New Reports

Natural Attenuation for Groundwater Remediation

By Jacqueline MacDonald and Laura Ehlers

At tens of thousands of sites around the United States, contaminated groundwater and soil are being treated with natural processes—a site remediation strategy called "natural attenuation." Such processes can transform contaminants to less harmful forms or immobilize them, and they result from biological, chemical, and physical reactions that take place in the subsurface. Regulatory definitions of natural attenuation include not only contaminant degradation by subsurface microbes, reactions with naturally occurring chemicals, and sorption onto geologic media, but also other natural processes that dilute contaminants or transfer them from water to air. At an increasing number of sites, responsible parties and environmental regulators are relying on natural attenuation to control contamination, in part because of the high costs of engineered cleanup systems. The WSTB sheds new light on this important issue with the release of its report *Natural Attenuation for Groundwater Remediation.* The report examines public concerns about natural attenuation, the scientific bases for natural attenuation, and the criteria for evaluating the potential success or failure of natural attenuation.

Community representatives often express significant reservations about using natural attenuation as a formal cleanup remedy. Often viewed as a "do-nothing" approach, natural attenuation is perceived by many affected communities as allowing responsible parties to save on cleanup costs while exposing the community to undue health and environmental risks. For this reason, public involvement in decision making is especially important at sites where natural attenuation is proposed as a remedy. The report recommends that environmental agencies and responsible parties provide communities with clear evidence indicating which natural attenuation processes are responsible for the loss of contaminants (when natural attenuation is proposed as a formal remedy for groundwater contamination). In addition, federal and state environmental regulations and guidelines for cleaning up contaminated sites affecting communities should be changed to allow community involvement as soon as the presence of contamination is confirmed. Current regulations provide for community involvement only after a list of potential remedies has been proposed. A central repository of all data concerning the contamination and potential remedies at sites is essential to the success of natural attenuation.

The report discusses the likelihood that natural attenuation will succeed as the key part of a site cleanup strategy. In general, natural attenuation is well established as a remediation approach for only a few types of contaminants, primarily benzene, toluene, ethylbenzene, and xylene (BTEX). For other contaminant classes, it is not as likely to succeed or not well established. In some cases, the likelihood of success is low because of the possible production of toxic intermediate compounds. In other cases, the presence of contaminant mixtures can influence natural attenuation of any one component of the mixture. Natural attenuation processes cannot destroy metals but only immobilize them. Finally, potential for success is low because our scientific understanding is limited. For these reasons, the report recommends that natural attenuation never be considered a default or presumptive remedy.

The report discusses the criteria necessary for documenting that natural attenuation is occurring at a waste site. These include not only data showing a decrease in contaminant concentration in groundwater samples, but also a site model and "footprints" of the underlying mechanisms. Footprints are concentration changes in reactants (other than contaminants) or products of the biogeochemical processes that transform or immobilize the contaminants. When coupled to an observation of the loss of a contaminant, footprints help to establish which processes are responsible for attenuation. The report recommends long-term monitoring of waste sites to ensure that documented attenuation processes continue to occur.

Within the past few years, many organizations have issued documents providing guidance on evaluating natural attenuation; 14 of these documents were reviewed by the report's authoring committee. A comprehensive natural attenuation protocol should cover community concerns, multiple scientific and technical issues (e.g., determining which natural attenuation processes are responsible for observed decreases in contaminant concentrations), and implementation issues. For a variety of reasons, none of the reviewed documents fulfilled all these criteria. The existing protocols are silent on when and how to involve the public in site decisions and when and how to implement institutional controls. Discussion of contingency plans in case natural attenuation does not work also is inadequate in many of the protocols. Guidance on how to conduct long-term monitoring to ensure that natural attenuation remains protective of public health and the environment is limited. Because EPA does not officially endorse any protocols other than those developed by the agency, it is unclear which protocols are appropriate for use in various regulatory programs. The report recommends that EPA develop national consensus guidelines for protocols on natural attenuation as soon as possible.

In summary, natural attenuation processes that degrade or transform contaminants can work well in controlling risks from groundwater contamination when the right combination of contaminants and environmental conditions exists. Natural attenuation is most likely to be effective for contaminants that are readily degraded or immobilized under a wide range of environmental conditions such as BTEX. For most other commonly encountered

environmental contaminants, natural attenuation may work in some cases only under very specific site conditions. Regardless of how simple or complex the contaminant and its environment are, documenting natural attenuation requires evidence that natural processes at the site are immobilizing or destroying the contamination to an extent that is sufficient to protect public health and the environment. Footprints of the attenuation reactions should serve as the basis for this evidence, and rigorous protocols are needed to ensure that the evidence is sufficient.

The committee was chaired by Bruce E. Rittmann of Northwestern University. Funding was provided by EPA, USGS, DOE, DOD, the American Petroleum Institute, the Chemical Manufacturers' Association, Chevron, Lawrence Livermore National Laboratory, the National Mining Association, and the Nuclear Regulatory Commission. To order a prepublication copy of the report, contact the National Academy Press at 800-624-6242 or www.nap.edu.

Research Needs in Subsurface Science at the DOE

By Patricia Jones

The Board on Radioactive Waste Management and the WSTB have just released a new report, *Research Needs in Subsurface Science: U.S. Department of Energy's Environmental Management Science Program*. The report provides an overview of subsurface contamination problems across the DOE complex, using experiences from the six largest DOE sites (Hanford, Idaho Engineering and Environmental Laboratory, Nevada Test Site, Oak Ridge Reservation, Rocky Flats, and Savannah River) to demonstrate how advances in scientific and engineering knowledge can improve the effectiveness of cleanup efforts.

Nuclear weapons production has resulted in the widespread contamination of DOE sites, ranging from contaminated waste burial grounds to contaminated soil, sediment, rock, and groundwater. Subsurface contamination is a difficult cleanup problem that represents an enormous liability for the nation. Its solution is partially dependent on the development and application of new and improved cleanup technologies. Such development will require advances in our basic understanding of the complex natural systems at DOE sites and DOE contaminants. Given the long-term nature of the DOE's cleanup mission and its projected cost—the program is planned to last until 2070 and cost on the order of $200 billion—the report states that DOE has sufficient time to do the basic research required to support the development and deployment of new cleanup technologies.

DOE's Environmental Management (EM) Science Program is one of the largest environmental research efforts in the federal government. The program has supported research projects relevant to many aspects of DOE's cleanup program, including subsurface contamination, high-level waste, and plant deactivation and decommissioning. The report concludes that there is a critical mass of projects covering remediation of subsurface contamination, especially treatment and destruction of organic contaminants through physical, chemical, and biological processes, but that there are research gaps in the areas of containment, model validation, and monitoring of treatment effectiveness. These are significant problem areas in the DOE complex, as it is inevitable that DOE will have to manage much of its subsurface contamination in place. In addition, there are relatively few projects that address radionuclide and metal contamination.

The major recommendations of the report focus on a long-term basic research program for subsurface contamination and address program vision, research emphases, and implementation. First, the report recommends that a vision for the program be supported both programmatically and financially by DOE upper management. The program should generate new knowledge to support DOE's mission to clean up its contaminated sites, it should be well connected to DOE's difficult cleanup problems; and it should have a long-term, multidisciplinary focus on resolving DOE's subsurface contamination problems.

Second, based on the analysis of DOE's subsurface contamination problems, the report recommends that the subsurface component of the EM Science Program have four research emphases. The first program component should be to better locate and characterize subsurface contaminants. Basic research that supports advances in capabilities to locate and characterize subsurface contamination and elucidate relevant subsurface conditions will help DOE to better assess the potential hazards of its contamination problems and design and implement appropriate corrective action strategies. The second program component is conceptual modeling. Basic research on the fundamental approaches and assumptions underlying conceptual model development could produce a "tool box" of methodologies that can be applied to contaminated sites both inside and outside the DOE complex. Third, the research program must emphasize containment and stabilization. There is a need to develop new waste containment and stabilization technologies to lower the cost, accelerate regulatory approvals, and increase public confidence in solving subsurface contamination problems. Finally, the program must include long-term monitoring and validation of treatment effectiveness. Improvements in capabilities to monitor and validate contaminant locations and perform remedial actions will greatly enhance the technical success of DOE's efforts. Within these four emphases, the EM Science Program should encourage research on metals and radionuclides, which are generally not receiving attention in other federal research programs.

To be successful, the program must be structured so that research results can be handed off to technology developers and problem holders at DOE sites. In

particular, the report encourages program managers to support program-wide integration activities that optimize the impacts of advances in subsurface science on DOE site cleanup. It recommends that program managers examine the feasibility of developing field research sites as one program component. Such sites could attract new researchers to the program, encourage both formal and informal multidisciplinary collaborations among researchers, and facilitate the transfer of research results into application. The current level of program funding was determined to be insufficient to support the research emphases outlined in the report, especially because subsurface research is just one of many research areas supported by the program.

The report concludes that basic research supported by the EM Science Program and other relevant federal research programs will have little if any impact on DOE cleanup unless research results are transferred into technology development programs and to problem holders at DOE sites. Strong scientific, technical, and management leadership is needed at all levels, from the EM Science Program to the assistant secretary for environmental management, if significant progress in the DOE cleanup program is to be made in the next decade.

The committee was chaired by Jane C. S. Long of the University of Nevada, Reno. This project was funded by the U.S. Department of Energy, Office of Environmental Management. To obtain a copy of this report, contact the National Academy Press at 800-624-6242 or www.nap.edu.

Current Projects

NRC Takes on New Fast-Track Study of Corps of Engineers' Upper Mississippi River-Illinois Waterway Navigation Improvement Planning Studies

Since 1993, the U.S. Army Corps of Engineers has been conducting a planning study of the feasibility of improvements (primarily larger locks on select dams) to the navigation system on the Upper Mississippi River. Based on economic analyses conducted by an economics work group in the Corps's St. Louis district office, preliminary (1998) results suggested that large-scale structural improvements to the navigation system would not be economically feasible. But in recent allegations prominently featured in the national media, the Corps stands accused of later improperly adjusting some key economic assumptions and methods in order to reach a conclusion supporting expanded capacity (through larger locks) of the Upper Mississippi-Illinois navigation system. One result of these allegations is that the Department of Defense has arranged for the NRC to conduct an independent review of the navigation study's economic analysis.

This project will be organized jointly by the WSTB and the Transportation Research Board. (The committee was not yet appointed when this item went to press.) The study will focus mainly on the Corps' economic analysis regarding proposed improvements, including economic assumptions, methods, and forecasts regarding barge transportation demands on the Upper Mississippi River-Illinois Waterway. A committee of about ten members with expertise in transportation economics, natural resource economics, water resources planning and analysis, econometrics, and cost-benefit analysis will be appointed. It is expected that the committee will meet three times between May and October. At its first meeting, the committee will likely be briefed by various participants involved in the Corps' economic analysis. Members of the public, along with representatives of environmental and transportation interest groups, will have the opportunity to express their perspectives on the analysis. Subsequent meetings will be spent preparing the committee's report and hearing from interested stakeholder groups. For questions about this study, please contact Jeffrey Jacobs at 202-334-2899 or jjacobs@nas.edu.

Bioavailability of Contaminants in Soils and Sediments

The first meeting of the new committee on bioavailability of contaminants in soils and sediments is scheduled for May 15–16 in Washington, DC. The committee will study processes that affect availability of contaminants in soils and sediments to humans and ecosystems. A variety of mechanisms—from sorption on solid materials to biological and chemical transformations—can render contaminants present in the environment virtually harmless to human and ecological systems. Yet existing risk assessment tools do not adequately account for these mechanisms. This study will assess broadly the current scientific understanding of processes—both in the environment and in the human body—that affect whether chemical contaminants present in soils and sediments at contaminated sites are bioavailable to humans, animals, and plants. The committee will also evaluate existing tools for measuring bioavailability. It will analyze how treatment with different remediation technologies affects bioavailability and how bioavailability impacts treatment processes that rely on microbial degradation of contaminants.

Committee members include Richard G. Luthy, *chair*, Stanford University; Richelle M. Allen-King, Washington State University; Sally L. Brown, University of Washington; David A. Dzomback, Carnegie Mellon University; Scott E. Fendorf, Stanford University; Joseph H. Graziano, Columbia University; Joseph B. Hughes, Rice University; John P. Giesy, Michigan State University; Samuel N. Luoma, USGS; Linda A. Malone, College of William and Mary; Charles A. Menzie, Menzie-Cura and Associates, Inc.; Michael V. Ruby, Exponent; Terry W. Schultz, University of Tennessee; Barth F. Smets,