Biomass Conversion and Biorefinery. Vol. 15 (31), 2025, pages 3457 - 3470

Gasification char adsorbent for dye removal: characterization, isotherm, kinetics and thermodynamic studies

Abstract

Previous research has shown GC's reliable performance as an adsorbent in water and wastewater treatment, but broader applications remain underexplored. This study focuses on treating GC with KOH to eliminate methylene blue (MB) dye. The FTIR results indicated an enrichment of carbonyl groups on the GC surface, which enhanced the rate of MB adsorption. SEM analysis of both treated and untreated GC revealed that the treated char exhibited prominently developed pores and displayed a distinct open-porous structure, reminiscent of a honeycomb-like porous formation. The result from Brunauer–Emmett–Teller (BET) analysis reveals that BET surface area (469.27 m^2/g) and total pore volume (0.2728 cm^3/g) of treated GC improved after activation. Increasing the initial concentration of MB from 100 to 250 mg/L resulted in a decrease in its removal from 82.1 to 50.87%, respectively. Meanwhile, raising the pH from 3 to 9 enhanced MB adsorption from 85.46 to 97.06%. As the temperature increased from 30 to 60 °C, the adsorption process accelerated, leading to an increase in the percentage of dye removal from 89.11 to 96.63%. Matlab curve fitting tools were used to fit non-linear isotherm and kinetic models. The n-BET isotherm and Pseudo-First-Order (PFO) kinetic models demonstrated an excellent fit to the experimental data, evidenced by the highest R^2 values, specifically 0.99206 and 0.9577–0.9855, respectively. These findings strongly suggest a multilayer adsorption process taking place on the uniform surface of treated GC. Thermodynamic analysis affirms the endothermic and spontaneous nature of the adsorption process, corroborated by negative ΔG° and positive ΔH° values ranging from -11.0722 to -8.1916 kJ/mol and from 0.694 to 0.857 kJ/mol, respectively.

Keywords

Activated carbon; Chemical activation; Dye adsorption; Gasification char; Methylene blue