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ASORPTIVE REMOVAL OF METHYLENE BLUE USING ACTIVATED CARBON DERIVED FROM JATROPHA CURCAS HUSK

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ABSTRACT

Adsorptive Removal of Methylene Blue Using Activated Carbon Derived from Jatropha Curcas Husk

Synthetic dyes such as methylene blue (MB) are widely used in industries, leading to environmental contamination due to their persistence and toxicity. In this study, activated carbon derived from *Jatropha curcas* husk (JCH-AC) was prepared through pyrolysis and synthesized using potassium hydroxide (KOH) as the activating agent. JCH-AC serves as a sustainable and low-cost adsorbent for the removal of MB from aqueous solutions. Batch adsorption experiments examined the effects of adsorbent dosage, initial concentration of MB, contact time, pH, and temperature. Furthermore, adsorption isotherms were evaluated using Langmuir, Freundlich, and Temkin models. The Langmuir model provided the best fit, indicating monolayer adsorption with an adsorption capacity of 226.89 mg/g and a correlation coefficient of 0.9940. Kinetic modelling was conducted using pseudo-first-order (PFO), pseudo-second-order (PSO), and intraparticle diffusion (IPD) models. PSO model showed an excellent fit with R^2 values ranging from 0.9997 to 0.9990 and predicted adsorption capacities (q_e) closely matching the experimental values, suggesting chemisorption as the dominant mechanism. Meanwhile, IPD indicated a multi-stage process involving surface diffusion and intraparticle diffusion with R^2 values between 0.2706 to 0.3422. Thermodynamic analysis was performed at temperatures ranging from 25 to 33°C, showing negative Gibbs free energy changes ($\Delta G°$ ranging from -18.18 to -22.22 kJ/mol) and positive enthalpy change ($\Delta H° = 132.31$ kJ/mol) values which confirm that the process was spontaneous and endothermic nature of the process. Additionally, the positive entropy change ($\Delta S°$ 504.99 J/mol·K) indicated increased randomness at the solid-solution interface and strong affinity of MB molecules and JCH-AC. In conclusion, JCH-AC demonstrates high adsorption efficiency, favourable thermodynamic behaviour, and environmental sustainability, making it an effective and eco-friendly adsorbent for MB removal, supporting sustainable wastewater treatment and valorisation of agricultural waste within circular economy initiatives.

EXECUTIVE SUMMARY

This study addresses the environmental challenge posed by synthetic dyes, specifically Methylene Blue (MB), in industrial wastewater, and explores the use of *Jatropha curcas* husk-derived activated carbon as a sustainable and cost-effective adsorbent for dye removal. The research aims to evaluate the adsorption efficiency of this material under varying conditions, including pH, temperature, contact time, and dye concentration, while also analysing adsorption isotherms (Langmuir, Freundlich, and Temkin), kinetic models (pseudo-first order, pseudo-second order, and intraparticle diffusion), and thermodynamic parameters. Using batch adsorption experiments, the findings reveal that the Langmuir isotherm and pseudo-second order kinetic models best describe the adsorption behaviour, indicating monolayer adsorption and chemisorption as the dominant mechanism. Thermodynamic analysis confirms the process is spontaneous and endothermic, with higher adsorption efficiency at elevated temperatures. The study demonstrates that *Jatropha curcas* husk-based activated carbon is a viable and eco-friendly alternative to conventional adsorbents, contributing to effective wastewater treatment and promoting the sustainable reuse of agricultural waste. These findings provide a framework for optimizing industrial wastewater treatment processes and advancing environmental sustainability initiative.