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Ph.D. DISSERTATION DEFENSE

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Title:	Evaluation of Commercial Reactive Media for the Removal of Emerging Contaminants and Metals from Groundwater
Chairperson:	Dr. Dibyendu Sarkar, Department of Civil, Environmental, and Ocean Engineering, Stevens Institute of Technology
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ABSTRACT

Groundwater contamination by per- and polyfluoroalkyl substances (PFAS) and heavy metals presents significant environmental challenges due to their persistence, mobility, and potential risks to human health. Conventional remediation technologies may face limitations in treatment efficiency, cost, and long-term performance, emphasizing the need for effective alternatives. This dissertation evaluates commercially available sorbents and reactive materials for removing PFAS and heavy metals from groundwater, with particular emphasis on their potential application in permeable reactive barriers (PRBs).

First, the adsorption and desorption behavior of perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and perfluorononanoic acid (PFNA) was investigated using commercially available sorbents, including granular activated carbon (GAC) and organoclay-based materials. Batch experiments evaluated removal efficiency, adsorption kinetics, and isotherm behavior, while desorption experiments assessed contaminant retention stability. The findings demonstrated differences in adsorption performance among sorbents and PFAS compounds, highlighting the influence of material characteristics and contaminant properties on removal efficiency.

Building on these investigations, the removal of selected inorganic contaminants, including arsenite [As(III)] and cobalt [Co(II)], was evaluated using commercially available reactive materials. Batch adsorption and desorption experiments were performed to investigate the interactions between these contaminants and the selected sorbents, as well as their retention and potential release.

Furthermore, the effects of solution pH and ionic strength on As(III), Co(II), PFOA, PFOS, and PFNA removal were investigated using GAC and zero-valent iron (ZVI). Experiments were conducted across a pH range of 3–11 at sodium nitrate ($NaNO_3$) concentrations of 1 and 10 mM. As(III) removal increased from acidic to near-neutral conditions, reaching its maximum at pH 7 before declining under alkaline conditions. In contrast, Co(II) removal by GAC increased with increasing pH, while PFOA and PFOS removal generally decreased. Ionic strength exerted a comparatively smaller influence on removal efficiency than pH, highlighting the importance of solution chemistry and contaminant–surface interactions.

Subsequently, continuous-flow column experiments using real groundwater evaluated the performance of GAC and its combination with ZVI for removing PFOA, PFOS, PFNA, arsenic, and cobalt. Breakthrough experiments revealed differences in contaminant retention and transport behavior under dynamic flow conditions, demonstrating the importance of reactive media composition and contaminant characteristics in determining treatment performance.

Overall, this research integrates batch adsorption and desorption investigations, solution chemistry experiments, and continuous-flow column studies to evaluate reactive media performance. The findings provide insight into contaminant retention mechanisms and support the selection and optimization of reactive materials for sustainable groundwater remediation using PRBs.