

## Use of Reactive Minerals to Remediate Chlorinated Solvents in Groundwater at a Locomotive Repair Shop

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**Background/Objectives.** Groundwater beneath a former locomotive repair shop at an active rail yard in Battle Creek, Michigan is impacted with chlorinated aliphatic hydrocarbons (CAHs) including tetrachloroethylene (PCE) and trichloroethylene (TCE). Source zone concentrations in the shallow sand/gravel aquifer of these and other CAHs are relatively low, ranging up to approximately 130 micrograms per liter, but are in excess of applicable cleanup criteria. It was unknown if traditional reductive dechlorination techniques would be suitable for remediation of the low CAH concentrations. AECOM therefore investigated the feasibility of using an innovative approach involving reactive minerals for groundwater remediation. **Approach/Activities.** The ability of reactive minerals to degrade CAHs is well reported, in some cases occurring naturally. A sampling and pilot study program was initiated in 2012 to investigate the current presence and activity of reactive minerals as well as the potential to stimulate their formation in an engineered remediation process. Groundwater samples collected to estimate the natural occurrence and activity of reactive iron sulfide minerals were analyzed for CAHs, ferrous and ferric iron, sulfate, sulfide and dissolved gases. Soil samples were analyzed for solid-phase iron and solid phase sulfides. After assessing the sampling data, AECOM performed a 9-month pilot test from August 2013 through April 2014 to determine if reactive minerals could be artificially created with subsequent degradation of CAHs by injecting a labile carbon source (fructose corn syrup) and additional sulfate (magnesium sulfate) into the source area shown to already contain significant amounts of iron. The single injection event was performed in August 2013. Pre- and post-injection groundwater samples were analyzed for CAHs, ferrous and ferric iron, sulfate, sulfide, dissolved gases, dechlorinating bacteria and functional genes. Pre- and post-injection soil samples were analyzed for strong acid soluble iron, acid volatile sulfides and minerals using x-ray fluorescence and x-ray diffraction. **Results/Lessons Learned.** The results of the 2012 sampling program as well as the pre-injection samples collected during the pilot test indicate that naturally occurring iron-sulfide minerals are minimal, abiotic reaction byproducts are not present and rates of CAH degradation are relatively slow. Therefore existing conditions do not significantly stimulate the degradation of CAHs via a pathway catalyzed by reactive minerals. The results of the pilot test, performed to assess the potential to create reactive minerals, indicate that conditions for formation of reactive minerals were enhanced and reductive dechlorination was stimulated. Post-injection analytical data suggest that both biotic and abiotic mechanisms were involved in reductions in CAH concentrations. The predominant mechanism for degradation was biotic degradation, although abiotic degradation processes were also likely occurring. Chlorinated ethanes were nearly completely degraded and chlorinated ethenes were partially dechlorinated after one injection event. These results may be of broad significance to the railroad industry given that chlorinated solvents were potentially widely used for degreasing and cleaning parts during locomotive maintenance and repair.

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