Report for 2001NH501B: Effect of Surface Coatings and Ionic Strength on Bacterial Removal Rates in Porous Media

There are no reported publications resulting from this project.

Report Follows:

Project Title: Effect of Surface Coatings and Ionic Strength on Bacterial Removal Rates in Porous Media.

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Problem and Research Objectives:

The transport of pathogenic viruses and bacteria in the subsurface poses a potential threat to public health. Contamination of water supplies by fecal material is the most common source of waterborne pathogens. In the 1980's, the use of untreated ground water was responsible for 43% of waterborne disease outbreaks occurring in the U.S. In New England, greater than 96% of all drinking water supplies in violation of drinking water standards are contaminated with bacteria (USEPA 2000). Failing septic systems are considered by EPA to be one of the biggest problems today for New England water bodies and have been suggested as the source of bacterial contamination in surface waters of New Hampshire (Margolin and Jones 1991).

The prevention of microbial contamination of drinking water supplies and surface waters requires an understanding of the processes controlling microbial transport and removal within the subsurface. Among the most important factors shown to influence bacterial transport through porous media are ionic strength (e.g. Fontes 1991) and the presence of metal-oxyhydroxide coatings on sediment surfaces (e.g. Scholl, 1990 #62). In circumneutral pH waters, bacteria and quartz sand grains both exhibit a net negative charge leading to unfavorable conditions for bacterial attachment to sediment surfaces. Increasing ionic strength has been shown to increase this attachment by increasing van der Waals attractive forces. In addition to high ionic strength waters, the presence of metal-oxyhydroxide coatings has also been shown to result in greater attachment rates of bacteria to sediment surfaces owing to the charge reversal imparted by the oxyhydroxide coatings at circumnuetral pH.

While numerous studies have been conducted looking at the effects of ionic strength and surface coatings independently on bacterial deposition rates, no systematic study yet exists looking at the combined effects of ionic strength and surface coatings on bacterial attachment rates. To better understand bacterial attachment and transport in NH aquifers, research needs to be conducted on the combined effects of high ionic strength waters and metal-coated sands. This project examines the effects of ionic strength on bacterial attachment rates to iron-coated sands.

Methods:

To test the effects of ionic strength and surface coatings on bacterial retention rates, laboratory column experiments have been conducted using commercial-grade sediments coated with synthetic iron-oxyhydroxides. Homogeneous columns were constructed using Unimin™ quartz sand sieved into a discrete size fraction. The sand was coated with Fe-oxides by a method similar to that employed by Mills et al. (1994). Sterilized sand was slowly poured into 30-cm Kontes™ chromatography columns containing sterilized

buffer water. Columns were operated at a flow rate of ~1 m day^{-1}. Ionic strength was modified by addition of KCl to the buffer water. Ionic strength of the carrier fluid will range from 10^{-4} to 10^{-1} M.

A short pulse of ^{14}C-labeled bacteria was be passed through the columns at initial concentrations ranging from approximately 1×10^7 cells mL^{-1} to 2×10^7 cells mL^{-1}. These low concentrations help ensured that clean-bed conditions existed within the column. Organisms were grown on R2A medium (Difco) amended with ^{14}C-glucose (1 μCi mL^{-1} of growth medium) and allowed to reach stationary phase. Effluent samples were collected from duplicate columns and the effect of ionic strength on bacterial attachment rates was evaluated.

Sticking efficiency, a measure of the affinity of the bacteria to a sediment surface, was calculated from the method of Bolster (1998). This method allows for the calculation of the sticking efficiency from the fraction of influent bacteria (*fr*) recovered in the column effluent by the following equation:

$$\alpha = \frac{2d_c}{3(1-\theta)x}\frac{1}{\eta}\left[-\ln(fr) + \frac{\alpha_L \ln(fr)^2}{x}\right] \quad (1)$$

where x is the length of the column (L), θ is porosity, d_c is the diameter of the sand grains, η is the collector efficiency which is a measure of the physical mechanisms that bring a bacterial cell to the surface of a sand grain, and α is the sticking efficiency which is a measure of the affinity of the bacterial cells to the sediment surface. All variables were directly measured except for the he single collector efficiency, η, which was calculated from the model of Rajagopalan and Tien (1976).

Results

To date we have only collected and analyzed data from one set of column experiments. In numerous studies in the literature it has been observed that increasing ionic strength increases attachment of bacteria to clean quartz sand by increasing sticking efficiency. This enhanced attraction between two like-charged particles is a result of the compression of the double layer allowing attractive van der Waals forces to dominate. However, we observed opposite behavior of bacterial attachment to positively charged iron-coated sand. A clear log-linear decrease in sticking efficiency with increase in ionic strength was observed (figure 1). We plan on additional experiments to verify these findings.

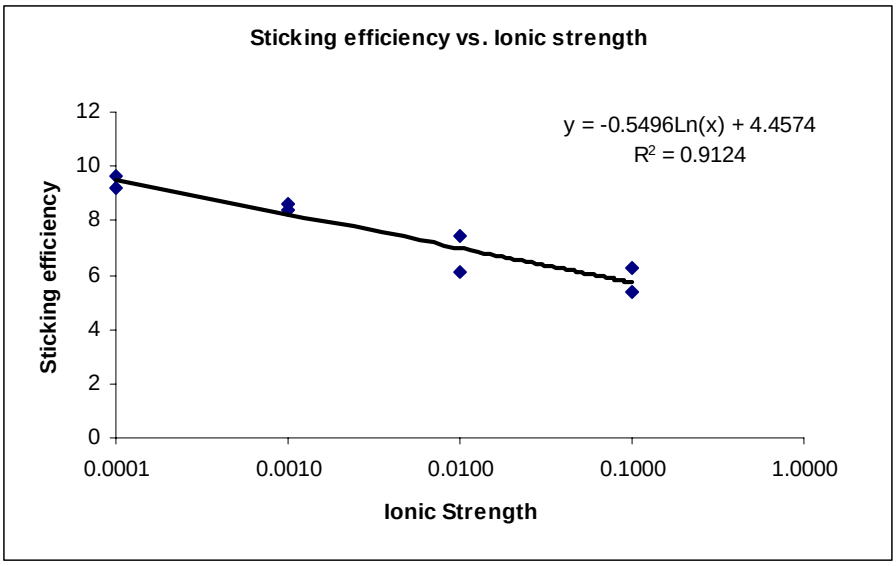

Figure 1. Effect of increasing ionic strength on sticking efficiency of an *e. coli* isolate to iron-coated Unimin sand grains.

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Students involved:

Two graduate students worked on this project during the past two summers.

Publications, Reports, and Presentations:
None to date.