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PFAS adsorption from Landfill Leachate

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ABSTRACT

Per- and polyfluoroalkyl substances (PFAS) are synthetic contaminants defined by their extreme environmental persistence, and toxicity. Their high mobility and low sorption affinity result in poor removal by traditional water and wastewater treatment methods, such as coagulation, sedimentation, and filtration. PFAS are ubiquitous in landfill leachate due to their origins from domestic, municipal and industrial waste products. Landfill leachate also contains a complex chemical matrix with high concentrations of organic and inorganic co-contaminants, such as total organic carbon (e.g., humic and fulvic acids), total suspended and total dissolved solids, alkalinity, ammonia, volatile fatty acids, and putrefaction products. PFAS removal using traditional adsorption technologies such as granular activated carbon (GAC) and ion exchange (IX) resins often exhibit reduced PFAS removal due to preferential adsorption of dissolved organic matter, resulting in rapid fouling, poor PFAS retention, and increased media consumption.

This study investigated the use of alternative solid-phase adsorbents for the removal of PFAS from high organic-loading matrices, such as landfill leachate. Bentonite was identified as a promising candidate owing to its layered (2:1) structure and high cation exchange capacity. However, unmodified bentonite exhibits limited affinity for anionic and hydrophobic compounds such as PFAS. Thus, the clay was modified with cationic species cetyltrimethylammonium bromide (CTAB), cetyltrimethylammonium chloride (CTAC), and polyDADMAC to alter the clay's physicochemical properties, thereby enhancing its ability to interact with and retain PFAS compounds. The PFAS adsorption performance of the modified clays were compared to a commercial clay-based product, Fluorosorb 400®.

Initially, methyl orange (MO) was used as a PFAS surrogate to evaluate the effectiveness of the surface modification. All modified clays demonstrated significantly enhanced MO adsorption compared to unmodified bentonite. Specifically, unmodified bentonite exhibited negligible adsorption capacity, whereas CTAB-, CTAC-, and polyDADMAC-bentonite, along with Fluorosorb 400, achieved MO removal efficiencies of 60, 70, 98, and 20%, respectively. Subsequently, adsorption isotherm experiments were conducted over a 24 h period to evaluate adsorbent performance in landfill leachate. At an adsorbent dose of 10 g/L—corresponding to the point at which the adsorption curves approached equilibrium—total PFAS removals of 90%, 85%, 75% and 5% were observed for Fluorosorb 400, CTAC-, CTAB-, and polyDADMAC-bentonite, respectively. This study demonstrates that modified clays can effectively remove PFAS from highly complex waste waters, such as landfill leachate, where conventional GAC and IX adsorbents are unsuitable. Future work will focus on adsorption kinetics and column studies to determine optimum contact times and design criteria for practical implementation.

KEY WORDS

PFAS, Adsorption, Leachate

BIOGRAPHY

Steven holds a PhD in Chemistry from Queensland University of Technology (QUT) and has undertaken postdoctoral research positions at both QUT and the Karlsruhe Institute of Technology (KIT), Germany. During this time, his research focused on the development of reversible chemical systems and their integration into additive manufacturing platforms to enable the fabrication of programmable and responsive materials. This work has resulted in multiple publications in high-impact journals within the fields of chemistry and materials science.

In 2025, Steven transitioned into industry to apply his expertise in chemistry and materials science to wastewater treatment and environmental remediation. His current work focuses on the development of advanced treatment technologies for complex waste streams, including the removal of persistent contaminants such as per- and polyfluoroalkyl substances.

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