



Fixed-Bed Removal of Crystal Violet Dye Using Activated Carbon Fibers: Experimental and Numerical Investigation

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The widespread use and improper disposal of crystal violet (CV) dye into aquatic ecosystems have raised serious environmental concerns. Developing efficient removal strategies to prevent CV's accumulation in water bodies is therefore essential. Activated carbons are widely used as highly effective adsorbents for treating contaminated water. Among various approaches, the fixed-bed adsorption method offers continuous operation and enables the treatment of large volumes of wastewater using a constant amount of adsorbent. This study investigates the use of oxidized activated carbon fibers (Felt-Ox) for efficient CV removal dye through the fixed-bed adsorption method. The performance of Felt-Ox was compared with three other activated carbon-based adsorbents (MSC-Ox, F400 and Luffa-Ox). The physicochemical properties of the adsorbents were systematically characterized by conducting gas sorption analysis, scanning electron microscopy, X-ray photoelectron spectroscopy and Fourier-transform infrared spectroscopy. The maximum CV adsorption capacity of the adsorbents was quantitatively evaluated by fitting the experimental breakthrough curves to the Yan model. Moreover, the effect of adsorbent mass on CV removal efficiency was also examined. The results revealed that the Felt-Ox material exhibited the highest maximum adsorption capacity (19.6 mg/g) among all tested adsorbents. Additionally, to gain deeper insights into the hydrodynamics within the fixed-bed column and to evaluate the influence of key operational parameters, including flow rate and inlet concentration, a computational fluid dynamics model was developed and applied to analyze the adsorption performance.