Adsorption of heavy metals from aqueous solutions by waste coffee residues: kinetics, equilibrium, and thermodynamics

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\textbf{ABSTRACT}

Waste coffee residues (WCRs) are used to remove heavy metals (Cu\textsuperscript{2+}, Pb\textsuperscript{2+}, and Zn\textsuperscript{2+}) from aqueous solutions. The surface characteristics of WCRs were analyzed by scanning electron microscopy, specific surface area analysis, zeta-potential analysis, and Fourier-transform infrared spectroscopy. The specific surface area, mean pore diameter, and pH\textsubscript{pzc} of the WCRs were 0.19 m\textsuperscript{2}/g, 14 nm, and 3.5, respectively. Adsorption experiments are performed to evaluate the kinetics, equilibrium, and thermodynamic parameters. The percentage of Cu\textsuperscript{2+} that was removed from a solution increased as the pH and the WCR dose increased, but it declined as the Cu\textsuperscript{2+} concentration increased. The adsorption kinetics and equilibrium fit pseudo-second-order and Langmuir models, respectively. At pH 5 and 25\degree C, the maximum adsorption capacities of the WCRs for Cu\textsuperscript{2+}, Pb\textsuperscript{2+}, and Zn\textsuperscript{2+} were 8.2, 27.6, and 8.0 mg/g, respectively. The \(\Delta H^0\) values for the adsorption of Cu\textsuperscript{2+}, Pb\textsuperscript{2+}, and Zn\textsuperscript{2+} on WCRs were 9.73, 13.77, and 9.15 kJ/mol, respectively, and the corresponding \(\Delta S^0\) values were 109.4, 127.0, and 96.6 J/mol/K. The adsorption of Cu\textsuperscript{2+}, Pb\textsuperscript{2+}, and Zn\textsuperscript{2+} on WCRs is an endothermic, spontaneous physisorption process, and the adsorption kinetics is controlled mainly by surface diffusion.

\textbf{Keywords:} Adsorption; Coffee residues; Heavy metals; Kinetics; Equilibrium; Thermodynamics

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