Downgradient Chlorinated Ethene Bulk Attenuation Rates and Extent of Mass Reduction at 40 ERD Sites

Jason M. Tillotson (jason.tillotson@arcadis.com) and Jennifer Martin Tilton
(Arcadis US, Raleigh, NC, USA)
Matt Schnobrich (Arcadis US, Lexington, KY, USA)

Background/Objectives. Electron donor addition is a proven and effective in situ technology for stimulating enhanced reductive dechlorination (ERD) of chlorinated ethenes. There are many design approaches to address the range of site-specific conditions (i.e., hydrogeological, geochemical, magnitude of contamination) to reduce exposure risks to potential receptors. One ERD design strategy is to inject an organic carbon substrate into contaminant source zones to facilitate mass reduction of the source term, which in turn limits mass flux downgradient. While degradation within the source zone is important within the context of the overall remedial timeframe and life-cycle costs, barrier-based approaches are also viable to truncate plumes and reduce short-term reduction in downgradient mass flux. Whether a result of direct source treatment or barrier control, understanding the rate of mass discharge reduction downgradient of the treatment zone is a key factor for design development and demonstrating ERD success.

Approach/Activities. In this work, we build upon two previous meta studies performed by these authors that examined degradation rates within the ERD injection zone to include the rates of change and extent of mass reduction in wells farther downgradient beyond the area of carbon substrate delivery. We calculate first-order bulk attenuation rates for chlorinated ethene species (i.e., PCE, TCE, cis-1,2-DCE, and VC) and total organic chlorine (ΣCl) using data collected from downgradient wells at over 40 different ERD sites. Monitoring wells are segregated into different groups based on distance and/or travel time downgradient. These rates are then compared to key geochemical, geological, and design parameters (e.g., iron, sulfate, and methane concentrations, bulk groundwater velocity, type of organic carbon substrate) to identify relationships between chlorinated ethene removal rates and site conditions. Key questions in this analysis include: What are typical dechlorination rates and extent of mass reduction downgradient of injection areas? How does distance downgradient affect degradation rates and extent of removal? Are there geochemical, geological, and/or design parameters that can best predict ERD effectiveness downgradient of the injection zone?

Results/Lessons Learned. This evaluation has yielded several preliminary observations. Firstly, bulk attenuation rates generally decreased with decreasing order of chlorination. Specifically, median first-order bulk attenuation rates for PCE, TCE, cis-1,2-DCE, and VC were 0.0062 d^{-1}, 0.0053 d^{-1}, 0.0049 d^{-1}, and 0.0049 d^{-1}, respectively. The median first-order removal rate for ΣCl was 0.0036 d^{-1}. When comparing these rates to those obtained from wells located within injection zones during previous analyses, median downgradient bulk attenuation rates were 9 to 49% lower than median injection area rates. Bulk attenuation rates and the extent of chloroethene removal generally declined with increasing distance downgradient. Additional statistical analyses will be presented discussing the relationship between bulk attenuation rates/extent of removal and geochemical, geological, and/or design parameters.