Acceleration of Microbially Mediated U(VI) Reduction at a Uranium Mill Tailings Site, Colorado Plateau

Phil Long[1], Todd Anderson[2], Aaron Peacock[3], Steve Heald[1]; Yun-Juan Chang[3], Dick Dayvault[4], Derek R. Lovley[2], C. T. Resch[1], Helen Vrionis[2], Irene Ortiz-Bernad[2], and D. C. White[3]

[1]Pacific Northwest National Laboratory, [2]University of Massachusetts, [3]University of Tennessee, [4]S. M. Stoller Corporation

Pacific Northwest National Laboratory

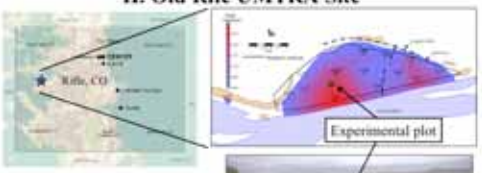
Operated by Battelle for the U.S. Department of Energy

I. Introduction

A second field-scale electron donor amendment experiment was conducted in 2003 at the Old Rifle Uranium Mill Tailings Remedial Action (UMTRA) site in Rifle, Colorado. The objective of the 2003 experiment (done in collaboration with the U.S. Department of Energy's UMTRA Groundwater Project) was to test the hypothesis that amendment of increased concentration of electron donor would result in an increased export of electron donor down gradient which in turn would create a larger zone of down-gradient U(VI) bioreduction sustained over a longer time period relative to the 2002 experiment (Anderson et al. 2003). During the first experiment (2002), ~3 mM acetate was amended to subsurface over a period of 3 months in a 15m by 18m by 2.5m volume comprised of 3 upgradient monitoring wells, 20 injection wells, and 15 down-gradient monitoring wells. After an initial one-month phase of metal reduction, bioavailable oxidized Fe was consumed near the injection gallery and the dominant terminal electron accepting process became sulfate reduction, rapidly consuming the injected acetate. For the 2003 experiment, we amended sufficient acetate (~10 mM) to consume available sulfate and export acetate down-gradient where bioavailable oxidized Fe was still present. Data from the experiment indicate that acetate was exported further down gradient, resulting in a larger zone of microbial U(VI) reduction than for the 2002 experiment.

Geohydrologic, geochemical, and microbiological data collected during the course of both experiments enable assessment of relative importance of a number of factors controlling the experimental outcomes. Companion posters by Anderson et al. and White et al. provide additional results.

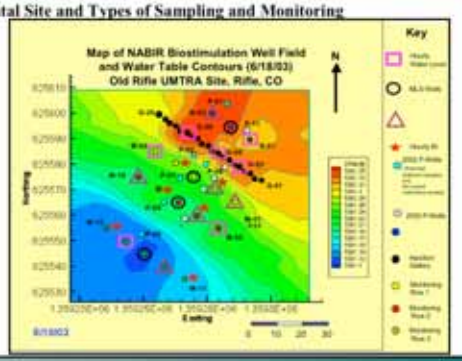
II. Old Rifle UMTRA Site



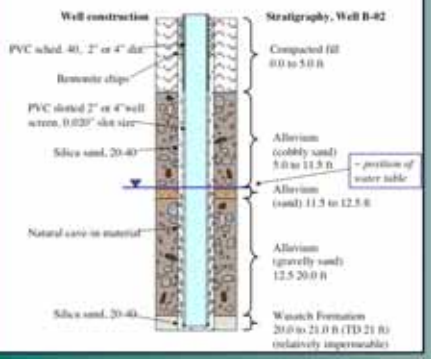
The experimental plot is located in a part of a uranium plume with ~ 0.6 to 1.2 uM U(VI), residual from when the site was used as a uranium ore processing facility. The Colorado River flow has a major impact on groundwater flow at the site.

III. Layout of Experimental Site and Types of Sampling and Monitoring

To accomplish the biostimulation, electron donor was metered into the subsurface under natural gradient conditions4 months in a 15m by 18m by 2.5m volume comprised of 3 up-gradient monitoring wells, 20 injection wells, and 15 down-gradient monitoring wells. Monitoring and sampling performed in each well is shown on the map to the right. All 15 monitoring wells are used for pumped samples collected every 2 weeks during acetate amendment and monthly during the post-amendment monitoring phase. Four wells down the center are also used for passive multi-level sampling. Water table contours show the gradient with groundwater flow from northeast to south west (from background wells, down gradient to injection gallery and then to monitoring wells).

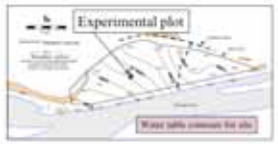


IV. Geology and Well Construction



V. Gradient and flow field during the experiment

The elevation of the water table at the Old Rifle site varies with time, largely as function of the discharge in the Colorado River. For both the 2002 and 2003 experiments, the water table dropped during most of the experiment. However, just prior to the to the 2003 experiment, the water table rose sharply due to spring snow melt. During this period the flow reversed direction (for several days) and DO rose sharply (see panel VI). Before the 2003 experiment was started, the flow direction and gradient returned to normal. Significantly, there are no secular trends in gradient that indicate a change in permeability induced by the injection of acetate for either experiment. The mean gradient varies between 0.0018 and 0.0022 (~25% change), and overall flow direction remained sensibly constant (see computer animation).



VI. Background U(VI), Dissolved Oxygen, and Water level as function of time

During the 2002 experiment, background U(VI) concentrations remained relatively constant. However, starting as early as Dec 12, 2002, U(VI) began to increase. DO, however, did not rise until mid-June 2003, apparently synchronous with a steep rise in the water table. U(VI) and DO declined sharply in the background about the same time acetate addition began but after water level had been declining for ~3 weeks. Background U(VI) data are critical for interpreting the impact of acetate addition for the 2003 experiment. The association of an increase in DO with a rise in the water table provides opportunity for a "natural" experiment on reoxidation of bioreduced U(VI) during spring runoff 2004.