Hazardous Substance Research Center
South & Southwest

Research Brief #25

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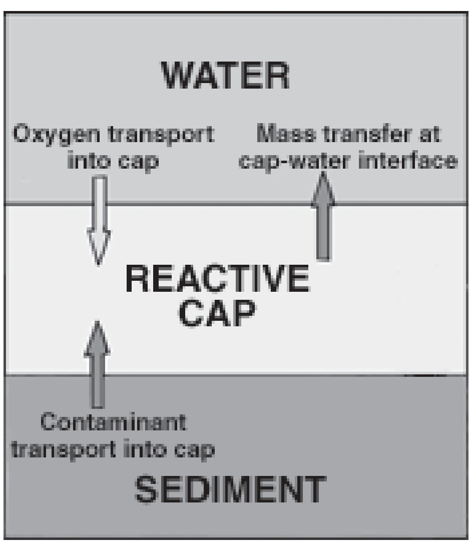
In-Situ Containment and Treatment: Engineering Cap Integrity and Reactivity

Introduction and Objectives

A team of researchers from Rice University, Louisiana State University, and Texas A&M University is addressing key problems that have restricted the use of *in-situ* (in-place) capping for containment and treatment of contaminated sediments. Capping is a remedial technology that uses clean layers of sand, silt, rock, geotextiles or some combination of these materials to isolate contaminated sediments. Though the method shows considerable promise, environmental professionals have hesitated to rely on capping for sediment management because caps leave pollutants untreated and their structural integrity may be damaged by a major storm surges (e.g., hurricanes).

In the project, the collaborating researchers hope to accelerate the development of "second-generation" caps that: 1) react with contaminants during sequestration to eliminate their toxicity; and 2) have greater structural strength due to better deposition and placement processes. They are testing the hypothesis that the surface chemistry of conventional capping materials can be adapted to create caps with the desired strength and reactivity.



One of the aims of an HSRC-funded project on sediment capping is to evaluate reactive caps that sequester and treat contaminated substances.

The university research groups participating in the project are carrying out the following roles:

- Rice University is developing enhanced depositional and placement processes for caps;
- Texas A&M's Ocean Engineering Program is improving modeling tools and using them to assess the stability of caps under a variety of turbulent water conditions; and
- Louisiana State University is studying the effectiveness of reactive caps and developing tools to improve predictions of cap performance.

Study of Depositional Processes

Implementation of second-generation caps requires a detailed understanding and control of depositional processes. In year one, researchers from Rice University built a plexiglas sedimentation/diffusion column to study the transport properties of various sediment caps. Nonreactive tracer tests determined the permeability of caps composed of clay, loam, sand, and clay/cement composites. These experiments showed that composite caps made of clay and cement have greater shear strength and permeability than clay or sand caps. Another test determined the diffusion properties of the contaminant dichlorophenol in sediment caps of different compositions.

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Summary of the Problem

The high costs of dredging and the difficulty of safely removing dredge spoils have led researchers to develop methods for sediment management that do not require removal of contaminants. One potentially attractive remedial approach is capping, in which clean layers of sand, silt, rock, geotextiles, or combinations of these materials are placed over contaminated sediment beds. These caps stabilize sediments and isolate pollutants from benthic organisms, which frequently ingest dangerous contaminants and return them to the food chain.

While capping has proved effective for field use, the technology has won only limited acceptance from environmental managers, regulators, and the public. The fact is that caps sequester contaminants but do not remove them, and many environmental decision makers are uncomfortable with clean-up methods that leave untreated pollutants in place. Their hesitations have only been exacerbated by researchers' general lack of knowledge about the viability of caps under extreme pressure—in particular, their ability to withstand the water surges of major storm events such as hurricanes.

Researchers are trying to address these concerns by developing "reactive" caps that simultaneously isolate and treat contaminants. They are also studying the precise impacts of storms on caps and sediments so that they can design more durable capping structures. This *Research Brief* summarizes efforts of a three-university team to shed light on these questions.

Researchers showed the applicability of environmental scanning electron microscopy for studies of water saturation levels (*in-situ* hydration) in cements and cement-clay composites. They found the presence of clay minerals significantly alters processes of cement hydration and strength development.

The research team developed a methodology for resin impregnation of 100 percent water-saturated sediment caps to facilitate thin-sectioning and morphological studies. They also developed an innovative lattice gas automata (LGA) diffusion model and demonstrated its almost perfect scalability. This non-traditional LGA model is able to simulate fractal boundaries, which are typical in porous media such as soils and responsible for anomalous transport in such media.

Proposed work for the second (and current) year of the study will include further deposition and diffusion experiments with the contaminants pentachlorophenol, naphtahalene, and RDX. Researchers will continue to study cement/clay composites by:

- documenting their water saturation levels over time for differing proportions of cement;
- studying the transport of heavy metal contaminants through cement/clay composite caps; and
- obtaining data on their structure and elemental composition.

Modeling the Stability of Sediment Caps

In estuarine and coastal systems, storms highly influence and sometimes even control the transport, resuspension or redistribution of particles in sediment beds. To establish a basis for predicting the effects of severe storms on long-term sediment stability, Texas A&M researchers are modeling the impact of storm events on circulation patterns in coastal waters. To this end, they are using the extended three-dimensional version of the Advanced Circulation (ADCIRC) hydrodynamic circulation model.

Unlike most previous modeling efforts of this kind, the Texas A&M group is modeling baroclinic effects, which explain the variability of the vertical shear in turbulent water currents. In stratified water, the inclusion of information about baroclinic effects may better describe how storms affect sediment resuspension and the life cycle of capped sediments.

In year one, the researchers adapted existing models to provide a three-dimensional depiction of salinity, temperature, and density in a flowing stratified fluid. They also developed renderings of idealized rectangular basins, in which simulated turbulent storm currents could be circulated. These basins have a variety of initial and boundary conditions that will allow the research group to estimate the impact of storms on different types of sediment capping structures.

In year two, Texas A&M researchers will improve models of the transport of suspended sediment particles in coastal waters. These enhancements will help to predict the extent of sediment and cap scouring in storms.

Reactive Sediment Caps

LSU researchers are studying the ability of various reactive capping materials to sequester and treat contaminated sediments. Researchers are developing modeling tools and experimental approaches that can be used to predict a given cap's effectiveness.

In year one, they have modeled the fate and transport of contaminants across reactive caps. Future work will involve laboratory-scale studies to calibrate these mathematical models. Lab experiments will make use of field data from a Baton Rouge, Louisiana, sediment and the Anacostia River in Washington, DC, where the Hazardous Substance Research Center/South & Southwest is leading a research project to demonstrate the performance of reactive capping materials.

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