

Mixed-valence Iron Nanoparticles Generation by Iron Electrocoagulation to Achieve Rapid Chromium Removal from Groundwater

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Historically marginalized communities in the Western United States are disproportionately affected by hexavalent chromium, Cr(VI), a geogenic groundwater contaminant, and human carcinogen. Conventional treatment methods like reverse osmosis are effective at removing Cr(VI) but are financially inaccessible to low-income communities reliant on groundwater. The withdrawal of the 10 µg/L Maximum Contaminant Level (MCL) for Cr(VI) in California in 2017 due to economic impracticality highlights the urgent need for affordable technologies capable of meeting the 10 µg/L goal, especially in rural areas lacking centralized treatment facilities.

In natural systems, reactive iron species such as Fe(II)_{aq} and Fe(II,III)-containing nanoparticles, like green rust, efficiently reduce Cr(VI) to less-soluble Cr(III), subsequently immobilizing it through adsorption and/or co-precipitation. One promising approach to generate these species on-site is iron electrocoagulation (Fe-EC), where Fe(II)_{aq} ions are produced in situ by applying a potential between iron plates submerged in an electrolyte. Existing literature has shown that operating at high Fe(II) dosage rates (> 20 mM/min) and low anodic interface potentials (< 1.0V vs Ag/AgCl) favors the formation of such reactive iron species. However, current Fe-EC designs face challenges in maintaining these optimal conditions because high iron dosage rates have high voltage demands. Further development and understanding of Fe-EC systems under realistic conditions are thus necessary for Fe-EC to be considered a viable technology for Cr(VI) removal in the United States.

We have developed a novel flow-through Fe-EC reactor with spiral wound plates. In this novel reactor, the interelectrode distance is significantly reduced, and the active surface area to volume ratio is increased ~155 times. This design enhancement allows for efficient treatment of low-conductivity waters and higher iron dosage rates without a corresponding increase in voltage requirements. Using ICP-MS and XPS, we have studied the effects of varying operating conditions and water chemistry conditions on the formation of mixed-valence iron nanoparticles and Cr(VI) removal efficiency. Future research will employ advanced characterization methods like Raman and X-ray absorption spectroscopy to determine iron speciation during electrolysis and elucidate the Cr(VI) removal mechanism.