Laboratory Evaluations of ZVI: Impacts of Particle Size, Loading Rates, Sulfidation, Compounds Treated, and Combinations with Organic Substrates

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Background/Objectives. Laboratory batch and column studies were conducted to compare the ability of several different zero valent iron (ZVI) particles to react with chlorinated solvents at different loadings, incubation times, contaminants, and with other amendments such as various forms of sulfur or organic substrates such as emulsified vegetable oil product (SRS®), the emulsified ZVI products EZVI or SRS®-Z, or a bioaugmentation culture containing Dehalococcoides mccartyi.

Approach/Activities. Fifteen laboratory batch studies were completed across a diverse range of conditions: 21 different ZVI particles ranging from nanoscale (50 nm) to an average of 130 microns (μm), ZVI loadings of 1 to 11 g/L, with and without sulfidation, and in some cases organic substrates. Contaminants included chlorinated ethenes (CEs) such as tetrachlorethene (PCE), trichloroethene (TCE); chlorinated methanes (CMs) such as carbon tetrachloride (CT), chloroform (CF); chlorinated ethanes (CAs) such as 1,2-dichloroethane (2DCA), 1,1,1-trichloroethane (1TCA); bromoform (BF), and ethylene dibromide (EDB). Incubation times ranged from 21 to 70 days at room temperature under static conditions. Some studies used water and other amendments and other studies incorporated soil. Column tests were conducted with four ZVI particles at 4% loadings in sand and a sulfidated ZVI particle or combinations of 10 g/kg of a small ZVI particle, SRS®, and a ferrous sulfide solution (FSS).

Results/Lessons Learned. ZVI loadings of 4.0 g/L or greater of bare ZVIs in batch studies typically resulted in >90% reductions in CF, CT, 1TCA, BF, and EDB and >50% >50% reductions in the parent PCE and TCE when incubated for 28 days or more. None of the bare ZVIs at any loading were very effective (>90% removals) against 2DCA. Two fine ZVI particles with SRS® were more reactive against CT than CF with >99% removal of CT at ZVI loadings of 2.5 g/L or greater compared to 10 to 30% for CF. Higher loadings above 2.5 g/L ZVI did not improve the reactivity against CT. Combinations of ZVI at loadings of 10 g/L with substrates such as SRS® or EZVI generally did not perform as well as bare ZVI at the same loadings for CF, CT, PCE, 1TCA, BF, and EDB, possibly as the substrate coated the ZVI particles and slowed reaction rates. Many of the studies did not contain dechlorinating bacteria and were not conducted under conditions or for sufficient time where significant biodegradation would occur. There was no consistent difference between the performance of fine ZVI particles versus larger ZVI products in the batch studies. The addition of sulfide with sodium dithionite, calcium polysulfide, sulfur, and FSS to the ZVIs generally increased the extent and rate of dechlorination for PCE, 1TCA, and EDB over the corresponding untreated ZVIs. CT or BF generally went almost to completion with and without sulfide. In the first column studies, the 4% by weight ZVI loading resulted in average CE removals from the influent of 79.2% (larger ZVI) to a maximum of 98.2% (smaller ZVI). With the same size ZVI particle, the addition of sulfide increased the average CE removal from 79.2% to 93.3% in the sulfide-treated column. The second column study showed greater removals of the parent and daughter products with the combinations of ZVI and FSS than ZVI alone. The combinations of SRS, ZVI, and FSS resulted in 97.8% or greater of TCE, 1TCA, and CF in the influent. ZVI loadings > 4 g/L and in combination with sulfidation and organic substrates, was shown to be very effective in degrading many solvents.