Reduce Long-Term Back-Diffusion from Low Permeability Zone with Horizontal ISCO Barriers

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Background/Objectives. Back-diffusion of contaminants of concern (COCs) from low permeability zones is often a long-term source impacting groundwater for extended time periods. In the situation where the low permeability unit is difficult to reach by excavation or in situ mixing, options for source zone remediation are very limited and plume remediation options usually require long-term operation and maintenance due to the nature of the slow-releasing source. The objective of this study was to explore the concept of horizontal long-term permeable oxidation zones embedded into the low permeability zone to reduce back-diffusion mass flux of COCs and mitigate the impact to the overlying groundwater.

Approach/Activities. The concept of horizontal permeable oxidation zones was implemented in the field by emplacing horizontal $KMnO_4$ lenses into a low permeability unit. $KMnO_4$ was selected as the oxidant mainly because $KMnO_4$ has greater longevity than other oxidant options and can be injected as slurry. The lenses were emplaced by horizontal hydraulic fracturing from injection wells that were installed into the top of the low permeability unit. $KMnO_4$ slurry was propagated in horizontal fractures within a dense, saprolitic weathered bedrock formation. Thus, the $KMnO_4$ lenses were physically inserted into the COC back-diffusion pathway. Furthermore, it is anticipated that dissolved $KMnO_4$ will diffuse into the low permeability unit above and below the lenses to remove more COC mass and create thicker oxidation reactive zones. Over the long term, the COC mass flux from the impacted zone beneath the $KMnO_4$ lenses will be oxidized and decreased when it diffuses through the oxidation barriers. Intensive remedial investigation and bench-scale studies were conducted to evaluate critical information for design and implementation of these horizontal oxidation barriers. A simplified mathematical model based on one-dimensional diffusion and first-order decay of the COC was constructed to provide estimates on the performance of the barriers and identify key parameters that affect the performance.

Results/Lessons Learned. A detailed conceptual site model is essential for the design and implementation of the horizontal oxidation barriers. The vertical distribution of COC mass within the low permeability unit was used to understand the depths at which the $KMnO_4$ lenses should be emplaced. The amount of $KMnO_4$ required to establish the lenses and the oxidation barriers was estimated based on the total mass of COCs present and the native oxidant demand of the formation. The mathematic mass balance yielded a generalized equation used to calculate the theoretical effectiveness of the oxidation barriers. The model indicated that the performance of the oxidation barrier is mainly a function of the thickness of the barrier, the effective diffusion coefficient of the COC within the barrier, and the first-order decay constant of the COC within the barrier. Field performance of the remediation will be evaluated by confirmatory soil borings and groundwater monitoring program.