

Solid waste management

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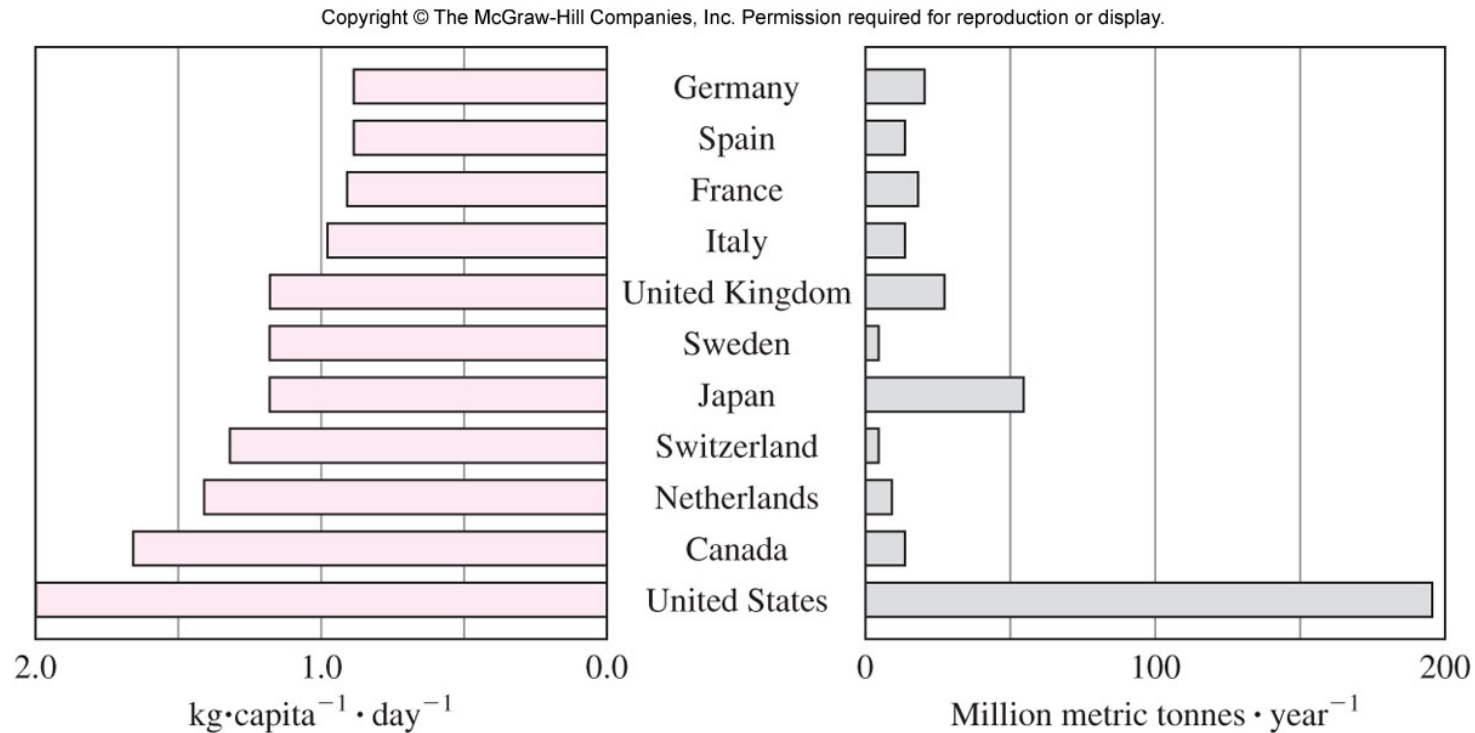
- Magnitude and sources of solid wastes
- Classification of solid wastes
- Fate of solid wastes
- Solid waste management
 - Recycling
 - Composting
 - Incineration
 - Sanitary landfill

Solid waste

- Things we throw away
- Called garbage, refuse, trash



Magnitude of the problem



(2010)

Korea: $0.95 \text{ kg} \cdot \text{capita}^{-1} \cdot \text{day}^{-1}$ (2012)

Sources of solid wastes

Source	Typical facilities, activities, or locations
Residential	Homes
Commercial	Stores, restaurants, markets, office buildings, hotels, etc.
Institutional	Schools, hospitals, prisons, government buildings
Construction	New construction sites, road repair sites, demolition of buildings
Municipal services	Street cleaning, landscaping, parks and beaches, waste and wastewater treatment processes
Industrial	Construction, fabrication, manufacturing, refineries, chemical plants, power plants
Agricultural	Crop field, rice paddies, orchards, animal farms

Classification of solid wastes

- The regulation, classification, and management of solid wastes varies for different countries
- Classification system in Korea
 - By sources
 - Residential daily waste
 - Industrial and commercial waste
 - By hazard
 - Non-designated waste
 - Designated waste

Solid waste classification in Korea

- By sources
 - Residential daily waste
 - 1) Non-recyclables: not classified into any of below; collected in plastic bags
 - 2) Recyclables: paper, metals, plastics, PET, glass, Styrofoam, clothes
 - 3) Food waste: collected in plastic bags or containers designated to collect food waste
 - 4) Bulky waste: furniture, home electronics, etc. - collected separately

Solid waste classification in Korea



Solid waste classification in Korea

- Industrial and commercial waste

- 1) Daily industrial and commercial waste:
everyday waste generated from offices, restaurants, etc.
(waste characteristics are similar to the residential daily waste)

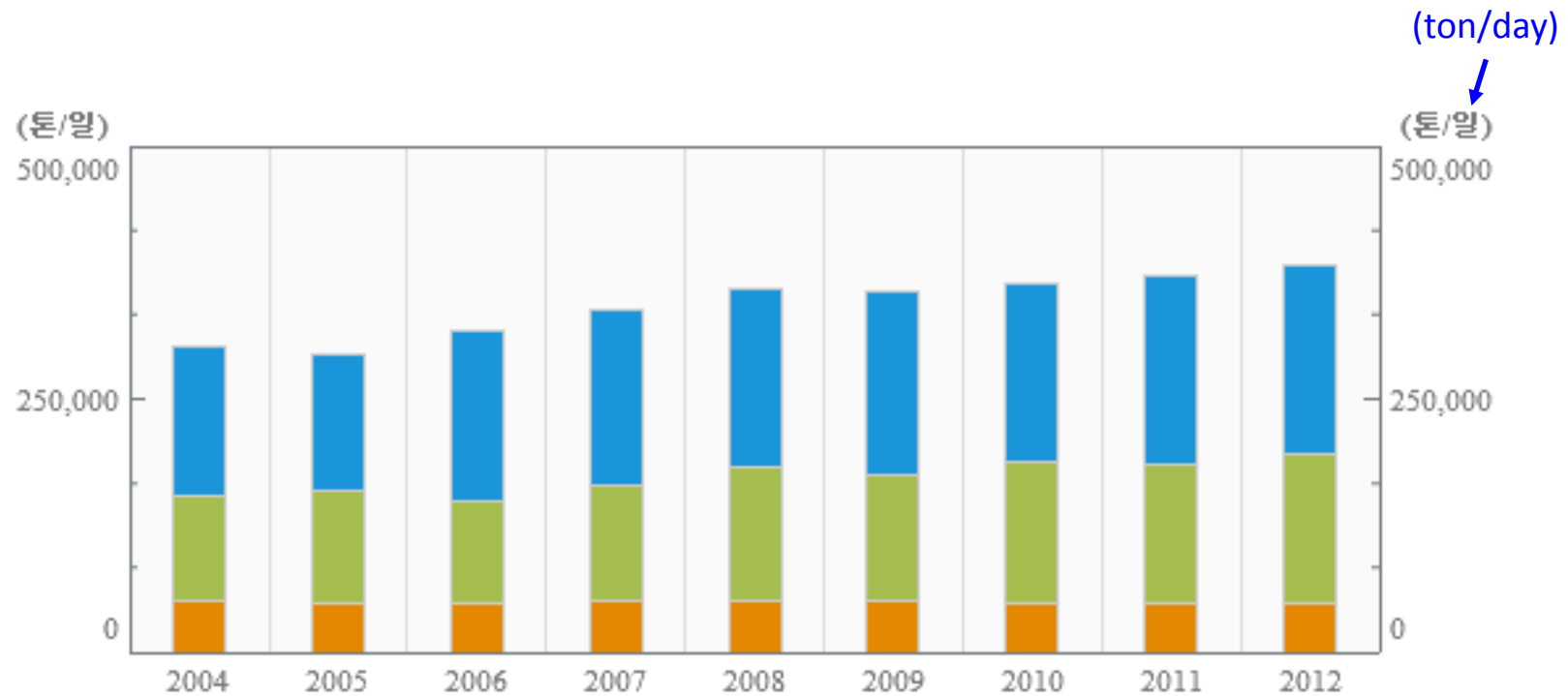
- 2) Emission facility waste:
waste generated from designated emission facilities
(specific waste characteristics depending on the facility)

- 3) Construction waste:
construction or demolition of buildings, plants, roads, bridges, etc.

Solid waste classification in Korea

- By hazard
 - Non-designated waste
 - Designated waste: wastes generated from industrial and commercial facilities that are expected to have significant environmental impact
 - Waste acid, alkali, oil, organic solvent, polymer, asbestos, minerals, particulates, incineration residue, sludge, etc.
 - Medical waste
 - Any waste that are determined to release a significant concentration of hazardous compounds by a leaching test

Waste generation in Korea



Residential daily waste
(가정생활계폐기물)

Industrial & commercial waste
neither classified as designated
waste nor construction waste

Construction waste

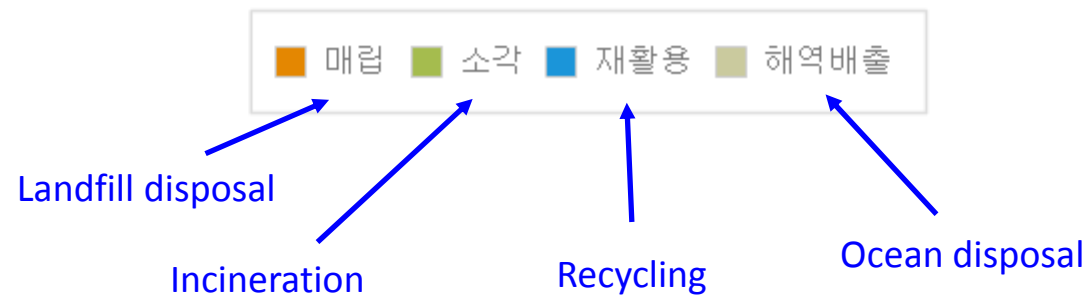
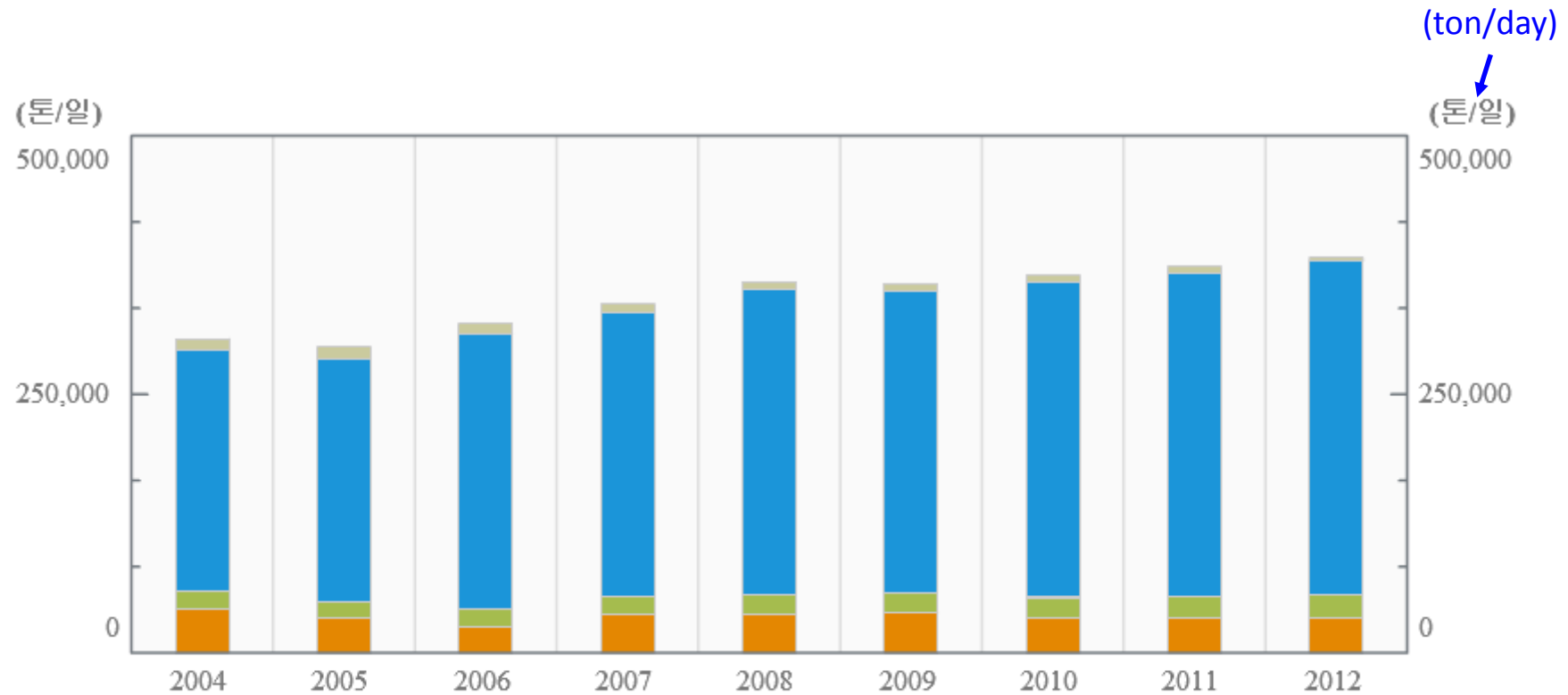
Fate of residential daily wastes (Korea)

- Non-recyclables: collected by trucks → mostly landfilled or incinerated
- Recyclables: collected by trucks → recycling center for further classification → industrial consumers
- Food wastes: collected by trucks → food waste resource center (generate resources such as animal feed, compost, or fuel) → the resources are sent to consumers, and the final wastes are landfilled or incinerated

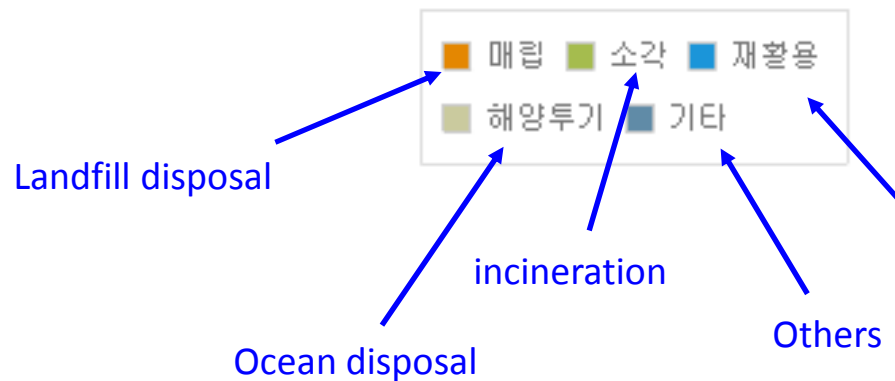
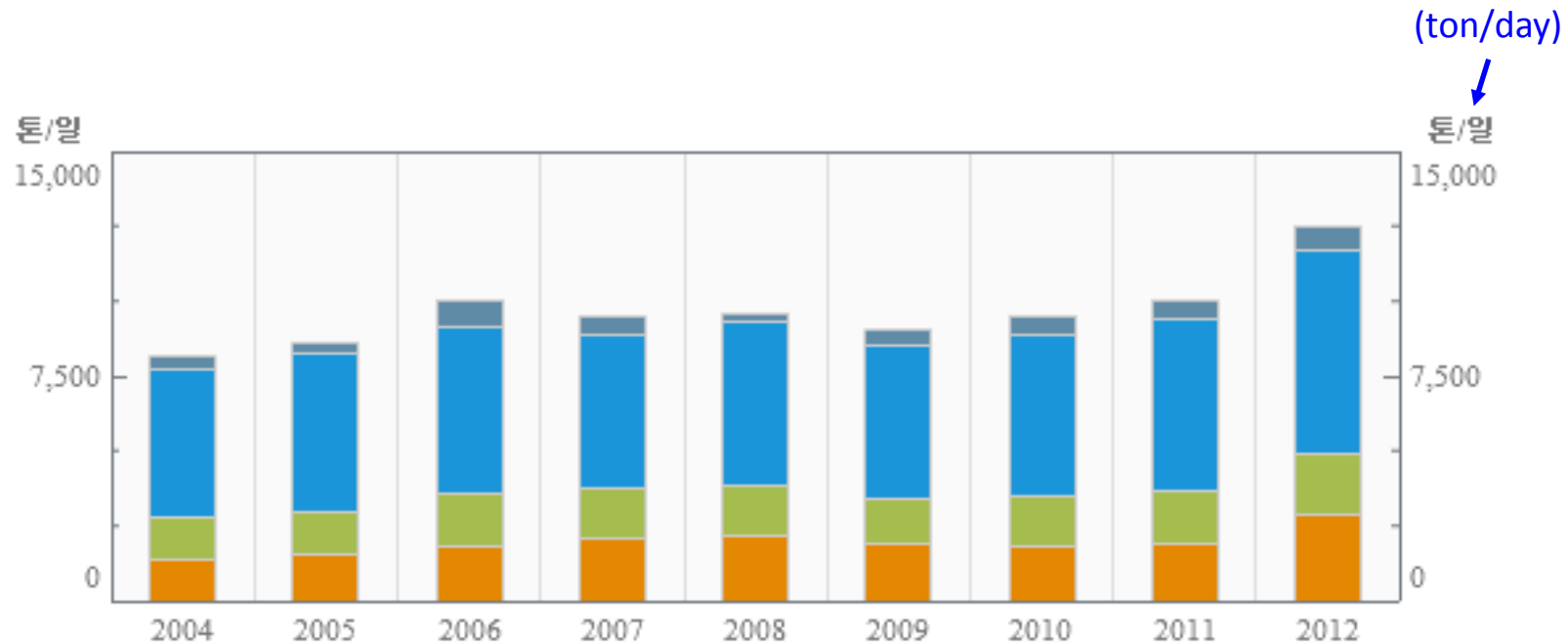
Fate of industrial & commercial wastes (Korea)

- Daily industrial and commercial wastes: combined with daily residential waste
- Other industrial and commercial wastes
 - Non-designated waste: mostly recycled (ex: construction waste – recycled as construction materials)
 - Designated waste: treated by specific procedures, recycled, incinerated or disposed in secure landfills

Statistics – fate of non-designated wastes in Korea



Statistics – fate of designated wastes in Korea



Reduce, reuse and recycling (3R)

- Reduce: minimize the production of wastes (most preferred)
- Reuse: use products or materials again for the same purpose for which they are intended
- Recycle: collect used, reused, or unused items, make them into raw material, and re-manufacture the raw material into new products

Recycling

- Closed-loop (primary) recycling
 - Use of recycled products to make the same or similar products
 - Example: use of used glass bottles to make new glass bottles
- Secondary recycling
 - Use of recycled products to make new products with different characteristics than originals
 - Example: use of polyethylene milk jugs to make toys
- Tertiary recycling
 - Use of recycled products to recover chemicals or energy
 - Example: recovery of solvents from manufacturing with distillation so they can be reused in same or other operations

Composting

- Controlled decomposition of organic materials such as plant materials, animal waste, food waste, and wastewater sludge by microorganisms
- By the composting process, the microorganisms degrade easily degradable organic materials, odor-generating compounds, and toxic compounds into stable and non-toxic materials
- The product is a crumbly, earth-smelling, soil-like material that can serve as carbon and nitrogen source for crops

Incineration (combustion)

- Definition: a chemical reaction in which the elements in materials are oxidized in the presence of excess oxygen
- Effective for reducing the amount of solid wastes
- Major elements to be oxidized: carbon and hydrogen (and some sulfur) → major product of oxidation: CO_2 and H_2O (and some SO_2)

Incineration (combustion)

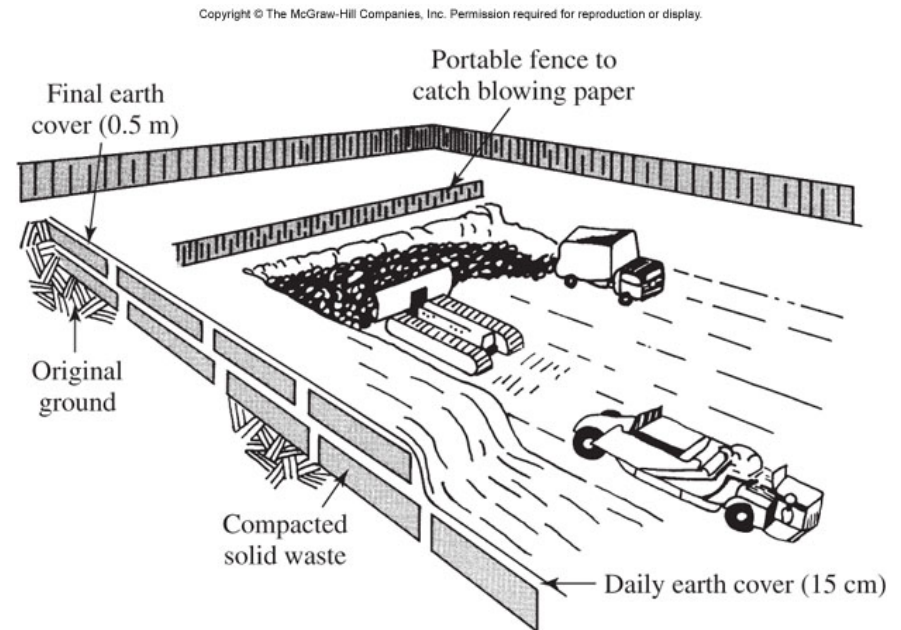
- Advantages
 - Can minimize the solid waste generation → save landfill space (good when land use is restricted)
 - Can recover heat (energy) from waste if the waste has a relatively high heating value
- Disadvantages
 - Requires additional energy input if wastes have low heating value
 - Health and environmental issues
 - Emission of air pollutants such as particulates, acid gases (SO_x , HCl , HF), NO_x , CO , organics, heavy metals
 - Emission of carcinogenic compounds such as dioxins and PAHs (polycyclic aromatic hydrocarbons)

Sanitary landfill disposal

- Landfill of some solids wastes is inevitable
- Landfill site selection is not easy (esp. in Korea!)
- Things to consider for site selection
 - Restricted locations, including wetlands, flood plains, seismic impact areas
 - Public opposition
 - Proximity to major roadways
 - Load limits on roads and bridges
 - Underpass limitations
 - Traffic patterns and congestion
 - Location of groundwater table and sole-source aquifers
 - Soil conditions and topography
 - Availability of cover material
 - Climate
 - Zoning requirements
 - Buffer areas surrounding the site
 - Location of historic buildings, endangered species, and similar environmental factors

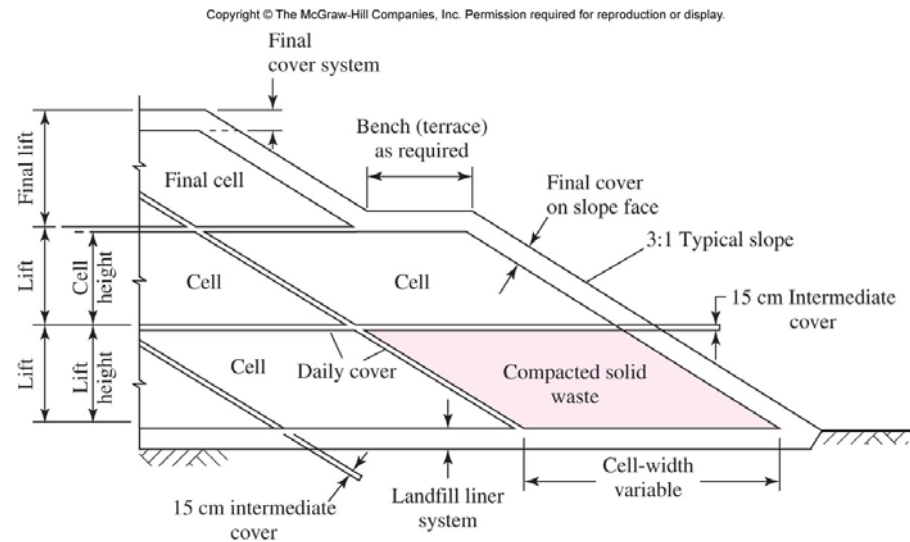
Operation of sanitary landfills

- Area method
 - Most common method of operation
 - Three step process (usually done on a daily basis)
 - Spread the waste
 - Compact the waste
 - Cover the waste with soil (daily cover)



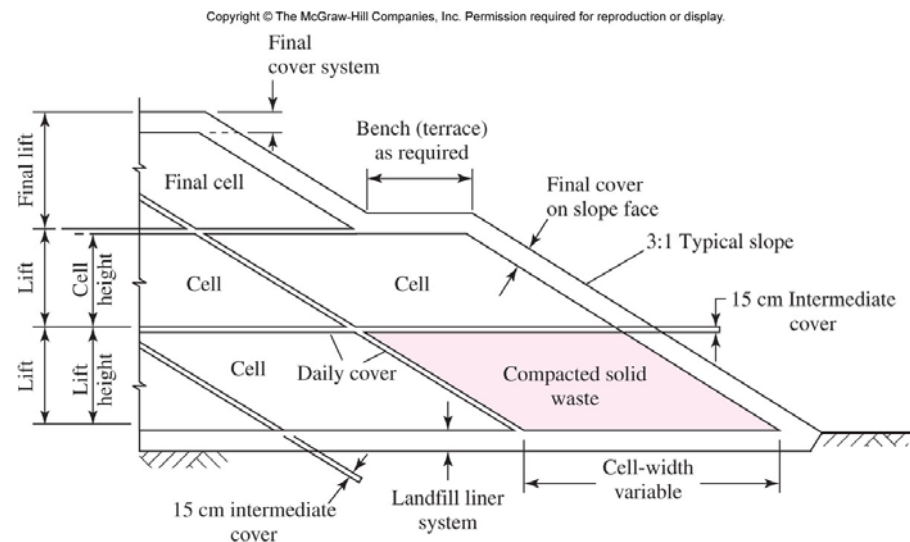
Operation of sanitary landfills

- Area method
 - The waste and daily cover placed in a landfill during one operational period (commonly one day) form a **cell**.
 - The waste is dumped onto the working **face**.
 - A **lift** refers to the placement of a layer of waste or the completion of a horizontal active area of the landfill



Operation of sanitary landfills

- Area method
 - The first lift is called a **fluffy lift** because the waste is not compacted until 2 m of waste is deposited. This is done to protect the liner.
 - **Benches** are used where the height of the landfill > 15-20 m.
 - The **final cover** is applied after all land-filling operations are complete.



Landfill leachate

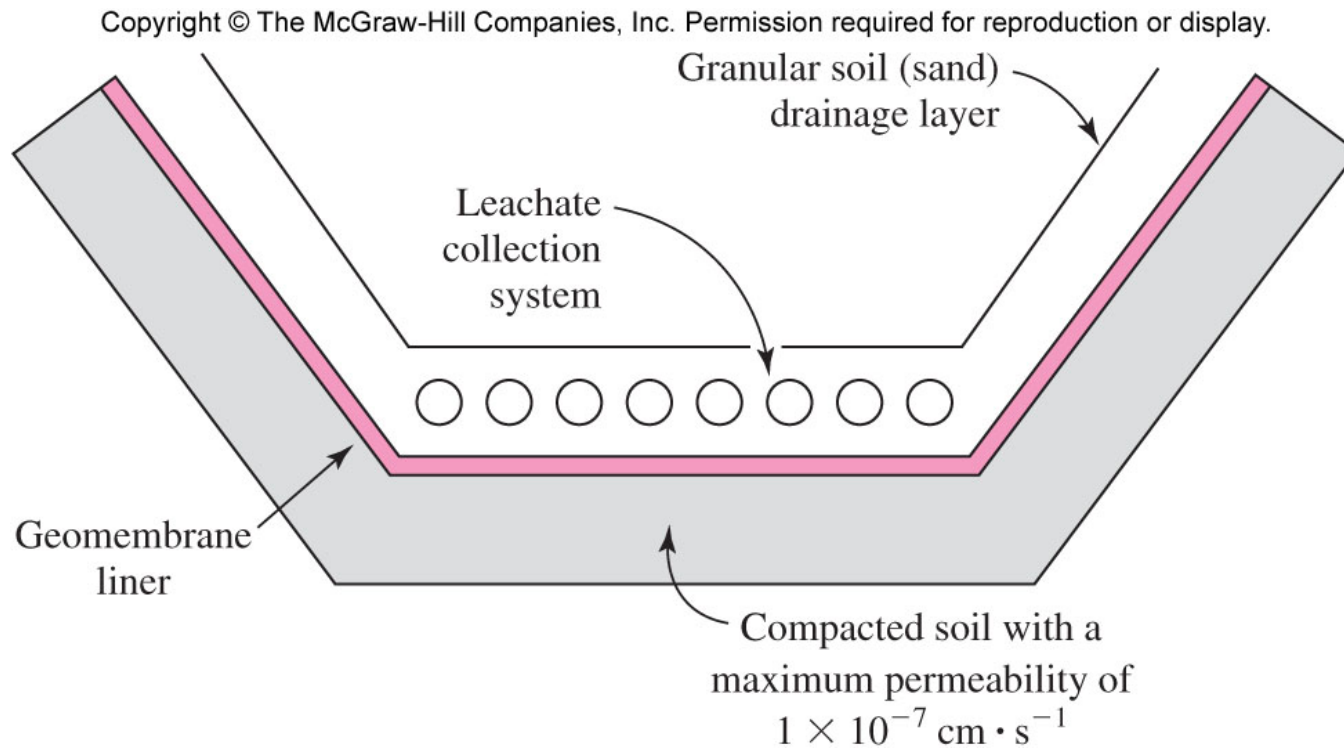
- Leachate is the liquid that passes through the landfill, extracting dissolved and suspended matter from the landfill.
- The liquid enters the landfill from rainfall, surface drainage, groundwater or is present or produced within the landfill.
- The leachate usually has a high BOD and COD, ammonia, and may contain heavy metals. The characteristics of the leachate vary with age.

Landfill leachate control

- Landfill must be designed to prevent the seepage of leachate from the landfill into underground and finally to groundwater
- The leachate is collected to the ground and treated
- The final cover must also prevent the seepage of surface water to landfill

Landfill leachate control

- Landfill liner to prevent seepage of leachate



Landfill gas control

- Landfill produces CO_2 , CH_4 , NH_3 , and other toxic trace gases
- High CH_4 content (45-60%) – explosive, greenhouse effect, damage crops
- So, landfill gas collection systems should also be installed
- Treatment of landfill gas
 - Recover CH_4 for fuel
 - Combustion to CO_2

Reading assignment

Textbook Ch 13 p. 661-686