International Geosynthetics Society

Geosynthetic Barriers in Waste Containment Facilities (Landfills)

Barriers in Landfills

One of the largest uses of geosynthetic barriers in the world is in the construction of barriers for waste containment facilities. The two main uses of geosynthetic barriers in these facilities are as the bottom liner barrier system, under the solid waste that prevents liquids and contaminants from entering the underlying soil, groundwater, and environment (see Figure 1), and as the final cover barrier system after solid waste placement is complete to prevent precipitation from entering the facility and creating additional contaminated liquid, i.e., leachate. The combination of the bottom liner and final cover barrier systems encapsulate the solid waste so no liquid can enter and liquid and gas can only leave through controlled outlets after closure for treatment, which protects the groundwater regime and connected streams and rivers as shown in Figure 2.

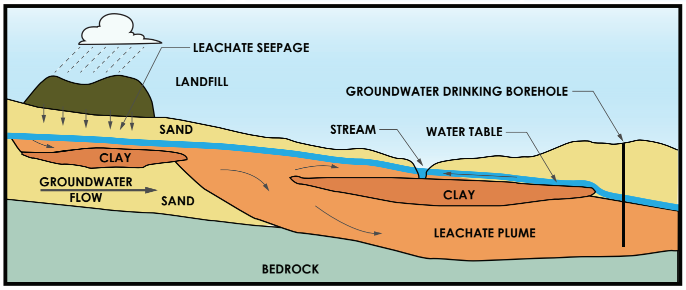

Figure 1. Schematic diagram of the hydrological risk of an unlined municipal solid waste landfill.

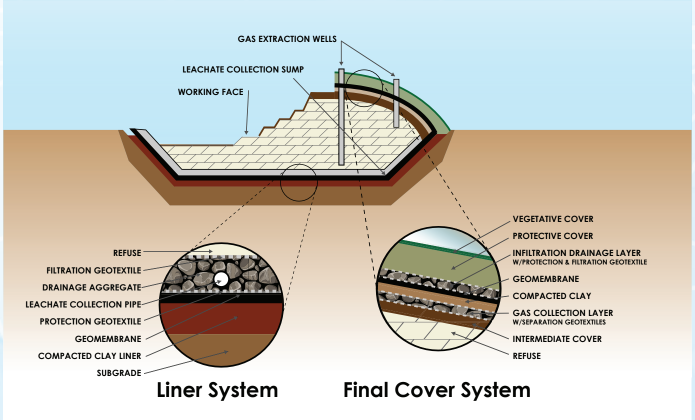

Figure 2. Schematic cross section showing potential ground and surface water contamination from a landfill without use of geosynthetics.

Types of Geosynthetics in Barriers

In early landfill designs the bottom liner system consisted of only a Compacted Clay Liner (CCL). A CCL is comprised of fine-grained soils compacted in lifts to a thickness of between 0.6 to 1.5 m. However, studies by Brown et al. (1984) show that many contaminants caused micro and macro changes in the CCL, that could significantly increase its hydraulic conductivity, and could therefore lead to groundwater contamination. This resulted in many countries, e.g., the USA in the 1990's (U.S., 2012), requiring a geomembrane (GM) over a CCL, so that the CCL would only be subjected to the contaminants at the location of a defect in the GM, if any, as shown in Figure 2. The resulting containment system is termed a composite liner barrier system and consists of a geomembrane in intimate contact with the underlying CCL (Rowe, 2012) with a drainage layer above it. More recently, when the subgrade material on the site does not meet the permeability requirements for a CCL, the CCL is being replaced with a geosynthetics clay liner (GCL) as shown in Figure 3, although regulatory guidance on the use of these materials varies world over based on demonstrating equivalence. Because the geomembrane reduces leakage only to the area of small GM defects, if any, due to its very low hydraulic conductivity, the leakage is negligible compared to that of just a CCL alone because leakage occurs over the entire area of the CCL if no GM is present. Likewise, a GM alone, over a permeable base layer, can also have a significant leakage rate as flow is only limited by the size of the defects in the liner. The composite liner barrier system can therefore reduce the release of contaminants from the base of a landfill by orders of magnitude compared to a GM or CCL alone.

Figure 3 presents a landfill cross-section with a composite liner barrier system consisting of only geosynthetics. A composite liner system is typically used for municipal, i.e., household, solid waste (MSW) and consists of the following geosynthetics from top-down under the solid waste:

• Drainage composites that consist of two (2) non-woven geotextiles (GTX) heat bonded to a geonet or cuspated sheet above the GM. The GTX perform separation and filtration functions (see Geosynthetics - Part 1: Terms and definitions (ISO 10318-1:2015) that prevent the intermixing of the overlying solid waste with the void former in the drainage composite, so it does not become clogged, and it prevents small waste particles from flowing into the void former with the leachate and eventually clogging it. The void former performs the drainage function required for collecting and transmitting the contaminated liquid (leachate) to the sump where it can be pumped out and treated. Limiting the leachate depth on the liner limits the rate at with it can flow out of the landfill if there is a defect in the liner system. Typically, drainage composites are used on landfill side slopes, with a gravel leachate collection system used on the base of a landfill, although guidance on the use of these materials varies world over. Drainage composites do not offer

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significant protection to the geomembrane, so are often used with a layer of selected waste or a gravel drainage/protection layer.

• Geomembrane (GM) is a near impermeable polymer material that performs the barrier function that prevents movement of contaminated liquid and gas from the landfill into the soil and groundwater to protect the environment.

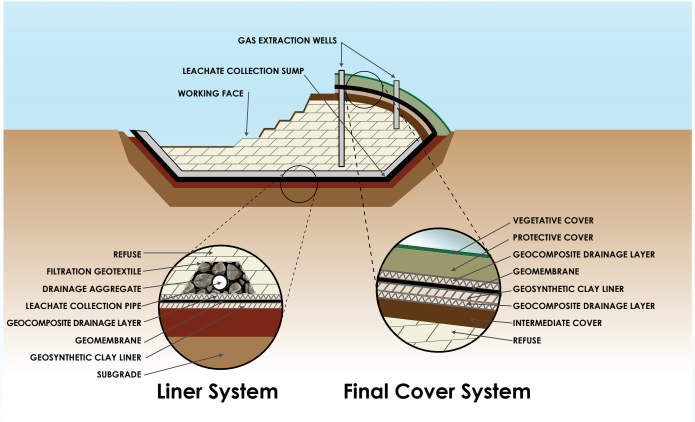

Figure 3. Schematic diagram of a single composite liner system in a landfill base and capping system.

• Geosynthetic clay liner (GCL) performs the soil barrier function of a CCL because it contains a thin layer of extremely low hydraulic conductivity bentonite that prevents movement of contaminated liquid, if any, that passes through a geomembrane defect.

Based on the type of waste, the hydrological risk and local regulations, which varies the world over, double composite liners are also used to contain waste. This addition of a secondary drainage layer provides the benefits

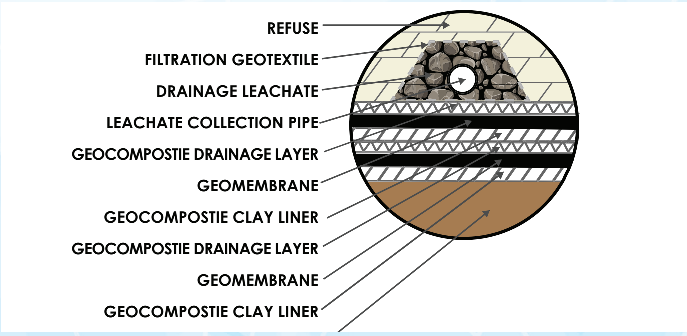

Figure 4. Schematic diagram of a double composite liner system.

of significantly reducing the head of leachate acting on the secondary liner, therefore reducing the risk of leachate seepage to groundwater. It also provides the opportunity to monitor the performance of the primary composite barrier through monitoring the volume of leakage between the two composite liners, see a schematic of this in Figure 4.

Benefits of Geosynthetics

The GCL has a number of additional benefits over a CCL including; it is a manufactured product subject to quality controlled processes, it can be rapidly installed without the need for specialist welding equipment, it can tolerate larger differential settlement than a CCL, it can generate additional landfill storage space as it is only 10 mm thick compared to a CCL which can be 0.6 to 1.5 m thick, and it has excellent self-sealing characteristics. The GCL is also a more sustainable alternative than a CCL because a significant amount of petroleum powered construction equipment is required to quarry, transport, place, and compact a 0.6 to 1.5 m thick CCL. Koerner et al. (2019) shows that the use of a GCL instead of a CCL results in a 30% reduction in embodied carbon for bottom liner system construction. For landfill cover systems, the use of various geosynthetics can result in up to a 75% reduction in embodied carbon over the use of soils and a CCL (Koerner et al., 2019). As a practical example, for a 4,500 m^2 CCL versus GCL installation the GCL can be transported to site in a single truck, whereas the CCL would require 187 trucks. This also generates significant cost and time savings when the two barriers are compared. Because waste containment facilities cover large areas, i.e., many hectares, the savings realised by using geosynthetics in landfill construction is significant, even before taking into account those used in the final cover system.

Landfill Cover Barriers

The final cover system is placed over the solid waste after filling is complete to encapsulate the waste and prevent precipitation from entering the facility and creating additional leachate and to contain greenhouse gasses formed as a result of the methanogenic breakdown of organic material in the waste, which is typically equal percentages of methane and carbon dioxide. Figures 1 and 3 show that the final cover system essentially consists of a single composite liner system overlain by natural soils to protect the geosynthetics and promote vegetative growth over the surface of the containment area, which may be used for recreational or other purposes, although regulatory guidance on the use of these materials varies world over. The granular soil drainage layer (see Figure 1) or drainage composites (see Figure 3) placed above the GM in the final cover system prevent moisture from building up on the GM and causing slope stability failures. The drainage layer below the GM can also be a drainage composite (see Figure 3) to collect and vent gases generated by degradation or reaction of the encapsulated solid waste. As this decomposition process results in a flux of mass out of the landfilled waste, as gas, the waste can undergo fairly large settlements. Geosynthetics in

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cover system design can assist to accommodate these settlements, often more effectively than a traditional clay only cap.

Other Geosynthetics Used in Landfills

Descriptions and definitions of other geosynthetics that are commonly used in waste containment facilities are described below. For the formal definition of these materials see Geosynthetics - Part 1: Terms and definitions (ISO 10318-1:2015):

• Geotextile - permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. These are used as cushion layers to protect the geomembrane from damage from the leachate collection layer aggregate and as filtration layers to limit the movement of fines from the waste into the drainage aggregate layer.

• Geopipe - A buried pipe made from polymeric material, used to collect and transport seepage fluid.

• Geogrid - polymer materials used to provide tensile reinforcement to soils used in landfill access roads to stabilise the road base and minimise gravel use, to increase slope stability, to reduce stress-induced strains in the geomembrane over soft subgrades or in vertical expansions, and to reinforce final cover systems.

About the IGS

The International Geosynthetics Society (IGS) is a non-profit organization dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies. The IGS promotes the dissemination of technical information on geosynthetics through a newsletter (IGS News) and though its two official journals (Geosynthetics International - www.geosynthetics-international.com and Geotextiles and Geomembranes - www.elsevier.com/locate/geotexmem). Additional information on the IGS and its activities can be obtained at www.geosyntheticssociety.org or contacting the IGS Secretariat at IGSsec@aol.com.

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Acknowledgments

This document was prepared by Jonathan Shamrock and Timothy D. Stark for the IGS Technical Committee on Barriers (TC-B). Updated February 2022.