# Injection of Potassium Persulfate via Hydraulic Fracturing to Address a Recalcitrant Fuel-Related and Chlorinated VOC Plume

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**Background/Objectives.** Fuel-related volatile organic compound (VOC) impacts to site soil and groundwater were discovered during underground storage tank (UST) removal activities at a former oilfield service facility in the western United States. Later, a chlorinated volatile organic compound (CVOC) groundwater plume was identified near a former wash bay and was found to be migrating to an adjacent downgradient property. Beginning in the mid-1990s, soil and groundwater impacted with benzene, naphthalene, tetrachloroethene (PCE), 1,1-dichloroethene (DCE), and 1,1-dichloroethane (DCA) have been gradually addressed with excavation and soil vapor extraction (SVE) in the source area and injection of zero valent iron (ZVI), groundwater pump and treat (P&T) (still operating), and in situ chemical oxidation (ISCO) in the downgradient portion of the plume. Though considerable plume attenuation had been achieved via the multi-technology treatment strategy, recalcitrant VOC and CVOCs in a 10-foot thick silt and silty-clay interval in the source area saturated zone continue to sustain the downgradient groundwater plume. Addressing the persistent groundwater plume source was critical for achieving site closure.

**Approach/Activities.** Following bench-scale treatability testing, ISCO using iron-activated persulfate was selected to remediate the soil and groundwater in the source area. Because the residual contaminant mass is in a relatively low permeability interval from 15 to 25 feet below ground surface, a combination of hydraulic fracturing and conventional low pressure injection methods was selected to deliver and distribute the reagents. The multi-phase application process is as follows: 1) inject sodium persulfate (Klozur SP), potassium persulfate (Klozur KP, chelated iron, and proppant sand via hydraulic fracturing, 2) install injection wells in the borings, 3) inject additional sodium persulfate and chelated iron, and 4) inject carbon substrate (later, if needed). The persulfate combination was selected to provide and an initial kick-start to the oxidation process (sodium) and a longer-lasting oxidant (potassium) to address the VOCs and CVOCs that gradually diffuse/desorb from the silt and silty clay. In addition to activating the persulfate, the iron will support also 1,1-DCA reduction. Finally, the optional carbon substrate was added to promote further 1,1-DCA reduction and/or reduce residual sulfate from the persulfate to meet state secondary water quality parameters.

**Results/Lessons Learned.** Phase I of the hydraulic fracturing ISCO application is scheduled for fall 2017. It is anticipated that findings from the injection process and four months of groundwater monitoring data will be available at the time of the presentation, which will include remediation objectives, a description of the field activities, reagent doses, costs, and results. If effective, the application will be expanded to address a larger area to ultimately reduce the time to achieve site closure.