GeoEnvironmental Engineering
(CE 4231)

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### Landfills

#### Relative Merits of Disposal Options

<table>
<thead>
<tr>
<th>Disposal Option →</th>
<th>Non-engineered Disposal</th>
<th>Sanitary Landfill</th>
<th>Composting</th>
<th>Incineration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>↓ Sustainability Indicator</strong></td>
<td></td>
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<tr>
<td>Volume reduction</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>√</td>
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<tr>
<td>Expensive</td>
<td>x</td>
<td>√</td>
<td>√</td>
<td>√</td>
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<tr>
<td>Long term maintenance</td>
<td>√</td>
<td>√</td>
<td>x</td>
<td>x</td>
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<tr>
<td>By product recovery</td>
<td>x</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Adaptability to all wastes</td>
<td>√</td>
<td>√</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Adverse environmental effect</td>
<td>√</td>
<td>√</td>
<td>x</td>
<td>√</td>
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</tbody>
</table>
Landfills

Selection criteria

**Technical** (type, characteristics and quantity of waste, existing practices, location of disposal site, engineering material, technology)

**Institutional** (structures, roles and responsibilities, operational capacity, incentives)

**Financial** (financing and cost recovery, current revenue and expenditure, potential need for external finance for capital cost)

**Social** (waste picking, health and income implication, public opinions)

**Environmental** (short term and long term impact)
Landfills

From Dump to Sanitary Landfill

• Dump = uncontrolled dump causing hazards to human and environment

• Controlled Landfill = dump with covering of waste

• Engineered Landfill = controlled landfill + engineered measures to limit impact

• Sanitary Landfill = engineered landfill + landfill gas extraction + groundwater monitoring + highly trained staff + water treatment facility + ...
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Impacts from Dumps

• Its presence (area need, visual impact, social and economical impact)
• Transport of waste (noise and air)
• Waste attracts animals (vermins, insects)
• Waste emits landfill gas (odor, fires, global warming)
• Waste emits dust and other materials (plastic)
• Waste emits pollutant water impacting soil, surface water and groundwater (drinking water problems, food)
Landfills

Impacts from Dumps

- Landfill Gas
- Odor, Dust, Noise
- Polluted Surface
- Water
- Polluted Groundwater
- Rainwater
- Surface Water
- Leachate
- Groundwater
Landfills

Types of Engineered landfill

• Area fill
• Trench fill
• Above and below ground fill
• Canyon fill
• Slope fill
Landfills

Area fill

• Landfill progresses with little or no excavation
• Used in areas with high ground water
• Unsuitable terrain
Landfills

Trench fill

• Waste is filled in series of deep and narrow trenches
• Suitable for small waste quantities
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Above and below ground fill

- Combination of area fill and trench fill
- Excavation area is much more than trench fill
- Depth of excavation depends on position of ground water table
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Canyon fill

- Waste is filled in the valley region
- Control of surface drainage is often a critical factor
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Slope fill

• Where flat ground is not available
• Control of surface drainage from hill slopes is critical
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Life cycle of a landfill

• **Planning phase**: This typically involves preliminary hydro-geological and geo-technical site investigations as a basis for actual design.

• **Construction phase**: This involves earthworks, road and facility construction and preparation (liners and drains) of the fill area.

• **Operation phase (5 – 20 years)**: This phase has a high intensity of traffic, work at the front of the fill, operation of environmental installations and completion of finished sections.

• **Completed phase (20 – 100 years)**: This phase involves the termination of the actual filling to the time when the environmental installations need no longer be operated. The emissions may have by then decreased to a level where they do not need any further treatment and can be discharged freely into the surroundings.

• **Final storage phase**: In this phase, the landfill is integrated into the surroundings for other purposes, and no longer needs special attention.
Landfills

Systematically engineered landfill
Landfills

Systematically engineered landfill
Landfills
Landfills

Site selection

• Large enough to accommodate the SW needs of the area it serves (lifetime, 10 yrs, ...)
• Compatible with the local SW management programs
• Site must protect public health, safety, welfare, & environment
• Minimize adverse impacts on surrounding area
• Minimize adverse impacts on property value
• Minimize impacts on traffic flow
• Minimize potential for fire, spill, accidents
• e.g. outside the 100 year flood plain
• Far from airports (birds) - jet airports, other airports
• Provide emergency response plan including notification, evacuation, & containment procedures
Landfills

Site selection

- Land availability
- Haul distance
- Impact on SW management program
- Soil conditions and topography
- Geological conditions - unstable areas, seismic activity
- Hydrologic conditions (surface and ground water)
- Climatic conditions (rainfall and wind)
- Environmental and ecological conditions
- Public input and concerns
- Potential use after closure
Landfills

Area Requirements

• Leachate treatment plant
• Gas management and treatment
• Access requirements (streets, railroads, ...)
• Economics (height vs. Area of landfill)
• Co-located waste processing (recyclables processing, special wastes, household, hazardous wastes....)
• Composting of Biowaste
• Administration of the Landfill (Buildings, ...)
• Scale house (located at the Entrance)
• Stormwater control (ponds, rainwater infiltration, ...)
• C&D debris recycling and disposal
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Landfill Design Consideration

- Essential components
- Design life
- Waste volume, waste compatibility and landfill
- Landfill layout and section
- Phased operation
- Estimation of leachate quantity
- Liner system
- Leachate drainage, collection and removal
Landfills

Landfill Design Consideration

- Leachate management
- Landfill gas management
- Final cover system
- Surface water drainage system
- Base stability, slope stability and seismic aspects
- Site infrastructure
- Environmental monitoring system
- Closure and post-closure maintenance system
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Construction and operation Criteria

- Landfill site construction and development
- Site procedures: Record keeping and waste inspection
- Phase development
- Phase operation
- Pollution prevention and safety during operation
- Phase closure
- Landfill Closure
- Post-closure vegetative stabilization
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Landfill components and configuration

• Bottom and lateral side liner systems
• Leachate collection and removal system
• Gas collection and control system
• Final cover system
• Storm water management system
• Groundwater monitoring system
• Gas monitoring system
• Leak detection system
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Actions required for constructing/design of a landfill

• Landfill footprint layout
• Subbase grading
• Cell layout and filling
• Temporary cover selection
• Final cover grading
• Final cover selection
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Typical cross section of landfill
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Bottom and side liner system

- Single most important element of a landfill
- Placed at the bottom and sides of a landfill
- To prevent migration of leachate to the surrounding soil and water
- Liner consists of multiple barrier and drainage layers
- May consists of compacted clay liner, geomembrane, geosynthetic clay liner, geotextiles and/or a combination of these.
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Leachate collection and removal system

- To collect the leachate produced in a landfill

- To prevent the buildup of leachate head on the liner and to drain leachate effectively outside the landfill for treatment

Leak detection system

- To drain the leachate if at all present in the secondary liner system
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Gas collection and removal system

- Municipal solid waste can generate large quantities of gas during decomposition.
- Two primary constituents: Methane and Carbon dioxide
- System to collect and extract gas from within the landfill
- Landfill gas can either be used to produce energy or flared under controlled conditions
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Top liner system

- Enhances surface drainage, prevents infiltrating water and supports surface vegetation
- Consists of barrier and drainage layers
- Main purpose is to minimize the water infiltration into the landfill to reduce amount of leachate generated after closure
- Soil layer is included at the top to protect the underlying layers against intrusion, damage and to enhance surface drainage & vegetation
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Leachate drainage system
Landfills

Leachate collection system
Landfills

Perspective view of cell type construction
Landfills

Detailed diagram of cell construction
Landfills

Single composite liner system for non-hazardous landfill
Landfills

Double composite liner system for hazardous landfill
Landfills

Top liner system

- Surface vegetation layer
- Drainage layer
- Non-woven geotextile
- HDPE geomembrane
- Compacted clay liner
- Waste
Landfills

Details of gas venting system
Landfills

Cross-sectional view of the landfill
Landfills

Cumulative land requirement for MSW disposal
Landfills

Emissions of methane from landfills
Landfills

Groundwater control measures

• groundwater regime
• permeability and transmissivity of all strata
• distribution, thickness and depth of subsoils and bedrock
• location of wells, springs, sink and swallow holes or other groundwater features
• groundwater contours, gradients, rates of flow, and direction of flow
• groundwater quality
• predicted influence of short/long term dewatering
• relationship with surface waters
• aquifer category.
Landfills

Groundwater conditions

A. Outward Gradient

B. Inward Gradient (Zone of Saturation)

C. Perched Groundwater

D. Confined Aquifer