Long Term Effect of Biotic Reductive Dechlorination on Permeable Treatment Walls

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Abstract: Increased, reactivity is a potentially important phenomena with respect to the cost effectiveness of zero-valent iron permeable barriers. A column study followed by batch experiments using microcosms was performed to analyze biotic reactions and their impact on kinetic reaction rates. In the biotic iron column study ethylene formation as a by-product of the TCE degradation was decreasing gradually after 200 pore volumes. Cis-DCE was the sole byproduct in TCE degradation. These observations suggested that TCE degradation was largely the result of microbial activity. Iron participation in the TCE degradation was decreased due to various precipitates blocking reaction sites and reducing the iron reactivity. Scanning electron microscopy (SEM) was used to investigate organic and inorganic precipitates on the iron surface. For biological analysis, a fluorescent microscope was used to identify any biological film developed after 200 pore volumes.

Introduction: Halogenated solvents are among the most commonly found groundwater contaminants in the world (Blowes *et al.*, 1995). Due to the limitations of pump-and-treat methods for groundwater remediation, considerable attention has now turned to the use of in situ permeable treatment walls (PTW). In this concept, a permeable "wall" containing the appropriate reactants is constructed across the path of a contaminant plume. Among the advantages over pump-and-treat, PTWs offer reduced capital cost, low operating and maintenance costs, and conservation of water and energy.

Zero-valent zinc and iron significantly enhanced the reductive dehalogenation of aliphatic compounds with iron being particularly attractive due to its low cost and availability. Batch tests in which aqueous solutions of a wide range of chlorinated methanes, ethanes, and ethenes were added to 100-mesh iron filings resulted in degradation rates that were three to seven orders of magnitude greater than natural abiotic rates reported in the literature (Gillham and Burris, 1992). Generally, the rates increased with the degree of chlorination and with increasing iron surface area to solution ratio. The chlorinated products of degradation subsequently degraded to non-chlorinated compounds. Biotic reactions could impact field kinetic rates, and thus retention time and mass of reactant, as well as construction costs. This research examines the potential effects on performance, of biotic reductive dechlorination occurring within a zero-valent iron PTW.

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Research objectives are to (1) quantify TCE removal kinetics in the presence of zero-valent iron and active microbial consortia using laboratory columns, (2) evaluate the effect of biological activity on reactive iron kinetics, and (3) identify operative microbial consortia through measurement of dechlorinated byproducts under controlled and inhibited conditions.

Materials & Methods-Column Studies: Four parallel glass columns (0.1 m I.D., 1 m in length) were filled with abiotic concrete sand (AS), biotic sand (BS), abiotic sand and 20 % by wt. peerless iron (AI), and biotic sand and 20 % by wt. peerless iron (BI). Approximately 600 g of biologically active soils were added to each column.

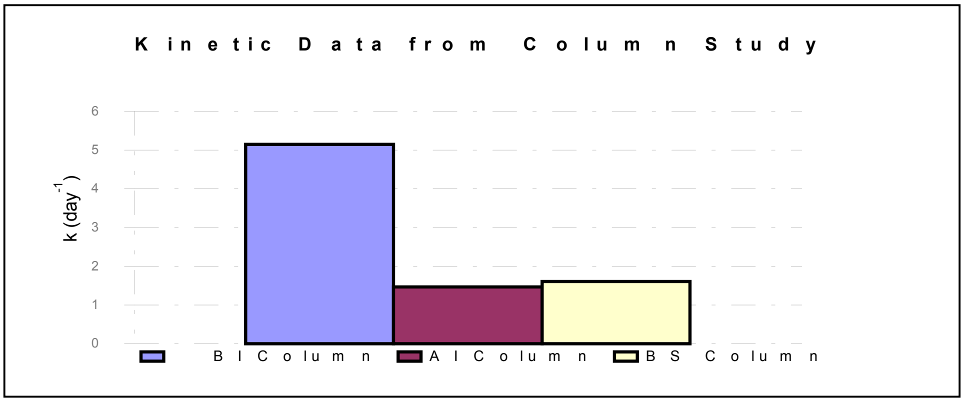

Figure 1 - Rate of TCE degradation in Abiotic Iron, Biotic Iron and Biotic Sand Column

Results and discussions-Column Study: The AS column was shut down after more than 50 pore volumes passed through and no decline in the concentration of TCE was observed. The kinetic rate for TCE disappearance is presented in Figure 1 for BI, AI, and BS columns. The presence of microbial organisms and iron in the BI column seems to have had a positive effect on the destruction of TCE relative to both the column containing no iron (BS) and the column containing no microbial life (AI). The primary degradation product in the BS column was cis-DCE. During the addition of more than 200 pore volumes to the BI column, the effluent cis-DCE gradually increased from 0.009 to 0.89 mg/L for TCE influent concentrations ranging from 0.6 to 4.3 mg/L. Ethylene formation as a by-product of the TCE degradation was decreasing gradually after 200

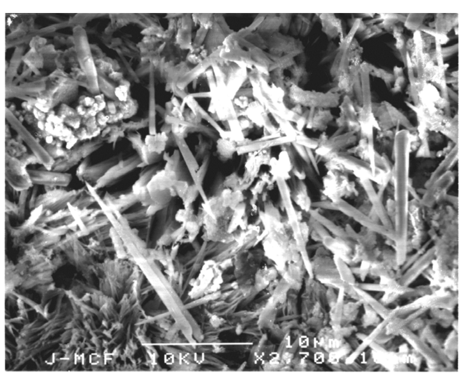

Figure 2 - SEM of deposits on the iron surface in the Biotic Iron Column at 2700 magnification

pore volumes. These observations suggest that TCE degradation was largely the result of microbial activity with no apparent iron participation in the TCE degradation. A sample of the iron in the biotic iron column was examined using an SEM (Figure 2).

Materials & Methods-Microcosms studies: Fifteen different microcosms were developed in triplicates (total of 45) spiked with 5mL of anaerobic digested sludge. Microcosms composed of Abiotic Sand (AS), Biotic Sand (BS), Abiotic Iron and Sand (AI), Abiotic Iron and Sand with sodium azide (AI w/NaAz), Biotic Iron and Sand (BI), Biotic Iron and Sand with BES (BI w/BES), Biotic Iron and Sand with Molybdate (BI w/Mo) and Biotic Iron and Sand with Vancomycin (BI w/Vanc) were used. Two sets of triplicates were developed, one with low sulphates (~2mg/L) and the second set with high sulphates (~100 mg/L). The results of the study are summarized in Figure 3.

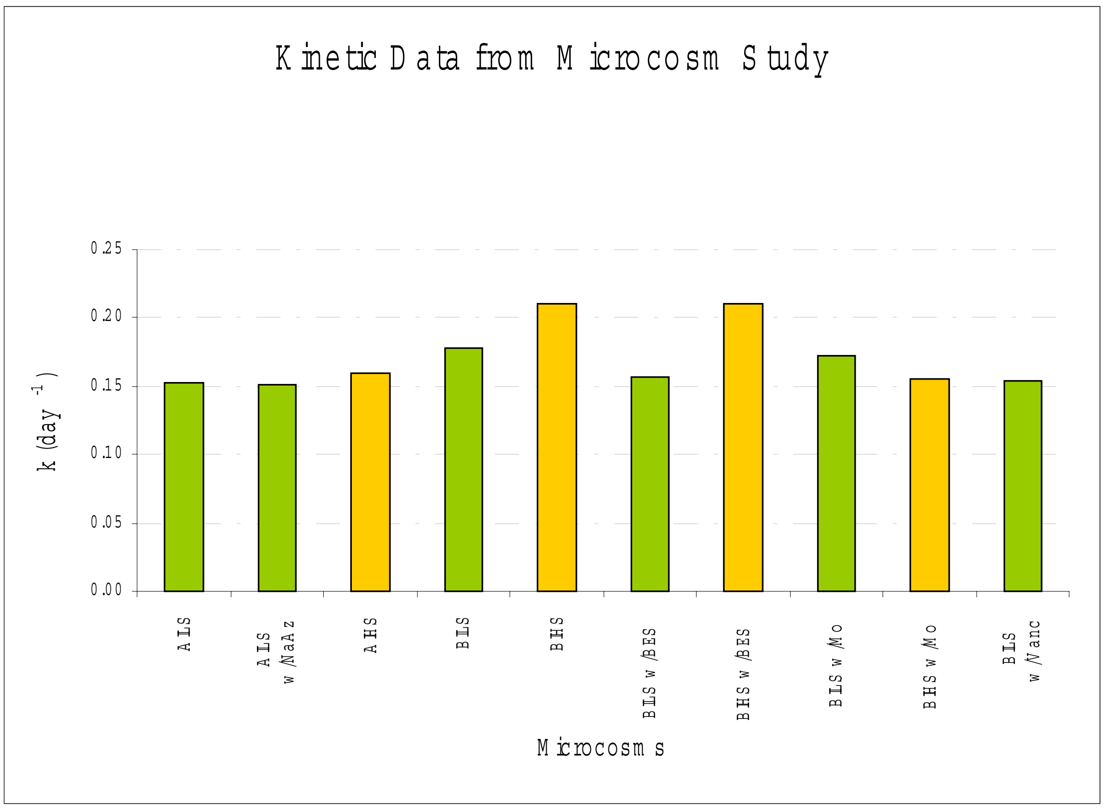

Figure 3 - Kinetic rate for TCE degradation using a batch of microcosms

Results and discussions- Microcosm study: Abiotic sand had no change in TCE concentration. Almost all the microcosms with high sulphates had a higher kinetic rate than low sulphates with the exception of the ones spiked with Molybdimun to inhibit sulphidogen activities. Further data analysis of gas production and surface studies using a flourescent microscope will be conducted in the near future.

References

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