Biostimulation of In-Situ Uranium Reduction at the NABIR Field Research Center
Using a Nested Recirculation Scheme and Aboveground Groundwater Conditioning

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Objectives

Belowground Experiment:

Primary Objective: To perform experiments to evaluate the rates and mechanisms of U(VI) reduction in situ at FRC, subject to biostimulation.
Secondary Objective: To develop an effective ex-situ treatment system to precondition the site and maintain an appropriate environment during the experiments.

Major Engineering Challenges

Several factors complicate the stimulation of subsurface microbial uranium reduction:
1. High levels of nitrate (\(>8 \text{ g/L}\)) inhibit microbial uranium reduction because denitrification intermediates reoxidize U(VI).
2. The extremely low pH (\(<3.5\)) and the presence of volatile organic compounds (VOCs) are inhibitory to biological activity.
3. As pH is increased to levels suitable for microbial activity, Al, Tc, Ca, Mg, and Mn precipitate. Precipitate formation in the subsurface could clog the aquifer.

The FRC Site

The site for the field experiment is located in Area 3 of the Field Research Center (FRC), adjacent to the S-3 ponds cap. We have installed injection wells, geophysics wells, and multilevel sampling wells.

Outline of Basic Strategy

Ex-situ:
- Eliminate clogging agents, precondition treatment zone
  - remove aluminum and calcium through two precipitation steps
  - remove volatile organic compounds through stripping
  - remove nitrates in a denitrifying fluidized bed reactor
  - neutralize acid

In-situ:
- Biostimulation for denitrification of residual nitrate and U(VI)

Treatment Configuration

Geologic Media

A two-region model was developed to simulate bromide and nitrate data of the tracer test and recovery. Results indicate that over 80% of nitrate is inside the immobile region or low-conductivity region, which implies a long clean-up time for nitrate. The mobile region responds well to advective removal, so nitrate concentration in this region can be maintained at a low level.

Belowground Experiment: Flow Configuration

Two recirculation loops establish a protected zone for uranium reduction. The outer loop captures contaminated site water for above-ground treatment and surrounds the inner uranium reduction zone with a layer of treated water.

In the inner loop, a high percentage of injected water is captured in the extraction well for recirculation. Ethanol as an electron donor is added to this water before it is reoxygenated, and its pH and TIC level is adjusted as necessary.

Belowground Experiment: Tracer Recovery Test

The recovery behavior of dominant metals and ligands during the test is mainly due to the kinetic mass transfer between the immobile region and the mobile region. All metals analyzed showed a similar recovery pattern.

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