

## Remediation of Hexavalent Chromium in a Permanganate-Treated Plume: Comparative Evaluation of Five Reducing Agents

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**Background/Objectives.** Remediation of a chlorinated solvent impacted plume at a manufacturing facility located in McPherson, Kansas via large-scale injection of permanganate resulted in persistence of elevated hexavalent chromium [Cr(VI)] concentrations in groundwater due to significantly altered subsurface redox conditions. Challenges for Cr(VI) remediation at the Site included: (1) large areas of the plume with residual permanganate ( $\text{MnO}_4^-$ ) and manganese dioxide ( $\text{MnO}_2$ ) that exerted a strong reductive demand, thereby inhibiting Cr(VI) reduction to trivalent chromium [Cr(III)], and (2) newly identified down gradient areas that did not contain permanganate but Cr(VI) impacts were noted near an active Public Water Supply (PWS) Well. A suitable remedial solution was sought to reduce Cr(VI) to below the Kansas Department of Health and Environment (KDHE) Risk Based Standards for Kansas (RSK) Level of 100 micrograms per liter ( $\mu\text{g/l}$ ) without adversely impacting concentrations of other regulated metals.

**Approach/Activities.** A series of reducing agents were evaluated under laboratory conditions on both permanganate-impacted and permanganate-free samples collected from the site. Selection of reducing amendments was based on published literature as well as previous experience combining Cr(VI) treatment and permanganate scavenging in order to first reduce Mn(VII) in  $\text{MnO}_4^-$  to Mn(IV) and then to Mn(II) during  $\text{MnO}_2$  reduction. Then, Cr(VI) is reduced to Cr(III), which has low solubility in water and hence, precipitates out of solution. The reducing amendments included ferrous ion with acid (Fe-A), ferrous ion with chelate (Fe-C), calcium polysulfide (CPS), ascorbic acid (AA), and combination of ascorbic acid and calcium polysulfide (AA+CPS). Phase I experiments were performed on slurries prepared from a 1:1 ratio of soil and groundwater collected from the Site using all 5 reducing amendments. Based on data collected from Phase I experiments, Phase II bench scale study was designed using the best reagents selected from the above list with focus on optimizing dosage for field scale application. Soil and groundwater samples generated via phase separation of slurries from the tests were analyzed for Cr(VI) as well as target analyte list (TAL) metals to evaluate impacts from reagent amendment addition on other regulated metals, primarily total chromium, arsenic, barium, lead, vanadium and nickel.

**Results/Lessons Learned.** Results of Phase I experiments indicated that all reducing reagents evaluated were effective towards Cr(VI) in both permanganate-impacted and permanganate-free areas. However, the effect on TAL metals was largely varied with Fe-C creating a lead and nickel issue, AA and AA+CPS creating arsenic, total chromium, barium, nickel and vanadium issues, and CPS creating a barium and nickel issue. The choice of reducing reagents for Phase II experiments was based on amendments that caused the least side effects. Data collected showed greater challenges in overcoming reducing demand in permanganate-impacted area especially at lower and medium dosage level; nonetheless, lower dosages were found to be critical in minimizing potential side effects on other metals.