# THE ROLE OF GEOMEMBRANES AND GEOSYNTHETIC CLAY LINERS IN LANDFILL COVERS

Final cover systems for MSWLFs must be constructed to have permeabilities less than or equal to the permeability of the bottom liner system. When 40 CFR 258.60 was formulated, geomembranes and geosynthetic clay liners were thought to be cost prohibitive or technically unproven.

Research conducted by the Environmental Protection Agency (EPA), has shown that surface water infiltration into a landfill is not significantly impeded until the permeability of the cover system is equal to or less than $1x10^{-6}$ cm/sec. If the permeability is greater than this value, a significant amount of surface water has been shown to infiltrate into the landfill. With the cost reductions and general acceptance of geosynthetics, geomembrane and GCL composite systems are now an accepted barrier in MSWLF covers.

This paper recommends that state agencies consider composite final covers (geomembranes and GCLs) for all MSWLFs.



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P O S I T I O N  P A P E R

# The role of geomembranes and geosynthetic clay liners in landfill covers

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## Executive summary

The rules recently adopted for municipal solid waste landfill (MSWLF) closures (40 CFR 258.60) say that states may approve alternative final landfill cover designs for MSWLFs. These alternative designs must be constructed to have permeabilities less than or equal to the permeability of the bottom liner system or natural subsoils present, or permeabilities no greater than 1 by $10^{-5}$ cm/sec, whichever is less. These designs must include an infiltration layer and a synthetic erosion layer.

When 40 CFR 258.60 was formulated, two significant materials available for use in forming the closure layer (geomembranes and geosynthetic clay liners [GCLs]) may have been considered cost prohibitive or technically unproven.

Prior research by the U.S. Environmental Protection Agency (EPA) on water balance in landfills has shown that the natural infiltration of surface water is not significantly impeded until the permeability of the barrier is equal to or less than approximately 1 by $10^{-6}$ cm/sec (Schroeder, 1994). Furthermore, a liner with a constant permeability of 1 by $10^{-6}$ cm/sec would theoretically leak 13 inches of water per year (at unit hydraulic gradient) through a final-cover system (Schroeder, 1994).

Since the publication of 40 CFR 258.60, geomembranes and GCLs have seen cost reductions and increased acceptance of their technical sophistication and now are generally accepted, along with compacted clay liners, as the materials of choice for landfill liners. The performance characteristics of geomembranes and GCLs as infiltration barriers make these materials very effective infiltration barriers for landfill covers.

This position paper recommends that state agencies consider geomembranes or GCLs for all MSWLF covers, regardless of whether the MSWLF has a bottom liner, and that state agencies select as a superior general design, a composite geomembrane/GCL in the cover of all MSWLFs that contain a geomembrane/clay composite bottom liner, unless it can be demonstrated that the geomembrane liner, the GCL or the composite geomembrane/GCL is unnecessary or inappropriate.

These recommendations provide a cost-effective method to reduce the potential for most MSWLFs to contaminate ground water.

## Introduction

The EPA recently adopted new rules for closure of MSWLFs. The rules were published in October 1991 and became effective in October 1993. The rules (40 CFR 258.60) state:

(a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final-cover system must be designed and constructed to:
(1) have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1 x 10-5 cm/sec., whichever is less
(2) minimize infiltration through the closed MSWLF via an infiltration layer that contains a minimum of 18 inches of earthen material
(3) minimize erosion of the final cover through the use of an erosion layer that contains a minimum of 6 inches of earthen material, which is capable of sustaining native plant growth.

(b) The director of an approved state may approve an alternative final cover design that includes:
(1) an infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in paragraphs (a)(1) and (a)(2) of this section
(2) an erosion layer that achieves an equivalent protection from wind and water erosion as the erosion layer specified in paragraph (a)(3) of this section.

A clarification to the MSWLF closure rules was published in the Federal Register June 26, 1992. In the clarification, the table on page 46 provided guidelines for implementation of the rule.

As discussed by Austin (1992), landfill closure experts believe the generation of leachate in and discharge from both older, unlined landfills and newer, lined landfills can be restricted by addressing two areas.

The first area discusses existing landfills without liners (that is, landfills with only in situ soils present beneath the waste). These landfills may be capped with earthen material that may inadvertently allow significant infiltration of water into buried waste, with the resulting contaminants leaching into ground water. These earthen material closures may have permeabilities as great as 1 by $10^{-5}$ cm/sec.

According to Schroeder (1994), who has extensively researched water balance in landfills for the EPA, "In the absence of a FML (flexible membrane liner), soil liners having saturated hydraulic conductivities of $10^{-6}$ cm/sec or greater are largely ineffective."

Schroeder also notes, "A liner leaking at a constant rate of $10^{-6}$ cm/sec all year would leak 13 inches per year." An infiltration rate of 13 inches per year corresponds to approximately 350,000 gallons per acre per year. This infiltration will generate leachate as it contacts the refuse.

The second area discusses cover systems for new landfills (that is, landfills with a composite geomembrane/compacted soil liner). To limit the long-term development of leachate mounds acting on the bottom liner, cover systems must have a permeability no greater than the bottom liner. Therefore, cover systems for a landfill with a bottom liner that consists of a composite geomembrane/low-permeability soil liner should contain a composite geomembrane/low-permeability soil cover.

## Recommendation

This position paper recommends that state agencies consider the following two refinements in the implementation of the MSWLF closure rules (40 CFR 258.60).

First, that geomembranes or GCLs should be considered for all MSWLF closures. This consideration should be given regardless of whether the MSWLF has a bottom liner, unless it can be demonstrated that the ground water beneath the landfill will not be impacted by the increased leachate generation caused by the elimination of the liner or if it can be demonstrated that a liner would be inappropriate for other reasons (such as a lack of physical stability on steep slopes).

Second, that composite geomembrane/clay barrier closure systems should contain a clay component that has a permeability less than or equal to that in the bottom liner. GCLs provide a technically sound alternative to compacted clay liners (CCLs) unless steep slopes prevent their use. CCLs may not be a good choice for the clay component in an MSWLF closure because of differential settlement caused by uneven compression of the underlying waste and difficulty in constructing a compacted soil liner directly above compressible waste.

The rationale for these recommendations is summarized as follows.

**Guidelines for the implementation of 40 CFR 258.60**

| MSWLF design | Minimum final cover |
|---|---|
| No liner (in situ soils) | Minimum infiltration layer of 18 inches of 1 x $10^{-5}$ cm/sec earthen material overlaid by a minimum 6-inch erosion layer. |
| Recompacted 1 x $10^{-6}$ cm/sec soil liner | Minimum infiltration layer of 18 inches of 1 x $10^{-6}$ cm/sec earthen material overlaid by a minimum 6-inch erosion layer. |
| Composite liner (60 mil synthetic) over two foot recompacted 1 x $10^{-7}$ cm/sec soil line | Minimum infiltration layer of 18 inches of 1 x $10^{-5}$ cm/sec earthen material overlaid by a synthetic liner (the EPA recommends a minimum of 20 mils; 60 mils if HDPE ) overlaid by a minimum 6-inch erosion layer. |

### *For geomembrane or GCL liners in all closures*

- It is important to minimize infiltration of water through final cover systems for MSWLFs so that the generation of leachate is limited and the potential for ground water contamination is reduced.

• The MSWLF may be located in a hydrogeologically vulnerable location, and limiting infiltration of water into an unlined MSWLF may be the only way to prevent ground water contamination.

• Properly installed geomembranes and GCLs generally are the least permeable barrier materials available for final cover systems.

• A properly installed geomembrane or GCL is expected to be more effective than a CCL in limiting percolation of water through a MSWLF cover and into the underlying waste. Even with occasional penetrations through the liner, the water infiltration rate through a geomembrane or GCL in a MSWLF cover is expected to be up to several orders of magnitude below the water infiltration rate through a CCL.

• A geomembrane is more effective in controlling releases of landfill gases (LFG) than a CCL because the permeability of geomembranes to gas is much lower than the permeability of soils to gas. The control of LFG releases is particularly important for older, unlined landfills. Hydrated bentonite layers in GCLs also are effective gas barriers.

• Geomembranes and GCLs are easily repaired by patching if damage occurs.

• GCLs, which have been developed in the past few years, are thin layers of bentonite sandwiched between two geotextiles or attached to a geomembrane with an adhesive. These materials are far less vulnerable to damage from differential settlement, desiccation and freeze-thaw than compacted clay liners. GCLs are survivable in MSWLF cover systems; CCLs generally are not (Daniel and Koerner, 1992).

• The water infiltration rate through a GCL in a MSWLF cover is less than the water infiltration rate through a CCL. The ability of a GCL to seal penetrations allows it to survive damage that may compromise a geomembrane.

***Summary***

Geomembranes have been proven to be more effective and GCLs are expected to be more effective than CCLs in limiting the movement of water or LFG through final-cover systems. These materials are cost competitive with CCLs. State agencies are advised to consider geomembranes or GCLs in all MSWLF closures, unless

• it can be demonstrated that the ground water beneath the landfill will not be impacted by the increased leachate generation caused by the elimination of the geomembrane or GCL

• it can be demonstrated that the geomembrane or GCL would be inappropriate, for example, as a result of physical instability on steep slopes.

*For GCLs in landfill closures for MSWLFs with composite liners*

• Small penetrations in geomembrane liners or their seams can lead to seepage rates that are higher than the theoretical values for an intact geomembrane. If penetrations are present, the seepage rate is controlled by the permeability of the underlying layer. A GCL is a cost-effective alternative that can perform this function.

• 40 CFR 258.60(a)(1) requires the barrier in the cover system to be less permeable than any bottom liner system. If the geomembrane contains occasional penetrations (a few small penetrations per acre usually are anticipated), the composite bottom liner's underlying layer of low-permeability material (generally clay) ensures the cover system's permeability is less than or equal to the composite bottom liner.

• A low-permeability CCL, the usual "clay liner" in a composite geomembrane/clay liner, is not expected to function as well as a geomembrane/GCL liner does for MSWLF closures because differential settlement (and possibly desiccation plus freeze-thaw) ensures that the CCL will not maintain a long-term permeability < 1 by $10^{-7}$ cm/sec. Also, it is very difficult to compact clay on top of compressible solid waste because the waste does not provide sufficient resistance to compaction forces. Although it is possible to cover the CCL with sufficient soil to protect it from freeze-thaw (protective soil layers can be many feet thick in northern climates), this alternative can be cost prohibitive. A GCL is less vulnerable to damage from differential settlement, desiccation and freeze-thaw than a CCL.

• Use of a composite geomembrane/GCL liner in a MSWLF closure generally will ensure that the rate of surface water infiltration through the cover will be less than the rate of leachate loss through the bottom liner. The use of a geomembrane/ GCL composite liner in the MSWLF cover system will minimize the long-term buildup of leachate within the landfill.

• The internal shear strength of the material, as well as the interface shear strength between the material and the overlying and underlying materials should be analyzed. While internal shear strength values are available from GCL manufacturers for their reinforced GCL products, it may be necessary to generate interface shear strength values between the GCL and other geosynthetic or natural materials directly in contact with the GCL.

***Summary***

MSWLFs that contain a geomembrane/clay composite liner should incorporate a composite final cover which is at least as impermeable as that of the bottom liner to prevent buildup of liquids in the closed landfill. With the advent of GCL technology, there exists a technically sound, economical alternative that enables construction of a survivable composite barrier with a permeability less than or equal to the permeability of the composite geomembrane/clay bottom liner in a MSWLF closure. State permitting agencies are encouraged to recommend the use of geomembranes and GCLs to accomplish the objective stated in 40 CFR 258.60(a)(1).

### Supporting technical information

A variety of references contain data to support the recommendations stated in this paper. Technical issues concerning geomembranes and compacted soil in final covers are discussed in EPA (1991). General concepts for final covers that emphasize the cost effectiveness of geomembranes in covers, problems with compacted soil liners and benefits of GCLs are provided by Koerner and Daniel (1992). The equivalency of GCLs to CCLs is discussed by Koerner and Daniel (1993). Schroeder (1994) summarizes the latest sensitivity studies concerning engineering design of cover systems based on the computer program HELP (hydrologic evaluation of landfill performance).

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