Landfill Liner and Cover Systems: Design Guidelines

• A liner suggests a single layer, a liner system suggests a series of layers working together

• Leakage from liner systems can be very low with proper engineering and construction

• Design principles versus regulations
Landfill Design

6 in. top soil
1 ft. drainage layer
0.06 in. plastic liner
2 ft. clay
1 ft. soil
40–300 ft. waste
1–2 ft. drainage layer
0.06 in. plastic liner
2 ft. clay
Geosynthetics

- Synthetic polymers
  - Polyethylene and polypropylene most common
    - some PVC
- Geotextiles (relatively permeable)
  - Separation and Filtration
    - Retain soil particles
    - Let water pass
    - Do not clog over time ??
  - Typically used to protect a leachate collection system from clogging
Geosynthetics

- Geonets
  - Substitute for sand or gravel
  - Very high transmissivity, low storage
Geosynthetics

- Geomembrane (low permeability)
  - Vapor and liquid barrier
  - Diffusion may control
- Sheets 23 - 35' wide, 60 - 80 mil thick
- Smooth vs. textured
Geocomposites

- A combination of any of the above
- Geobentonite composites:
  - Include a layer of bentonite between two layers of geotextile
  - Geosynthetics may save airspace
Typical Design Guidelines

- **Subbase**
  - 6 - 12" thick
  - Compact to 95% of maximum density
  - $K < 10^{-5}$ cm/sec
  - Slope: 2 - 25% or 1V:4H
  - Soil must be rock free
    - <3/4” if geomembrane in contact
    - <1.5” if clay contact
Secondary Liner  
Final Protection Between Waste and Environment

- Clay \(<10^{-7} \text{ cm/sec}\) compacted in 6” lifts 
- Overlain by a geomembrane 
- Possibly a geobentonite instead 
- Must present and follow a QC/QA program 
  - Quality Assurance - 3rd party inspector
Leachate Detection Zone

• Must rapidly detect, collect and transmit liquid to a collection system

• Function without clogging

• 12" thick

• $K > 10^{-2}$ cm/sec (gravel or geonet)

• Contain a perforated piping system at least 4" diameter, sch 80
  – Wrapped in a geotextile

• Slope $\geq$ 2%

• Distance for flow $\leq$ 100’ (200' on centers)
Primary Liner System

Prevent leachate migration and force water into overlying leachate collection system

Options:

1. Compacted clay + geomembrane
   Clay: 2' - 3' compacted in 6" lifts
   geomembrane - 60 mil

2. Geobentonite + geomembrane

Must follow a rigorous QC/QA program
Leachate Collection and Removal

• Must cover bottom and sides of landfill
• Function without clogging (biological, chemical, physical)
• Keep head on liner $\leq 12''$
• 12 - 18'' thick
  • 24” between liner and waste
• $K \geq 10^{-2}$ cm/sec (move towards stone)
• Contain a perforated piping system typically 6'' diameter, sch 80 surrounded by non-carbonate stone, wrapped in a geotextile (??)
Leachate Collection and Removal

• No stone > 0.25”

• Slope ≥ 2%
  – 8” Headers typically at 1% - 2%, provide cleanouts

• Distance for flow ≤ 100’ (200' on center)

• Some protection above the leachate collection system is needed

• Options include:
  – Baled refuse
  – Additional soil
  – Tire chips
  – Layer of uncompacted select refuse
Leachate Collection Systems

Sawtooth

Continuous Incline
Leachate Collection Systems

NOTE: The leachate collection and recovery system collects and removes liquids from the landfill. The liner system prevents leachate from leaving the landfill.

Slide Courtesy of Waste Management
Leachate Collection Systems

Slide Courtesy of Waste Management
Liner Slopes

• Maximum slope is 3(h):1(v) both above and below grade

• Excavations
  – Sand 2:1
  – Clay 0.5:1
  – Other 1:1
Leachate Rates Through Composite Liners

\[ Q = 0.21a^{0.1}h_{w}^{0.9}K_{s}^{0.74} \]

\( Q \) = leakage rate (m\(^3\)/s)
\( a \) = area of one hole (m\(^2\))
\( h_{w} \) = head on liner (m)
\( K_{s} \) = hydraulic conductivity (m/s)

For poor contact, use 1.15 in place of 0.21

Poor contact: no control over membrane wrinkling and poor surface preparation

Leaks And Composite Liners

Data for a 0.5" hole, 12" of head

<table>
<thead>
<tr>
<th>Liner</th>
<th>Release rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic</td>
<td>4200 gal/day</td>
</tr>
<tr>
<td>Synthetic over sand</td>
<td>24.36 gal/day</td>
</tr>
<tr>
<td>$K = 10^{-4}$ cm/sec</td>
<td></td>
</tr>
<tr>
<td>Synthetic over silt</td>
<td>4.43 gal/day</td>
</tr>
<tr>
<td>$K = 10^{-5}$ cm/sec</td>
<td></td>
</tr>
<tr>
<td>Synthetic over clay</td>
<td>0.15 gal/day</td>
</tr>
<tr>
<td>$K = 10^{-7}$ cm/sec</td>
<td></td>
</tr>
</tbody>
</table>
Geomembrane Leak Testing

- 20% of leaks were in the side slopes at sites tested
- 87% of leaks were at the seams
- 13% in parent material
  - Dropped tools
  - Cigarette burns
Geomembrane Leak Testing

• Critical factors:
  – Corners, sumps, penetrations

• Methods are available for leak detection
  – Visual inspection
  – Pressure or vacuum testing of seams
  – Electric leak detection
Final Cover

Functions:

– keep water out
– control runoff
– separate the waste from plants and animals
– gas collection/odor control

Complicating Factors:

– plant root penetration
– freeze/thaw
– vehicle haul roads
– differential settlement
Cover Cross Section

- 6 in. top soil/ additional soil for freeze protection
- 1 ft. drainage layer
- 0.06 in. plastic liner
- 2 ft. clay
- 1 ft. soil/gas distribution
- waste
Clays

• Hard to compact over sand or refuse
• Desiccate and shrink from both top and bottom
• Thin layers (even 18") of cover do not prevent desiccation
• Final grade > 3% on top, slopes @ 3:1
Vegetation

- Objectives
  - Stabilize soil
  - Minimize erosion
  - Promote evapotranspiration
  - Next possible planting season
  - > 70% ground cover
  - No deep rooted plants or shrubs
Additional Considerations

• Practice is to place final cover once site (or cell) is full
• Differential settlement will cause cracks in clay, geomembranes are more resistant and recommended
• Ideal - use an intermediate cover until settlement is complete
  – Financial implications
    – Recover airspace
    – Less maintenance
  – low permeability desirable for gas collection
    – biocover alternatives
Alternate (ET) Covers

- Sufficient soil to retain water until it evaporates
- Ongoing research
  - requires regulatory approval
Final Use

• Decide during design phase
• Can expect settling of 5 - 15%, more for bioreactors
• Open space / conservancy
• Park - requires more maintenance and cover soil
• Gravel parking lot
• Golf course
Liner and Cover Performance

(Source: Fig. 5-5 of USEPA, 2002)
### Liner and Cover Performance

**TABLE 5.9** Flow Rates from the Leachate Detection Systems (LDS's) of Modern Double-Lined Landfills (all flow rates in gallons/acre/day (GPAD)) (after Bonaparte et al., 2000)

<table>
<thead>
<tr>
<th>Liner and LDS Type</th>
<th>Type I (GM-Sand)</th>
<th>Type II (GM-GN)</th>
<th>Type III (GM/CCL-Sand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Stage</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Average Flow</td>
<td>41</td>
<td>18</td>
<td>6.8</td>
</tr>
<tr>
<td>Minimum Flow</td>
<td>0.81</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Maximum Flow</td>
<td>229</td>
<td>158</td>
<td>26</td>
</tr>
<tr>
<td># of “points”</td>
<td>30</td>
<td>32</td>
<td>8</td>
</tr>
<tr>
<td># of landfills</td>
<td>11</td>
<td>11</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Liner and LDS Type</th>
<th>Type IV (GM/CCL-GN)</th>
<th>Type V (GM/GCL-Sand)</th>
<th>Type VI (GM/GCL-GN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Cycle Stage</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Average Flow</td>
<td>18</td>
<td>8.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Minimum Flow</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Maximum Flow</td>
<td>74</td>
<td>54</td>
<td>14</td>
</tr>
<tr>
<td># of “points”</td>
<td>21</td>
<td>27</td>
<td>12</td>
</tr>
<tr>
<td># of landfills</td>
<td>6</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

**NOTES:**
- **Life Cycle Stages**
  - Stage 1 - Initial Life
  - Stage 2 - Active Life
  - Stage 3 - Post Closure
- **GM** = geomembrane;
- **GN** = geonet;
- **GCL** = geosynthetic clay liner;
- **CCL** = compacted clay liner
- **ND** = No Data
- (“points” = Number of measuring points i.e., outlets of single or multiple cells)
Liner and Cover Performance

**FIGURE 5.28** Average Flow from Leak Detection Layers of Double Lined Landfills (Note that each plotted point represents the average of the number of monitored cells given in parentheses) (from Bonaparte et al., 2000)