SWIM and Horizon 2020 Support Mechanism

Working for a Sustainable Mediterranean, Caring for our Future

Landfill Basics

Presented by:

Dr. Ahmed Gaber, Professor of Chemical Engineering, Cairo University and Chairman, Chemonics Egypt Consulting

Leachate Management Training Program

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Lecture 1

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Outline

1. Introduction
2. Principles
3. Processes
4. Design considerations
5. Emerging technologies in landfills

Introduction: Hierarchy of integrated waste management

hierarchystructure.com

- Even with the implementation of waste reduction, recycling, material recovery and transformation technologies, disposal of solid waste in a landfill remains an important component of solid waste management strategies.
- It is not always economical to recycle/recover all waste under all conditions.
- ***Safe and reliable*** long-term disposal of solid waste is one of the most essential components of solid waste management.
- The landfill is the most economical form of solid waste disposal that minimises adverse environmental effects, associated risks and inconveniences; allowing the waste to decompose under controlled conditions.

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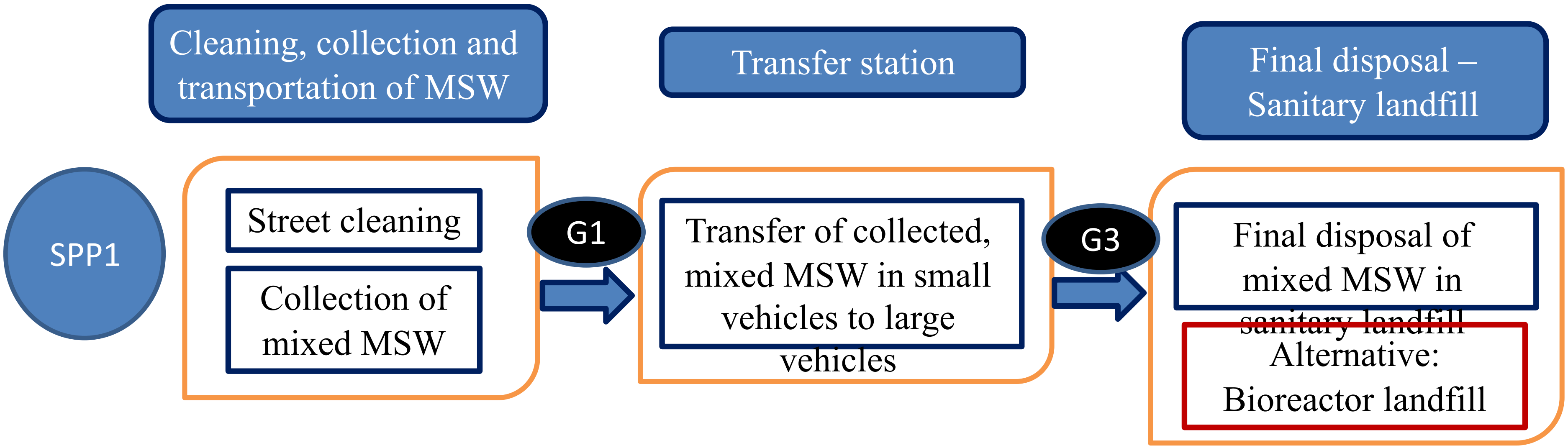
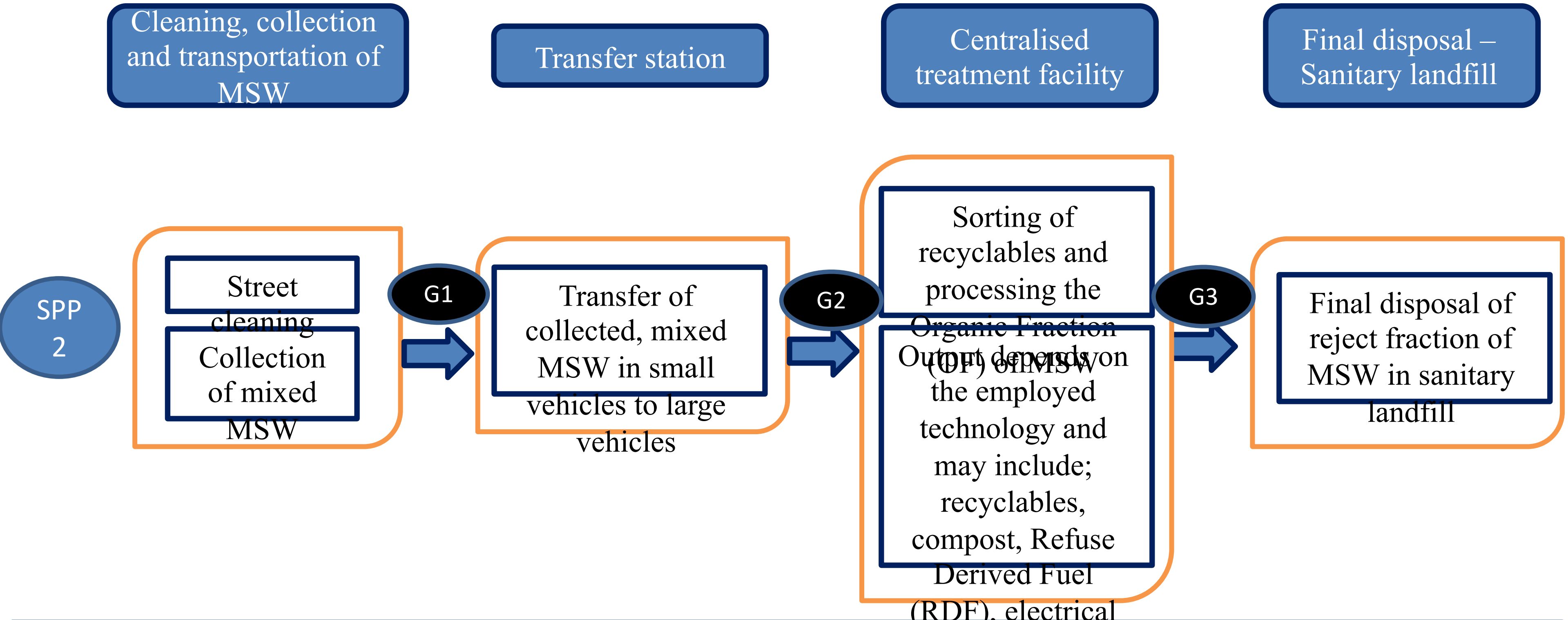
Introduction: Service Provision Plans (SPPs) and the need for final disposal



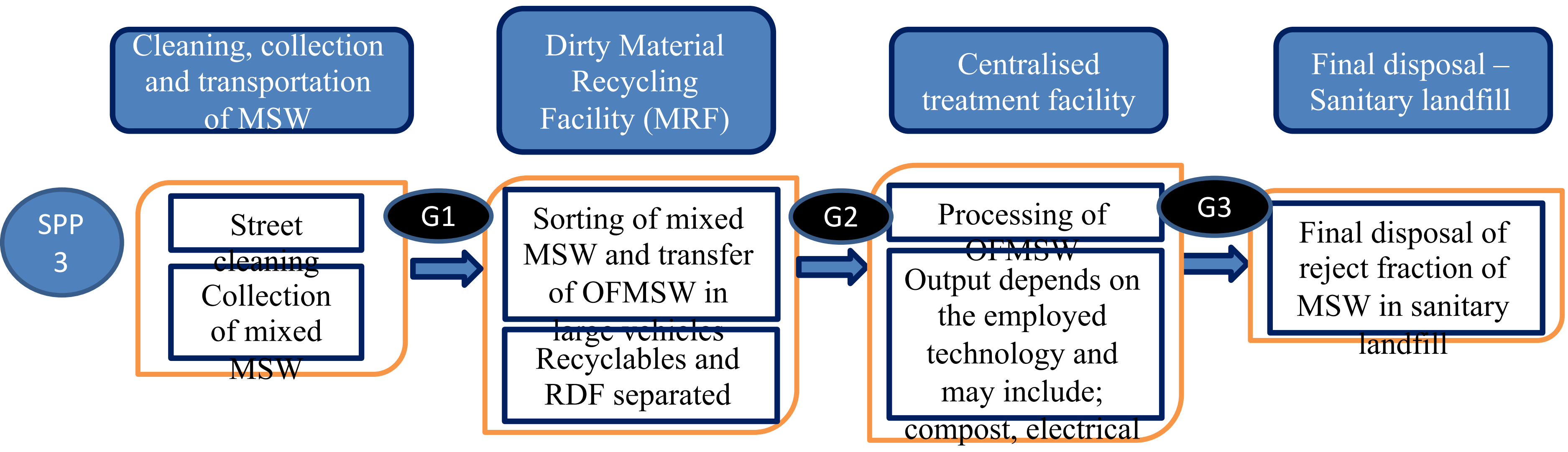
Service Provision Plan (SPP) 1: Collection of mixed MSW → G1 (Transfer Station) → G3 (Sanitary Landfill for the disposal of mixed MSW)

Introduction: Service Provision Plans (SPPs) and the need for final disposal



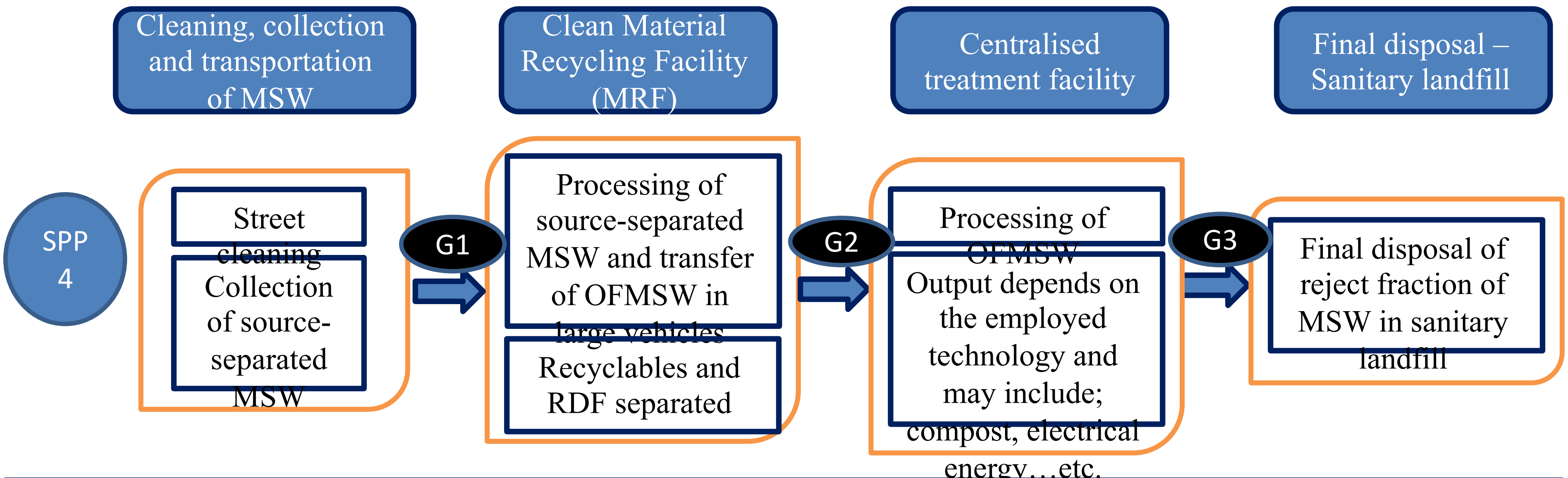
Service Provision Plan (SPP) 2: Collection of mixed MSW → G1 (Transfer Station) → G2 (Centralised Treatment Facility) → G3 (Sanitary Landfill for the final disposal of the rejects fraction of the MSW)

Introduction: Service Provision Plans (SPPs) and the need for final disposal



Service Provision Plan (SPP) 3: Collection of mixed MSW → G1 (Dirty MRF) → G2 (Centralised Treatment Facility) → G3 (Sanitary Landfill for the final disposal of the rejects fraction of the MSW)

Introduction: Service Provision Plans (SPPs) and the need for final disposal



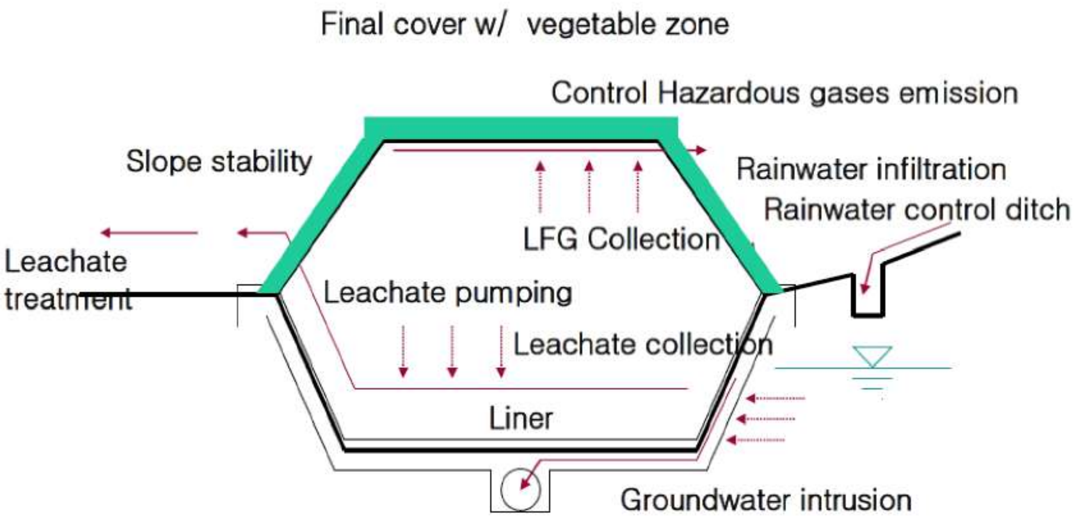
Service Provision Plan (SPP) 4: Collection of source-separated MSW → G1 (Clean MRF) → G2 (Centralised Treatment Facility) → G3 (Sanitary Landfill for the final disposal of the rejects fraction of the MSW)

Introduction: Landfills and their classification

- ***A landfill is*** any form of waste disposal land, ranging from an uncontrolled rubbish dump to a full containment site engineered with high standards to protect the environment.
- Landfilling practices in developing countries differ from that of developed countries; which, follow advanced landfilling practices such as ***sanitary landfills as opposed to open dumping practices***.

Two main types of landfills

- Sanitary landfills: For Municipal Solid Waste (MSW) i.e. waste from residential and commercial areas.
- Secure landfills: For hazardous waste.



Cross section of a typical engineered landfill
Source: http://waste.snu.ac.kr

Introduction: Evolution of landfills (definitions adapted from the World Bank technical paper No. 26)

- Open dumping: Uncontrolled dump causing h
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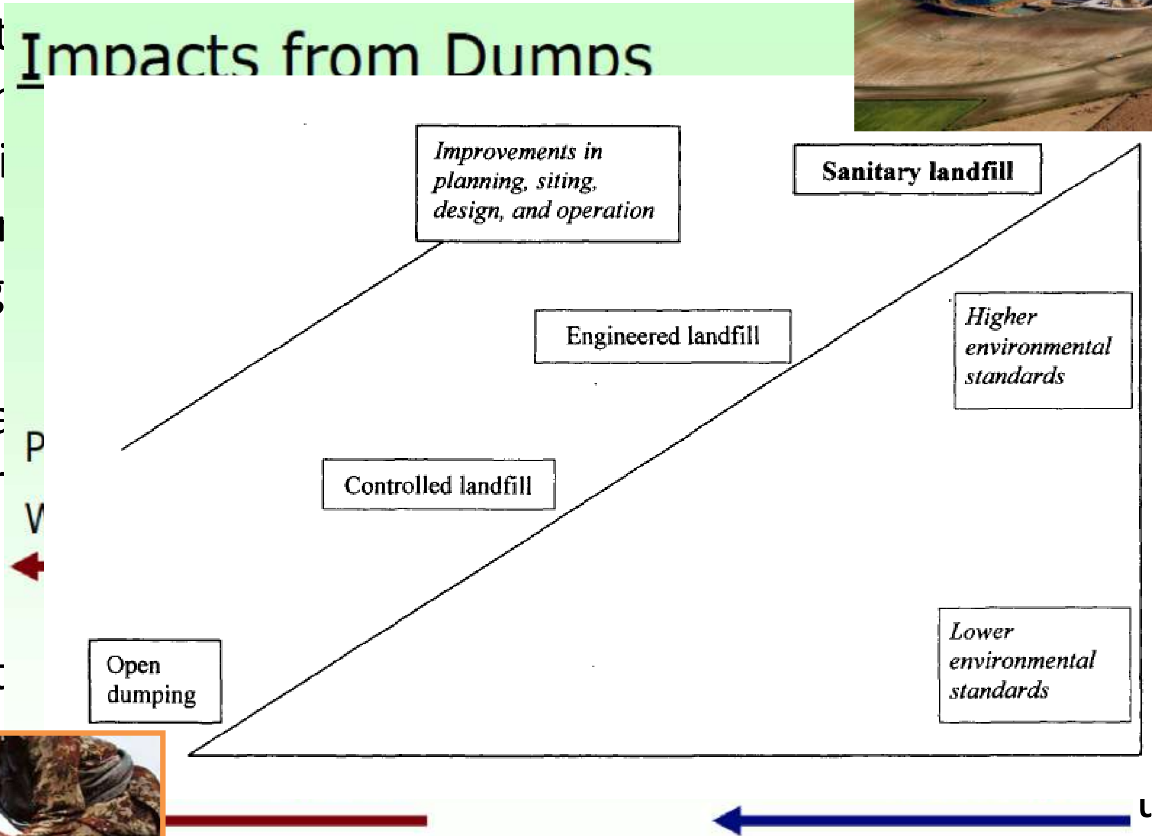

and environmental monitoring…etc.

Source: Haubrichs, Sanitary landfill Design, waste and water environmental engineering

Introduction: Landfills and their minimum requirements

- Sanitary landfill implementation, therefore, requires careful site selection, preparation and management.

- There are four minimum requirements to be considered:
  - Full or partial hydrological isolation (usually using liners)
  - Formal engineering preparation
  - Permanent control
  - Planned waste emplacement and covering

- These issues are discussed by addressing
  - Landfill principles
  - Landfill process

Landfill Principles (source: Municipal solid waste management, unit 4: waste disposal)

Purpose: To bury or alter the chemical composition of the waste so as not to pose any threat to public and environmental health.

Landfills are *NOT* homogeneous and are made up of ***cells.*** *Cells are discrete volumes of waste, kept isolated from adjacent waste cells using suitable barriers.*

Landfilling most commonly ***relies on containment rather than treatment*** (for control) of waste. If executed appropriately, it can be safer and cheaper than incineration.

An environmentally sound landfill comprises appropriate liners for the protection of groundwater, run-off controls, leachate collection and treatment, monitoring wells and appropriate final cover design (Phelps, 1995)

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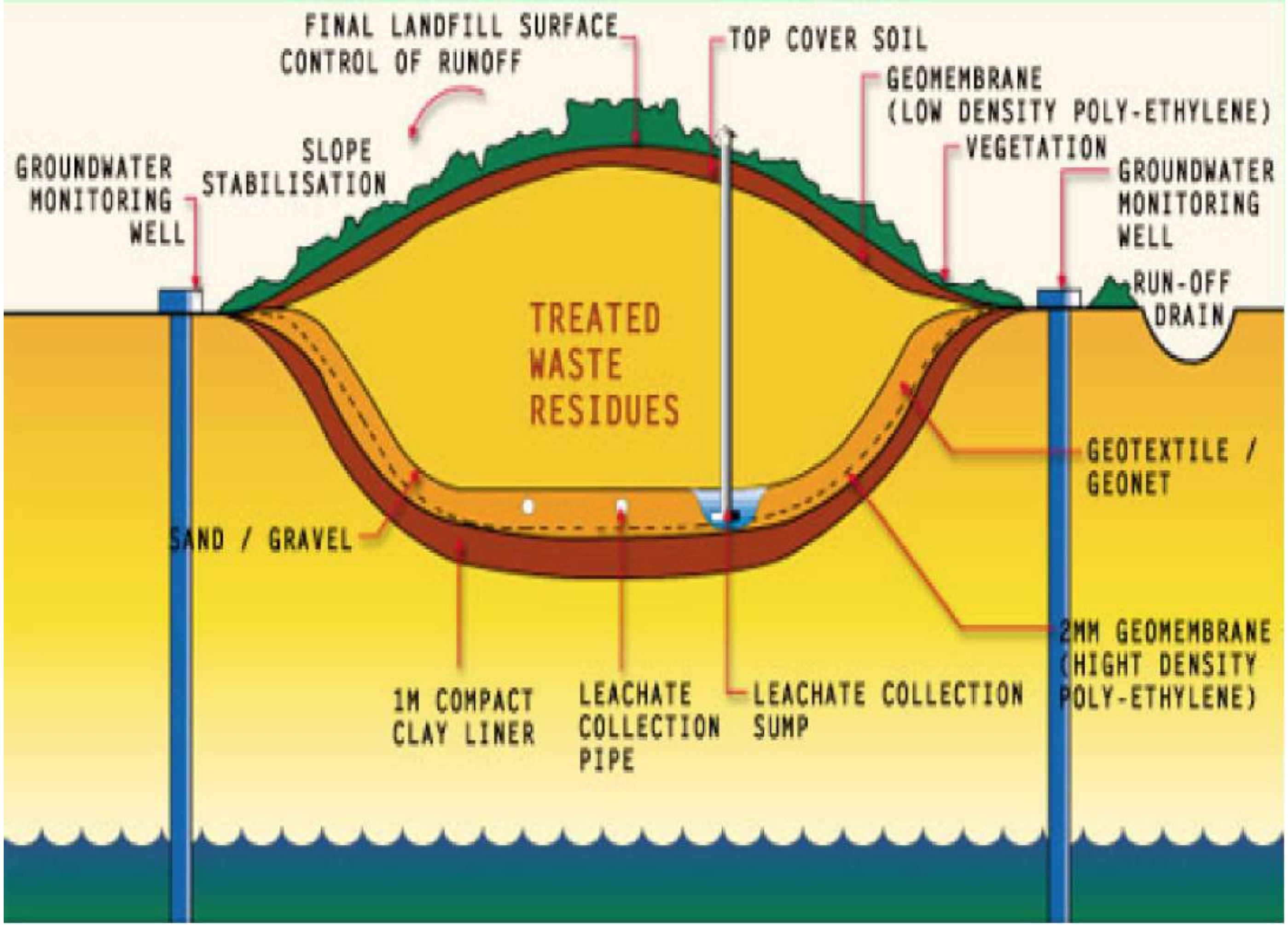
Landfill Principles



Source: Haubrichs, Sanitary landfill Design, waste and water environmental engineering

Landfill Principles: life cycle and costs

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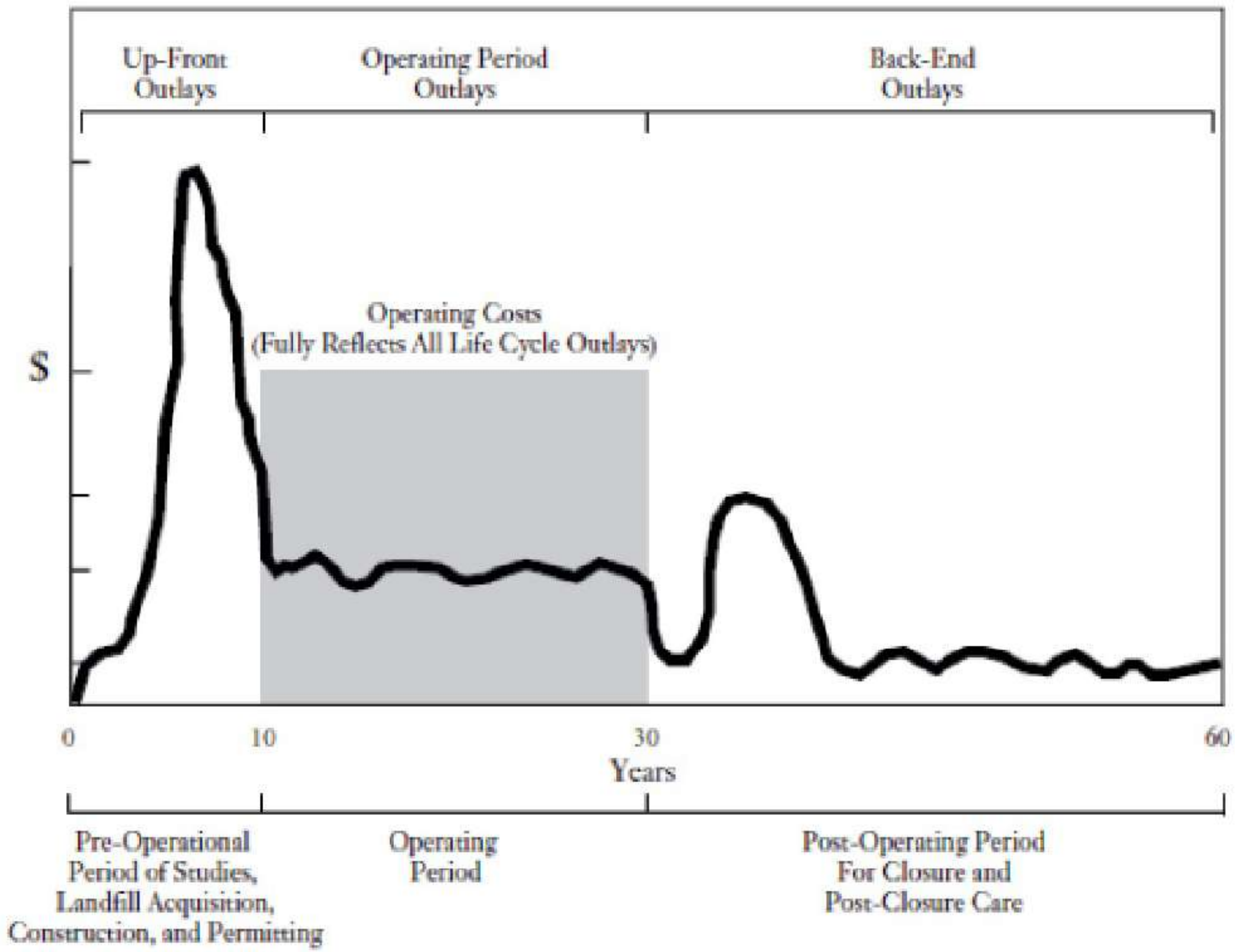

Source: https://foresternetwork.com/wp-content/uploads/ms1611_26.jpg

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Landfill Processes: Site selection process

Site selection process and consideration require a working plan or a series of plans outlining the development and descriptions of site location, operation, engineering and site restorations.

Site selection considerations include

- Appropriate location e.g. far from airports, flood plains
- Land availability
- Soil conditions and topography
- Geological conditions e.g. unstable areas, seismic activity
- Hydrologic conditions e.g. surface and ground water
- Climatic conditions e.g. rainfall and wind
- Environmental and ecological conditions e.g. endangered species..etc.
- Minimise haul distance
- Large enough site to accommodate the SW needs of the service area
- Compatible with local SWM programmes
- Minimise adverse effects on surrounding area and property value
- Minimise impacts on traffic flow
- Minimise potential for fire, spill, accidents e.g. outside flood zones
- Public input and concerns
- Potential use after closur

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Landfill Processes: Settling process

Primary consolidation

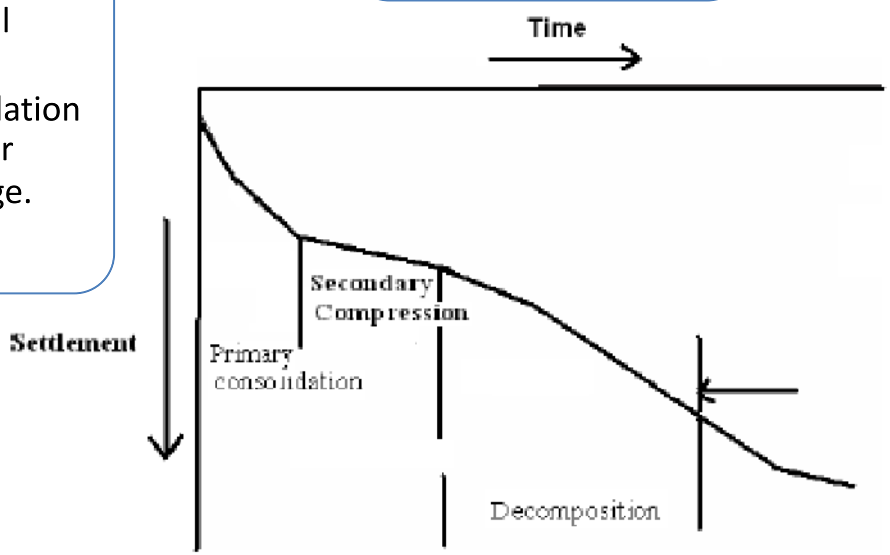
- Short-term deformation stage with substantial settling.
- It results from the weight of the waste layers and the movement of trucks, bulldozers and mechanical compactors.
- Aerobic degradation processes occur during this stage.

Secondary compression

- Rate of settling is much lower than primary consolidation.
- Settling occurs due to compression which can't be enhanced.

Decomposition

- During this process, organic material is converted into gas and leachate.
- The settling rate increases compared to secondary compression and continues until the OFMSW has degraded.
- The settling rate gradually decreases with the passage of time.



Source: Municipal solid waste management, unit 4: waste disposal

Landfill Processes: Microbial degradation process

This process is the most important biological process occurring in a landfill. These processes ***induce changes in the chemical and physical environment*** within the waste body which determine the ***quality of leachate and both the quality and quantity of landfill gas (LG)***.

Assuming that landfills mostly receive organic wastes, microbial processes will dominate the stabilisation of the waste and will thus govern LG generation and leachate composition.

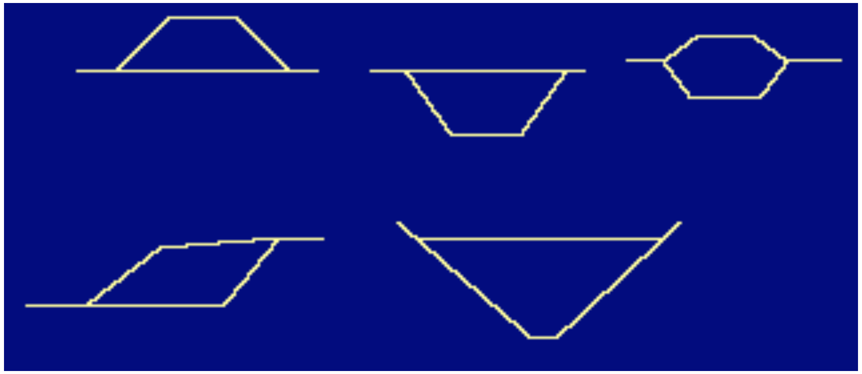
After waste disposal in the landfill, the predominant part of the waste degradation becomes anaerobic, where, bacterial will degrade the solid organic carbon eventually to produce carbon dioxide and methane. This process can be enhanced using:

- Adding partly composted waste
- Recirculating leachate

Source: Municipal solid waste management, unit 4: waste disposal)

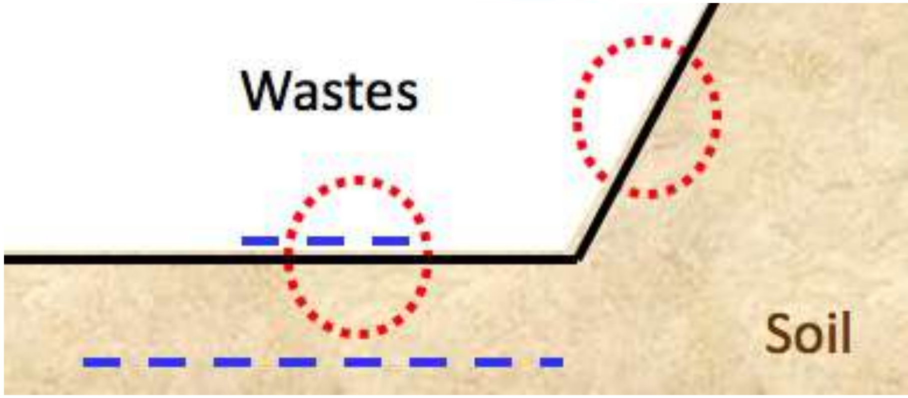
Design considerations

- The design should be acceptable to the public (hide/keep distance).
- The shape of the area has major impacts on the design of the landfill.



- Appropriate gas collection systems and leachate management systems should be employed
- Limit negative environmental impacts by limiting the transport of pollutants by constructing liners and waste covers.
- Additional facilities may be included such as fences, rainwater drainage ditches, leachate and LFG treatment facilities, groundwater monitoring wells…etc.

Design considerations Landfills = Containment



Passive Barrier
+
Active Barrier

Passive Barrier: Protects the bottom/side layer (in contact with the soil)

- Geological barrier formed with natural material that is found in-situ or brought in
- Material with low permeability
- Must not be sollicitated

Active Barrier: Protects the top layer (in contact with the waste)

- Synthetic membrane (liners)
- Drainage and leachate collection systems

Design considerations: Liner systems

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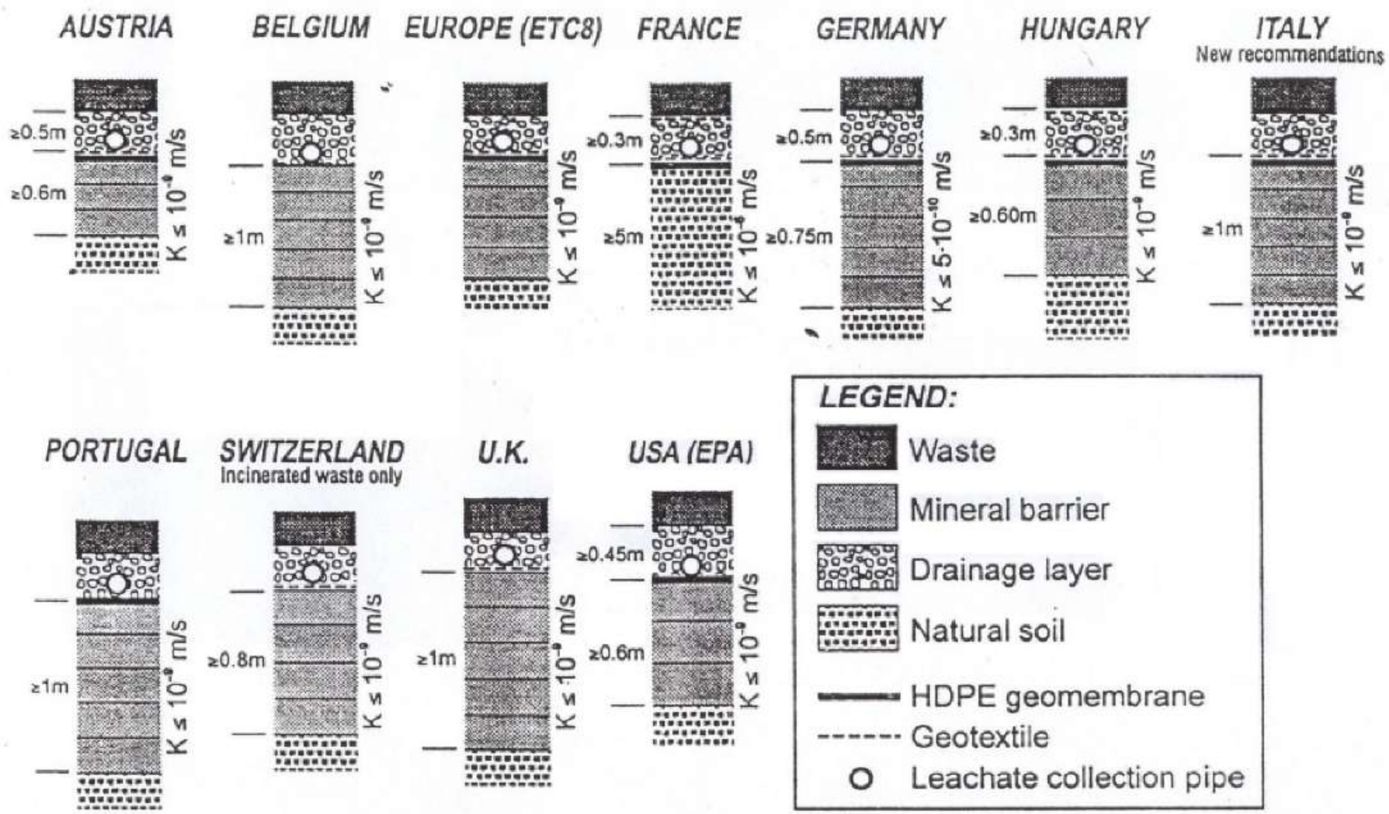
Source: Seoul National University; Design, operation and management of solid waste landfills; Laboratory of waste management and resource recirculation

Design considerations: Standards for liner systems



Bottom lining systems for municipal waste landfills from different regulations and recommendations

Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

Design considerations: Landfill gas and Leachate

- LFG and leachate resulting from the degradation of the OFMSW are considered a major hazard associated with landfills and can contaminate soils, water and air.

- Factors that affect the production of LFG and leachate include:
  - Nature of the waste i.e. the content of biodegradable material.
  - Moisture content since most microorganisms require a minimum of 12% moisture for growth.
  - pH: The bacteria producing methane gas will only grow around a neutral pH.
  - Particle size and density which affect the surface area and volume which in turn affect moisture absorption and rate of degradation.
  - Temperature which affects the .optimum operating conditions for different types of bacteria

- ***Note:*** In the past, it was believed that in a closed landfill, leachate was only generated by the percolation of precipitation. However, leachate will be generated irrespective of whether there is precipitation or not.

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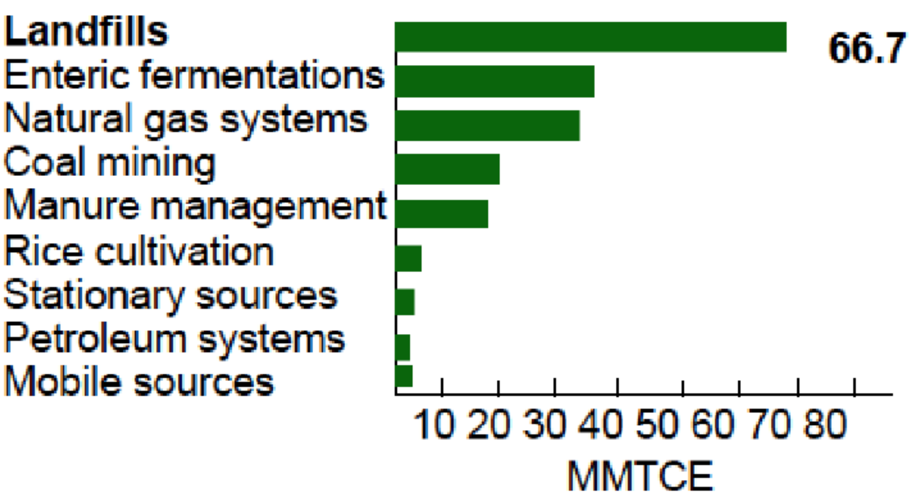
Design considerations: Landfill Gas Collection System

- Methane gas is emitted to the atmosphere from natural wet lands, rice paddy fields, gas and oil wells, landfills…etc.
- Among the emission sources, landfills are the most dominant anthropogenic source.

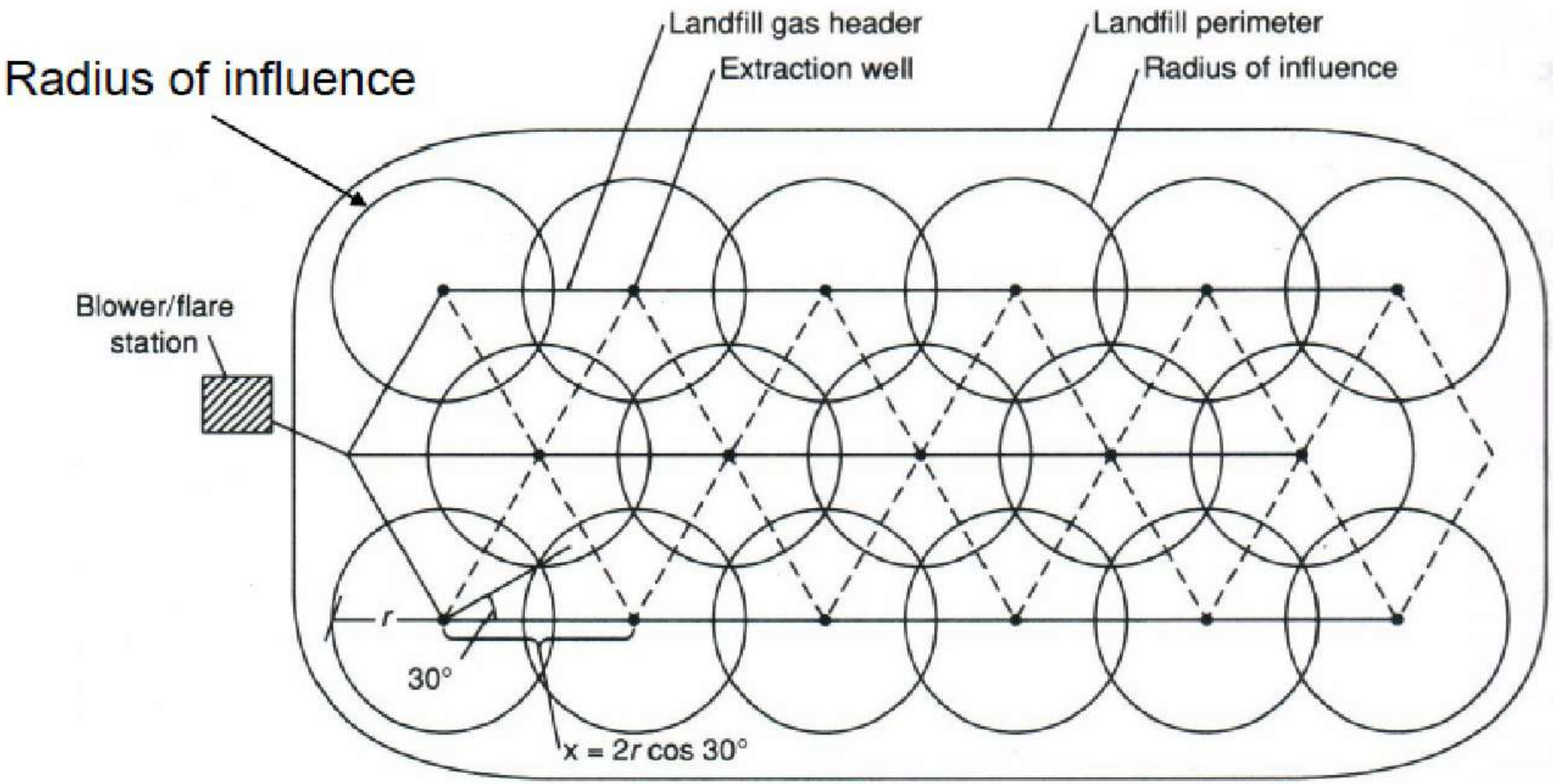


Gas	GWP	Lifetime (years)
CO_2	1	Variable
CH_4	21	12
N_2O	310	120
PCFs	140	6,300
HCFs	6,500	9,200
SF_6	23,900	3,200

Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

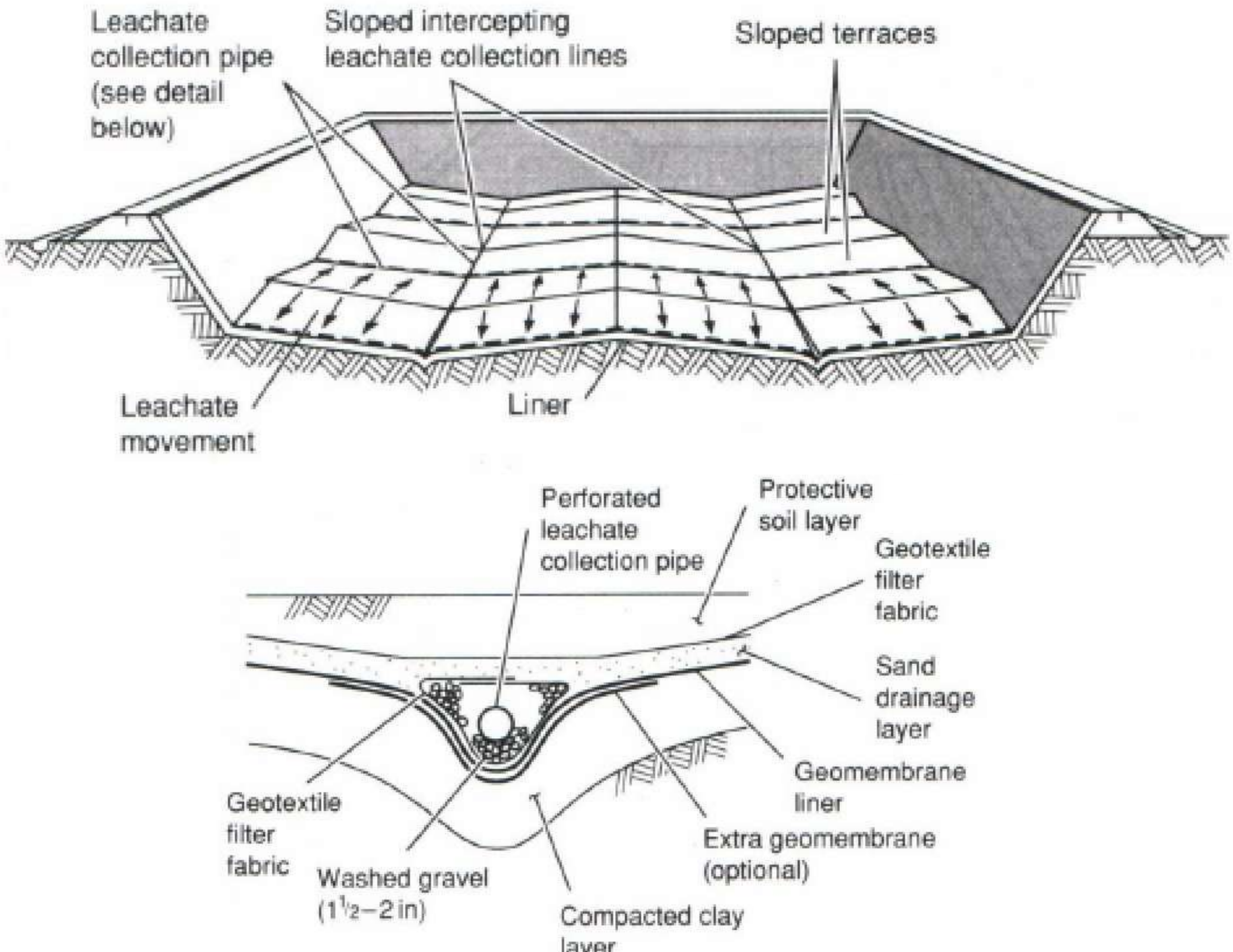
Design considerations: Landfill Gas Extraction Wells

Equilateral triangular distribution for vertical gas extraction wells



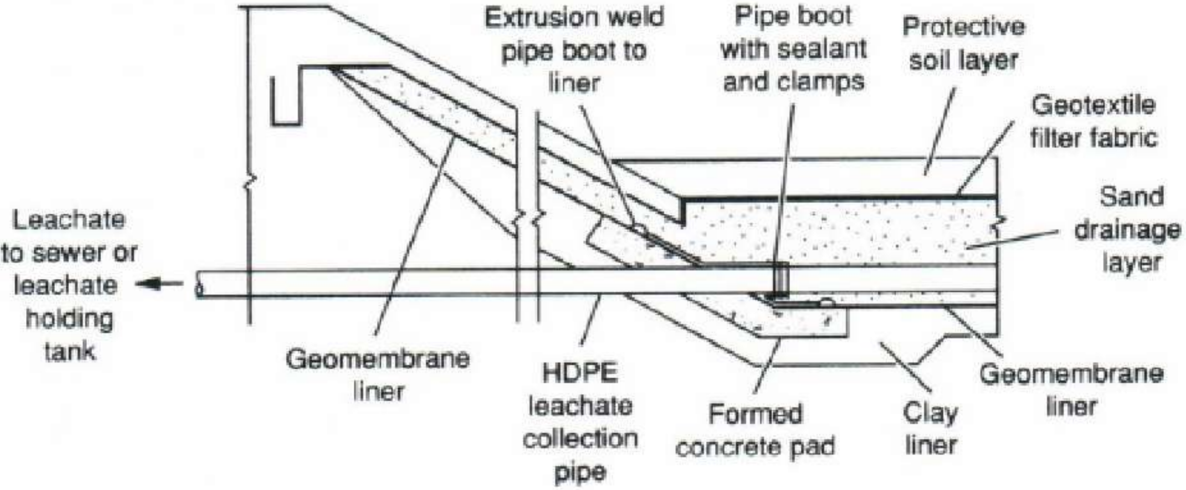
Source: Seoul National University Laboratory of waste management and resource recirculation;
Design, operation and management of solid waste landfills

Design considerations: Leachate Collection System

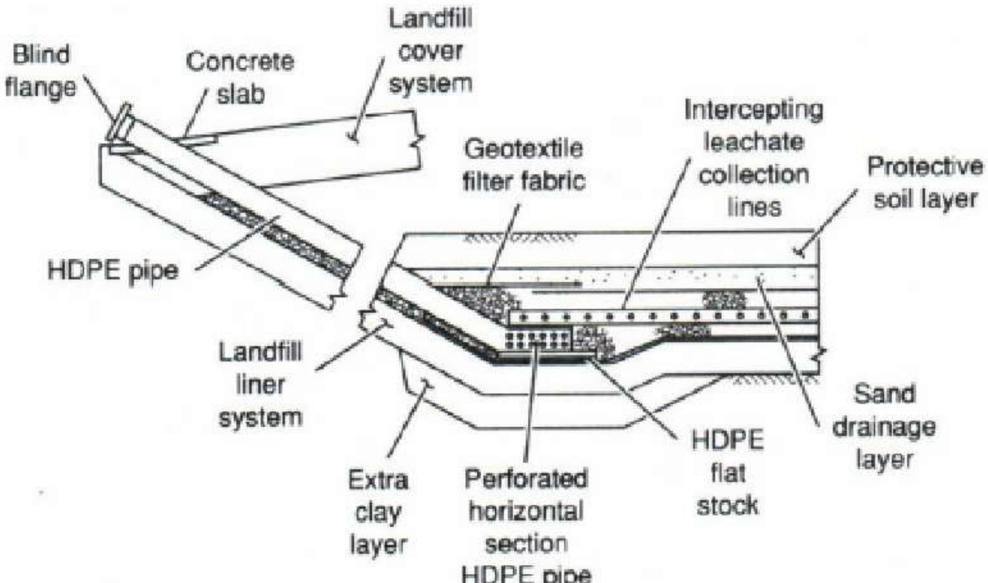


Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

Design considerations: Leachate Collection System



Source: CH2MHILL; Understanding leachate generation and management



Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

Design considerations: Covers

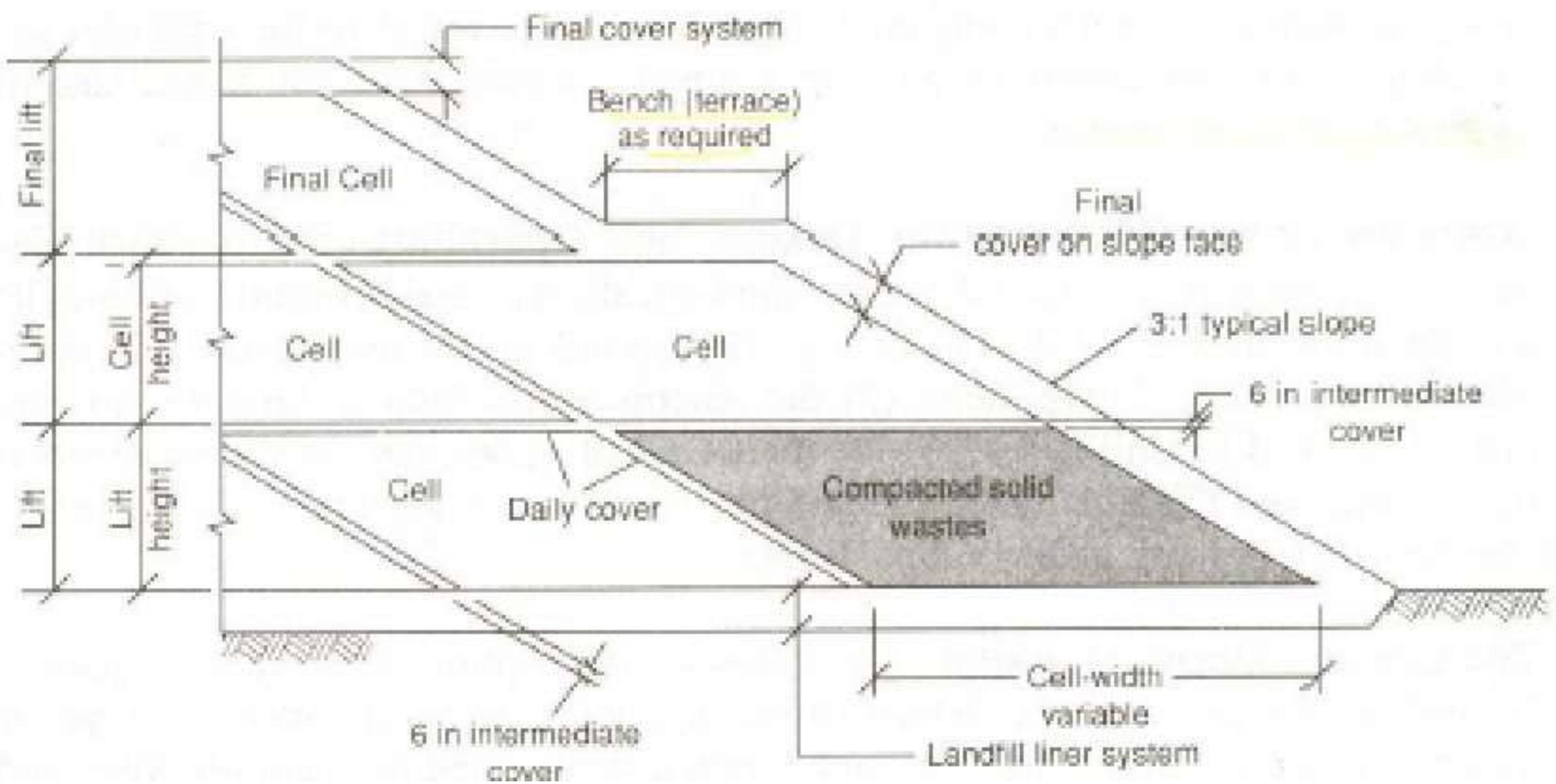
Two types of covers:

Daily/intermediate cover	Final cover
Protects against: • The scattering of waste • Odours • Insect pests and animals • Rainwater drainage • Accessibility • Aesthetic	Protects against: • Rainwater drainage • Gaseous contaminants • Vegetation (erosion, aesthetics) • LFG control (fire) • Insect pests and animals

*Intermediate cover needs better accessibility of heavy equipment

Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

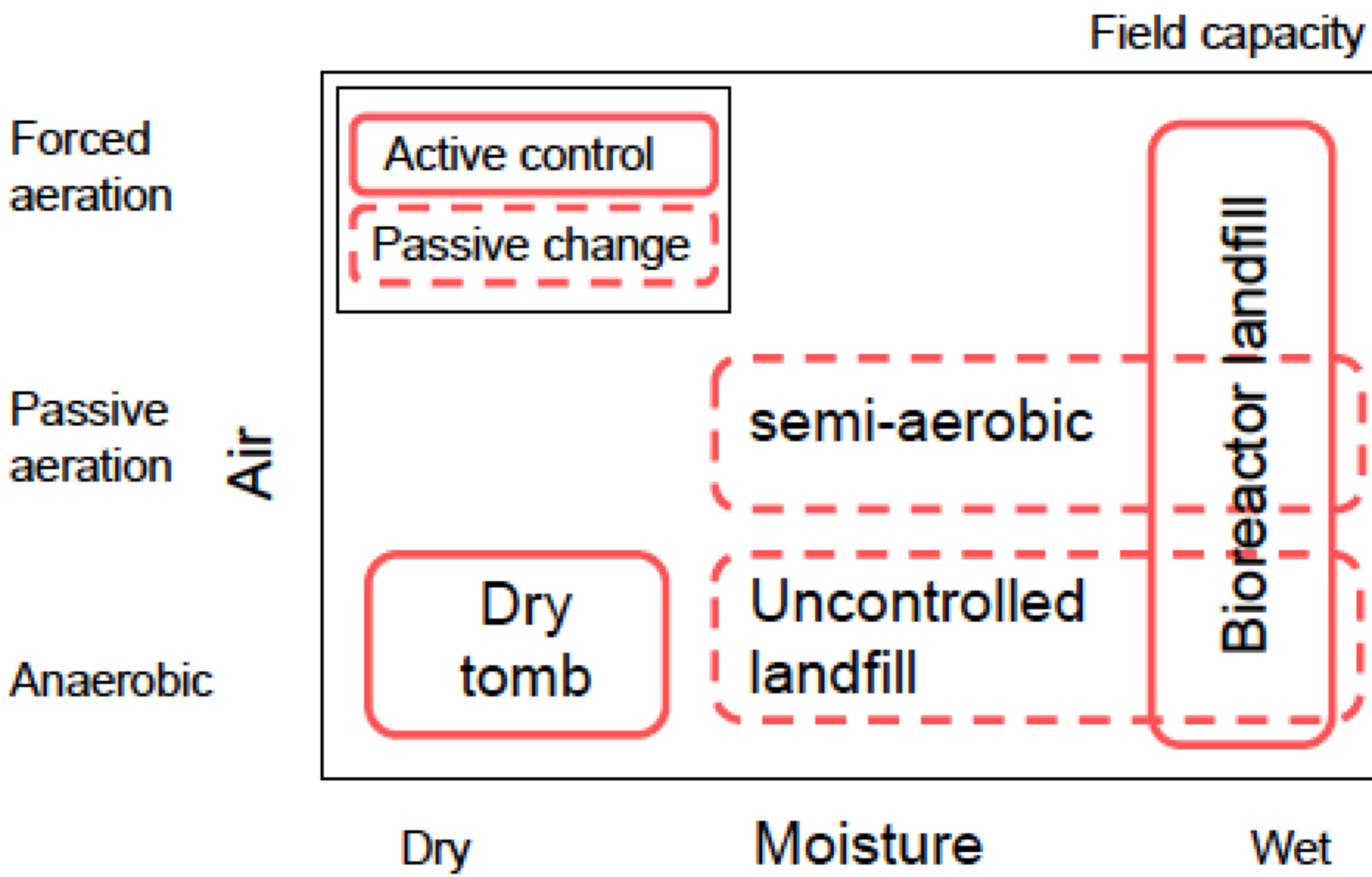
Design considerations: Covers



Source: Seoul National University Laboratory of waste management and resource recirculation; Design, operation and management of solid waste landfills

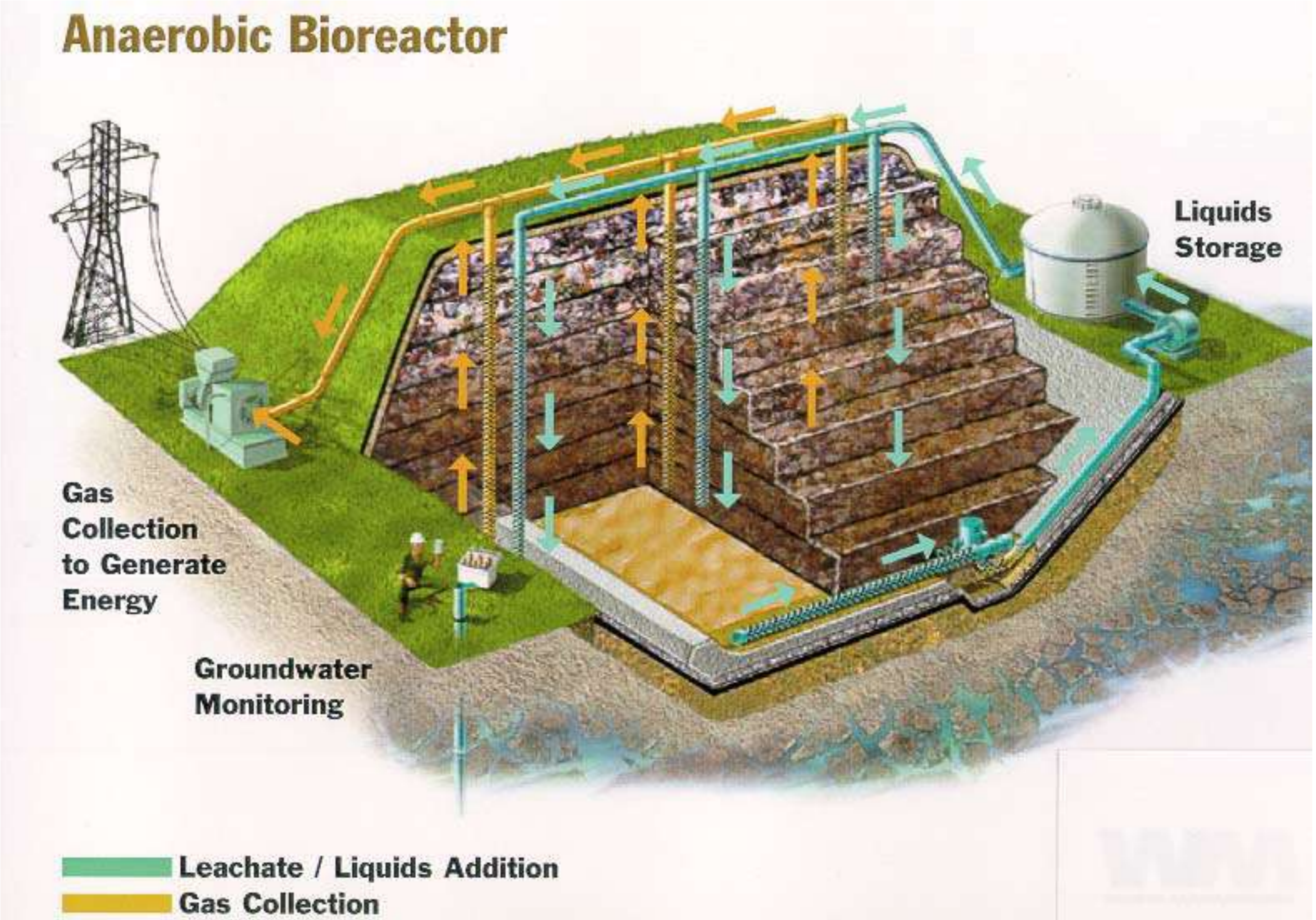
Emerging Technologies in Landfills: Selected cases (Source: Seoul National University; Design, operation and management of solid waste landfills; Laboratory of waste management and resource recirculation)

Landfill classifications



Emerging Technologies in Landfills: Selected cases

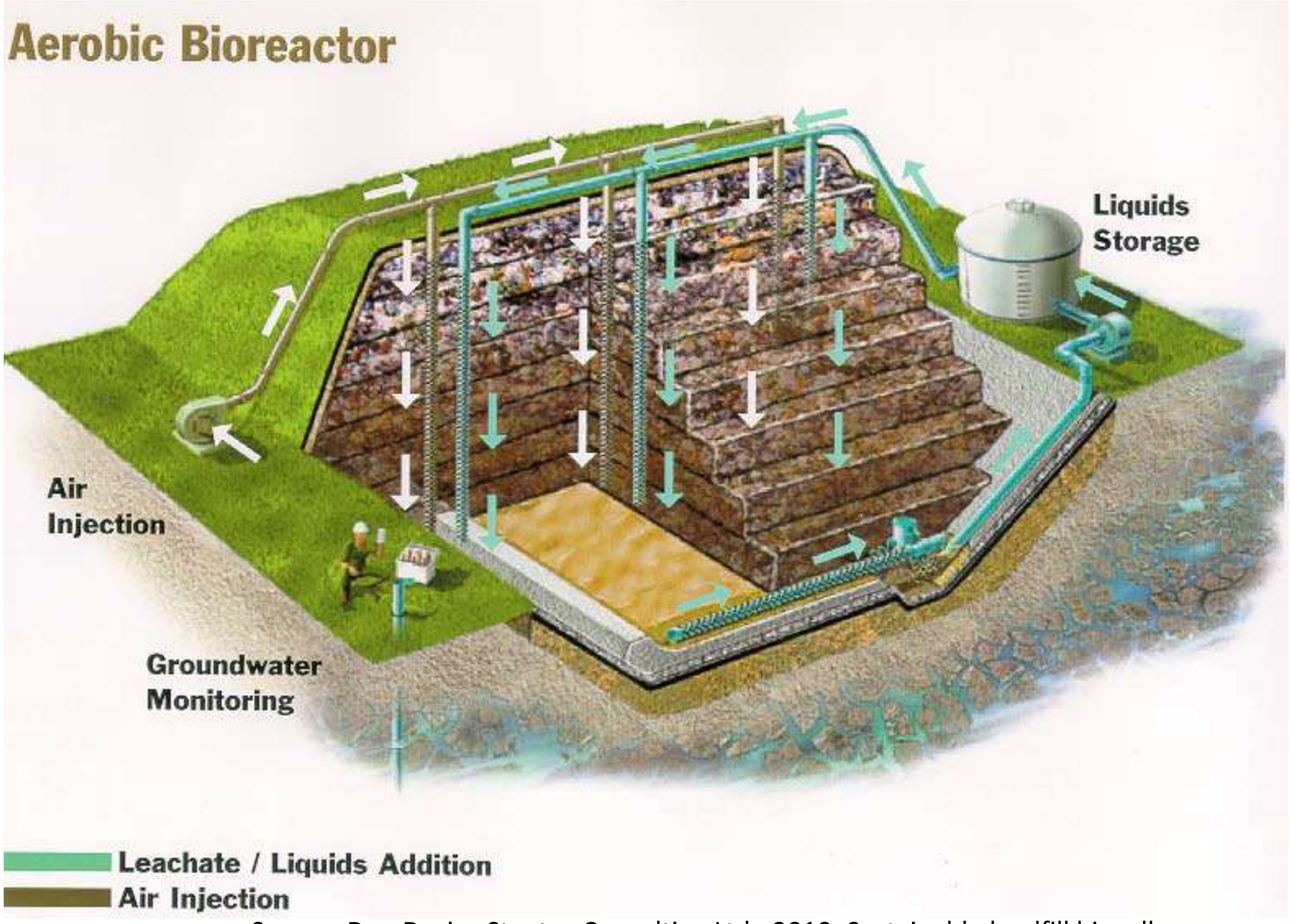
Bio-reactor landfill (anaerobic bioreactor)



Source: Don Davies Stantec Consulting Ltd.; 2010; Sustainable landfill biocell

Emerging Technologies in Landfills: Selected cases

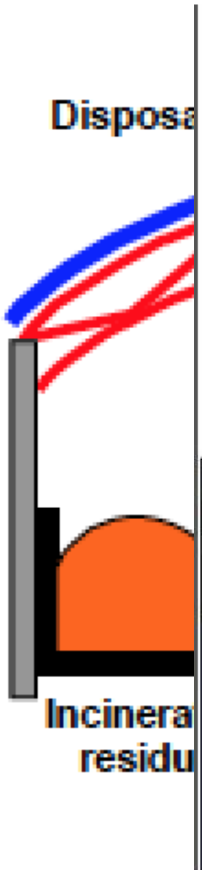
Bio-reactor landfill (forced aeration)

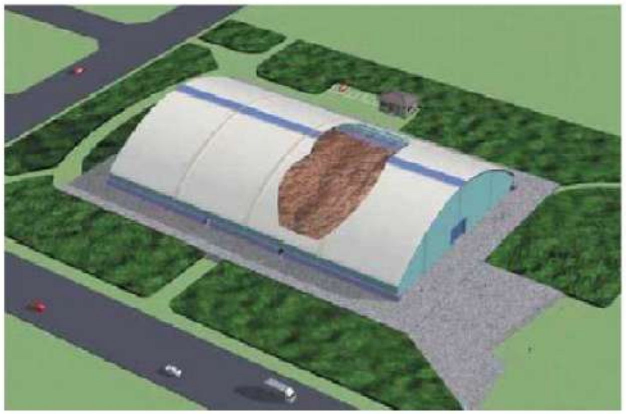


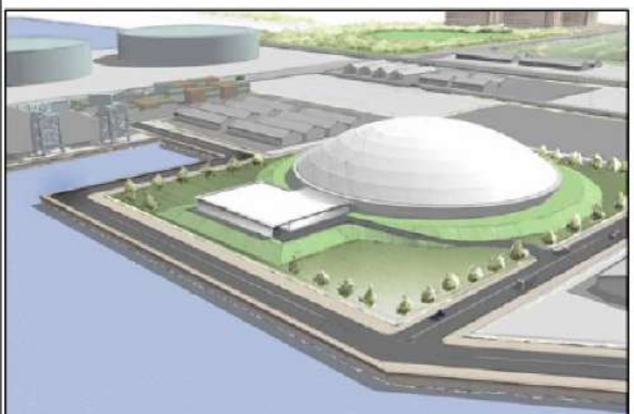
Source: Don Davies Stantec Consulting Ltd.; 2010; Sustainable landfill biocell

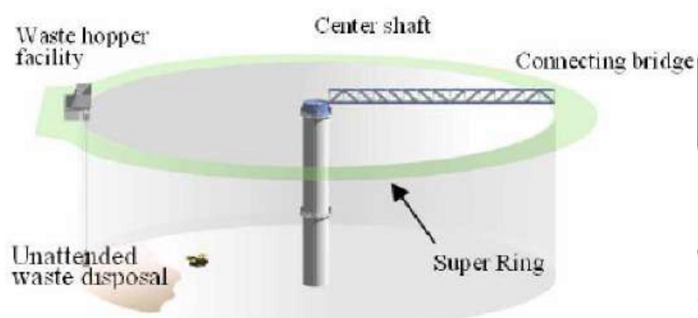
Emerging Technologies in Landfills: Selected cases (Source: Seoul National University; Design, operation and management of solid waste landfills; Laboratory of waste management and resource recirculation)

Closed landfill – steel cover









Emerging Technologies in Landfills: Selected cases (Source: Seoul National University; Design, operation and management of solid waste landfills; Laboratory of waste management and resource recirculation)

Offshore disposal sites

Figure 1. Pulau Semakau (Singapore)

Figure 2. Amagasaki (Japan)