Enhanced Removal of Multiple Emerging Pollutants: Tetracycline, Bisphenol A, PFAS from Water using Graphene Oxide Vortex Ring

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There is growing concern about emerging organic pollutants (EOPs) in aquatic environments and their short- and long-term effects on human and ecosystem health, creating an urgent need for efficient methods to remove trace levels of EOPs from wastewater. In this study, graphene oxide–vortex ring (GO-VR) aerogel particles were fabricated via a cetyltrimethylammonium bromide (CTAB)-assisted electrohydrodynamic self-assembly method and evaluated for the adsorption of four representative EOPs: the antibiotic resistance–promoting tetracycline (TC), endocrine-disrupting bisphenol A (BPA), and the 'forever chemicals' perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). The GO-VR particles exhibited a three-dimensional highly porous architecture with a distinctive core–shell structure and graphene surfaces enriched with oxygenated and cationic functional groups, supporting both hydrophilic and hydrophobic pollutant capture. A wide range of parameters, including pH, adsorbent dosage, adsorbate concentration, and contact time, were studied to assess adsorption performance. The aerogels showed excellent removal efficiencies under optimised pH-dependent conditions, with maximum capacities of 424 ± 7.4 mg g^{-1} at pH 3 for TC, 370 mg g^{-1} at pH 9 for BPA, and 925 ± 12 ng mg^{-1} and 921 ± 21 ng mg^{-1} at pH 5 for PFOA and PFOS. Kinetics followed a pseudo-second-order model, indicating chemisorption as the predominant mechanism, while isotherms suggested monolayer–multilayer coexistence due to surface heterogeneity. Adsorption was governed by electrostatic attraction, hydrogen bonding, π–π stacking, and hydrophobic interactions. Reusability tests revealed excellent regeneration with a combined sodium chloride and ethanol wash. Overall, GO-VR aerogel particles represent a versatile, recyclable, and highly efficient adsorbent platform for removing diverse EOPs from contaminated water.

References

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Figures

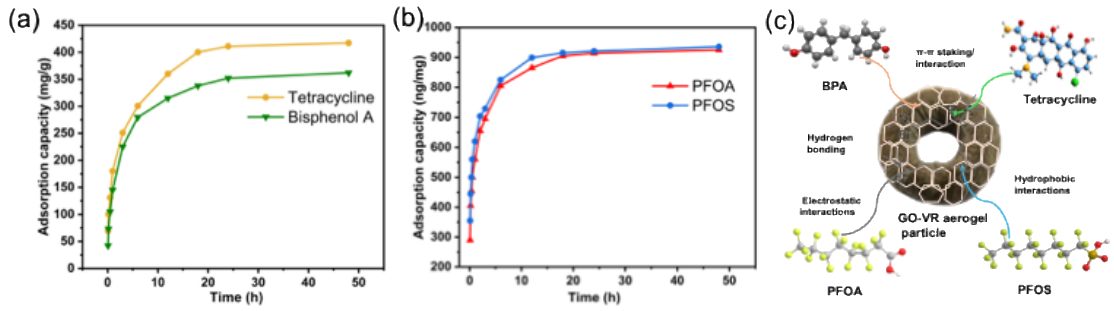

Figure 1:(a) Adsorption capacity of TC & BPA, (b) PFOA & PFOS, (c) Schematic illustration of multi-mechanistic adsorption pathways of emerging contaminants on GO-VR aerogel particle