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A COMPARATIVE STUDY OF MERIT KAPIT ACTIVATED COAL PREPARED VIA MICROWAVE AND TUBE FURNACE PYROLYSIS PROCESSES FOR METHYL VIOLET 2B DYE REMOVAL

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ABSTRACT

This study: a comparative study of Merit Kapit activated coal prepared via microwave and tube furnace pyrolysis processes for methyl violet 2B dye (MV dye) removal explores the conversion of Malaysian low-rank coal, known as Merit kapit coal (MKC), into high-surface-area mesoporous activated carbon adsorbents via $ZnCl_2$-assisted activation using microwave and tube furnace pyrolysis methods. MV dye is selected for its applications in textiles, cosmetics, and the paper industry because of its vibrant color properties. However, its presence in wastewater poses significant health risks to aquatic and human lives because it is non-biodegradable and contaminates the water bodies. Merit Karpit coal is selected as a precursor for activated carbon due to its low cost and its ability to aid in converting waste into valuable materials, as it is regarded as waste. The activated carbon produced from microwave pyrolysis is designated as MK-ACMP, while that produced from the tube furnace pyrolysis is referred to as MK-ACTP. The adsorption capabilities of MK-ACMP and MK-ACTP were evaluated for removing MV dye, a model cationic pollutant. Microwave-assisted activation produced mesoporous MK-ACMP with a surface area of 798.18 m^2/g and an average pore diameter of 3.67 nm, whereas tube furnace pyrolysis yielded MK-ACTP with a higher surface area of 1229.1 m^2/g and a pore diameter of 2.9 nm. Brunauer Emmett-Teller (BET), x-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and the determination of the pH at the point of zero charge (pH_{pzc}) analyses were performed to evaluate the physicochemical properties. A Box-Behnken design (BBD) was used to optimize adsorption parameters, including adsorbent dosage (0.02–0.1 g), solution pH (4–10), and contact time (5–25 min) for MK-ACMP and adsorbent dosage (0.02–0.1 g), solution pH (4–10), and contact time (2–12min) for MK-ACTP. Adsorption experiments demonstrated that both MK-ACMP and MK-ACTP had significant adsorption capacities, with maximum values (q_{max}) of 134.1 mg/g and 238.6 mg/g, respectively. The equilibrium adsorption of MK-ACMP followed the Freundlich isotherm, while MK-ACTP adhered to the Langmuir model. Both adsorbents exhibited pseudo-second-order kinetic behaviour, indicating chemisorption. Mechanistic analysis revealed that MV dye adsorption was facilitated by electrostatic attraction, π–π stacking, pore diffusion, and hydrogen bonding. This study identifies the feasibility of converting low-grade Malaysian coal into high-performance adsorbents for effective dye removal, offering a sustainable solution for wastewater treatment.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Water contamination is presently a significant global issue, exacerbated by population growth and heightened economic activity. The world health organization (WHO) states that around 80% of infections are waterborne, and if this issue is not addressed, it will persist and affect everyone. Industrial wastewater constitutes the primary source of heavy metals, dyes, and various organic contaminants. Heavy metals, dyes, and organic compounds, micropollutants are present in the industrial effluents of battery production, dyeing, textiles, paper, paint manufacturing, and various other industries (Jebin Ahmed, 2022) Karimifard and Alavi Moghaddam (2018) and Yasasve et al. (2022). These toxic pollutants are the primary contaminants of water. Therefore, eliminating these pollutants from industrial wastewater has garnered significant practical interest due to heightened concern regarding their environmental impact. Significant quantity of these pollutants was identified in industrial wastewater in developed and developing nations, posing risks to human and animal health. The imperative quest for clean, fresh, and potable water has consistently been undertaken. Before the Industrial Revolution, the water sourced from lakes, rivers, and subterranean reservoirs was pristine and conducive to human existence (Donkadokula et al., 2020). Regrettably, numerous firms inadequately manage their wastewater, leading to the introduction of pollutants into water bodies and hence adversely impacting aquatic life and the ecosystem at large (Alharbi et al., (2022).

Dyes are important chemical compounds extensively utilized as colour across multiple industries, such as paper, textiles, cosmetics, and leather. They may be natural or synthetic, capable of absorbing visible light radiation, and comprise two primary components: chromophores and auxochromes (Barani and Maleki, 2020; Haji and Naebe, 2020). Dyes are categorized according to their solubility in water and are primarily coloured chemical compounds that dissolve in aqueous solutions. The presence of dyes in water results in various physicochemical effects, including increased total suspended solids, elevated biochemical and chemical oxygen demand,