THE NATIONAL ACADEMIES
REPORT IN BRIEF

Assessing the Performance of Engineered Waste Containment Barriers

Modern engineered containment systems used at landfills and other waste disposal sites are designed to isolate municipal, industrial, and hazardous wastes and to prevent contaminated leachates and gases from escaping into the environment. Available data suggest that most of these systems have performed well so far, but few engineered barriers have not been in existence long enough to assess long-term (post closure) performance, which may need to extend for hundreds of years. Furthermore, much of the available data are from monitoring the environment downstream of the barrier; there is little direct monitoring of the barriers themselves. To further increase confidence in barrier system performance, waste site managers should develop new monitoring techniques, expand the collection and reporting of data, and undertake periodic assessments of barrier system effectiveness.

It has been thirty years since the enactment of the Resource Conservation and Recovery Act, a federal law implemented by the U.S. Environmental Protection Agency, and designed to protect the public from hazards associated with waste disposal. This law was the first substantial effort by Congress to establish a regulatory structure for the management of solid, toxic, and hazardous wastes and it ushered in a new era of "cradle-to-grave" waste management. In 1980, the Comprehensive Environmental Response, Compensation, and Liability Act, commonly known as Superfund, established prohibitions and requirements concerning closed and abandoned hazardous waste sites, made the persons responsible for releases of hazardous waste at these sites liable for their cleanup, and established a trust fund to provide for cleanup when no responsible party could be identified.

There are approximately 4,000 landfills used to contain hazardous and non-hazardous waste in the United States and about 7,800 contaminated sites awaiting corrective actions and cleanup.

The potentially harmful effects of buried wastes became a public issue when President Carter declared a state of emergency at Love Canal, New York in 1980, recognizing that residents' health had been affected by environmental contaminants from nearby chemical waste sites. As part of corrective actions taken at Love Canal, this "geomembrane" cover was placed over contaminated ground in 1989. PHOTO SOURCE: Scott Parkhill, Miller Springs Remediation Management, Inc.

Corrective actions have already been completed for approximately 328 sites under the Resource Conservation and Recovery Act, and many sites under state jurisdiction and owner or operator control have also undergone closure or corrective action in compliance with current regulations.

Modern landfills are required to have “engineered” barrier systems designed to contain waste, prevent movements of contaminants offsite and minimize infiltration of outside water into the waste, thereby rendering the waste harmless to nearby people and ecosystems. Engineered barriers may also be used to contain existing contaminated sites. The engineered barriers must comply with specific federal, state, and local requirements for performance.

Undertaken at the request of the U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), National Science Foundation (NSF), and Nuclear Regulatory Commission (USNRC), this National Research Council report assesses available information on engineered barrier performance over time. The report focuses on the performance of barriers designed to contain municipal solid waste, other nonhazardous solid waste, hazardous and toxic wastes, and low-level radioactive wastes.

How Waste Containment Barriers Work

There are several types of waste containment barriers. They can be classified either by the functional mechanism they use to contain contaminants or by their orientation in the containment system. The four functional mechanisms, shown schematically in Figure 2, act to:

- block the contaminants from passing through the system (resistance)
- immobilize the contaminants to make it harder for them to flow through the system (capacitance)
- control the contaminants by making them flow back into the system instead of outwards (advection)
- remove the contaminants for treatment and/or disposal (extraction).

Barrier performance is greatly affected by the material that it is made of as well as what wastes the barrier contains. Barrier materials typically include natural or modified soil; cementitious, bituminous, and polymeric geosynthetic materials; and aggregates. These materials are usually arranged in layers.

Most waste contaminant systems are buried and their component systems are usually monitored indirectly. Tests for how easily water moves through the system (hydraulic conductivity), chemical compatibility, and chemical transport properties are done in the design phase. The surrounding waters and environment are tested for the presence of contaminants using a variety of direct and indirect methods. For instance, once the containment system is constructed, the groundwater surrounding the site is monitored and compared with the original water quality. If the concentrations of contaminants in wa-

Leachate and Gas Collection and Removal – ***Extractive Barrier***

Cover Vegetative Layer – ***Capacitive Layer***

Ground

Waste

Water Table

Inward gradient – ***Advective Barrier***

Leachate Mound

Bottom Liner – ***Resistive Barrier***

Figure 1. The functional mechanisms of an engineered waste containment system.

ter outside of the containment system are within the mandated guidelines, the barrier system is deemed to be performing adequately.

The functioning of engineered barriers may also be monitored using techniques which assess the migration of contaminants within the waste containment system. Leakage of fluid through the primary liner in a double-liner system can be monitored using measured pumping or flow rates and the chemical composition of leachate from the leak detection system. Data on flow rates and chemical composition of gas and leachate have also been obtained using samples collected from underdrains installed beneath cover systems (flow rate only) and single- and composite liner systems. Exhumation and undisturbed sampling have been used to assess material degradation and occasionally to obtain chemical concentrations in compacted clay liners.

Assessing System Performance to Date

To assess the performance of engineered barrier system, the report's authoring committee analyzed available documents, including case studies, and also met with technical professionals in the waste management community. The committee considered:

- Overall liner system performance
- Fluid leakage through liner systems
- Diffusion through bottom liner systems
- Gas migration control for bottom and side slope liner systems
- Mechanical damage to or deterioration of bottom liner systems
- Overall cover system performance
- Percolation through cover systems
- Gas emissions
- Deterioration of cover systems
- Thermal conditions
- Leakage through vertical barriers

Based on the available data, the committee concluded that most modern engineered barrier systems that have been designed, constructed, operated, and maintained in accordance with current requirements have functioned well thus far. The barrier systems currently in use have been successful in preventing and controlling the migration of contaminants into the surrounding environment.

Need for Continuation of Monitoring

Many engineered waste containment barriers are currently nearing the end of the statutory initial monitoring period (typically 30 years). At the discretion of the regulatory authorities, the owners and operators of these sites may no longer be required to conduct measurements at regular intervals. There is little to no data documenting the performance of engineered barriers after such a 30 year initial monitoring period has ended. Models have been created to predict future performance, but without long-term data these models cannot be verified. The report makes several recommendations about what should be done to help ensure continued protection of public health, reduce potential risks for barrier failure, and maximize reliability of waste containment systems. In addition, the report's assessment of data gaps can help to focus research programs on efforts that will most directly result in improved barrier performance and reliability.

Recommendation 1: Monitoring programs for new facilities should include provisions for collecting long-term performance data of engineered barriers to the extent practical using in-place monitoring systems.

Recommendation 2: Regulatory agencies should develop guidelines to increase direct monitoring of barrier systems and their components, and NSF should sponsor research for the development of new cost-effective monitoring techniques for barrier systems, especially for assessing the effectiveness of vertical barriers.

Recommendation 3: Federal agencies responsible for engineered barrier systems should commission and fund assessments of performance approximately once every 5 to 10 years. The results of the assessment should be placed in the public domain in a form that is readily accessible.

Recommendation 4: EPA, USNRC, NSF, and DOE should establish a set of observatories at operational containment facilities to assess the long-term performance of waste containment systems at field scale. The program would involve building one or more field facilities, monitoring the site, and analyzing and archiving the data. New sites could be created or adjustments could be made to existing observatories when promising new and innovative concepts and materials become available.

Recommendation 5: Regulatory agencies (e.g., EPA, DOE, USNRC) and research sponsors (e.g., NSF) should support the validation, calibration, and improvement of models to predict system and component behavior over long periods of time. These models should be validated and calibrated using the results of field observations and measurements.

Recommendation 6: EPA should develop mechanisms to ensure that funding is available for monitoring and care for as long as the waste poses a risk to human health and the environment. The optimum time for monitoring varies with the facility, type of waste, climate, and the observed performance. Yet funding is often not available to continue monitoring until the site no longer poses risk to human health and the environment, and no national policy exists to assure that such funding will be available.

Recommendation 7: EPA and USNRC should develop guidance for the practical implementation of performance-based criteria as an alternative to prescriptive designs. Performance criteria are needed that account for both barrier performance and impacts to public health and safety that extend beyond the barrier system.

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This report brief was prepared by the National Research Council based on the committee's report. For more information, contact the Board on Earth Sciences and Resources at (202) 334-2744 or visit http://nationalacademies.org/besr. Copies of *Assessing the Performance of Engineered Waste Containment Barriers* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu. This study was sponsored by the U.S. Environmental Protection Agency, U.S. Department of Energy, National Science Foundation, and U.S. Nuclear Regulatory Commission.