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EPA

Engineering Bulletin
Landfill Covers

Purpose

Section 121 (b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the latest information available on selected treatment and site remediation technologies and related issues. They provide summaries of and references for the latest information to help remedial project managers, on- scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their Superfund or other hazardous waste site. Those documents that describe individual treatment technologies focus on remedial investigation scoping needs. Addenda will be issued periodically to update the original bulletins.

Abstract

Landfill covers are used at Superfund sites to minimize surface water infiltration and to prevent exposure to the waste. In many cases, covers are used in conjunction with other waste treatment technologies, such as slurry walls, groundwater pump- and-treat systems, and in situ treatment.

This bulletin discusses various aspects of landfill covers, their applicability, and limitations on their use and describes innovative techniques, site requirements, performance data, current status, and sources of further information regarding the technology.

Technology Applicability

Covers may be applied at Superfund sites where contaminant source control is required. They can sense one or more of the following functions:

- Isolate untreated wastes and treated hazardous wastes to prevent human or animal exposure
- Prevent vertical infiltration of water into wastes that would create contaminated leachate
- Contain waste while treatment is being applied
- Control gas emissions from underlying waste
- Create a land surface that can support vegetation and/or be used for other purposes

Covers may be interim (temporary) or final. Interim covers can be installed before final closure to minimize generation of leachate until a better remedy is selected. They are usually used to minimize infiltration when the underlying waste mass is undergoing most of its settlement. A more stable base will thus be provided for the final cover, reducing the cost of post-closure maintenance.

Covers also may be applied to waste masses that are so large that other treatment is impractical. At mining sites for example, covers can be used to minimize the entrance of water to contaminated tailings plies and to provide a suitable base for the establishment of vegetation. In conjunction with water diversion and detention structures, covers may be designed to route surface water away from the waste area while minimizing erosion.

The effectiveness of covers on underlying soils and groundwater containing contaminants is shown in Table 1. Effectiveness is defined as the ability of the cover to perform its function over the long term without being damaged by the chemical characteristics of the underlying waste. Examples of constituents within contaminant groups are provided in the "Technology Screening Guide for Treatment of CERCLA Soils and Sludges" [1, p. 10].

The degree of effectiveness shown in Table 1 is based on currently available information or on professional judgment when no information was available. The effectiveness of the technology for a particular site or waste does not ensure that it will be effective at all sites. Demonstrated effectiveness means that, at some scale, chemical resistance tests showed that landfill covers were resistant to that particular contaminant in a soil or groundwater matrix. The ratings of potential effectiveness and no expected effectiveness are based on expert judgment. Where potential effectiveness is indicated, the technology is

* [reference number, page number]

believed capable of successfully containing the contaminant groups so indicated in a soil or groundwater matrix. If the technology were not applicable or probably would not work for a particular combination of contaminant group and matrix, a no expected effectiveness rating is given. Note that this rating does not occur in Table 1 for any of the contaminant groups.

Limitations

Landfill covers are part of landfilling technology, which is generally considered a technology of last resort in remediating hazardous waste sites. Landfilling of hazardous waste is not permitted without first applying the best available treatment. Landfilling technology does not lessen toxicity, mobility, or volume of hazardous wastes. However, when properly designed and maintained, landfills can isolate the wastes from human and environmental exposure for very long periods of time.

Covers are most effective where most of the underlying waste is above the water table. A cover, by itself, cannot prevent the horizontal flow of groundwater through the waste, only the vertical entry of water into the waste. Other procedures (e.g., landfill liners, slurry walls, extraction wells) may be needed to exclude, contain, or treat contaminated groundwater.

It is generally conceded that landfill components (liners and covers) will fail eventually, even though failure may occur after many tens or hundreds of years. Their effective life can be extended by long-term (30 years or more) inspection and maintenance [20]. Vegetation control and repairs associated with construction errors, cover erosion, settlement and subsidence are likely to be required. The need for cover repairs can be lessened considerably by adherence to a rigorous quality assurance program during construction.

Table 1
Effectiveness of Covers on General Contaminant Groups for Soil and Groundwater

	Contaminant Groups	*Effectiveness of Covers*
Organi	Halogenated volatiles	▼
	Halogenated semivolatiles	■
	Nonhalogenated volatiles	▼
	Nonhalogenated semivolatiles	■
	PCBs	■
	Pesticides (halogenated)	■
	Dioxins/Furans	■
	Organic cyanides	■
	Organic corrosives	■
Inorgani	Volatile metals	■
	Nonvolatile metals	■
	Asbestos	■
	Radioactive materials	■
	Inorganic corrosives	■
	Inorganic cyanides	■
Reacti	Oxidizers	■
	Reducers	■

■ Demonstrated Effectiveness: Short-term effectiveness demonstrated at field-scale.

▼ Potential Effectiveness: Expert opinion that technology will work.

❑ No Expected Effectiveness: Expert opinion that technology will not work.

Technology Description

The U.S. Environmental Protection Agency (EPA) has published several documents that provide guidance on the technology of cover construction at land disposal facilities [2] [3] [4] [5] [6] [7]. Other documents specifically address remediation of radiologically-contaminated Superfund sites, including the use of covers [8] [9]. Design and construction of clay liners (not covers specifically), properties of clay, testing methods, soil permeabilities, liner performance, and failure mechanisms are discussed at length in Reference 10.

The design of covers is site-specific and depends on the intended functions of the system. Many natural, synthetic, and composite materials and construction techniques are available. The effectiveness of covers (and other structural components of engineered landfills) has been shown to be primarily a function of the attention given to quality in choosing, installing, and inspecting those materials and techniques [24].

Covers can range from a one-layer system of vegetated soil to a complex multi-layer system of soils and geosynthetics. In general, less complex systems are required in dry climates and more complex systems are required in wet climates. The most complex systems are usually found on engineered landfills in the humid eastern United States, where the cover must meet the erosion and moisture requirements of the associated liner designed to contain the waste. Figure 1 depicts a vertical section of such a cover. Table 2 summarizes the function, materials of construction, and purpose of each of the components. Covers on Superfund sites usually contain some, but not necessarily all, of these components.

The materials used in the construction of covers include low-permeability and high-permeability soils and geosynthetic products. The low-permeability materials (geomembrane/soil layer) divert water and prevent its passage into the waste. The high-permeability materials (drainage layer) carry water away that percolates into the cover. Other materials may be used to increase slope stability.

The most critical components of a cover in respect to selection of materials are the barrier layer and the drainage layer. The barrier layer can be a geomembrane or low- permeability soil (clay), or both (composite).

Geomembranes are supplied in large rolls and are available in several thicknesses (20 to 140 mil), widths (15 to 100 ft), and

Figure 1
Cross-section of Multi-layer Landfill Cover

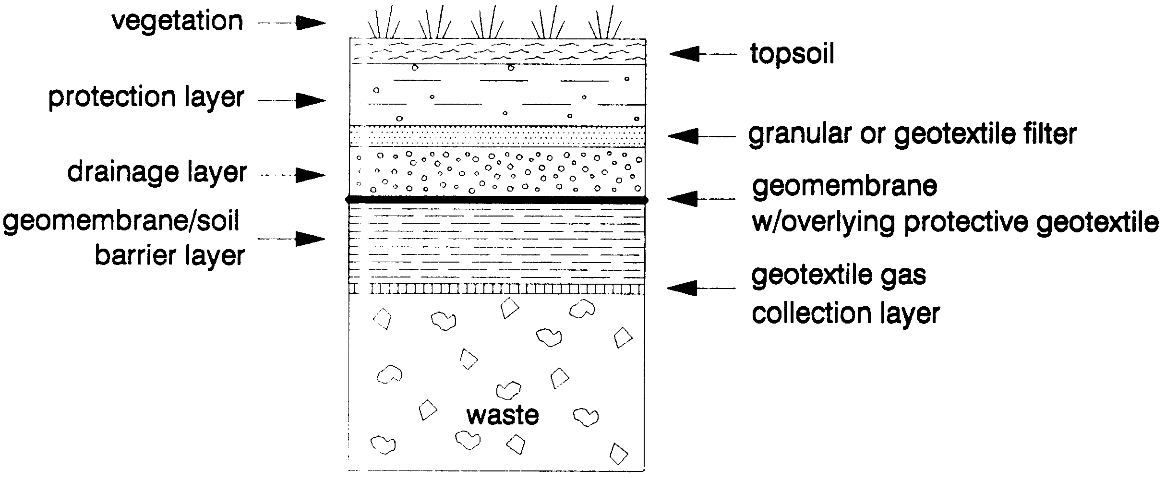

Table 2
Configuration of Cover Systems

Layer	*Primary Function*	*Usual Materials*	*General Considerations*
1. Surface Layer	Promotes vegetative growth (Most covers); Decrease erosion; Promote evapotranspiration.	Topsoil (humid site); Cobbles (arid Site); Geosynthetic erosion control systems	Usually required for control of water and/or wind erosion
2. Protection Layer	Protect underlying layers from intrusion and barrier layer from desiccation and freeze/thaw damage; Maintain stability; storage of water	Mixed soils; Cobbles	Usually required; May be combined with the protective layer into a single "cover soil" layer
3. Drainage Layer	Drain away infiltrating water to dissipate seepage forces	Sands; gravels; geotextiles; geonets; geocomposites	Optional; Necessary where excessive water passes through protection layer or seepage forces are excessive
4. Barrier Layer	Reduce further leaching of waste by minimizing infiltration of water into waste; Aid in directing gas to the emissions control system by reducing the amount leaving through the top of the cover	Compacted clay liners; Geomembranes; Geosynthetic clay liners; Composites	Usually required; May not be needed at extremely arid sites
5. Gas Collection Layer	Transmit gas to collection points for removal and/or cogeneration	Sand; geotextiles; geonets	Usually required if waste produces excessive quantities of gas

lengths (180 to 840 ft). The polymers currently used include polyvinyl chloride (PVC) and polyethylenes of various densities. Geomembranes are much less permeable than clays; measurable leakage generally occurs because of imperfections created during their installation; however, the imperfections can be minimized [15].

Soils used as barrier materials generally are clays that are compacted to a hydraulic conductivity (usually referred to as permeability) no greater than 1×10^{-6} cm/sec or a combination of bentonite and other soil that will achieve a comparable or even lower permeability. Compacted soil barriers are generally installed in 6-inch minimum lifts to achieve a thickness of 2 feet or more.

A composite barrier uses both soil and a geomembrane, taking advantage of the properties of each. The geomembrane is essentially impermeable, but, if it develops a leak, the soil component prevents significant leakage into the underlying waste. A composite liner has proven to be the most effective in decreasing hydraulic conductivity [2, p. A-2].

Geosynthetic clay barriers are beginning to be used in place of both the geomembrane and clay components. The geosynthetic clay barriers are constructed of a thin layer of bentonite sandwiched between two geosynthetic materials. In use, the bentonite expands to create a low-permeability, resealable ("self-healing") barrier. It is supplied in rolls, but does not require seaming as geomembranes do [21].

Other identified alternative barrier materials are flyash-bentonite-soil mixtures; super absorbent geotextiles; sprayed-on geomembranes and soil-particle binders; and custom-made bentonite composites with geomembranes or geotextiles [11, p. 63] [12, p. 6]. Potential advantages of alternative barriers include quick and easy installation, better quality control, cost savings potentially greater than use of compacted soil or standard soil/geomembrane composite, reduction in volume of material, lighter construction equipment required, and some self-healing capabilities [11, p. 65] [12, p. 6] [13, p. 225].

The following discussion briefly describes the construction of a multi-layer cover. It does not attempt to describe all of the possible configurations and materials.

Covers are usually constructed in a crowned or domed shape with side slopes as low as is consistent with good runoff characteristics. The bottom layer, which may be a granular gas collection layer, forms the base on top the waste mass for the remainder of the cover. The clay component of the barrier layer is constructed on this base layer. The clay is spread and compacted in "lifts" a few inches thick until the desired barrier thickness is reached (usually 24 inches or more).

Each lift is scarified (roughed up) after compaction so there will be no discernible surface between it and the next higher lift when the latter is compacted. The top lift is compacted and rolled smooth so the geomembrane may be laid on it in direct and uniform contact. During the entire process the clay must be maintained at a near-optimum moisture content in order to attain the necessary low permeability upon compaction.

Low hydraulic conductivity is the most important property of the clay/soil barrier. Hydraulic conductivity is significantly influenced by the method of compaction, moisture content during compaction, compactive energy, clod size, and the degree of bonding between lifts [11, p. 6].

Geomembranes require a great deal of skill in their installation. They must be laid down without wrinkles or tension. Their seams must be fully and continuously welded or cemented and they must be installed before the underlying clay surface can desiccate and crack. If vent pipes protrude through the cover, boots must be carefully attached to the membrane to prevent tearing if the cover subsides later. Care must be taken that the membrane is not accidentally punctured by workers or tools.

Extremes of temperature can adversely affect geomembrane installation, e.g., stiffness and brittleness are associated with low temperatures and expansion is associated with high temperatures. Thus, air temperature and seasonal variation are important design considerations [15].

A geotextile may be laid on the surface of the geomembrane for the geomembrane's protection, particularly if relatively coarse and sharp granular materials are applied as the drainage layer. Another geotextile can then be put on top of the drainage layer to prevent clogging of the drainage layer by soil from above. Fill soil and topsoil are then applied (compaction is not so critical) and the topsoil seeded with grass or other vegetation adapted to local conditions.

The drainage layer in a cover is designed to carry away water that percolates down to the barrier layer. It may be either a granular soil with high permeability or a geosynthetic drainage grid or geonet sandwiched between two porous geotextile layers. A geotextile may be used as a filter at the top of a granular soil drainage material to separate it from an overlying soil of different characteristics to prevent the drainage layer from becoming plugged with fine soil. A geotextile may also be used at the bottom of a granular drainage layer to protect the underlying geomembrane barrier from abrasion or puncture by sharp particles.

Other component layers may be used in landfill covers. Wider tolerances are generally acceptable in the material and construction requirements for these layers. Topsoil and subsoil from the vicinity are likely to be suitable for the surface and protection layers, respectively. The gas collection layer may be similar to the drainage layer in its characteristics, but it does not need to be. For example, gravel or coarse sand may be appropriate. Geosynthetic drainage materials may be used here too, but the chemical resistance to volatile wastes may be of greater concern due to the proximity of the waste and possibility for contact with it. However, EPA has no data that suggest damage to covers by volatiles.

Many laboratory tests are needed to ensure that the materials being considered for each of the cover components are suitable. Tests to determine the suitability of soil include grain size analysis (ASTM D422), Atterberg limits (ASTM D4318), and compaction characteristics (ASTM D698 or D1557). These tests generally are performed on the source material (called "borrow" material) before and during construction at predetermined intervals. EPA is expected to publish a new manual on construction quality assurance in the spring of 1993 [23].

The major engineering soil properties that must be defined are shear strength and hydraulic conductivity. Shear strength may be determined with the unconfined compression test (ASTM D2166), direct shear test (ASTM D3080), or triaxial compression test (ASTM D2850). Hydraulic conductivity of soils may be measured in the laboratory with either ASTM D2434 or D5083. Field hydraulic conductivity tests are generally recommended and may be performed, prior to actual cover construction on test pads to ensure that the low-permeability requirements can actually be met under construction conditions. EPA strongly encourages the use of test pads [3] [4].

Laboratory tests are also needed to ensure that geosynthetic materials will meet the cover requirements. For example, geosynthetics in covers may be subjected to tensile stresses caused by subsidence and by the gravitational tendency of a geomembrane or material adjacent to it to slide or be pulled down slopes. Hydraulic conductivity of geomembranes is not defined but leakage should not be significant in undamaged materials. Geosynthetic drainage materials (reinforcement type products such as geonets and geotextiles) can become clogged or compressed under pressure and lose some or all of their drainage capacity.

The geosynthetics in a cover generally are not in direct contact with the underlying waste, so chemical resistance to the waste is not often a limitation [14, p. 79] [3, p. 109]. On the other hand, vapors from volatile contaminants have the potential to degrade cover materials. Note in Table 1 that although the organic volatiles are the only chemical groups with less than demonstrated effectiveness, the opinion of experts is that the use of geosynthetics in cover systems will work. EPA has no evidence to suggest damage to covers by volatile organic compounds.

High-quality seams are essential to geomembrane integrity. Test-strip seaming, in which the actual seaming process is imitated on narrow pieces of excess membrane, can help to ensure high seam quality. The test strips should be prepared and subjected to strength (shear and peel) testing whenever equipment, personnel, or climatic changes are significant [15, p. 14]. Failure to meet specifications with the test strips indicates the necessity for destructive testing of actual field seams and correction of deficiencies in the seaming process.

Although construction quality assurance, including testing, will increase the installation cost about 10 to 15 percent and the time required to complete the project, it has been shown to improve the performance of the installation [22].

Steeply mounded landfills can have a negative effect on the construction and stability of the cover. A steep slope can make it difficult to compact soil properly due to the limited mobility and reduction of compacting effort of some compaction equipment. The rate of erosion is also a function of slope. Difficulty may arise in anchoring a geomembrane to prevent it from sliding along the interfaces of the geomembrane and soils. In some instances, geosynthetic reinforcement grids may be used to increase slope stability. Engineering design guidance addressing geomembrane stability can be found in Reference 16.

When constructing a new landfill or when covering an existing landfill where the surface of the waste mass can be graded, EPA suggests that side slopes of a landfill cover not be less than 3 per cent or exceed 5 per cent [4, p. 24].

High air temperatures and dry conditions during construction may result in the loss of moisture from a clay barrier layer, causing desiccation cracking that can increase hydraulic conductivity. Desiccation cracking can be prevented by adding moisture to the clay surface and by installing the geomembrane in a composite barrier quickly after completion of the clay layer.

The hydraulic conductivity of compacted soil is also significantly influenced by the method of compaction, soil moisture content during compaction, compactive energy, clod size, and the degree of bonding between the individual lifts of soil in the barrier layer [11, p. 6].

Geomembranes are negatively influenced by different factors than soils during the construction process. Generally more care must be taken to prevent accidental punctures. Sunlight can heat the material, causing it to expand. If installed while hot, the geomembrane can then shrink to the point of seam rupture if compensating actions are not taken. Seams must be carefully constructed to ensure continuity and strength. They should run up and down slopes rather than horizontally in order to reduce seam stress. Details of geomembrane installation can be found in Reference 15.

Site Requirements

The construction of covers requires a variety of construction equipment for excavating, moving, mixing, and compacting soils. The equipment includes bulldozers, graders, various rollers, and vibratory compactors. Additional equipment is required in moving, placing, and seaming geosynthetic materials, e.g., forklifts and various types of seaming devices.

Storage areas are necessary for the materials to be used in the cover. If site soils are adequate for use in the cover, a borrow area needs to be identified and the soil tested and characterized. If site soils are not suitable, other low-permeability soils may have to be trucked in. An adequate supply of water may also be needed for application to the soil to achieve optimum soil density.

Performance Data

Once a cover is installed, it may be difficult to monitor or evaluate the performance of the system. Monitoring well systems or infiltration monitoring systems can provide some information, but it is often not possible to determine whether the water or leachate originated as surface water or groundwater. Few reliable data are available on cover performance other than records of cover condition and repairs.

The difficulty in monitoring the performance of covers accentuates the need for strict quality assurance and control for these projects during construction. It is important to note that no landfill cover is completely impervious. It is also important to note that small perforations or poorly seamed or jointed materials can increase leakage potential significantly.

Technology Status

The construction of landfill covers is a well-established technology. Several firms have experience in constructing covers. Similarly, there are several vendors of geosynthetic materials, bentonitic materials, and proprietary additives for use in constructing these barriers.

In EPA's FY 1989 ROD Annual Report [17], 154 RODs specified covers as part of the remedial action. Table 3 shows a selected number of Superfund sites employing landfill cover technology. While site-specific geophysical and engineering studies are needed to determine the appropriate materials and construction specifications, covers can effectively isolate wastes from rainfall and thus reduce leachate and control gas emissions. They can also be implemented rather quickly in conjunc-

Table 3
Selected Superfund Sites Employing Landfill Covers

SITE	*Location (Region)*	*Status*
Chemtronics	Swannada, NC (4)	In design phase
Mid-State Disposal Landfill	Cleveland Township, WI (5)	In pre-design phase
Bailey Waste Disposal	Bridge City, TX (6)	In design phase
Cleve Reber	Sorrento, LA (6)	In design phase
Northern Engraving	Sparta, WI (5)	In operation since 1988
Ninth Avenue Dump	Gary, IN (5)	In design phase
Charles George Reclamation	Tyngsborough, MA (1)	In operation
E.H. Shilling Landfill	Ironton, OH (5)	In design phase
Henderson Road	PA (3)	In design phase
Ordinance Works Disposal	WV (3)	In design phase
Industri-Plex	Woburn, MA (1)	In design phase
Combe Fill North	Mount Olive Township, NJ (2)	Completed in 1991
Combe Fill South	Chester and Washington Township, NJ (2)	In design phase

tion with other anticipated remedial actions. Long-term monitoring is needed to ensure that the technology continues to function within its design criteria.

EPA Contact

Technology-specific questions regarding landfill covers may be directed to:

Robert E. Landreth or David A. Carson
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268
(513) 569-7871

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Dr. David Daniel	University of Texas
Mr. Robert Hartley	Private Consultant
Ms. Mary Boyer	SAIC

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United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

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