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Field Demonstration and Numerical Evaluation of In-Situ Remediation of Subsurface Organic Contaminants Using Reductive Reactive Zone Technologies

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Effective management of groundwater contamination caused by subsurface organic pollutants is a pressing environmental challenge. This study presents an innovative approach using In-situ Reductive Zone (IRZ) technology, which introduces reagents directly into the contaminant flow path, thereby creating a reactive zone that not only impedes but also diminishes the migrating contaminant plume. Our focus is on deploying diverse reagents such as nZVI@SiO2/PS and AC-ZVI CAC/PS, which demonstrate potential in treating a range of organic contaminants via oxidation, reduction, and adsorption processes. The core of our research involves a comprehensive field demonstration of IRZ technology, utilizing these reagents to ascertain their effectiveness in controlling contaminant spread and facilitating treatment/reduction. The method's success is intricately linked to the strategic delivery of reagents to the contamination site and ensuring ample interaction between the reagents and contaminants, thereby necessitating a tailored approach to injection technology based on site-specific characteristics. Further, our study extends to a meticulous numerical evaluation, employing COMSOL Multiphysics 6.2, to simulate the reactive transport processes and assess the technology's performance. This simulation integrates hydrogeological and geochemical data from the site, offering insights into the optimal design of the reactive zone and predicting the system's behavior under various operational scenarios. Additionally, we explore the long-term viability and environmental impacts of the IRZ method, considering the persistence and migration of reagents and by-products in the subsurface environment. The outcomes aim to provide a robust framework for scaling the technology from bench-scale models to field applications, emphasizing the adaptability and efficacy of IRZ in diverse geological settings. The findings from this study are poised to contribute significantly to the domain of subsurface remediation, offering a novel, efficient, and adaptable method for the treatment of organic contaminants, thus paving the way for sustainable groundwater management strategies.