Permanganate Distribution and TCE Source Area Results Three Years after Full-Scale Injection of Solid Reagent by Controlled-Jet Injection

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Background/Objectives. We present groundwater data and soil core visual observations of macro- and micro-scale permanganate distribution following injection of solid permanganate slurry in dense, relatively low-permeability saprolite and partially weathered bedrock. Source-area groundwater TCE concentrations were as high as 1,200 mg/L. Controlled-jet injection was utilized to emplace lenses of solid potassium permanganate. A dense network of 20 wells within and adjacent to a 60 ft x 40 ft source area affords a detailed perspective on dissolved permanganate distribution and persistence and TCE results over time. Coring performed during the full-scale and supplemental injections further affords detailed views of distribution of the solid reagent at both macro- (i.e., radius of distribution around an injection point and vertical diffusion of permanganate between injection levels) and microscales (i.e., transport and distribution of permanganate around fine-scale heterogeneities in saprolitic soil structure).

Approach/Activities. Permanganate was selected as the source remedy due to high TCE concentration, little natural degradation, and desire for rapid source reduction. Potassium permanganate blended with sand (PP/sand) was injected as a solid slurry to improve radial distribution of oxidant in the low-permeability saprolite, and to deliver a sufficiently large mass of reagent to provide a slow-dissolving, long-term supply of oxidant to address TCE desorption and back-diffusion from the fine-grained soil matrix. Full-scale construction completed in March 2014 consisted of injection of 38 tons of PP/sand into 28 discrete intervals in eight injection wells. A supplemental injection of 31 tons of solid PP/sand into 48 discrete intervals in 10 injection wells was completed in July 2014 to target areas not fully addressed in the primary injection. Two wells previously used as recovery wells initially exhibited permanganate, which rapidly attenuated and TCE concentration rebounded. Focused injection of liquid sodium permanganate and recirculation of groundwater were conducted around these wells at various times between September 2015 and March 2017, with only temporary effect. An additional six tons of solid PP/sand were injected into 17 discrete intervals in two new injection wells in June 2017 to target those two former recovery wells.

Results/Lessons Learned. Three years of groundwater data illustrate patterns of dissolved permanganate distribution, transport, and attenuation. Most of the treatment area exhibited nearly immediate presence of dissolved permanganate, which has persisted through three years. Areas in which permanganate attenuated rapidly or that were not reached in the primary injection were targeted by the supplemental injections. Groundwater recirculation only temporarily enhanced permanganate transport. Analysis of cores and soil borings from installation of full-scale and supplemental injection wells shows wide (>15 ft) lateral distribution of discrete permanganate lenses, and vertical diffusion for 2-3 feet above and below lenses. Permanganate distribution at the hand-sample scale and smaller shows greater heterogeneity, including transport around (without apparent penetration into) thin clay seams. Permanganate is expected to slowly diffuse into (and TCE to diffuse out of) these lenses over time; permanganate distribution even at the micro-scale appears sufficient to mitigate desorbed TCE.