NEW REPORT

Bioavailability of Contaminants in Soils and Sediments

by Laura J. Ehlers

Bioavailability processes are defined as the individual physical, chemical, and biological interactions that determine the exposure of plants and animals to chemicals associated with soils and sediments. Although long employed in toxicology and agricultural sciences, the concept of bioavailability has recently sparked the interest of the hazardous waste industry as an important consideration in deciding how much waste to clean up. This interest stems from observations that some contaminants in soils or sediments appear to be less available to cause harm to humans and ecological receptors than is suggested by their total concentration, such that cleanup levels expressed as bulk concentrations may not correlate with actual risk. After two years of deliberation, a WSTB committee has weighed in on the concept with the report *Bioavailability of Contaminants in Soils and Sediments: Processes, Tools, and Application*.

The report notes that the potential for the consideration of bioavailability to influence decision-making is greatest where:

? the contaminant is (and is likely to remain) the risk driver at a site;

? the default assumptions made during risk assessment that affect the final cleanup goal are inappropriate;

? significant change to remedial goals is likely, for example, because substantial quantities of contaminated soil or sediment are involved;

? conditions present at the site are unlikely to change substantially over time; and

? regulatory and public acceptance is high.

Defining Bioavailability processes

"Bioavailability processes" are defined as the individual physical, chemical, and biological interactions that determine the exposure of organisms to chemicals associated with soils and sediments. This incorporates all the steps that take a chemical from being bound or isolated in soil or sediment to being absorbed into an organism (A through D in Figure 1). For a given situation, a few select processes are expected to dominate. However, mechanistic understanding of these processes is highly variable, and quantitative descriptive models of bioavailability processes are in most cases lacking.

Bioavailability in Risk Assessment

In both ecological and human health risk assessment, bioavailability is usually reflected in default values or site-specific data that are inserted into exposure equations. Although a multitude of processes can affect bioavailability (see Figure 1), a typical bioavailability assessment generates *one* value that is used to adjust the applied dose. For this reason, many bioavailability processes are hidden within risk assessment, and assumptions made about these processes are not clear.

Studies using animals as surrogates for humans to determine bioavailability for different chemical–solid combinations have been conducted at a small number of sites. To improve the accuracy of risk assessment, the report encourages further work in this area, and it recommends guidance from EPA that addresses what information must be included in a bioavailability assessment, its scientific validity, acceptable tools and models, and other issues. Bioavailability processes are more frequently accounted for in ecological risk assessments, although they have not been labeled as "bioavailability adjustments" per se.

Bioavailability Tools

Many physical, chemical, and biological tools that have been used to measure bioavailability are evaluated. The tools span the range from physicochemical techniques like microscopy to chemical extractions and finally to bioassays. The report concludes that tools that further mechanistic understanding and promote predictive model development are preferred over conventional empirical approaches.

The report ranks the strengths and weaknesses of all tool types, using the following criteria:

? the tool's applicability to field settings;

? its applicability to the solid phase;

? whether it measures a single process vs. lumped processes;

? its relevance to initial biouptake across a membrane;

? whether its results can be generalized to other hazardous waste sites;

? its relevance to regulation; and

? its usefulness as a research tool.

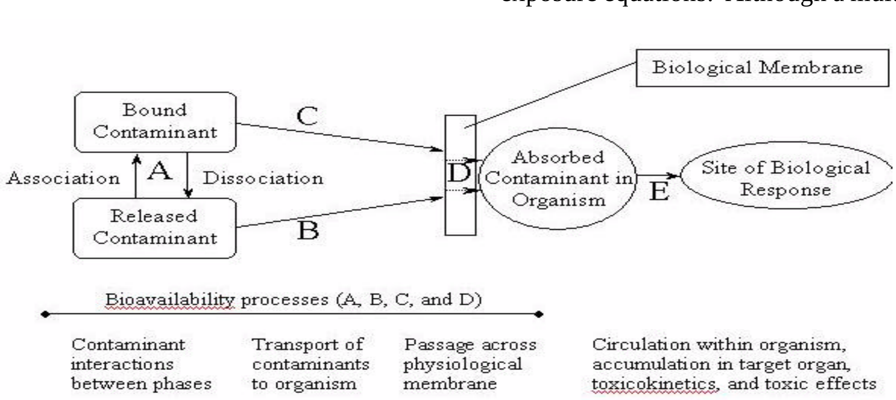

FIGURE 1 Bioavailability processes in soil or sediment, including release of a solid-bound contaminant (A) and subsequent transport (B), direct contact of a bound contaminant (C), uptake by passage through a membrane (D), and incorporation into a living system (E). E processes are not considered bioavailability processes per se because soil and sediment are no longer a factor.

continues on page 6

continued from previous page

Bioavailability...

No one method achieves the highest rating in all categories, and none fail all criteria, illustrating that every tool has tradeoffs.

The development of tools relevant to bioavailability is a rapidly growing field, such that there can be confusion regarding which tools and how many to choose. Thus, the report advocates a weight-of-evidence approach to bioavailability tool selection to make near-term progress at sites. This involves initially relying on operational tools (e.g., extractions, normalizations, and simple models) along with an intensive effort to develop mechanistic tools and conceptual models based on mechanisms.

Bioavailability and Site Management

Limitations in our understanding of bioavailability processes have important ramifications for site management. In particular, there are treatment remedies that rely on increasing or decreasing bioavailability, and without a better understanding of bioavailability processes it is difficult to know if such treatments are effective. In addition, treatment technologies may unintentionally alter contaminant bioavailability, especially sediment dredging and new technologies that have yet to be fully tested.

To achieve more widespread consideration of bioavailability processes and promote the use of site-specific measurements of bioavailability, the report proposes an adaptive management approach. This would involve pilot studies to experiment with different tools and models, and then using the results to develop a common systematic approach for how and when to incorporate bioavailability concepts into regulations in a consistent manner. Examples of how this might be done are presented in the report.

The report concludes by noting that most information on bioavailability of contaminants comes from industry-funded studies at specific sites, particularly for human health risk assessments. These studies are usually not conducted in a way that advances mechanistic understanding of bioavailability processes. Unless a greater commitment is made to fund bioavailability studies from a research—rather than an industry-driven perspective, progress in explicitly incorporating bioavailability into human health and ecological risk assessments will be slow.

The study was sponsored by the Environmental Protection Agency, Department of Defense's Strategic Environmental Research and Development Program, the National Institute of Environmental Health Sciences, the Army, the Air Force, the Agency for Toxic Substances and Disease Registry, the DoD Office of Environmental Management, the Department of Energy, and the Gas Research Institute. It was chaired by Richard Luthy of Stanford University. Copies of the report are available from the WSTB office at 202-334-3422 or *lehlers@nas.edu.*

Laura Ehlers is a Senior Staff Officer with the Water Science and Technology Board.

NEW REPORT

Biosolids Applied to Land: Advancing Standards and Practices

By Mark Gibson

Since the early 1970s, the U.S. Environmental Protection Agency (EPA) and the wastewater treatment industry have promoted the recycling of treated sewage sludge (often referred to as *biosolids*) to agricultural or other lands in order to improve the properties of the soil. This "beneficial reuse" practice offers an alternative to disposal options such as land filling or incineration and its use has increased since disposal of sewage sludge in oceans was prohibited in 1992. Depending on the level of treatment, biosolids can be applied to sites where there is little exposure of the general public such as forests and reclamation sites, or on public-contact sites such as golf courses, lawns, and home gardens. Regardless, biosolids are complex mixtures that can contain pollutants from household, commercial and industrial wastewaters with organic contaminants (e.g., pharmaceuticals), inorganic contaminants (e.g., metals and trace elements) and pathogens (e.g., bacteria, viruses, and parasites). Today, roughly 60 percent of the 5.6 million dry tons of sewage sludge disposed of annually is used for land application in the United States.

In 1993, EPA established a regulation governing land application of sewage sludge under the Clean Water Act with the express intent to protect public health and the environment from reasonably anticipated adverse effects. Among other requirements, this regulation (Code of Federal Regulations Title 40, Part 503) sets chemical pollutant limits, operational standards designed to reduce pathogens and the attraction of disease vectors (such as rodents), and management practices for the land application of sewage sludge.

Public health concerns regarding the past and continued use of biosolids are growing and getting increasing coverage in the media, especially from those who live near application sites. In late 2000, the EPA asked the National Academies to convene a committee—under the auspices of the Board on Environmental Studies and Toxicology with staff support from the WSTB—to conduct an independent evaluation of the technical methods and approaches used to establish the chemical and pathogen standards for biosolids, focusing specifically on human health protection. Notably, the committee was not asked to determine whether EPA should continue to promote land application of biosolids or judge the adequacy of the individual standards in protecting human health, but rather to reassess the scientific basis of the Part 503 rule as a whole. Lastly, the committee was asked to review a previous (1996) WSTB report, *Use of Reclaimed Water and Sludge in Food Crop Production*, and determine whether its recommendations

continues on page 8