Revolutionizing dye removal in wastewater: An optimization study of curcumin-functionalized zeolite beads for methylene blue adsorption

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Abstract

The accelerated development of industrialization has resulted in the extensive discharge of dyes into aquatic habitats, creating significant health hazards due to their poisonous and cancer-causing characteristics. This work introduces a new adsorbent called CUR-CPTMS-NZC, constructed of curcumin-functionalized natural zeolite clinoptilolite encapsulated in alginate beads. This adsorbent aims to improve the removal of methylene blue (MB) dye from wastewater. The functionalized adsorbent underwent characterization utilizing FT-IR, TGA, N_2 gas adsorption-desorption, SEM, and zeta potential studies. The adsorption assessments examined the impact of contact time, adsorbent dosage, initial dye concentration, and pH on the efficacy of removing MB. Response Surface Methodology (RSM) with Central Composite Design (CCD) was employed to optimize the adsorption conditions, improving efficiency in removing dyes. Under optimized conditions: pH 7.8, adsorbent dosage of 0.5 g/L, and MB concentration of 13 mg/L, CUR-CPTMS-NZC beads achieved 100 % removal efficiency. The maximum adsorption capacity was found to be 69.81 mg/g, demonstrating the high efficiency of the adsorbent. Regeneration studies have verified the capacity to reuse the adsorbent for six cycles with less than 25 % reduction in the removal efficiency. This study offers an enduring remedy for the issue of dye contamination in wastewater, hence encouraging environmental sustainability and promoting breakthroughs in wastewater treatment technologies. © 2025 Elsevier B.V.

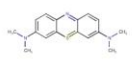
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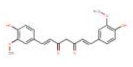
Adsorption optimization; Alginate beads; Curcumin-functionalized zeolite; Response surface methodology; Wastewater treatment

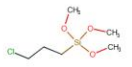
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