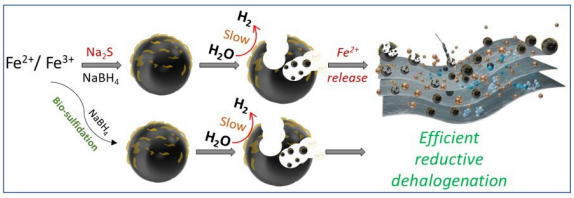
Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.33523



Addressing Iron Corrosion and Toxic Sulfidation Agents in S-nZVI: Sustainable Strategies for Organic Contaminant Degradation

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Reductive dehalogenation of chlorinated solvents and degradation of other harmful organic substances in groundwater using nanoscale zerovalent iron (nZVI) has emerged as a powerful in-situ treatment strategy. Sulfidation of nZVI (S-nZVI) significantly improves electron selectivity toward contaminants by limiting hydrogen evolution such as enhancement of dechlorination efficiency multi-fold for Trichloroethylene (TCE) and other organohalides. However, a major unresolved and recently identified limitation is the extensive release of dissolved Fe^{2+} generated through anaerobic corrosion of S-nZVI, which can deteriorate treated water quality and hinder sustainable field deployment. Another emerging challenge is the reliance on toxic sulfidation reagents such as Na_2S and dithionite for developing these particles.

Our recent and ongoing works are focused on addressing both of these challenges. We have observed more than 30% dissolution of S-nZVI particles during TCE degradation under electron limited conditions due to limited transition from soluble Fe^{2+} to insoluble Fe^{3+} in oxygen-limited groundwater conditions. Based on the geochemical understanding of Fe-P complexation, we have evaluated dittmarite ($NH_4MgPO_4 \cdot H_2O$) nanosheets as potential surface to nucleate S-nZVI particles resulting in a dual-functional DS-nZVI composite capable of simultaneous TCE degradation and in-situ iron sequestration. The composite achieved complete TCE dechlorination while reducing Fe leaching by nearly three orders of magnitude (<0.3 mg L^{-1}) compared to conventional S-nZVI (>350 mg L^{-1}). Mechanistic studies confirmed continuous capture of released Fe^{2+} via Mg^{2+} exchange and transformation into stable iron-phosphate phases such as baricite, ensuring sustained reactivity without secondary contamination.

To address the challenge of using toxic sulfidation agents, our ongoing research focuses on developing eco-friendly, natural compound-based sulfidation strategies that mimic geochemical processes. These green-sulfidated iron materials are being evaluated for the degradation of a wide range of contaminants, including TCE, feed additives, and pesticides. Initial results demonstrate effective and sustained dechlorination at optimized sulfidation ratios, highlighting their potential as safer and sustainable alternatives for groundwater remediation.

Reference

Khandelwal, N.; Mu, S.; Ghoshal, S. *Dittmarite Nanosheets Capture Dissolved Iron Released by Anaerobic Corrosion of S-nZVI and Enhance Trichloroethene Degradation in Groundwater*. Environmental Science & Technology Letters, 2026, 13, 137–143