Field-Integrated Studies of Long-Term Sustainability of Chromium Bioreduction at Hanford 100H Site

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The focus of these project is to understand the coupled hydraulic, geochemical, and microbial conditions necessary to maximize Cr(VI) bioreduction and minimize Cr(III) reoxidation in groundwater. To demonstrate the feasibility of a cost-effective remediation technology for bioimmobilization of Cr(VI) in contaminated groundwater, using a slow release polylactate Compound, HRC™, we have conducted a series of bench-scale and field-scale integrated treatability studies.

Using bench-scale studies, we have shown the presence of several types of bacteria in the sediments from the Hanford 100H site, including *Bacillus/Arthrobacter* and *Geobacter* species, which are known to reduce or sorb hexavalent chromium. Under background conditions, the total microbial population in Hanford sediments is $<10^5$ cells g^{-1}, which is likely insufficient for direct enzymatic Cr(VI) reduction. We have shown that different types of HRC and metal remediation compound (MRC™) products could stimulate an increase in biomass to $>10^8$ cells g^{-1}, generate highly reducing conditions, and enhance Cr(VI) removal from the pore solution.

At the Hanford 100H field site, we drilled and equipped two new wells—injection Well 699-96-45, located 15 ft downgradient from the existing monitoring well 699-96-43, and a monitoring and pumping Well 699-96-44, located 15 ft downgradient from the injection well. To assess the background hydraulic properties of the Hanford formation, three Br-tracer injection tests and two pumping tests (concurrently with the Br-tracer tests) were performed before the HRC injection. We also performed a series of geophysical (seismic and radar) cross-borehole measurements.

A pilot field-scale test was conducted, injecting 40 lb of ^{13}C-labeled HRC via injection Well 699-96-45 into the Hanford formation (over 44 ft to 50 ft depth intervals). Redox potential, pH, dissolved oxygen (DO), nitrate, Cr(VI), and sulfate concentrations in groundwater were monitored. Following HRC injection (27 days), redox potential dropped to –130 mV, and DO and nitrate practically disappeared. Cr(VI) concentrations declined steadily over 6 weeks. Analysis of $\delta^{13}C$ ratios in dissolved inorganic carbon confirmed microbial metabolism of HRC. Hydrogen sulfide production was first observed after about 20 days post-injection, which corresponds with the enrichment of a *Desulfovibrio* species identified using fluorescent antibodies. DO and nitrate began to return to background concentrations two months after HRC injection, despite bacterial densities remaining high ($>10^7$ cells/mL). Cr(VI) concentrations in the monitoring and pumping wells remained below up-gradient concentrations. Thus, microbial and geochemical analysis of groundwater coupled with stable isotope monitoring allowed for accurate tracking of microbial processes during this field treatability study, and confirmed that Cr(VI) was successfully removed from groundwater at a contaminated site using HRC as an electron donor and a carbon source.

Directions of ongoing research include the determination of whether dissolved oxygen and manganese oxides could reoxidize Cr(III) to Cr(VI), and the development of a 3D reactive transport code, TOUGHREACT-BIO, to simulate coupled biological and geochemical processes.