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Preface

The Scientific Project Colloquium offers a platform for publishing Diploma Science final year projects (FYP). The objective is to effectively distribute research findings throughout all scientific disciplines. The primary objective of including final year projects into the course curriculum is to encourage students to put their theoretical knowledge into practical applications.

We would like to express our gratitude to our primary establishment, the Faculty of Applied Sciences and Universiti Teknologi MARA, Perak Branch, for their invaluable assistance.

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EFFECT OF pH ON THE ADSORPTION OF METHYL ORANGE USING BASE MODIFIED ACTIVATED CARBON-BASED ON OIL PALM FRONDS

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Abstract: The present study has developed an eco-friendly method for green synthesis of base-modified activated carbon (NaOHAC) based on oil palm fronds. By utilizing a waste product from the oil palm industry, this approach not only addresses the issue of waste management but also contributes to environmental sustainability. The percentage of methyl orange removed was determined by monitoring the changes in its concentration using UV-Vis spectrophotometry as pH varied. The methyl orange of 50 ppm is almost completely removed at pH 2.0 within 1 hour of the reaction. The findings suggest that NaOHAC, which produced from a waste material, has a high potential as an adsorbent for removing dyes from water.

Keywords: *oil palm fronds, activated carbon, adsorption, pH, sodium hydroxide*

INTRODUCTION

The increasing demands of a growing global population have resulted in significant environmental challenges, particularly regarding water pollution. Among the various pollutants, synthetic dyes have emerged as a significant concern due to their extensive use in textiles, plastics, and food processing industries. These dyes, primarily composed of chromophores and auxochromes, pose serious environmental and health risks (Yusuf, 2019). The color of a dye is attributed to chromophores, while auxochromes influence the intensity of the color. The presence of synthetic dyes in water bodies can have adverse effects, including toxicity to aquatic life, disruption of ecosystems, and potential carcinogenic effects on humans (Turhan, 2022). Methyl orange is particularly relevant in this context due to its widespread use in various industrial applications and its known toxic effects on aquatic organisms and human health (Abollé et al., 2022; Ibrahim et al., 2014). The removal of methyl orange from wastewater is crucial for protecting water quality and ensuring public health. Consequently, there is an urgent and imperative need for effective and sustainable techniques to eliminate these pollutants from wastewater (Chen et al., 2011; Li et al., 2013). Various treatment methods have been proposed to address the issue of dye pollution, including precipitation, oxidation, coagulation, membrane separation, and adsorption (Athar et al., 2018; Kolya & Kang, 2024). Adsorption has garnered significant attention owing to its cost-effectiveness, simplicity, and, notably, its exceptional efficacy in the removal of organic dyes from wastewater (Fang & Qu, 2023). Activated carbon is the most commonly used as an adsorbent in industrial applications due to its high surface area and porous structure, which facilitate the adsorption process (Eris & Bashiri, 2016; Zhao et al., 2014). The unique properties of activated carbon make it suitable for a wide range of applications, including the removal of both organic and inorganic pollutants from water (Eris & Bashiri, 2016). However, producing commercially viable activated carbon can be costly, leading researchers to explore alternative sources for its production. Agricultural waste, livestock byproducts, and other renewable resources have been identified as potential feedstocks for activated carbon production (Kanawade & Gaikwad, 2011). One promising source is oil palm fronds, a byproduct of the oil palm industry, a significant agricultural sector in Malaysia. The high lignin content of oil palm fronds makes them particularly suitable for activated carbon production, as lignin contributes to the development of the porous structure during the activation process (Eris & Bashiri, 2016). The exploration of cost-effective and sustainable methods for dye removal, mainly through the use of activated carbon derived from agricultural waste such as oil palm fronds, offers promising solutions. The significance of studying the preparation of base-modified activated carbon from oil palm fronds lies in its potential to provide sustainable and cost-effective solutions for water treatment. The base modification process can enhance the adsorption capabilities of activated carbon, leading to improved removal rates for contaminants such as methyl orange, a commonly used model pollutant in water treatment studies (Abollé et al., 2022). Thus, this study aims to investigate the effect of pH in removing methyl orange from aqueous solutions using base-modified activated carbon from oil palm fronds.

METHODOLOGY

1.0 Materials

Analytical grade chemicals were used for sodium hydroxide (NaOH) and hydrochloric acid (HCl), which were purchased from Merck, Fluka. Methyl Orange was acquired from R&M Chemicals.

2.0 Preparation of Raw Material

The oil palm fronds (OPF) were collected from Tapah Road, Perak. The oil palm fronds (OPF) were thoroughly washed and then cut into small pieces to facilitate the drying process. The OPF was dried in an oven at 80°C for 24 hours. The dried OPF was ground into a powdered form for further use.

3.0 Preparation of Base-Modified Activated Carbon

A known amount of dried OPF was heated in a furnace at 400 °C, with a heating rate of 10°C per minute for 3 hours. About 25 g sample was stirred with 250 mL of 0.1 M NaOH for 2 hours. After that, it was filtered and washed with distilled water until a neutral filtrate was obtained. Then, the activated carbon was dried in an oven at 80 °C for 24 hours. The dried sample is collected and kept for further use. The samples were denoted as NaOHAC samples.

4.0 Uv-Vis Analysis for Methyl Orange Adsorption

In this study, the batch mode was used to evaluate the adsorption of methyl orange from an aqueous solution onto NaOHAC. Initially, we placed 0.10 g of the sample in a 250 mL conical flask with 25 mL methyl orange. The effect of pH on the solution (within a range of 2.0-7.0) was investigated at 298 K using an orbital shaker at 120 rpm for 1 hour. For the effect of pH, only the pH of methyl orange solutions was altered with 0.1 M HCl and 0.1 M NaOH. The supernatant of the reaction mixture was separated by filtration. The content of methyl orange in the filtrate was evaluated using UV-Vis (UV/Vis Spectrometer Lambda 25 Perkin Elmer). Equation (1) was used to calculate the removal percentage (%):

$$\text{Removal (\%)} = \frac{(C_o - C_e)}{C_o}\ x\ 100 \qquad (1)$$

where C_o (mg/L) is the initial adsorbate concentration, and C_e (mg/L) is the final adsorbate concentration.

FINDINGS

The pH of a solution has a substantial impact on the chemical speciation of metal ions in sorbents. It also affects the ionization of functional groups on the adsorbent surface. This means that the concentration of hydrogen ions in a solution can significantly alter the behavior of metal ions in sorbents and the reactivity of functional groups on the adsorbent surface. Understanding these effects is crucial for various applications, including environmental remediation and industrial processes. The pH of the initial solution varied from 2.0 to 7.0. The effect of pH on the adsorption of methyl orange on NaOHAC adsorbents is depicted in Figure 1. The observed data indicates a significant decrease in the removal of methyl orange as the pH level increased from 2.0 to 7.0. The maximum removal was observed to be 99.9 % at pH 2.0, but it markedly decreased to 6.34 % at pH 7.0. Therefore, the removal of methyl orange by using NaOHAC is more favored in less acidic environments.

At a lower pH, the active sites on the surface of NaOHAC exhibited a notably high positive charge. As a result, a strong electrostatic attraction occurred between the positively charged surface of the NaOHAC and the negatively charged methyl orange (Wang et al., 2023). Thus, the adsorption is increased at low pH. The lignocellulosic structure undergoes deprotonation on an adsorbent surface due to NaOH treatment, which results in the increased negative charge of surface functional groups. As the pH of the solution increases, the functional groups experience increased ionization and deprotonation. Hence, electrostatic repulsion occurred between the negatively charged NaOHAC surface and anionic methyl orange. Similar types of observation were previously reported by for arsenic removal by zero-valent iron-modified activated carbon (Cui et al., 2012).

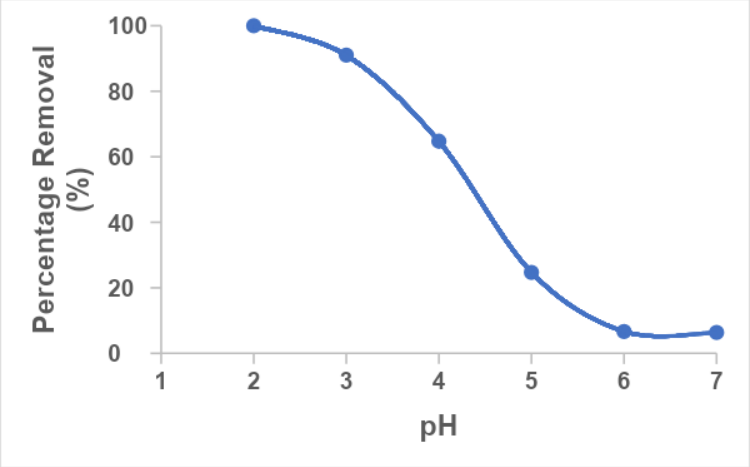

Figure 1. Effect of pH on the percentage removal of methyl orange from NaOHAC. Conditions: 25 mL methyl orange, agitation time: 1 h, initial concentration: 50 mg/L, agitation speed: 120 rpm, sorbent dosage: 0.1 g, temperature: 298 K, and pH 2.0 – 7.0.

CONCLUSIONS

In this work, we have successfully prepared the base-modified activated carbon (NaOHAC) based on oil palm fronds. The NaOHAC was investigated for its ability to remove methyl orange from aqueous solutions. The oil palm fronds used in this study are inexpensive and typically considered waste products. Therefore, using them as adsorbents to remove dyes would help solve the issue of their disposal and provide effective adsorbents for treating wastewater containing metals. At pH 2.0, methyl orange was completely removed within 1 hour of the reaction. This suggests that activated carbon based on oil palm fronds can be effectively used as inexpensive and readily available materials to remove methyl orange from wastewater before it is discharged into the environment.

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