Summing Up the Contributions of the Hazardous Substance Research Center/ South & Southwest

Mark H. Hodges (mark.hodges@gtri.gatech.edu) and Leigh F. McCook (Georgia Institute of Technology, Atlanta, Georgia) and Danny D. Reible (University of Texas, Austin, Texas)

ABSTRACT: For the past 15 years, the U.S. Environmental Protection Agency's Hazardous Substance Research Center/South & Southwest (HSRC/S&SW) has advanced the state of practice in contaminated sediment management through a varied program of research, technology transfer, and community outreach. This paper focuses on the contributions of this university-based consortium to sediments management, the environment in which the center has worked, and the center's distinctive approach to technology transfer.

INTRODUCTION

In the early 1990s, contaminated sediments were becoming widely recognized as a major environmental challenge in the United States. Most sources of active pollution had declined, but a legacy of industrial emissions from past decades remained locked in many sediment layers. In some waterways, breaches of channel sediments threatened to return hazardous chemicals to open water and eventually into the food chain.

This problem wasn't limited by scope or geography: approximately 20 percent of National Priority List Superfund sites included contaminated sediments, and 25 percent of the 21,000 sites sampled in the National Sediment Quality Survey were potentially dangerous to aquatic animals and humans.

To make matters worse, the size and complexity of sediments posed a barrier to effective management. Typical cases involved millions of hard-to-reach acres of land and water, each functioning as a highly variable and constantly changing aquatic system. The problem was exacerbated by the variety of human activities and natural events that affected sediments, such as hurricanes and other storms, boating, dredging operations, and penetration by bottom-feeding organisms.

According to the conventional wisdom of the time, removal or incineration technologies were the most reliable and effective approaches for protecting the public from contaminated sediments. These methods, however, were often prohibitively expensive and technically difficult to undertake. To create a better set of options, researchers began to look closely at the possibility of controlling contaminated sediments without removal.

This was a hard sell for environmental regulators accustomed to thinking that contaminants must be treated and removed for the public to be truly safe. However, a decade and a half later, in-place sediments management has become much more widely accepted thanks to the intellectual spadework of a variety of research groups. One of the organizations that have made a forceful case for in-place management is the Hazardous Substance Research Center/South & Southwest (HSRC/S&SW). With funding from the

U.S. Environmental Protection Agency (EPA), this consortium of five Southeastern universities—Louisiana State University (LSU), Georgia Tech, Rice, Texas A&M, and the University of Texas at Austin—has provided basic research and technology development to support this new management paradigm since 1991.

DIVERSIFIED TECHNICAL APPROACH

In its early years, research sponsored by the HSRC/S&SW focused on the effectiveness of both in-place and removal technologies for managing contaminated sediments. These investigations led to results that questioned the wisdom of a widespread emphasis on ex-situ technologies in sediment remediation.

A case in point was the Bayou Bonfouca, Louisiana, Superfund site, for which $130 million was spent to dredge, remove, and incinerate contaminated sediments as well as to install a clean sediment cap. Dredging in itself was expected to reduce contaminant levels and risk in Bayou Bonfouca dramatically, but the majority of risk reduction observed at the site was due to placement of a clean sediment cap. There is strong evidence that, in many situations, in-place remediation approaches could be more economical than removal and incineration.

These advantages have led researchers to focus increased attention on capping, a method involving the placement of a layer of sand, silt, mud, geotextiles or some combination of all of these materials over a sediment bed. The purpose of a cap is to isolate contaminants from the surrounding environment and thus allow environmental managers to avoid the high cost of removal.

Capping proved less costly and easier to deploy, but it posed greater potential dangers because it left hazardous substances intact in sediments. Not surprisingly, higher burden of proof was needed before in-place remediation of sediments could become a standard engineering practice. The Bayou Bonfouca study showed that capping may, however, provide the best chance for rapid implementation of long-term risk reduction. This study specifically indicated that it would take almost a thousand years for PCBs to break through a 45-centimeter cap and, when a break came, the release rate would be less than 0.01 percent of the original release rate.

Other center-sponsored projects sought to improve phytoremediation, an in-place management approach that uses vegetative plants and trees to detoxify pollutants in soil or water. A project involving Rice University, LSU, and Georgia Tech confirmed that wetlands plants could effectively adsorb TNT contaminants in soil and groundwater. This research added considerably to knowledge about the transformation pathways of TNT after assimilation by plants. The fate of the compound has been a major concern because phytoremediation often does not fully break down these contaminants, making it possible for these toxic substances to return to the environment. Together, these research projects provided support for the view that in-place remediation of contaminated sediments is a feasible alternative to conventional dredge-and-treat schemes. HSRC/S&SW studies to increase knowledge of basic chemical, biological, and physical processes also led to the development of quantitative tools for predicting the fate of sediment contaminants.

Despite these advances, major questions remained before in-place remediation could be embraced. What approaches would be effective for remediating large, complex sites? How could "second-generation" sediment caps be designed so that they were strong enough to resist major storms and able to isolate and treat contaminants? What happened to metallic contaminants during dredging operations? And how could environmental managers assess the impact of bioturbating worms in penetrating sediments and releasing contaminants into the food chain?

To help resolve these question marks, HSRC/S&SW have sponsored a variety of studies to develop basic science and technology. Some of these projects have sought to clarify basic physical, chemical, and biological processes that affect the fate and transport of contaminants. Investigators supported by the center explored aerobic and anaerobic degradation of polynuclear aromatic hydrocarbons (PAHs); dechlorination of polychlorinated biphenyl (PCBs), dioxins, and chlorinated solvents; degradation of trinitrotoluene (TNT) in the root zones of trees; and microbial cycling of metals. They also studied how bioturbating worms digest contaminated organic matter and excrete toxic compounds back into water. Additional research provided strong evidence that a certain fraction in contaminants resists desorption. This finding suggested that cleanup might only be needed until that fraction of a given contaminant remains.

GREATER FOCUS ON IN-PLACE SOLUTIONS

The relevance of these questions and the ability of the HSRC/S&SW to address them were endorsed by EPA when the agency renewed the center's grant in 2001 after a competitive, peer-reviewed grant application process. The South & Southwest center that emerged in HSRC's Phase II was much like the old one, except that its focus was more squarely on in-place management of sediments and its research agenda focused even more explicitly on the particular problems faced by the South and Southwest regions.

Phytoremediation for long-term cleanup. The recommissioned center immediately focused on phytoremediation for long-term remediation of large, complex sediment sites. This method had previously shown promise as a relative inexpensive method for managing large sites contaminated with chlorinated organics, and while much had been done to investigate it, the basic science needed deeper study. The center funded a project led by LSU Professor John Pardue to develop a scientific basis for using phytoremediation in sediment treatment. The study's primary hypothesis was that organic matter in vegetative roots stimulates production of hydrogen, which in turn provides fuel for microorganisms to break down chlorinated compounds in sediments.

Results indicated that even "aged" chlorinated organics degraded in sediments after planting with wetland plants. Root matter generated greater hydrogen concentrations but also provided an environment for greater populations of dehalorespiring microorganisms. These results provide a scientific basis for in situ phytoremediation of sediments in shallow environments or in confined disposal facilities storing contaminated sediments removed for navigation purposes.

Second-generation caps. A second focal point for research was the need to accelerate development of "second-generation" caps with enhanced structural integrity and reactivity. One of the criticisms of caps had been that they isolate contaminants but do not detoxify them, meaning that if the cap failed or were penetrated dangerous pollutants would be likely to re-enter the food chain. Another complaint was that caps were not strong enough to withstand the rigors of a major coastal storm. Design of these second-generation caps required detailed understanding and control of depositional processes. Researchers from Rice University undertook a study to enhance knowledge of the strength and stability of various cap materials. In estuarine and coastal systems, storms highly influence and sometimes even control the transport, resuspension and 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's Ocean Engineering Program improved tools for modeling the stability of caps under a variety of turbulent water conditions.

Threat of heavy metal contaminants. Another major issue dealt with by the new HSRC/S&SW was the threat of heavy metal contaminants being released into the water when sediments were resuspended during dredging operations. Resuspension of sediments contaminated with heavy metals such as lead, cadmium, copper and arsenic poses special challenges. These sediments are not only highly toxic and resistant to breakdown, but it's impossible to estimate the likelihood and impact of their release with conventional diagnostic tests. Through this project, a research group composed of LSU and Rice University researchers clarified a complicated sequence of reactions, redox, and biological activities that drive the release of heavy metal release during dredging operations. The result was better understanding of the dynamics of their processes and better tools for assessing their significance.

Impact of sediment-dwelling worms. The center's fourth major project area has focused on one of the major influences on contaminant exposure and risk: the activity of the benthic community such as sediment-dwelling worms. The concern under investigation was the potential for these tiny organisms to reintroduce sediment contaminants into the food chain or directly to the water and to evaluate indicators of the bioavailability of sediment contaminants to these organisms. The organisms burrow into sediments, ingest sediment particles (contaminated or otherwise), and later release them into the open water through excretion. More basic information about these processes has been needed to understand the impact that these creatures can have on the toxicity of a body of water. LSU researchers determined that concentrations of a contaminant in porewater (the space between sediment particles) are the most reliable indicator for the levels of this contaminant that are bioavailable. They also found that speed of contaminant uptake depends on the route of exposure, the creature's assimilation efficiency, and the rate it eliminates ingested sediments. Continued research in this area is developing a means of more directly assessing the potential for uptake, transport or food chain transfer of contaminants.

DEMONSTRATION OF IN-PLACE "ACTIVE" CAPPING

Leveraging the research capability built up through these and earlier projects, the center began a major field demonstration in 2003 to demonstrate the effectiveness of various technologies of active capping, which combines isolation of contaminants with some treatment to detoxify them. The five-year effort, supported through the federal government's District of Columbia appropriation, is taking place on the Anacostia River in Washington, D.C., where historic industrial, municipal and military activities have resulted in toxic accumulations of PAHs, PCBs, metals and other contaminants.

HSRC/S&SW coalition members from Louisiana State University coordinated the demonstration in cooperation with the Anacostia Watershed Toxics Alliance, which includes a group of federal, state, and district environmental agencies as well as companies and conservation groups with interest in Anacostia water quality. Horne Engineering of Falls Church, VA, was the prime contractor, and researchers from Carnegie Mellon University, LSU, Rice University, Georgia Tech, and the University of New Hampshire evaluated several of the active capping technologies. They evaluated various cap technologies and selected the following for use in the demonstration: 1) AquaBlok™, a commercial product designed to reduce the permeability at the sediment-water interface; 2) Apatite, which encourages precipitation and sorption of metals; and 3) Coke breeze, which can absorb hydrophobic organic contaminants.

The project team designed a demonstration cell layout that included the three innovative active cap materials along with a traditional sand cap and a control cap in small pilot study cells. Each cell was approximately 100 feet by 100 feet, making the entire study area approximately 200 feet by 320 feet. The project team constructed the cap in spring 2004, demonstrating that a conventional clamshell bucket is able to accurately place all of the layers to the targeted thickness, except the AquaBlok layer, which was slightly thicker than desired. A followup survey revealed that the cell layout contained no bare spots. Researchers will now evaluate the performance of the cap over the next several years to determine how well the demonstration meets the promise of these technologies. The project has already shown the way for the increased use of treatment caps to help manage contaminated sediment sites.

TRANSFERRING THE RESULTS OF RESEARCH

The HSRC/S&SW carried out its technology transfer mission through a broad range of activities, beginning with the traditional means of publishing academic research results. Center-sponsored research has been the focus of 162 refereed journal articles, 33 book chapters, 19 books, 29 project reports, 62 theses or dissertations, and 253 conference presentations.

The center, however, has used a variety of other means to transfer knowledge about contaminated sediments management directly to researchers and practitioners. One approach has been to sponsor training sessions for the user community, such as a phytoremediation workshop in Atlanta in 1994 and participation in a Chicago workshop in 1993 on in-place capping sponsored by the U.S. Army Corps of Engineers. Center participants have also helped to train remedial project managers and other EPA personnel on current sediment remediation guidance with sessions at three regional offices in 2005 and 2006 and at the National Remedial Project Manager Conference in 2006. Center researchers have also helped write guidance (for example, Director Danny Reible was a co-author of EPA's publication, *Guidance on In-Situ Capping*), and several investigators have been members of key National Research Council committees on sediment related topics. In addition, over the past six years, the HSRC/S&SW has led three NATO-sponsored technical workshops on sediment contamination and remediation topics in the Czech Republic, Brazil, and the Slovak Republic. These meetings have provided a forum for American researchers to exchange knowledge about hazardous substance problems with their colleagues in developing countries.

The center has also made extensive use of the Internet as a medium for the dissemination of sediment management expertise. One example of this approach is the center's Sediments Web Community, which has provided opportunities for researchers and practitioners to exchange information and has published regular updates of news in the field via electronic newsletters. Technology transfer staff members of the center at Georgia Tech have also designed a variety of web-based communications tools for getting out the center's results, including an online primer on in-place capping designed to introduce practitioners, researchers, and communities to its potential advantages.

Yet another means of transferring technology has been the contribution of center researchers to the legislative and policy-making process. As indicated previously, several investigators have been members of key National Research Council committees including the Committee on Contaminated Sediments in Ports and Waterways, the Committee on a Framework for Managing PCB Contaminated Sediments, the Committee on Remediation at Navy Sites, and the current committees on Evaluating Dredging Effectiveness and the OMB Guidance on Risk Assessment. As a member of the National Academy of Engineering, center co-director Danny Reible serves on the National Research Council Board of Environmental Studies and Toxicology. He also chaired a workshop on the toxics and contaminant issues associated with Hurricane Katrina and co-authored an essay (with center co-director John Pardue and several other colleagues) on the subject in *The Bridge*, a newsletter published by the National Academies. Pardue has also served on the Environmental Task Force established by the Louisiana Recovery Authority to deal with the aftermath of Hurricane Katrina.

Finally, HSRC/S&SW researchers have provided third party technical support to EPA, states and industry—for example, contributing to reports on the state of practice, such as the Sediment Management Laboratory and Marine Environmental Support Office's 88-paper white paper on "Critical Issues in Contaminated Sediment Management." Investigators affiliated with the center also have given direct assistance at a wide range of contaminated sediment locations throughout the country, including sites at Brakes Bayou, TX; Calcasieu Estuary, LA; Fox River, WI; Grasse River, NY; Hackensack River, NJ; Hastings on Hudson River, NY; Indiana Harbor, IN; McCormick and Baxter, OR; Onondaga Lake, NY; Pine Street Canal, VT; Pompton Lake, NJ; Rio Grande, NM; three sites in the San Francisco, CA, Bay Area; Silver Lake, MA; Thea Foss, WA; and Welch Creek, NC.

CONCLUSION

As the preceding activities show, the HSRC/S&SW has had a major impact on hazardous substance management, advancing the state of scientific knowledge and practice concerning contaminated sediments. In particular, the center-sponsored projects have contributed to a broad national effort to show the advantages of in-place management approaches and develop the technology and science to enhance these methods. Of special importance has been a field demonstration on the Anacostia River in Washington, DC, which is now investigating the effectiveness of promising active capping technologies. The center's contribution, has extended beyond its research activities to its active efforts to transfer technologies directly to users through workshops in the U.S. and abroad, intensive training seminars, web-based communities, support of the legislative and policy-making communities, and direct technical assistance to EPA and industry. Finally, the HSRC/S&SW has helped environmentally damaged areas in Regions 4 and 6 to participate meaningfully in the cleanup and redevelopment of their communities. This broad range of accomplishments is one important reason that the center has remained active for a decade and a half.