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Design and Optimization of Cationic Adsorbents for Efficient Removal of Organic Pollutants from Wastewater

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ABSTRACT

Water contamination by anionic pollutants, such as synthetic dyes and per- and polyfluoroalkyl substances (PFAS), poses a significant environmental challenge. This study investigates the adsorption potential of a positively charged β-cyclodextrin polymer (B-CDP$^+$) for the efficient removal of methyl orange (MO), acid red 1 (AR1), and Perfluorooctanoic acid (PFOA) from aqueous solutions. The synthesized polymer was characterized using FT-IR, XRD, SEM, TGA, EDS and BET to determine its structural and morphological properties. Adsorption experiments revealed that B-CDP$^+$ exhibited a high affinity for anionic pollutants, with superior adsorption capacity compared to its neutral counterpart. Specifically, it achieved over 90% removal efficiency for MO (80 ppm) within 30 min. The modified polymer also demonstrated high removal efficiencies for MO in the presence of other anionic pollutants, such as AR1 and PFOA, with adsorption efficiencies of 99% and 93%, respectively, indicating its potential for the simultaneous removal of multiple contaminants from water. The polymer's effectiveness was influenced by pH and adsorbent dosage, with optimal conditions identified at pH 7 and a dosage of 1 g/L. The adsorption mechanism was evaluated using Langmuir and Freundlich isotherms, along with kinetic models including pseudo-first-order and pseudo-second-order. The results showed that the adsorption behavior is best described by the Freundlich isotherm (R^2 = 0.9965) and pseudo-second-order kinetics (R^2 = 0.999), suggesting multilayer adsorption with chemisorption as the dominant process. The modified polymer remained highly reusable for up to ten cycles without significant loss in adsorption efficiency. This study introduces a cationic cyclodextrin-based adsorbent for the first time, offering an eco-friendly and effective approach for the simultaneous removal of anionic pollutants from water, contributing to sustainable water treatment solutions.

KEY WORDS

PFAS, Synthetic dyes, Adsorption, Cationic β-cyclodextrin polymer, Anionic pollutants

BIOGRAPHY

Samira is a PhD candidate at Edith Cowan University, focusing on the development of novel adsorbents and photocatalysts for the removal of emerging pollutants from water. Her current research explores cyclodextrin-based polymers and their application in the adsorption of PFAS and synthetic dyes. She has experience in material synthesis, surface characterization, and environmental remediation . Samira has also completed an industry internship working on PFAS treatment technologies. She is passionate about sustainable water treatment and bridging the gap between academic research and real-world environmental solutions.

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