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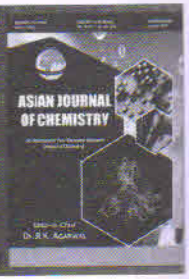

Adsorption of Methylene Blue Dye: Thermodynamics and Kinetics Studies of *Vigna unguiculata* L. Seed Shell Activated Carbon

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This study reports the efficient adsorption of methylene blue dye from aqueous solutions using activated carbon derived from *Vigna unguiculata* L. seed shells (VUSSAC). The activated carbon was prepared through a sulphuric acid impregnation process, followed by carbonization at 500 ºC. The adsorption efficiency of VUSSAC was evaluated under varying experimental conditions, including adsorbent dosage, pH, contact time and temperature. Optimal dye removal was achieved at pH 10, an adsorbent dosage of 100 mg and a contact time of 120 min. The adsorption process followed the pseudo-second-order kinetic model indicating that the adsorption rate was controlled by chemical interactions. Adsorption isotherms were analyzed using Langmuir, Freundlich and Temkin models, with Langmuir isotherm best describing the adsorption, suggesting monolayer adsorption on a surface with uniform adsorption sites. Thermodynamic parameters, including changes in enthalpy (ΔH°), entropy (ΔS°) and Gibbs free energy (ΔG°), indicated that the adsorption was endothermic and spontaneous, with increased temperature enhancing the removal efficiency. Characterization of the adsorbent before and after adsorption was conducted using FT-IR, SEM, BET, XRD and AFM techniques. These analyses revealed the presence of functional groups and changes in the surface morphology of VUSSAC, supporting the efficient dye uptake. The results demonstrate that VUSSAC is a cost-effective, eco-friendly adsorbent with promising potential for the removal of methylene blue dye from aqueous solutions.

Keywords: Adsorption, Isotherms, Kinetics, Thermodynamic study, Activated charcoal, Methylene blue dye.