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Highly porous iron-zirconium binary oxide for efficient removal of Congo red from water

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ABSTRACT

Wastewater from textiles and other industries containing dyes pose a serious health hazard. To address the issue, the present study reports the removal of a toxic Congo red (CR) from water by a non-toxic iron-zirconium mixed binary metal oxide (IZO) as adsorbent. The material was prepared by a controlled co-precipitation method under mild basic condition and isolated in an 85% yield. It was characterized using Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy, Brunauer–Emmett–Teller (BET) surface area and powder X-ray diffraction. High BET surface area (200.307 m^2 g^{-1}) supports an excellent adsorption capacity of 171 mg g^{-1} at pH 6. FTIR shows the presence of hydroxyl moieties along with surface water. The influence of adsorbent dose, contact time, pH, agitation speed, temperature, and concentration were optimized. The adsorption follows pseudo-second-order kinetics (R^2 = 0.998) and is best described by the Langmuir isotherm model (R^2 = 0.988). Negative free energy change suggests a spontaneous process. Co-existent ions impart moderate competitive inhibition to the adsorption process. 78% regeneration was achieved with sodium hydroxide solution. IZO retains its efficiency up to five cycles. Designed column experiments show that under the optimized condition of a column comprised of 4 cm bed height, 2 L dye discoloration was successful. The breakthrough was analyzed by Thomas, Yoon–Nelson, and Adams–Bohart model. Column run follows Thomas and Adams–Bohart model. High application potential, low cost, and reusability of the IZO make it a promising adsorbent for the removal of CR from contaminated water.

Keywords: Congo red; Binary oxide; IZO; Adsorption; Regeneration; Breakthrough

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