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Application of Combined In Situ Chemical Reduction and Enhanced Bioremediation to Accelerate TCE Treatment in Groundwater

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Abstract: Groundwater at trichloroethylene (TCE)-contaminated sites lacks electron donors, which prolongs TCE's natural attenuation process and delays treatment. Although adding electron donors, such as emulsified oil, accelerates TCE degradation, it also causes the accumulation of hazardous metabolites such as dichloroethylene (DCE) and vinyl chloride (VC). This study combined in situ chemical reduction using organo-iron compounds with enhanced in situ bioremediation using emulsified oil to accelerate TCE removal and minimize the accumulation of DCE and VC in groundwater. A self-made soybean oil emulsion (SOE) was used as the electron donor and was added to liquid ferrous lactate (FL), the chemical reductant. The combined in situ chemical reduction and enhanced in situ bioremediation achieved favorable results in a laboratory microcosm test and in an in situ biological field pilot test. Both tests revealed that SOE+FL accelerated TCE degradation and minimized the accumulation of DCE and VC to a greater extent than SOE alone after 160 days of observation. When FL was added in the microcosm test, the pH value decreased from 6.0 to 5.5; however, during the in situ biological pilot test, the on-site groundwater pH value did not exhibit obvious changes. Given the geology of the in situ pilot test site, the SOE+FL solution that was injected underground continued to be released for at least 90 days, suggesting that the solution's radius of influence was at least 5 m.

Keywords: ferrous lactate; in situ chemical reduction; bioremediation; trichloroethylene (TCE); green and sustainable remediation (GSR)

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1. Introduction

The remediation of sites contaminated by dense nonaqueous phase liquid (DNAPL) is extremely difficult, which is why the development of economic and effective remediation technologies for DNAPL-contaminated sites is crucial. Trichloroethylene (TCE), a common DNAPL, is used in textile processing, refrigeration, vapor degreasing, metal washing, dry wash facilities, lubricants, and adhesives [1]. TCE is a common pollutant in sites with contaminated groundwater. The International Agency for Research (IARC) on Cancer listed TCE as "carcinogenic to humans" [2,3]. Thus, TCE is one of the most common and hazardous pollutants.

Microbes can convert chlorinated pollutants into hazard-free final products through dechlorination under an anaerobic state. However, the lack of electron donors in the environment often prolongs the time required for microbes to degrade chlorinated pollutants. Adding a commercial emulsified vegetable oil (CEVO) as an electron donor to accelerate reductive dechlorination of contaminated groundwater is a frequently adopted in situ bioremediation technology [4–6]. Direct injection of edible oil into the contamination plume does not yield favorable remediation results because edible oil has poor transmissibility;