Simultaneous Degradation of Commingled Contaminants by a Microbially-Driven Fenton Reaction Operated in Fed-Batch and Flow-Through Reactor Configurations

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Background/Objectives. Organic solvents such as trichloroethylene (TCE) and perchloroethylene (PCE) are detected in contaminated soil and ground water near industrial sites that are often co-contaminated with the solvent stabilizer 1,4-dioxane and ubiquitous perfluorinated compounds (PFCs). Recent concern over commingled co-contaminants is driven by several factors, including improper industrial disposal practices, toxicity to liver, kidney and central nervous system function, and recalcitrance to conventional degradation processes. Current remediation technologies such as photolysis, sonolysis, and enzymatic reductive dehalogenation are not cost-effective and can be limited by nutrient requirements and production of toxic intermediates. Chemical oxidation processes are attractive alternative remediation technologies due to high reactivity and low cost. The objective of this study was to simultaneously degrade the commingled contaminants TCE, PCE, 1,4-dioxane, and potentially PFCs including perfluorooctanoic acid (PFOA) by a microbially-driven Fenton reaction in fed-batch and flow through reactor (FTR) configurations that operate at circumneutral pH and do not require continual addition of the Fenton reagents Fe(II) and peroxide.

Approach/Activities. The fed-batch reactor system for commingled contaminant degradation was converted to FTR configurations with biotic and abiotic advective flow columns loaded with Fe(III)-coated quartz sand and fed artificial groundwater amended with commingled 1,4-dioxane, TCE and PCE. Testing is currently underway on these columns. Pilot studies were performed on three contaminant-free columns: biotic with partially oxygenated media (A), biotic with degassed media (B), and abiotic with degassed media (C). Mathematical models were developed to predict co-contaminant degradation and validate experimental results under both fed-batch and flow-through reactor configurations. Batch testing with the same conditions as previous batch studies is underway with PFC-amended media.

Results/Lessons Learned. The generation of reactive hydroxyl radicals via the microbially-driven Fenton reaction effectively degraded 1,4-dioxane, TCE and PCE in single, double and triple combinations in fed-batch reactor configurations. The contaminants were not degraded in control experiments carried out in the presence of radical scavenging compounds or with bacterial cells (abiotic control) or Fe(III) omitted. During pilot studies with contaminant-free FTRs, FTR A displayed the highest rate of ferrihydrite reduction and hydrogen peroxide production compared with the almost negligible ferrihydrite reduction and minimal hydrogen peroxide production in FTRs B and C, which may be a result of increased cell viability in FTR A due to initial aerobic metabolism in the first section. Pumping oxygenated media through the FTR may separate the FTRs into two zones: an aerobic zone in the first section of the column causes an anaerobic zone in the rest of the column due to the complete consumption of oxygen by the cells in the first part of the column. Contaminant degradation via the microbially-driven Fenton reaction is predicted to occur at the interface of the oxic and anoxic zones. By adjusting the flow rate, a gradual shift from oxic to anoxic is predicted to occur with concomitant hydroxyl radical production and contaminant degradation.