

Pilot Study for In Situ Chemical Oxidation Using Potassium Permanganate for Remediation of Chlorinated Hydrocarbons in Groundwater

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Background/Objectives. An industrial property located in San Bernardino County, California, was formerly used as a dry cleaners (site). Their former use of solvents has caused groundwater to be impacted. Groundwater beneath the site is situated at a depth between approximately 30 and 35 feet below ground surface (bgs) and is impacted with chlorinated volatile organic compounds (VOCs), specifically tetrachloroethene (PCE), with maximum concentrations of 5,000 micrograms per liter ($\mu\text{g/L}$). The pilot study included the installation of 20 injection points and the administering of the in-situ chemical oxidation (ISCO) reagent into the subsurface.

The purpose of the ISCO pilot study was to assess the effectiveness of using potassium permanganate (KMnO_4) in: 1) reducing VOC concentrations in groundwater to acceptable levels; 2) collecting ISCO design and operation parameters prior to designing the full-scale groundwater remediation system; and 3) conducting periodic post injection monitoring and sampling.

Approach/Activities. A membrane interface probe (MIP) investigation was conducted at the site to determine the concentrations of VOCs in the saturated zone. The results of the MIP investigation revealed concentrations of PCE remained in the vadose zone, which combined with previous soil and groundwater results to design an initial chemical injection pilot study. The injection probe and groundwater monitoring well network included the installation of four groundwater wells and 20 injection points within a footprint of approximately 50,000 square feet in staggered layout with larger spacing between rows in the down gradient direction. In order to reduce the VOC concentrations in groundwater, dual nested semi-permanent injection points were placed in a grid pattern that assumed a 15-foot radius of influence (ROI) to generate a KMnO_4 solution overlap. Approximately 20,000-gallons of 3% KMnO_4 solution was injected in the injection points at a flow rate of about 5 gallons per minute in each injection point. The KMnO_4 injection was conducted in a stepped/phased approach, with the deepest zone injected first (bottom-to-top injection scheme) followed by the shallow-screened zone which received the least volume of KMnO_4 . In order to establish baseline groundwater quality, and evaluate the results of the injection event, the existing monitoring wells were sampled prior to administering the KMnO_4 .

Results/Lessons Learned. The ROI was estimated to reach approximately 15 feet in the cross-gradient direction of groundwater flow, and 25 feet in the down-gradient direction of groundwater flow. Based on the results of the ISCO pilot study, the VOC concentrations reduced significantly from 5,000 $\mu\text{g/L}$ to 1,000 $\mu\text{g/L}$. At times, the injected KMnO_4 solution migrated upwards and caused "daylighting" through the pavement cracks during the injection process. To minimize the surfacing of KMnO_4 fluids, the injection flow rate was reduced. Potential secondary groundwater byproducts such as hexavalent chromium and bromate were detected but below the maximum contaminant levels (MCLs) for drinking water during the injection. During injection of KMnO_4 , a neutral pH level was maintained. The results of the pilot study indicated that ISCO was successful in reducing PCE concentrations in groundwater and distributing the KMnO_4 in the aquifer. The achieved ROIs and significant decrease in PCE

concentrations demonstrate that KMnO_4 can be used to design a full-scale ISCO groundwater treatment system for the site.