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Title: Field Trial of the UNH Phosphate-Based Reactive Barrier Capping System for the Anacostia River
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Project Goal: The goal of this research is to determine effectiveness of naturally occurring phosphate minerals at inhibiting the migration of heavy metal contaminants from the sediment substratum into the overlying aquatic environment when deployed as a reactive barrier cap. The three major objectives of this project are to:

1. Determine the effectiveness of reactive phosphate capping materials for preventing the migration of heavy metals out of contaminated sediments under laboratory and pilot scale conditions.
2. Design and deploy a field scale phosphate mineral-based reactive barrier cap in the Anacostia River and monitor its effectiveness.
3. Determine the chemical and physical mechanisms by which heavy metal migration is inhibited by reactive phosphate barriers in the natural environment.

Project Rationale: Heavy metals are one of the more prevalent and tenacious contaminants in near-shore sediments and innovations are needed to manage these materials. The use of phosphate minerals such as apatites (e.g. $Ca_5(PO_4)_3OH$) as reactive barrier capping materials has been shown in preliminary studies to inhibit the migration of a variety of heavy metals from contaminated sediments and pore waters (Crannell et al., 2000; Wright et al., 1995). This field scale demonstration provides the opportunity to validate earlier results.

Approach:

Methodology: Recent work has focused on finalizing the necessary physical and environmental characteristics for the apatite that is to be placed in the river, as well as continued testing and monitoring of pilot scale experiments. The laboratory experiments at UNH are being conducted in 30-liter tanks with natural estuarine water flowing over different configurations of sediment and capping materials. Pore water and effluent water samples are periodically sampled to measure for contaminant release. Infaunal colonization and subsequent bioturbation are permitted in all but two of the experimental tanks. These tests will conclude this winter with a set of 28-day bioaccumulation experiments on the exposed capping materials.

Accomplishments: UNH and PCS Phosphate have developed a new gradation of phosphate sand materials specifically for the Anacostia River capping demonstration. This material will be generated by custom sieving the normal pebble materials produced from a proprietary single-float process that removes most of the dirt and low-density materials from the raw phosphate sand. While more costly than the phosphate reject material originally intended for this project, the new material

allows for greater quality control and significantly reduces the potential for suspended solids in the water column because most of fine material is washed away during processing. The material will conform to the following grain size distribution:

100% passing #6 mesh (3.35 mm)
90 % passing #10 mesh (2.00 mm)
5% passing #200 mesh (0.075 mm)

Preliminary tests on a trial run of the material had fines (passing #200 mesh) of around 1% by mass, which easily passes the lower boundary of the grain size distribution. Preliminary bulk densities for the new material are 81 lbs/ft^3 dry, 90 lbs/ft^3 at 9% moisture content, and 99 lbs/ft^3 tamped. The tamped bulk density was used as the final density of the in-place cap material. Earlier work showed that a 0.5 ft thick cap would be needed for this demonstration. Based on this figure, 250 tons of apatite are required for 100 ft by 100 ft by 0.5 ft cap.

The materials will have a chemical specification similar to the phosphate materials that are being used in the laboratory scale tests being performed at UNH. Table 1 reports the chemical analysis of the new product generated during a trial run. A representative composite sample will be taken from the material generated for this project and analyzed for the same elements to verify the potential reactivity of the apatite.

Major Elements	Concentration (%)	Minor Elements	Concentration (ppm)
P_2O_5	23.5*	As	4
CaO	45	Cd	8
Al_2O_3	0.3	Cu	8
Fe_2O_3	1.0	Cr	97
K_2O	0.2	Hg	< 0.05
MgO	0.6	Mn	33
Na_2O	1.0	Ni	23
SO_4	1.5	Pb	< 2
		V	23
		Zn	84

* Typically in the range 20-24% P_2O_5

Table 1. Composition of trial material for Anacostia River demonstration (data provided by PCS Phosphate).

During the permitting process there were some concerns raised about the potential of some contaminants such as arsenic leaching out of the apatite into the overlying water column. The most recent round of water quality testing at UNH showed that this does not occur. Table 2 shows contaminant levels for the incoming source water and effluent water for a tank containing Anacostia River sediment and a tank containing phosphate sand. In all cases except selenium, the concentrations of the effluent waters was either the same or less than the source water. With selenium, the effluent of the phosphate sand was equal to the detection limit, while the source water was below the detection limit.

Element	Source water (ppb)	Tank 4 Anacostia River Sediment (ppb)	Tank 6 North Carolina Single float phosphate (ppb)	Better than Anacostia or source?
Antimony	6	4	4	yes
Arsenic	3	< 2	3	same
Barium	5	6	5	yes
Beryllium	0.1	0.1	< 0.1	yes
Cadmium	< 1	< 1	< 1	same
Chromium	< 1	2	< 1	yes
Copper	12	4	< 3	yes
Lead	< 3	< 3	< 3	same
Mercury	0.7	< 0.5	< 0.5	yes
Molybdenum	< 10	< 10	< 10	same
Nickel	1	1	< 1	yes
Selenium	< 8	< 8	8	no / same
Silver	< 7	< 3	< 3	same
Zinc	< 10	< 10	< 10	same

Table 2. Source water and effluent water concentrations from tank experiments for rare metal concentrations (units = parts per billion).

Planned Work: Brad Crannell has been certified to work with radiolabeled Polyaromatic Hydrocarbons (PAHs), paving the way for new K_d experiments to determine the effectiveness of apatites at sequestering organic contaminants. During the fall and winter of 2003, 10-day amphipod tests and 28-day bioaccumulation testing will be performed on the apatite and Anacostia River sediments to determine the bioavailability of the contaminants. Actual deployment of the apatite reactive barrier cap is expected to take place in early November, 2003.

Supplemental Keywords: Apatite, Phosphate, Diffusion, Heavy metals, Reactive barrier