Viewing the End from the Beginning: Designing for the Transition to Long-Term Passive Phases of In Situ Chlorinated Solvent Treatment

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Background/Objectives. Theoretical research and practical experience over the past three decades have clearly demonstrated the limitations of the advection-dispersion equation to predict contaminant transport in most natural settings due to geologic heterogeneity, diffusion-driven mass exchange with lower-permeability zones, and complex contaminant sorption/desorption. For remedial technologies that only address contaminants in the more permeable zones and/or do not result in persistent and sustained in situ treatment (e.g., pump and treat, in situ chemical oxidation), these back diffusion and desorption processes can cause contaminant tailing and post-remediation rebound, extending the time to achieve remedial performance goals. However, reviews of long-term monitoring data from enhanced reductive dechlorination (ERD) sites suggest these sites have created zones where higher treatment rates are much more persistent than might be expected and contaminant rebound is largely mitigated. This indicates the active operational phase stimulates sustained treatment many years beyond the actual period of organic carbon injection. Therefore, there is an opportunity to more intentionally optimize and rely upon these processes (especially the formation of reactive iron minerals) to accelerate the transition to passive natural attenuation.

Approach/Activities. This presentation applies the concept of aquifer tuning, or alignment of remedial optimization with site-specific conditions within the natural environment, to the integration of in situ enhanced reduction (biotic-abiotic) remedies for chlorinated solvents and extend it to consider the remedy lifecycle in the design and operation. In particular, we present a review of long-term contaminant behavior at former ERD sites (with at least 7 years of post-injection data) as well as an empirical model of electron equivalents for aquifer tuning following organic carbon injection. We then consider conceptual design and monitoring frameworks to design and operate the active remedy phase in ways that specifically anticipate the persistence of resulting enhanced attenuation rates in the following transition and passive phases.

Results/Lessons Learned. A review of long-term contaminant behavior at ERD sites indicates a general lack of back-diffusion driven contaminant rebound. The empirical model indicates that the majority of electron equivalents associated with carbon injections are stored in the aquifer in reduced forms of iron and sulfate, resulting in the formation of reactive iron minerals that can prolong contaminant treatment and mitigate rebound. Remedial design considerations can include the addition of ferrous iron and/or sulfate during injection, performance monitoring to better assess the contributions of abiotic processes, and adjustment of the timing and frequency of injection events. We will conclude with a discussion on misperceptions of in situ enhanced remedial processes.