Ultra-rapid removal of per- and poly fluorinated alkyl substances from water using cyclodextrin polymer networks

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Abstract: Herein, we developed a β-cyclodextrin (β-CD)-based polymer (β-CD-TriPod) crosslinked with tripodal amine to demonstrate the synergetic effects in superior adsorption of both short- and long-chain per- and polyfluoroalkyl substances (PFASs). Kinetics studies showed rapid adsorption (~100% for nine PFASs at 1 μg L^{-1}, except PFBA, and >86% at 200 μg L^{-1} individually) within two minutes. Isotherm results showed exceptional adsorption affinity and capacity, with K_L = 0.310 ± 0.180 L mg^{-1}, q_m = 246.20 ±14.80 mg g^{-1} for PFBS, and K_L = 0.980 ± 0.260 L mg^{-1}, q_m = 587.10 ± 54.50 mg g^{-1} for PFOS, significantly outperforming traditional activated carbons (ACs) and resins. The adsorbent also exhibited excellent regeneration and reusability, maintaining stable performance (>94%) over five consecutive adsorption-desorption cycles. Additionally, it performed effectively in PFASs-spiked real industrial wastewater with 55-100% removal efficiencies, regardless of the presence of co-contaminants. The adsorption mechanism confirmed the combined role of hydrophobic inclusion within β-CD cavities and electrostatic interactions with amines groups using elemental mapping, composition and FTIR techniques. Overall, this work demonstrates advanced molecular design strategies for rapid PFASs removal, establishing β-CD-TriPod as a highly regenerable and promising adsorbent for the rapid and efficient treatment of PFASs-contaminated water and industrial wastewater.

Keywords: Short-chain PFASs; β-CD polymerization; Adsorption affinity; Wastewater treatment.