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Enhancing methylene blue removal efficiency using rice-husk derived, modified activated carbon via magnetic particle integration

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The extensive use of synthetic dyes in industries has increased environmental pollution, reducing oxygen levels and sunlight penetration in water bodies. Activated carbon (AC) is widely used for removing contaminants. However, the effective recovery and reuse of absorbents in post-treatment present a challenge. Hence, AC integrated magnetic particles (MAC), is seen as a better and innovative alternative due to its easy recovery and minimal environmental impact. This study focused on producing MAC using rice husk and evaluating its effectiveness in Methylene Blue (MB) removal using isotherm and kinetic studies. To produce AC, rice husks were initially washed with DI water, treated with HCl (5% v/v) for 24 hours, and dried at 383 K. Physical activation was carried out at 400°C for 2 hours. Synthesised AC was then mixed with $FeSO_4$ ($FeSO_4$: DI water =1:7.5) and freshly prepared $FeCl_3$ ($FeCl_3$: DI water = 1:72) mixture, stirred at 60-70°C for 30 min, and adjusted to pH 10 using NaOH (10 M). After mixing for 60 min, mixture was left for 24 hours at room temperature, washed with DI water and ethanol, followed by vacuum filtration and overnight drying at 50°C to yield MAC. Characterization was done using Fourier Transform Infrared Spectroscopy (FT-IR). Proximate analysis was carried out and the yield percentage of MAC was calculated. Batch adsorption studies were conducted to optimize parameters such as initial MB concentration, adsorbent dosage, contact time, and pH, for MB removal. Subsequently, under optimized conditions, isotherm and kinetic experiments were conducted. All experiments were duplicated and performed at room temperature. The FT-IR analysis of MAC revealed distinctive features: additional bands at 635.2 cm^{-1} and 882.7 cm^{-1}, indicating the presence of stretching and bending vibrations of Fe-O bonds. Additionally, a band at 1105.7 cm^{-1} suggested potential Fe-O-C interactions, confirming the integration of magnetic particles onto the AC surface. In batch adsorption studies, MAC (0.0212 ± 0.0001 g) had optimal MB removal at pH (7.01 ± 0.01) and an initial concentration of 4 mg/L, following 60 minutes of agitation. Adsorption isotherm analysis illustrated an excellent fitting to the Langmuir model (R^2=0.9934), revealing monolayer adsorption on a homogeneous surface, with a maximum adsorption capacity (q_{max}) of 102.04 mg/g. Kinetic studies indicated that the adsorption process followed a pseudo-second-order reaction (R^2 = 0.9884), suggesting chemical sorption as the governing mechanism. In conclusion, this study demonstrated the effective integration of magnetic particles with AC derived from rice husks, which enhances the recoverability of the adsorbent in the post-treatment phase due to its magnetic property. Furthermore, this innovative approach ensures effective MB removal from wastewater, providing an eco-friendly and cost-effective solution that advances wastewater treatment technologies without environmental compromise.

Keywords: Activated carbon, Magnetic property, Methylene blue, Rice husk, Wastewater