Anaerobic Biodegradation Rates and Controlling Factors for Trichloroethene and Its Fluorinated Surrogate in Fractured Rock

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Background/Objectives. Biodegradation rates of trichloroethene (TCE) can vary widely under natural and enhanced anaerobic conditions, often leading to accumulation of the primary toxic daughter products of reductive dechlorination, 1,2-cis-dichloroethene (cDCE) and vinyl chloride (VC). In situ biodegradation rates can be particularly variable and difficult to assess in complex hydrogeologic settings such as fractured rock and in source areas where DNAPL is present. Trichlorofluoroethene (TCFE) has been used as a fluorinated surrogate for TCE to quantify degradation rates in in situ methods, including push-pull tests and in situ microcosms. Limited data is available, however, on the variability and controls of TCFE biodegradation rates relative to TCE under different hydrogeologic and biogeochemical conditions. As part of a Strategic Environmental Research and Development Program study to develop a borehole test method that uses TCFE combined with other tracers to measure diffusion, sorption, and reaction rates for TCE in low permeability zones, we are determining TCE and TCFE anaerobic biodegradation rates and associated microbial communities in mudstone rock under varying conditions to better characterize the variability. Tests were also designed to address the objective of ongoing research at the site to understand causes of incomplete TCE reductive dechlorination.

Approach/Activities. TCE and TCFE degradation rates were measured in anaerobic microcosms constructed using microbial samples and groundwater from boreholes in mudstone rocks that underlie the former Naval Air Warfare Center (NAWC), West Trenton, New Jersey. Microbial samples were collected by in situ incubation of sand or rock chips, encased in stainless steel mesh and suspended in the boreholes. A portion of the incubated sand or rock chips was frozen immediately for microbial community analysis by 16S rRNA Illumina iTag sequencing; some samples for microbial analysis were also collected from microcosm treatments. Microcosm treatments compared sand and rock chip microbial samples collected from the same boreholes, effect of lactate addition, and effect of addition of a dechlorinating culture (WBC-2). Microcosms prepared with groundwater only were used to evaluate the effect of suspended versus attached microbial populations on degradation.

Results/Lessons Learned. Anaerobic degradation rates of TCE and TCFE were rapid and nearly the same, with first-order half-lives mostly ranging between 1 and 4 days and the ratio of TCE:TCFE rate constants ranging between 0.85 and 1.16 in microcosms constructed with either sand or rock chip microbial samplers. The addition of lactate to microcosms with rock chips appeared to slow TCE degradation rates and decrease the ratio of TCE:TCFE rate constants to less than 0.7, most likely because the lactate caused a release of sorbed TCE and DCE compared to rock chip microcosms without added lactate. DCE accumulated and little VC production was observed in these microcosms. Similarly, microcosms constructed with incubated sand, which had low sorption capacity, showed faster TCE and DCE degradation than in the rock chip microcosms with added lactate. The onset of degradation of both TCE and TCFE was delayed in the sand microcosms compared to the rock chip microcosms, indicating growth of initially lower microbial population densities on the sand. Additional microcosms and microbial community analyses are underway.