for a detailed examination of the structural characteristics of the bamboo material.

3.6.3 Brunauer-Emmett-Teller (BET)

The Brunauer-Emmett-Teller (BET) method is a widely employed technique for assessing the surface area of porous substances such as activated carbon. This method entails the adsorption of a gas, typically nitrogen (N2), onto the material surface at various pressures and temperatures. Through measuring the quantity of gas adsorbed across different pressures and applying the BET equation, the material surface area can be computed. In this study, the surface areas of Bamboo Activated Carbon before (B0) and after (B1) adsorption were evaluated using N2 adsorption-desorption analysis, providing valuable insights into its adsorption capacity and efficiency.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Standard Calibration Curve of Methylene Blue dye

A calibration curve, also known as a standard curve in analytical chemistry, is used to quantify the amount of a particular substance in a sample by comparing its measurement response to the calibration curve. In this study, the relationship between absorbance and a known concentration of the Methylene Blue (MB) dye was utilized to determine the values of unknown concentrations of MB dye after the adsorption process. To prepare the calibration curve, various concentrations of Methylene Blue (MB) ranging from 0.5 to 10.0 mg/L were measured at a wavelength of 665 nm using a UV-Visible spectrophotometer. Table 4.1 presents the absorbance readings corresponding to different concentrations of MB dye (mg/L).

Table 4 1: The absorbances readings for different concentrations of MB dye (mg/L).

MB dye concentration (mg/L)	Absorbance reading
0.5	0.067
2.0	0.289
4.0	0.661
8.0	1.201
10.0	1.451

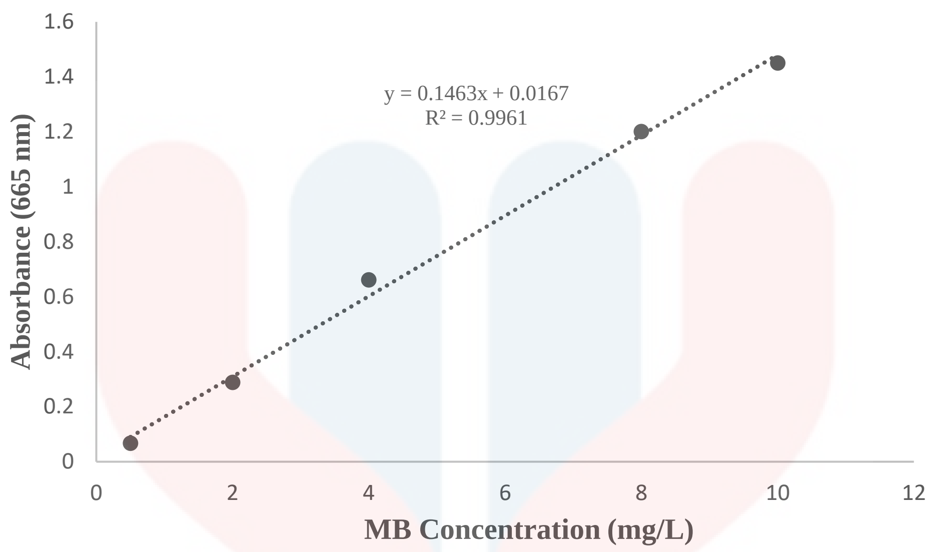


Figure 4 1: Calibration curve of MB dye.

Figure 4.1 depicts a clear linear relationship between absorbance readings and the concentration of MB dye. This graph illustrates that as the concentration of MB dye increases, there is a corresponding linear increase in absorbance, suggesting a proportional response. The sensitivity of the measurement is reflected in the steepness of the gradient line, with a larger slope indicating a more responsive measurement system.

The calibration curve in Figure 4.1 is plotted with absorbance readings of MB dye on the y-axis. This relationship is mathematically represented by the equation of a straight line: $y = 0.1463x + 0.0167$, where 0.1463 is the gradient of the straight line, and 0.0167 represents the y-intercept. To ascertain the unknown concentration (x) of MB dye after the adsorption process, the absorbance reading following adsorption serves as the y-value in the given equation. The coefficient of determination (R^2) for the standard curve gauges the fit of the curve to the experimental data. A higher R^2 value, closer to 1, signifies a more accurate fit. In this instance, the coefficient of determination is calculated as $R^2 = 0.9961$, indicating a robust alignment between the standard curve and the experimental data.

The R^2 value on a chart for a calibration curve represents the coefficient of determination, which is a measure of how well the regression line approximates the real data points. It is a measure of the goodness of fit of the regression line to the observed data points. Therefore, it is a measure of regression rather than correlation. A higher R^2 value indicates a better fit of the regression line to the data points, suggesting that the model explains a larger proportion of the variability in the response variable.

4.2 Control of methylene blue dye.

The control experiment serves as the foundational step, allowing researchers to establish a baseline measurement of the initial concentration of methylene blue dye in the absence of the adsorbent. This baseline becomes a crucial reference point against which subsequent experiments can be compared. By understanding the initial concentration without any interaction with the adsorbent, researchers can accurately assess the adsorption capacity of the bamboo-derived activated carbon. Table shows the absorbance reading on control of difference concentration of stock solution.

Table 4 2 : Absorbance reading on difference initial concentration.

Initial concentration (mg/L)	Absorbance reading
50	1.445
100	1.611
150	1.698
200	1.793
250	1.816

Moreover, the control experiment serves as a confirmation tool. It verifies that any changes observed in the subsequent experiments are indeed a result of the adsorption process and not influenced by variations in the initial concentration of the dye solution. This ensures the specificity of the experimental outcomes. Including a control group aligns with the standard practices of experimental design, providing a basis for isolating the impact of independent variables such as adsorbent dosage, initial concentration, and contact time on the dependent variable of dye adsorption. This approach enhances the statistical validity of the study, allowing for robust comparisons and analyses.

4.3 Effect of adsorbent dosage on Methylene Blue dye and Bamboo Activated Carbon

As the dosage of adsorbent increased, the percentage of dye removal also rose. At 4 g, the ideal adsorbent dose was reached. The proportion of dye removal stabilised at 4 g. A certain quantity of dye may be adsorbed using the graph is consistency, which results from the constant mass. In summary, the more adsorbent dosage used, the greater the amount of effluent that can be purified.

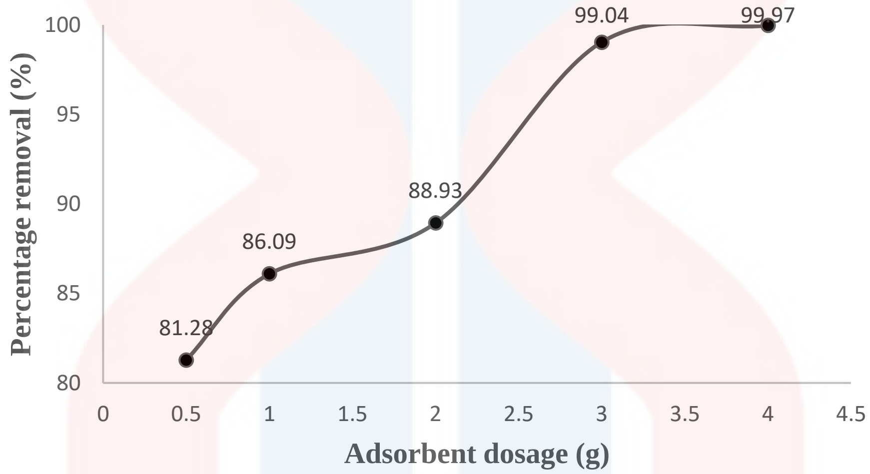


Figure 4 2: Effect of different adsorbent dosage on removal percentage of MB dye.

According to Figure 4.2, the removal percentage of Methylene Blue (MB) dye demonstrated a gradual increase as the adsorbent dosage increased from 0.5 g to 4 g. This phenomenon can be attributed to the increased adsorbent dose, which results in a larger adsorbent surface area and greater availability of adsorption sites. This observation aligns with a study by Nadafi et al. (2014) on the adsorption of Reactive Red 120 dye removal from aqueous solution on nano-alumina. In their study, they reported that an increase in adsorbent dose at a constant dye concentration led to the saturation of adsorption sites throughout the adsorption process, consequently resulting in an increase in the percentage of dye removal. Beyond this point, the graph plateaus, indicating a saturation of adsorption sites and a constant dye removal percentage. This suggests that, while increased adsorbent dosage enhances dye removal initially, there is a limit to the adsorption capacity. This insight is crucial for practical applications, suggesting that there is an upper limit to the amount of dye that can be effectively removed.

4.4 Effect of initial concentration on Methylene Blue dye and Bamboo Activated Carbon

The effect of initial concentration with the Methylene Blue (MB) dye removal percentage was determined using varied concentration from 50 mg/L to 250 mg/L at the fixed adsorbent dosage and contact time which is 4 g and 3 hours.

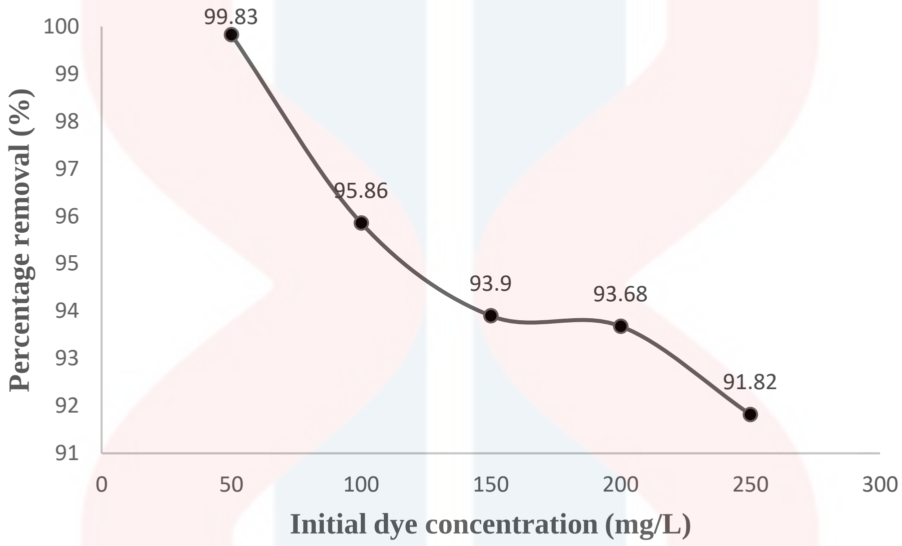


Figure 4 3: Effect of initial concentration on removal percentage of MB dye.

Figure 4.3 illustrates the impact of initial concentration on the removal percentage of MB dye. The graph indicates that as the initial dye concentration increases, the percentage of clearance of the initial dye concentration decreases. Specifically, at an initial concentration of 50 mg/L, the maximum removal percentage is 99.83%, whereas at an initial concentration of 250 mg/L, the lowest removal percentage is 91.82%. This trend may be attributed to the limited availability of active sites necessary to accommodate the high starting concentration of dyes. At lower concentrations, the adsorption sites absorb the available solute more readily.

This study examination the effect of initial concentration on the adsorption of dyes on activated carbon made from apricot stones and commercial activated carbon aligns with the findings of Djilani et al. (2015). They reported that as the concentration increased at a fixed adsorbent dose, the percentage of Methylene Blue dye and Methyl Orange removal decreased.

4.5 Effect of contact time on Methylene Blue dye and Bamboo Activated Carbon

To investigate the relationship between contact time and the removal percentage of Methylene Blue (MB) dye, the removal percentage was determined at contact times of 30 minutes, 1 hour, 4 hours, 6 hours, and 24 hours. This analysis was conducted using a fixed adsorbent dosage of 4g and a fixed initial concentration of 50 mg/L.

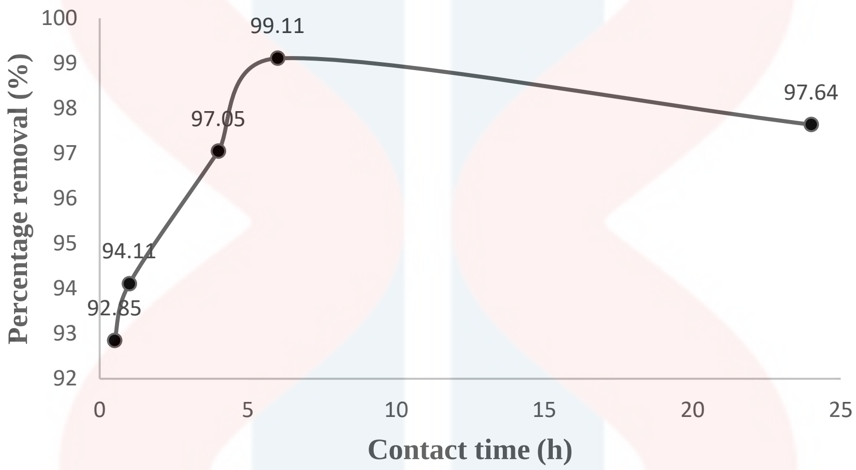


Figure 4 4: Effect of contact time on removal percentage of MB dye.

Based on Figure 4.4, the percentage removal was rising from the first 30 minutes to 6 hours but then decrease at 24 hours. The highest percentage of Methylene Blue (MB) dye removal is increasing to 99.11% at the contact time of 6 hours. The lowest removal percentage of MB dye removal was at 92.85% when the contact time is at 30 minutes. As the contact time increases, more and more MB dye molecules are attracted to and occupy the available sites on the activated carbon. It is possible that the adsorption sites on the adsorbent became saturated after 6 hours. At this point, most available sites for methylene blue (MB) dye adsorption may have been occupied, leading to a reduced capacity to adsorb additional dye molecules (Kuantari et al.2018).

After an initial phase of adsorption, the surface becomes saturated, and additional contact time which is 24 hours does not lead to a proportional increase in dye removal. At saturation, the adsorbent capacity is significantly reduced, and equilibrium is reached where adsorption and desorption are balanced. This understanding is crucial for optimizing adsorption processes and determining the maximum adsorption capacity of the material (Kujawska & Wasag, 2021).

4.6 Effect of Adsorption Parameter on Adsorption Capacity

The effect of adsorption parameters, including adsorbent dosage, initial concentration, and contact time, was systematically investigated in this study. Adsorption capacity was a critical parameter that indicated how effectively an adsorbent material could remove contaminants from a solution. It depended on various factors, including the properties of the adsorbent material, the characteristics of the contaminant, and the operating conditions (Elzahar et al,2023).

Adsorption batch experiments were used to investigate the adsorption characteristics and the variables influencing the adsorption in the adsorption test for Methylene Blue (MB) dye removal from aqueous solutions. Batch tests were carried out by adjusting the dye concentration, adsorbent mass, and contact time.

4.6.1 Effect of Adsorbent Dosage on Adsorption Capacity

The effect of adsorbent dosage on adsorption capacity was determined using different dosage from 0.5 g to 4.0 g with initial concentration of 50 mg/L and contact time of 3 hours. Figure 4.5 shows the effect of adsorbent dosage on adsorption capacity.

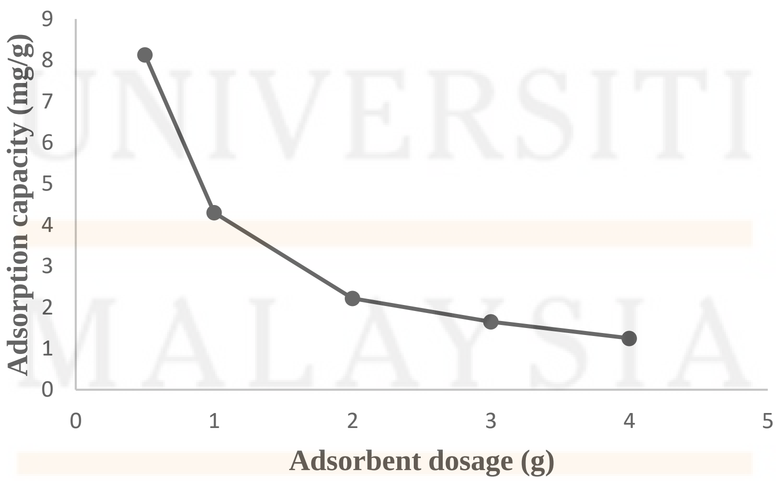


Figure 4 5: The effect of adsorbent dosage on adsorption capacity.

From the graph, the result shows that the adsorption capacity was keep decreasing from 8.128 mg/g, 4.305 mg/g ,2.223 mg/g, 1.651 mg/g and 1.250 mg/g as the adsorbent dosage is increased. This indicates that adsorption is more likely to be an attachment-controlled process at greater adsorbent doses later in the process, indicating that the system has achieved saturation (Gorzin et al., 2017). Because of this saturation, available adsorption sites are used less effectively, resulting in declining returns and emphasising the need of determining the ideal adsorbent dose for efficient and cost-effective methylene blue dye removal.

4.6.2 Effect of Initial Concentration on Adsorption Capacity

The effect of initial concentration on adsorption capacity (m/g) was assessed using varied concentrations ranging from 50 mg/L to 250 mg/L. This analysis was conducted with a fixed adsorbent dosage of 4.0 g and a contact time of 3 hours. The average absorbance reading was calculated, and the data were plotted on a graph to determine the adsorption capacity. Figure 4.6 illustrates the effect of initial concentration on adsorption capacity.

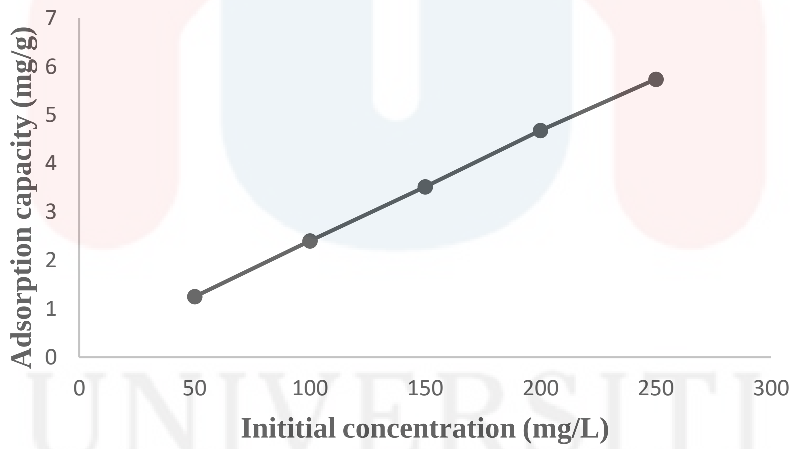


Figure 4 6: The effect of initial concentration on adsorption capacity.

The graph depicts a continuous increase in adsorption capacity from 1.248 mg/g, 2.397 mg/g, 3.521 mg/g, 4.684 mg/g, and finally to 5.739 mg/g. Notably, the highest adsorption capacity of 5.739 mg/g is observed at an initial concentration of 250 mg/L. This trend suggests that as the initial concentration of methylene blue dye increases, the concentration gradient between the solution and the adsorbent surface becomes more pronounced. This heightened gradient serves as an increased driving force, prompting more dye molecules to migrate from the solution to the adsorbent surface. Consequently, the adsorption capacity of the adsorbent rises correspondingly.

4.6.3 Effect of Contact Time on Adsorption Capacity

The relationship between contact time and adsorption capacity was investigated by measuring absorbance at different contact times: 30 minutes, 1 hour, 4 hours, 6 hours, and 24 hours. This study utilized an absorbent dosage of 4.0 g and an initial concentration of 50 mg/L. Average absorbance readings were computed for each contact time, and a graph was generated to depict the trend in the impact of contact time on adsorption capacity.

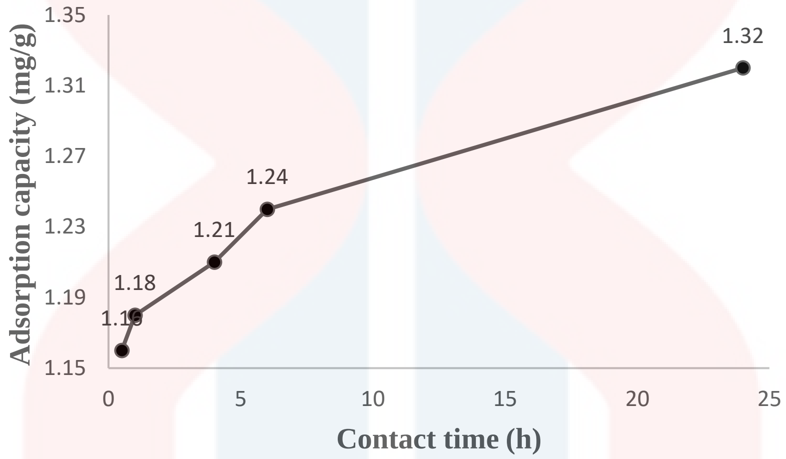


Figure 4 7: The effect of contact time on adsorption capacity.

Figure 4.7 shows the plotted graph, and it was shown that the reading of percentage removal keeps rising. When the contact time is at 30 minutes, the lowest adsorption capacity was determined at 1.161 mg/g. When the contact time is at 60 minutes (1 hour), 240 minutes (4 hours) and 360 hours (6 hours), the adsorption capacity rose to 1.176 mg/g ,1.213 mg/g ,1.239 mg/g and lastly at the highest point at 1.221 mg/g when the contact times reach 1440 minutes (24 hours).

As the contact time extends, more opportunities arise for the interaction between methylene blue dye molecules and the adsorption sites on the activated carbon surface. Initially, at shorter contact times, the adsorption process may be in its nascent stages, with fewer sites being utilized. However, with the progression of time, a greater proportion of available sites become engaged in the adsorption of dye molecules. The highest adsorption capacity recorded at 24 hours, emphasizing the significance of extended contact times for achieving optimal adsorption efficiency.

4.7 Characterization of Bamboo- Derived Activated Carbon

Fourier-Transform Infrared Spectroscopy (FTIR) analysis was used to characterise the adsorbent samples to ascertain their chemical composition and the mechanism behind the adsorption process. The surface shape of the bamboo was examined using SEM analysis, and the number of surface areas on the adsorbent samples was characterised using BET analysis (Alsubie et al., 2021).

4.7.1 Fourier-Transform Infrared Spectroscopy (FTIR) analysis of Bamboo Activated Carbon.

Figure 4.8 illustrates how Fourier-Transform Infrared Spectroscopy (FTIR) was used in this investigation to characterise the activated carbon generated from bamboo both before and after adsorption. The bamboo functional groups were detected at a wavelength between 500 and 4000 cm^{-1} both before and after adsorption.

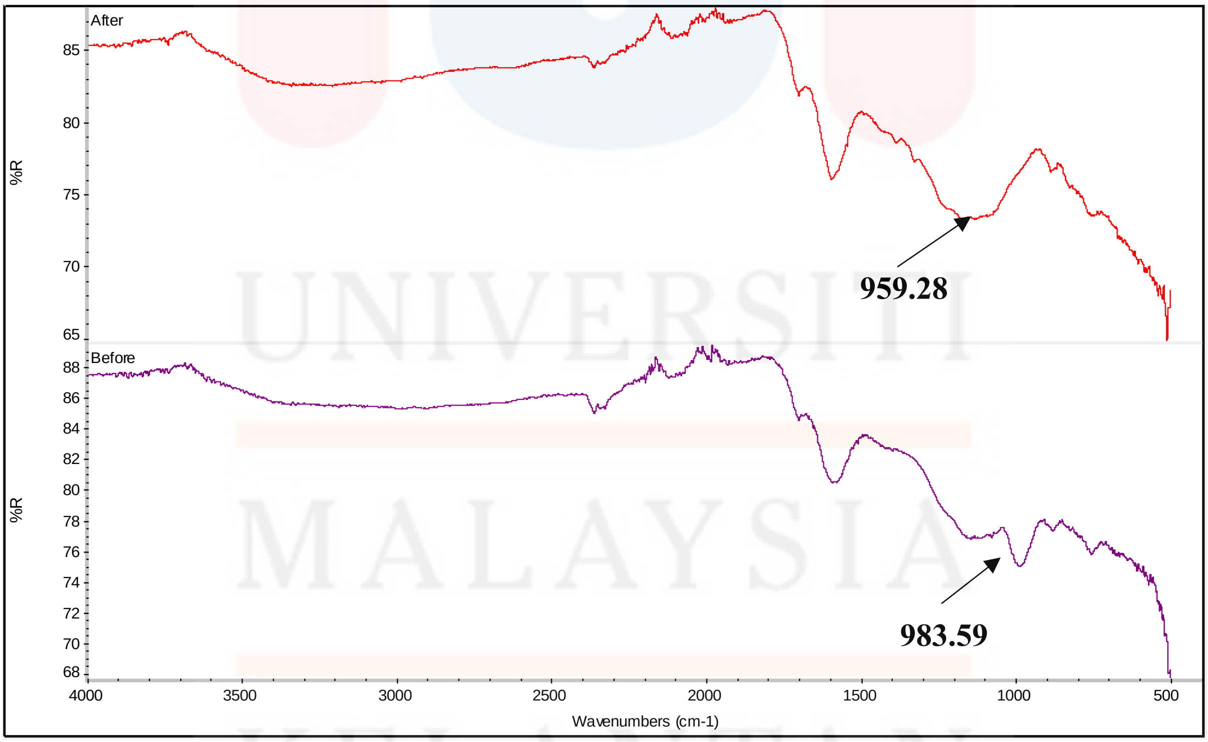


Figure 4 8: The spectrum of Bamboo-derived activated carbon before and after adsorption.

The purple line indicates the spectrum and functional group of bamboo-derived activated carbon before adsorption. For the bamboo-derived activated carbon before adsorption, it was discovered that the FTIR spectrum showed medium band at 3343.58 which was due to stretching of N-H and there is a presence of secondary amine. These results were also reported by Fernandes Queiroz et al., who observed the infrared spectrum of chitosan. They noted a strong band in the region of 3291.361 cm^{-1}, corresponding to N-H and O-H stretching, as well as intramolecular hydrogen bonds. Then, the band at 1403.761 is a medium band with bending of O-H bond and the presence of carboxyl acid. The bands at 1706.95 was due to strong C=O stretching of conjugated acid (Liu et al, 2021).

The red line indicates bamboo-derived activated carbon after adsorption takes place. Bands at 3343.581 before the adsorption shifted to 3336.22 respectively as shown in Figure 4.1. The shifts in the bands confirmed the participation of the functional groups in the adsorption of MB dye on bamboo-derived activated carbon. The appearance of the new bands 1320.08 was assigned to strong S=O stretching of sulfone. Apart from that, there was another band at 959.28 due to the strong C=C bending of alkane (Liu et al, 2021). The appearance of the new bands was due to the changes in binding after the interaction with MB dye. The details of infrared spectroscopy absorptions by frequency regions can be obtained in Table 4.3.

Table 4 3: Details of infrared spectroscopy absorptions.

IR Peak	Before adsorption (B0) (1/cm)	After adsorption (B1) (1/cm)	Assignment
1.	3343.58	3336.22	N-H Stretch
2.	2914.03	2925.59	C-H Stretch
3.	1706.95	1697.49	C=O Stretch
4.	1404.76	1389.04	O-H Bend
5.	983.59	959.281	C=C Bend

4.7.2 Scanning Electron Microscopy (SEM) of Bamboo-Derived Activated Carbon.

This study used Scanning Electron Microscopy (SEM) to examine the surface morphology of the bamboo both before and after adsorption. Figure 4.9 displayed the bamboo surface morphology before to adsorption, whereas Figure 4.10 displayed the surface morphology following adsorption.

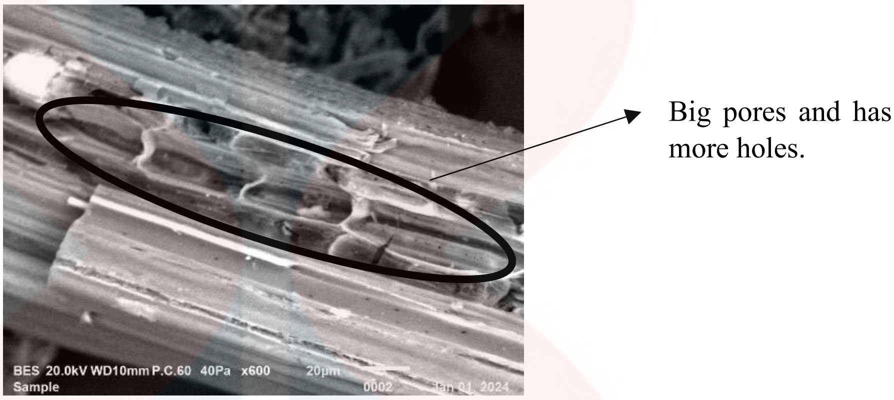


Figure 4 9: The scanning electron microscopy (SEM) image of bamboo activated carbon before adsorption.

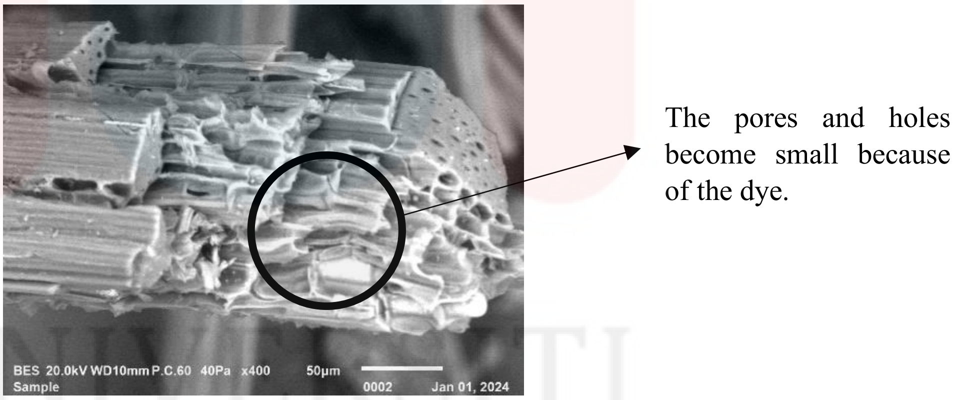


Figure 4 10:The scanning electron microscopy (SEM) image of bamboo activated carbon after adsorption.

Compared to photos of the bamboo-derived activated carbon after adsorption, the scanning electron microscopy (SEM) image of bamboo-derived activated carbon before adsorption had more, big pores and holes. There is a greater surface area available for adsorption when there are more pores and holes in the pre-adsorption state. Diffusion of dye molecules onto the adsorbent surface is the cause of the reduction of pores and holes following adsorption (Ragab et al. 2019). The pores and holes that had been observed before adsorption in bamboo activated carbon are a result of the material natural composition and the deliberate activation process, both of which contribute to the effectiveness of the adsorbent in capturing and removing substances from the surrounding environment.

4.7.3 Brunauer-Emmett-Teller (BET) analysis of Bamboo Activated Carbon.

Table 4.4 below shows the number of surface area by two sample which is Bamboo Activated Carbon before adsorption (B0) and Bamboo Activated Carbon after adsorption (B1). The analysis, conducted through N2 adsorption-desorption, provides valuable insights into the changes in surface area, average pore size, and total pore volume of the material following the adsorption process.

Table 4 4: Number of surface area by two (2) sample which of B0 and B1.

Type of Sample	Number of surface area (m^2/g)
(B0)	1.808
(B1)	22.679

The surface area is a critical parameter in determining the adsorption capacity of a material. In the case of B0, the initial surface area was found to be 1.808 m^2/g, indicating a relatively low adsorption potential. However, after the adsorption process (B1), there was a remarkable increase in surface area to 22.679 m^2/g. This significant augmentation implies enhanced adsorption capability, possibly due to the material interaction with the adsorbate.

The increased surface area and pore volume of B1 suggest a more favourable environment for adsorption to occur. This may be attributed to the formation of new adsorption sites or the enlargement of existing pores, facilitating a more efficient adsorption process.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Methylene Blue (MB) dye was effectively removed from the sample using activated carbon made from bamboo. The adsorbent dosage ranged from 0.5, 1, 2, 3, and 4 g; the starting concentration ranged from 50 mg/L to 250 mg/L and the contact period ranged from 30 minutes to 24 hours. These three parameters were the subjects of this investigation. The two responses the adsorption capacity and the % elimination of MB dye successfully demonstrate the accuracy of the model that was created. It is possible to draw the conclusion from the experiment that as the number of adsorbent doses grew, so did the percentage of MB elimination. While adsorption capacity of MB dye will increase with the increasing number of initial concentrations. The increase of contact time will increase the adsorption capacity.

Furthermore, the experiment indicates that the maximum percentage removal is 99.97% when the adsorbent dose is 4g, the beginning concentration is 50 mg/L, and the contact period is 3 hours. At the operating circumstances of 0.5g adsorbent dose, 50 mg/L initial concentration, and 3 hours of contact time, the lowest percentage removal is 81.28%. When the adsorbent dose is 0.5g, the starting concentration is 50 mg/L, and the contact period is 3 hours, the maximum adsorption capacity is 8.128 mg/g.

The physical and chemical characteristics of Bamboo-derived Activated Carbon before and after removal of Methylene Blue (MB) dye were analysed using FTIR analysis. Meanwhile, Scanning Electron Microscopy (SEM) was used to investigate the surface morphology of bamboo and Brunauer-Emmett-Teller (BET) analysis was used to identify the number of surfaces area.

5.2 Recommendation

Several suggestions can enhance the study. Firstly, employing energy dispersive X-ray (EDX) for initial elemental analysis, followed by X-ray diffraction (XRD) to determine crystallinity or amorphous nature, and concluding with X-ray fluorescence (XRF) to examine interactions between electron beams and X-rays with samples, can provide comprehensive insights into the sample composition.

Furthermore, considering the use of activated carbon derived from bamboo and biochar as adsorbents can offer environmental benefits. Activated carbon, widely recognized for its adjustable specific surface area, hierarchically porous structure, high adsorption capacity, and economic viability, as noted by Wang et al. (2023), remains a prevalent choice. This indicates that incorporating biochar into research projects need not negatively impact the environment.

Moreover, replacing filtration with the centrifugation method can enhance efficiency. Centrifugation, driven by power-operated machines, facilitates faster and more effective separation. It offers efficient separation of solids from liquid solutions or slurries compared to filtration using filter paper, which is time-consuming and less efficient. Therefore, employing centrifugation in the study can expedite the separation process and enhance efficiency.

Based on this study, the bamboo derived activated carbon proven to have potential to remove Methylene Blue Dye successfully. The bamboo can be easily obtained and less costly as it is available in the nature in abundance amount.

REFERENCES

Ardila-Leal, L. D., Poutou-Piñales, R. A., Pedroza-Rodríguez, A. M., & Quevedo-Hidalgo, B. E. (2021). A Brief History of Colour, the Environmental Impact of Synthetic Dyes and Removal by Using Laccases. *Molecules (Basel, Switzerland), 26*(13), 3813. https://doi.org/10.3390/molecules26133813

Maheshwari, Karishma & Agrawal, Madhu & Gupta, Akhilendra. (2021). Dye Pollution in Water and Wastewater. 10.1007/978-981-16-2892-4_1.

Divya, Divakaran & Suyambulingam, Indran & Bharath, K N. (2020). Bamboo: A Potential Natural Material for Bio-composites. 10.1007/978-981-15-8489-3_2.

Lamaming, Junidah & Saalah, Sariah & Rajin, Mariani & Ismail, Noor & Yaser, Abu. (2022). A Review on Bamboo as an Adsorbent for Removal of Pollutants for Wastewater Treatment. International Journal of Chemical Engineering. 2022. 1-14. 10.1155/2022/7218759.

BERNAMA. (2021, August 18). *ADVENTURE TOUR OPERATOR'S LUCRATIVE VENTURE INTO HONEY BAMBOO SHOOTS.* BERNAMA. https://www.bernama.com/en/news.php?id=1993980

Stothers, J. & Abrahart, E. N. (2019, March 5). Dye. In Encyclopedia Britannica. Retrieved from https://www.britannica.com/technology/dye

Sharma, Jyotshana & Sharma, Shubhangani & Soni, Vineet. (2021). Classification and impact of synthetic textile dyes on Aquatic Flora: A review. Regional Studies in Marine Science. 45. 101802. 10.1016/j.rsma.2021.101802.

Yang J, Wu L, Yang H, Pan Y. Using the Major Components (Cellulose, Hemicellulose, and Lignin) of *Phyllostachys praecox* Bamboo Shoot as Dietary Fiber. Front Bioeng Biotechnol. 2021 Mar 31; 9:669136. doi: 10.3389/fbioe.2021.669136. PMID: 33869163; PMCID: PMC8044402.

Roslan, Amni Husna & Rasid, Z & Hassan, Mohamad. (2018). Bamboo reinforced polymer composite - A comprehensive review. IOP Conference Series: Materials Science and Engineering. 344. 012008. 10.1088/1757-899X/344/1/012008.

Javaid, R., & Qazi, U. Y. (2019). Catalytic oxidation process for the degradation of synthetic dyes: An overview. *International Journal of Environmental Research and Public Health*, 16(11), 2066.

Udyani, K., & Purwaningsih, D. Y. (2021). Chemical and Physical Activation Using a Microwave to Increase the Ability of Activated Carbon to Adsorb Dye Waste. *Journal of Physics: Conference Series*, *2117*(1), 012030. https://doi.org/10.1088/1742-6596/2117/1/012030

Pavithra, K. G., P., S. K., V., J., & P., S. R. (2019). Removal of colorants from wastewater: A review on sources and treatment strategies. *Journal of Industrial and Engineering Chemistry*, *75*, 1–19. https://doi.org/10.1016/j.jiec.2019.02.011

Britannica, T. Editors of Encyclopaedia (2023, November 9). bamboo. Encyclopedia Britannica. https://www.britannica.com/plant/bamboo

Gohr, M. S., Abd-Elhamid, A. I., El-Shanshory, A. A., & Soliman, H. M. (2022). Adsorption of cationic dyes onto chemically modified activated carbon: Kinetics and thermodynamic study. *Journal of Molecular Liquids*, 346, 118227.

Patra, C., Gupta, R., Bedadeep, D., & Narayanasamy, S. (2020). Surface treated acid-activated carbon for adsorption of anionic azo dyes from single and binary adsorptive systems: A detail insight. *Environmental Pollution*, *266*, 115102. https://doi.org/10.1016/j.envpol.2020.115102

Shi, Z., Chow, C. W. K., Fabris, R., Liu, J., & Jin, B. (2020). Alternative particle compensation techniques for online water quality monitoring using UV–Vis spectrophotometer. *Chemometrics and Intelligent Laboratory Systems*, *204*, 104074. https://doi.org/10.1016/j.chemolab.2020.104074

Wang, S., Cai, Y., Sun, Y., & Cai, H. (2019). Preparation and application of bamboo-based activated carbon for the removal of dyes from wastewater. *Journal of the Air & Waste Management Association*, 69(8), 973-981.

Ahmad F. A. (2023). The use of agro-waste-based adsorbents as sustainable, renewable, and low-cost alternatives for the removal of ibuprofen and carbamazepine from water. *Heliyon*, *9*(6), e16449. https://doi.org/10.1016/j.heliyon.2023.e16449

Ameri, A., Tamjidi, S., Dehghankhalili, F., Farhadi, A., & Saati, M. A. (2020). Application of algae as low cost and effective bio-adsorbent for removal of heavy metals from wastewater: a review study. *Environmental Technology Reviews*, *9*(1), 85–110. https://doi.org/10.1080/21622515.2020.1831619

Benkhaya, S., M'rabet, S., & El Harfi, A. (2020). Classifications, properties, recent synthesis and applications of azo dyes. *Heliyon*, *6*(1). https://doi.org/10.1016/j.heliyon.2020.e03271

Saijo, K. (2022). Bamboo education: Learning the environmental benefits of bamboo. Open Access Government, January 2023, 270-271. Retrieved from https://www.openaccessgovernment.org/article/bamboo-education-learning-the-environmental-benefits-of-bamboo/147615/

Kamble, Sharad & Shinde, Sunita. (2020). A Review: Various Adsorbent Carriers used for Enhancing Dissolution Profile. 7. 5-9.

Teo, S. H., Ng, C. H., Islam, A., Abdulkareem-Alsultan, G., Joseph, C. G., Janaun, J., Taufiq-Yap, Y. H., Khandaker, S., Islam, G. J., Znad, H., & Awual, Md. R. (2022). Sustainable toxic dyes removal with advanced materials for clean water production: A comprehensive review. *Journal of Cleaner Production*, *332*, 130039. https://doi.org/10.1016/j.jclepro.2021.130039

Garg, V. K., Amita, M., Kumar, R., & Gupta, R. (2019). Basic dye (methylene blue) removal from simulated wastewater by adsorption using Indian Rosewood sawdust: a timber industry waste. Dyes and Pigments, 63(3), 243-250.

Activated Carbon – Aletihad Minerals. (n.d.). Retrieved January 6, 2024, from https://aletihadminerals.com/product/activated-carbon/.

Rápó, E., & Tonk, S. (2021). Factors Affecting Synthetic Dye Adsorption; Desorption Studies: A Review of Results from the Last Five Years (2017-2021). *Molecules (Basel, Switzerland)*, *26*(17), 5419. https://doi.org/10.3390/molecules26175419

Jumadi Jumadi, Azlan Kamari, Nasrudin Abd Rahim, Sze Chun Wong, S N M Yusoff, Ishak, S., Abdulrasool, M. M., & S. Thirumalai Kumaran. (2019). *Removal of methylene blue and congo red by magnetic chitosan nanocomposite: Characterization and adsorption studies*. *1397*(1), 012027–012027. https://doi.org/10.1088/1742-6596/1397/1/012027

Abbas, M. (2020). Experimental investigation of activated carbon prepared from apricot stones material (ASM) adsorbent for removal of malachite green (MG) from aqueous solution. *Adsorption Science & Technology*, *38*(1-2), 24–45. https://doi.org/10.1177/0263617420904476

Kaur, S., & Sandhu, I. S. (2018). Methylene blue: Revisited. Journal of Applied and Natural Science, 10(3), 1370-1375.

Uddin, M. T., Alharbi, O. M. L., & Mahmoud, M. E. (2019). Textile dyeing with reactive dyes: Recent developments, challenges, and opportunities. Journal of Industrial Textiles, 49(3), 322-362.

Oladoye, P. O., Ajiboye, T. O., Omotola, E. O., & Oyewola, O. J. (2022). Methylene blue dye: Toxicity and potential elimination technology from wastewater. *Results in Engineering*, *16*, 100678. https://doi.org/10.1016/j.rineng.2022.100678

Ren, H., & Zhang, X. (2019). *High-Risk Pollutants in Wastewater*. Elsevier.

van Haaren, C., De Bock, M., & Kazarian, S. G. (2023). Advances in ATR-FTIR Spectroscopic Imaging for the Analysis of Tablet Dissolution and Drug Release. *Molecules*, *28*(12), 4705. https://doi.org/10.3390/molecules28124705

Mohammed, H. M. (2021). Adsorption of methylene orange dye from wastewater using modified pumice stone: Kinetic and equilibrium studies. Journal of Chemical and Pharmaceutical Research, 13(6), 37-46.

Kaur, P., & Sharma, M. (2019). Azo dyes and their environmental impact. Journal of Environmental Chemical Engineering, 7(4), 103220

Yuan Gao, Qinyan Yue, Baoyu Gao, Aimin Li, Insight into activated carbon from different kinds of chemical activating agents: A review, Science of The Total Environment, Volume 746, 2020, 141094, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2020.141094.

Asif Ahmad, Tauseef Azam, 4 - Water Purification Technologies, Editor(s): Alexandru Mihai Grumezescu, Alina Maria Holban, Bottled and Packaged Water, Woodhead Publishing, 2019, Pages 83-120, ISBN 9780128152720, https://doi.org/10.1016/B978-0-12-815272-0.00004-0.

Ragab, A., Ahmed, I., & Bader, D. (2019). The Removal of Brilliant Green Dye from Aqueous Solution Using Nano Hydroxyapatite/Chitosan Composite as a Sorbent. *Molecules (Basel, Switzerland)*, *24*(5), 847. https://doi.org/10.3390/molecules24050847

Wang, B., Lan, J., Bo, C., Gong, B., & Ou, J. (2023). Adsorption of heavy metal onto biomass-derived activated carbon: review. *RSC advances*, *13*(7), 4275–4302. https://doi.org/10.1039/d2ra07911a

Kuntari, Kuntari & Fajarwati, Febi. (2018). Utilization of bamboo leaves wastes for methylene blue dye adsorption. AIP Conference Proceedings. 2026. 020062. 10.1063/1.5065022.

Alsubaie, Norah & Alshamrani, Rawan & Domyati, Doaa & Alahmadi, Nadiyah & Bannani, Fatma. (2021). Methylene Blue Dye Adsorption onto Polyoxometalate Ionic Liquid Supported on Bentonite: Kinetic, Equilibrium and Thermodynamic Studies. Open Journal of Physical Chemistry. 11. 106-127. 10.4236/ojpc.2021.112006.

Kujawska, J., & Wasag, H. (2021). Biochar: a low-cost adsorbent of Methylene Blue from aqueous solutions. *Journal of Physics: Conference Series*, *1736*(1), 012002. https://doi.org/10.1088/1742-6596/1736/1/012002

Liu, Xin. "6.3 IR Spectrum and Characteristic Absorption Bands." *Kpu.pressbooks.pub*, 2021, kpu.pressbooks.pub/organicchemistry/chapter/6-3-ir-spectrum-and-characteristic-absorption-bands/.

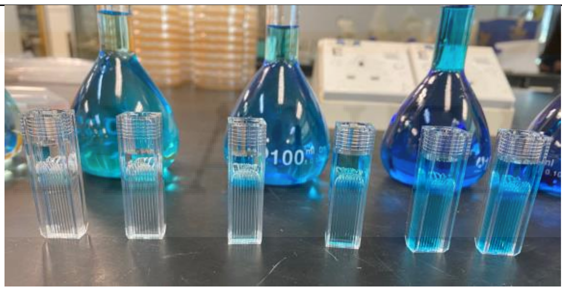
Abdullah, Avin & Mohammed, Azad. (2019). Scanning Electron Microscopy (SEM): A Review.

APPENDIX A

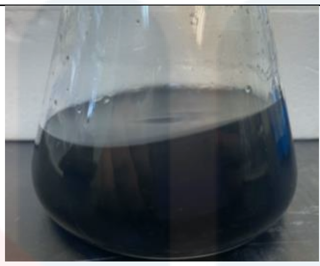
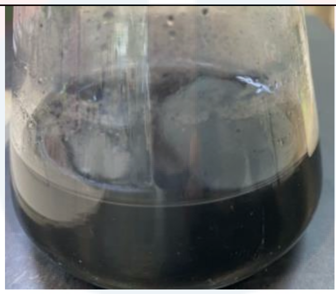
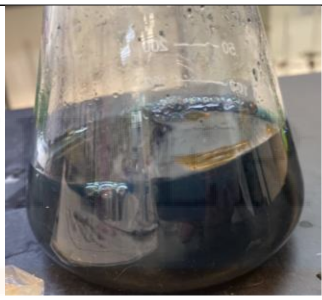
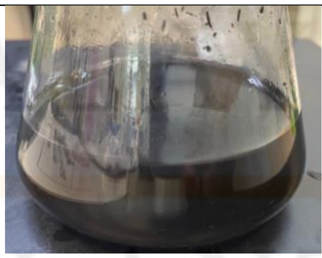
Stock solution of Methylene Blue Dye (1000 mg/L)	

Bamboo	   

Bamboo after furnace	 

Standard Cabliration curve (0.5,2.0,4.0, 8.0 and 10.0 mg/L)


Effect on Adsorbent dosage time on Methylene Blue dye and Bamboo Activated Carbon

Adsorbent dosage (g)	Before adsorption	After adsorption
		
		
		
		
		

Effect of initial dye concentration on Methylene Blue dye and Bamboo Activated Carbon

Initial concentration (mg/L)	50	100	150	200	250
After adsorption					

Effect of contact time on Methylene Blue dye and Bamboo Activated Carbon

Contact Time	30 minutes	1 hour	4 hours	6 hours	24 hours
After adsorption