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Abiotic Dissolution of a Tetrachloroethene (PCE) Pool in an Anaerobic Sand Tank Aquifer System with Heterogeneous Flow

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Intrinsic and engineered in situ bioremediation are made technologically challenging by the physically and chemically heterogeneous nature of the subsurface environment. Subsurface heterogeneities are important because they influence interfacial mass-transfer processes that impact the availability of substrates to the microorganisms. The laboratory experiments reported here examined the dissolution of a dense nonaqueous phase liquid (DNAPL) tetrachloroethene (PCE) pool, and transport of the dissolved PCE plume in a aquifer simulated system with heterogeneous flow. These abiotic experiments were performed in a saturated intermediate-scale flow cell (1.2 m), with flow parallel to the PCE pool. A steady-state mass balance approach was used to estimate the PCE dissolution rate at two different flow rates. As expected, increasing the flow rate decreased the effluent dissolved PCE concentration and increased the dissolution flux. However, the effluent PCE concentration was higher than expected based on modeling predictions assuming a uniform distribution of flow across the depth of the tank. Nonreactive tracer studies confirmed that there was a velocity profile with depth, with the slowest velocity at the top of the tank, and the highest velocity at the bottom of the tank, possible due to consolidation of the sand that occurred during a wetting/drainage cycle. Revised modeling using the vertical flow variation provided an improved prediction of the effluent PCE concentration. These results have important implications for predicting DNAPL pool dissolution in the field. Whereas experimental systems in the laboratory typically employ porous media with uniform flow distribution, flow heterogeneities are the rule rather than the exception in the field, and it is well known that velocity impacts pool dissolution. In the case of this experimental system, the pore water velocity near the pool was greater than the average pore water velocity across the system, resulting in a higher PCE dissolution rate than expected based on the average pore water velocity.

The research described here is part of a larger project working to improve the fundamental understanding of the impact of hydrodynamics and ecological interactions on DNAPL dissolution rate bioenhancement, and plume detoxification. These abiotic data provide the baseline for comparison to biotic experiments reported in another abstract submitted to Session HS8.1.6.