Chromate Reduction in Heterogeneous Porous Media

University-led research

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Chromate is a common groundwater contaminant at the U.S. Department of Energy (DOE) Hanford Site and poses a long-term threat to the water quality because of its high toxicity and aqueous solubility. Reduction of Cr(VI) to Cr(III), followed by the precipitation of Cr(III) hydroxide and / or mixed Fe/Cr (oxy) hydroxides, is one of the promising strategies to attenuate dissolved Cr(VI). Both aqueous and solid Fe(II) are abundant in Hanford sediments (biotite, clinochlore, magnetite, and ilmenite) and can serve as effective reductant for Cr(VI).

Under well-mixed laboratory conditions, the reduction of Chromate by aqueous Fe(II) often occur at a time scale of minutes. In natural systems, however, high Fe content sediments are typically unevenly distributed, with its majority in clay-rich low permeability zones. This can have a large impact on Fe(II) availability for the reduction of Cr(VI) and therefore the reduction rate of Cr(VI). The objective of this work is to investigate how and to what extent spatial distribution of Fe(II)-rich clay determine the rate of Cr(VI) reduction.

Column experiments with different mineral distribution patterns will be conducted, with quartz and illite representing the major solid components at the Hanford site. Illite will be pre-sorbed with Fe(II). Three columns will be set up, with one of the columns having Fe-saturated illite evenly distributed within the quartz matrix across the whole column (mixed column), while the other two having Fe-saturated illite distributed as one or three layers embedded within the sand matrix (1-layer column and 3-layer column). The total mass ratios of illite and quartz in the three columns will be kept constant. To investigate the effects of spatial distribution on the rate of Fe (II) desorption and Cr(VI) reduction under different geochemical conditions, flows at different pH conditions will be used. As the Fe(II) desorption and Cr(VI) reduction reactions are highly pH dependent and are sensitive to local geochemical conditions, a series of batch experiments is being conducted to determine 1) the suitable pH conditions for the Cr(VI) reduction in the column experiments, 2) the difference between Cr(VI) reduction rates with Fe(II) and with Fe(II)-sorbed illite. Understanding from batch reactor experiments will be used later to examine the difference between rates at the laboratory scale and the rates at the column scale. Reactive transport modeling will be used to quantify the rates under different conditions, to understand the role of heterogeneity, and to upscale laboratory rates to the field scale.