LBNL Sustainable Systems SFA: Unraveling Biogeochemical Pathways Mediating Sustained Chromium Reduction: Field-Scale Investigations at Hanford 100-H Site

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ABSTRACT

• The 2004-2008 field experiment at the Hanford 100-H Site showed that a single injection of the hydrogen release compound (HRC)—a slow release glycerol polylactate—into groundwater stimulated an increase in biomass and a depletion of terminal electron acceptors, resulting in a significant decrease in soluble Cr(VI) for more than 3 years after the HRC injection. Although the post-HRC injection monitoring indicated that Cr reduction via biostimulation is feasible, a number of questions regarding the mechanisms and sustainability of the approach remain unresolved; these questions form the basis of this research Challenge.

• The overall objective of current field-scale investigation is to characterize critical and interrelated microbial metabolic and geochemical mechanisms associated with *in situ* chromium reductive immobilization and reoxidation, from the molecular to the local field scale.

• On November 13, 2008, we injected a small amount (10 lbs) of HRC into the injection well at the Hanford 100-H site to revive the microbial community activity, and to stimulate the ability of indigenous microorganisms to create sustainable reducing conditions needed for the reductive bioimmobilization of Cr(VI) in the groundwater and the formation of insoluble Cr(III) complexes.

•We performed groundwater sampling for 11 types of different microbial and geochemical analyses. To directly assess microbial enrichment, specially designed biomass traps were placed in the monitoring wells (the work is conducted jointly with the Center for Biofilm Engineering, Montana State University).

• We plan to perform a push-pull test using a KNO_3 injection into the Hanford aquifer.

• This project is conducted in collaboration with Genomics: GTL. Two other components of the SFA Unraveling Challenge are presented in the posters:

• Beller et al., Use of biomolecular signatures to unravel biogeochemical reaction networks underlying chromium reduction at the Hanford 100H site.
• Steefel et al., Reactive Transport Modeling of Microbially-Mediated Processes at the Old Rifle and Hanford 100H Site

BACKGROUND, HYPOTHESIS & APPROACH

Main Hypotheses

• Microbial processes mediate both direct (enzymatic) and indirect Cr(VI) reduction at Hanford 100H, but indirect pathways dominate sustained reduction. Furthermore, sulfate reduction is the electron-accepting process ultimately driving sustained Cr(VI) reduction at Hanford 100H.

• The rate and extent of Cr(III) (re)oxidation will be controlled by the abundance and mineral form of Mn (III/IV) oxides in the sediment.

• Fermentative/acetogenic versus respiratory metabolism will promote retention of organic carbon in the aquifer .

Additional Objectives

• Define "Microbial Memory Response" for Cr(VI) bioimmobilization

• Elucidate biogeochemical interactions that affect resiliency of biostimulated communities to episodic stressors at Cr(VI) contaminated sites.

• Provide the information needed to integrate different components of the Unraveling Challenge, including laboratory, column, numerical studies, to address the main three hypotheses.

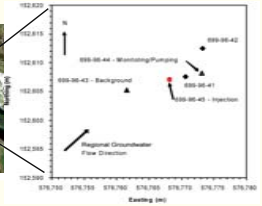
Methods

Inject a small amount of HRC in groundwater at Hanford 100-H and perform 11 types of different microbial and geochemical analyses and biomass collection using bug traps in the monitoring wells.

FIELD SITE AND TEST DESCRIPTION

Hanford 100 Area

Hanford 100-H Field Site



HRC Injection in Well 699-96-45 on November 13, 2008

The HRC injection procedure was similar to that applied in 2004.

Pre-HRC injection—1:42 pm
- 2.5 gal groundwater used as a primer
- HRC diluted using 3.5 L groundwater from the injection well
- HRC-water mixture was heated to 95 deg. F.

HRC Injection—1:45 pm
- Injection using a peristaltic pump.
- Injection over the interval from 43 ft to 49 ft from the TOC.

Post-HRC injection:
- 1.5 gal groundwater used as a chaser.
- Injection packer remained in the well for ~1 hour to allow the HRC to sink.
- The packer was withdrawn and changed to the monitoring packer by ~7 pm.


Borehole casing


Bug trap installation


Samplers/packers installation


On site measurements


Sampling manifold

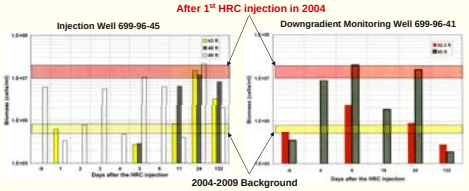

Sample filtering


Sample collection

RESULTS

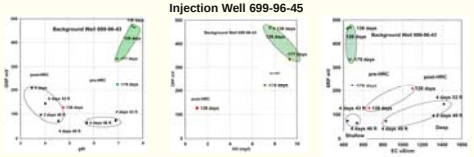
Microbial AODC Analysis

After 1st HRC injection in 2004

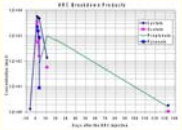


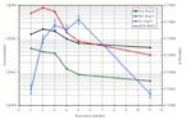
On Site Measurements of EC, ORP, pH, and DO

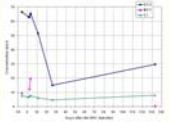
Injection Well 699-96-45

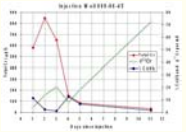


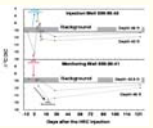
Cations/Anions and Isotopic Analyses









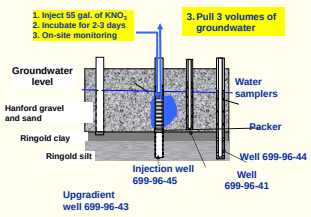


PLANNED ACTIVITIES

- Field single well push-pull test
- Column studies to assess biogeochemical reaction networks
- Cr, Fe, Mn speciation studies
- Microbial analysis
- Reactive transport modeling

These activities are to be conducted in association with SFA challenges on biomolecular signatures and reactive transport modeling

Design of a Single-Well Push-Pull Test



SUMMARY

- The 2nd biostimulation using a small amount of HRC indicates a biomass recovery to the same level as after the 1st injection in 2004 and generation of slightly reducing conditions in the injection and downgradient monitoring wells.
- The increase in $\delta^{13}C$ immediately after HRC injection in the injection well 699-96-45 is likely caused by dissolution of carbonates due to the low pH from the organic acids. The drop in the $\delta^{13}C$ values below background in both the injection and nearby monitoring wells is due to metabolism of the HRC in the shallow groundwater zone.
- The November 2008 through March 2009 data provide evidence of sustained metabolism of HRC in the groundwater downgradient from the injection well, which is consistent with the sustained reduction of nitrate.
- The rise in $^{87}Sr/^{86}Sr$ is consistent with the dissolution of calcite. The Ca concentrations fall back earlier than the $^{87}Sr/^{86}Sr$ ratio (which is unaffected by precipitation), which could be consistent with precipitation of Ca-phosphate (the phosphate is from the HRC) with continued dissolution of calcite.
- The increase in the total Cr concentration could be explained by dissolution of Cr(III) under the low pH conditions resulting from the HRC injection. The increase in the $\delta^{53}Cr$ of the Cr(VI) suggests that reduction of Cr(VI) is one of the mechanisms that is developed after the biostimulation.
- Further monitoring and data analyses are needed to assess the persistence of Cr bioimmobilization and to determine whether the biomass and iron concentrations are sufficient to run a push-pull test, and whether there is a need for additional biostimulation.

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