

Environmental Management Science Program

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Manipulating Subsurface Colloids to Enhance Cleanups of DOE Waste Sites

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Research Objective

This project seeks to increase the effectiveness of pump and treat systems for removal of pollutants from sandy aquifers. Pollutants which sorb strongly to aquifer solids are not efficiently remediated using pump and treat technologies. However, if the sorbents most active in immobilizing pollutants (e.g., clays, humics, and iron oxides) were dispersed into colloidal size particles (colloid mobilization), these colloids and their associated pollutants might be pumped from aquifers. At a chromium contaminated sandy aquifer, this project seeks to: (1) understand the forces which stabilize colloidal particles in the aquifer, (2) devise solutions which will disrupt these colloid stabilizing forces, and (3) demonstrate the effectiveness of colloid mobilization as a remediation technique for removing sorbed chromium from the aquifer.

Research Progress and Implications

This progress report summarizes work completed after 1 1/2 years of a three-year project. Our efforts have focused on remediation of a chromium contaminated aquifer located on the property of National Chromium in northeastern Connecticut. Our work to date may be divided into three areas: (1) site characterization; (2) identification of colloid binding forces and development of an effective colloid dispersion treatment; and (3) field testing of the aquifer remediation strategy.

(1) Site Characterization

National Chromium is a chromium plating company which has been in operation since approximately 1940. The sandy aquifer underlying the plant is contaminated with chromium due to past manufacturing practices. Ninety nine percent of the chromium in the aquifer is sorbed to aquifer solids (Nikolaidis et al., 1994).

In June and September 1997, soil cores and water samples were collected from the site to characterize the mineralogy and determine the extent of chromium contamination at the location of future remediation tests. These cores also provided material for laboratory experiments elucidating mechanisms of colloid attachment and dispersal. We also performed pumping and slug tests to determine the aquifer's hydraulic conductivity.

The aquifer contains fine to silty sands with, in some areas, gravel and small stones. Aquifer material derives from both glacial and river deposits and appears to vary in texture and chromium content depending on its origin. Hydraulic conductivities are on the order of 10^{-5} to 10^{-6} cm/sec. In the vicinity of the cores collected in 1997, groundwater is oxic with pH values around 4.1. Dissolved chromium levels (presumably as HCrO_4^-) range from 38 to 51 mg/L. Chromium levels vary both horizontally and vertically (84 to 590 $\mu\text{g Cr/g}$ dry sediment). After aggregates were dispersed by sonication, size fractionation of one sample revealed 90 % of the chromium and 74% of the iron to be in the less than 74 μm fraction. Mineral analysis indicated the presence of quartz, probably mica, and possibly chlorite, vermiculite, and feldspar in aquifer sediments. No crystalline iron minerals were observed suggesting that the 2.5 to 0.94 % iron found in the aquifer is contained in clay minerals and amorphous oxides.

(2) Identification of Colloid Binding Forces and an Effective Colloid Dispersion Treatment

Batch tests were performed with aquifer materials and solutions designed to mobilize colloids stabilized by different types of forces (e.g., electrostatic, covalent bonds, cementitious phases)

(Swartz and Gschwend, 1998). A review of the literature and previous work performed at this site indicated that iron oxides should play a major role in binding chromium to aquifer solids; therefore, batch tests were also designed to specifically attack amorphous oxide phases. Initial tests were performed on aquifer materials with the highest chromium contents. Batch experiments were designed to quantify dissolved chromium and chromium associated with particles 7 μm or less in diameter. Solutions used in batch experiments include water, and aqueous solutions of phosphate, ascorbate, and citrate at different pH values as well as combinations of these compounds.

Citrate solutions (1.0 mM) at pH values of 5.5 or greater were found to remove roughly half the sediment chromium. Citrate solutions appear to mobilize a fine sediment fraction, probably consisting of amorphous iron oxides and clay minerals, which is not strongly bound to sand grains. Treatment effectiveness is highly pH dependent which suggests that changing particle surface charge is crucial to dispersing this fine fraction.

(3) Field Testing of the Aquifer Remediation Strategy

Single well injection-withdrawal experiments will be used to determine the effect of colloid mobilization solutions on aquifer materials in-situ. An initial injection-withdrawal test using a bromide tracer added to groundwater has been performed to check the performance of the pumping and packer system. This initial test was also designed to determine the increase in aquifer turbidity resulting solely from the injection-withdrawal procedure.

References

- N.P. Nikolaidis, G.A. Robbins, M. Scherer, B. McAninch, G. Binkhorst, J. Asikainen, and S.L. Smith. (1994) Vertical distribution and partitioning of chromium in a glaciofluvial aquifer. *Ground Water Monitoring and Remediation*, 14: 150-159.
- C.H. Swartz and P.M. Gschwend. (1998) Mechanisms controlling release of colloids in groundwater in a southeastern coastal plain aquifer sand. *Environmental Science and Technology*, in press.

Planned Activities

Further batch experiments will be performed to characterize the forces which stabilize colloids in the aquifer and optimize colloid mobilization solutions. Single well injection-withdrawal experiments will be used to determine the response of the aquifer material to solutions designed to mobilize colloids. Additional field experiments involving examination of aquifer material exposed for several days to colloid mobilizing solutions in-situ may also be performed.