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An insight into the adsorptive, kinetic, and mechanistic behavior of the sulfonated magnetic multi-walled carbon nanotubes adsorbent in the removal of methylene blue

Abstract

A simple and environmentally friendly, facile solvent-free direct doping (FSFDD) approach was employed to synthesize sulfonated magnetic multi-walled carbon nanotubes (s-MMWCNTs) which in turn employed for the eliminating of methylene blue (MB) dye from aqueous solution. While prior studies have emphasized the synthesis and innovation points of s-MMWCNTs, this work delves into the fundamental adsorption behaviors (adsorption isotherm, kinetic, thermodynamic and mechanism analysis) to provide a deeper understanding of the interactions between the adsorbent and methylene blue (MB). The developed s-MMWCNTs were characterized by zeta potential analysis, transmission electron microscope (TEM) and Brunauer-Emmett-Teller (BET). Moreover, the characterization of spent s-MMWCNTs by X-ray diffraction (XRD), scanning electron microscope-energy dispersive X-ray (SEM-EDX) and Fourier transform infrared (FT-IR) were carried out to compare their characteristics to the freshly synthesized s-MMWCNTs. Results indicated that the Freundlich isotherm model was the best-fitted model, providing a maximum adsorption capacity of 44.64 mg g^{-1}. As for the adsorption kinetic studies, the MB adsorption onto s-MMWCNTs was discovered to comply with the pseudo-second-order model. Besides, the thermodynamic results suggested that the adsorption process of MB onto s-MMWCNTs occurred endothermically with spontaneity. Furthermore, the adsorption mechanisms encompassed electrostatic interaction, hydrogen bonding and π–π stacking interaction with the electrostatic interaction as the most salient attractive force in the MB adsorption onto s-MMWCNTs.

Keywords

Adsorption isotherm; Adsorption kinetic; Adsorption thermodynamic; Magnetic adsorbent; Multi-walled carbon nanotubes