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Final Disposal of Solid Waste: Landfill

Prof. Jai-Young Lee

leejy@uos.ac.kr

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Dept. of Environmental Engineering

University of Seoul
South Korea

UNIVERSITY OF SEOUL

☞ Major career details

- Current, Professor, Dept. of Environmental Engineering, The University of Seoul
- 2021, President, Korea Society of Waste Management
- 2014, President, Korean Society of Soil and Groundwater
- Current, Head of the Central Green Environmental Center
- Current, Head of Waste-to-Energy Specialized Graduate School
- Current, Director, Environmental Engineering Center Affiliated with University of Seoul
- Current, The Ministry of Environment, The Environmental Dispute Mediation Committee
- Current, Chairman, The Ministry of Environment, The Soil Remediation Advisory Committee
- Current, Sudokwon Landfill Site Management Corporation(SLC), Technical advisory and design review Committee
- Current, Seoul Environmental Impact Assessment Committee
- Current, Hanriver Environment Office, Impact Assessment Review/Advisory Committee
- Current, National Institute of Environmental Research, Technical Deliberation Committee
- Current, Ministry of National Defense, Construction Technology Deliberation Committee
- 2013, Ministry of Land, Transport and Maritime Affairs, The Central Construction Deliberation

more than 20 Committee involved

Contents

- Overviewing of Landfill
- **Construction Materials of the Landfill**
- **Landfill Liners**
- **Bioreactor landfill**
- Sudokwon Landfill Corporation in Korea

Overviewing of Landfill

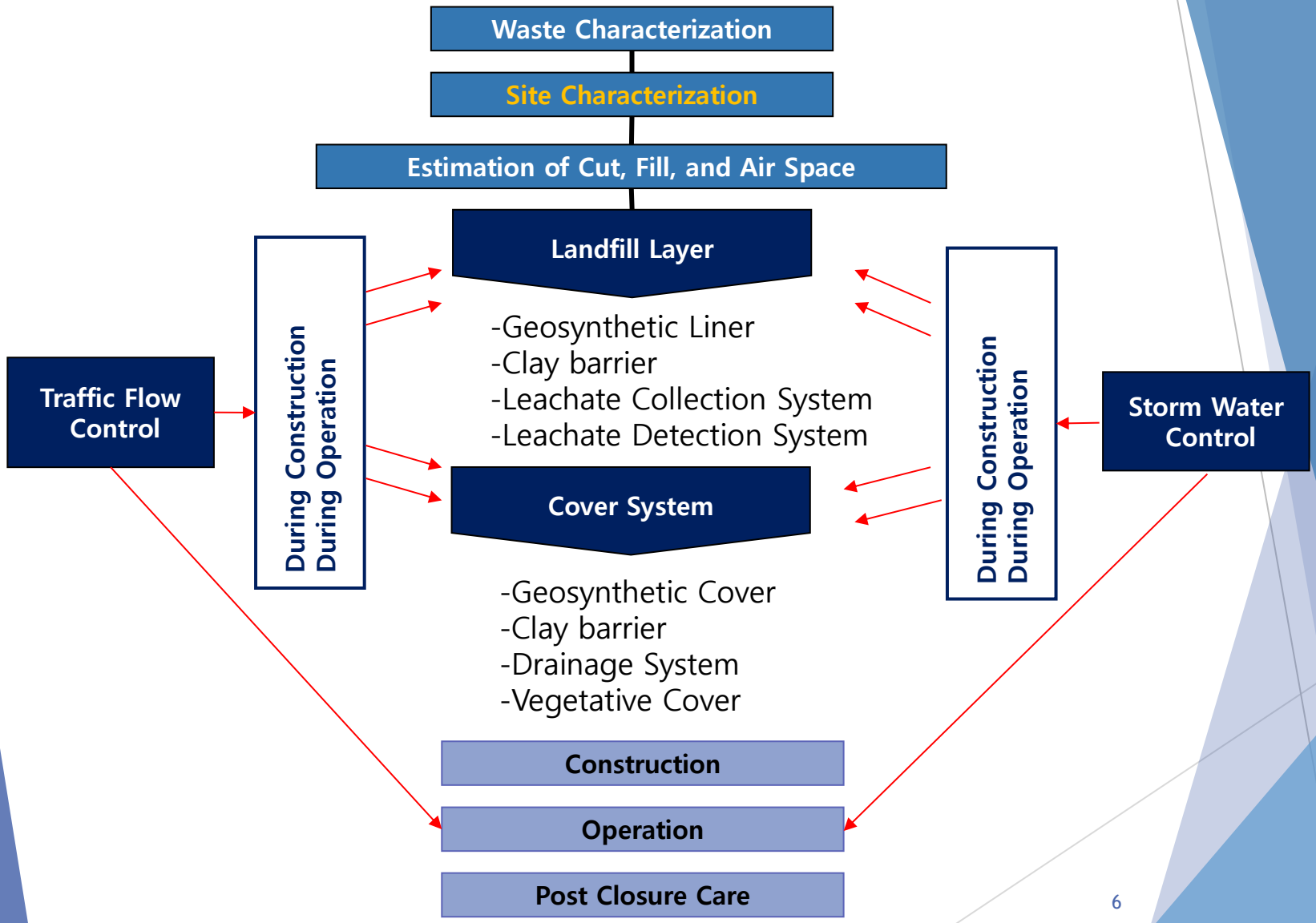
Overviewing of Landfill

- **Landfill**

  : Historically, landfills have been the most economical and environmentally expectable method for the disposal of wastes

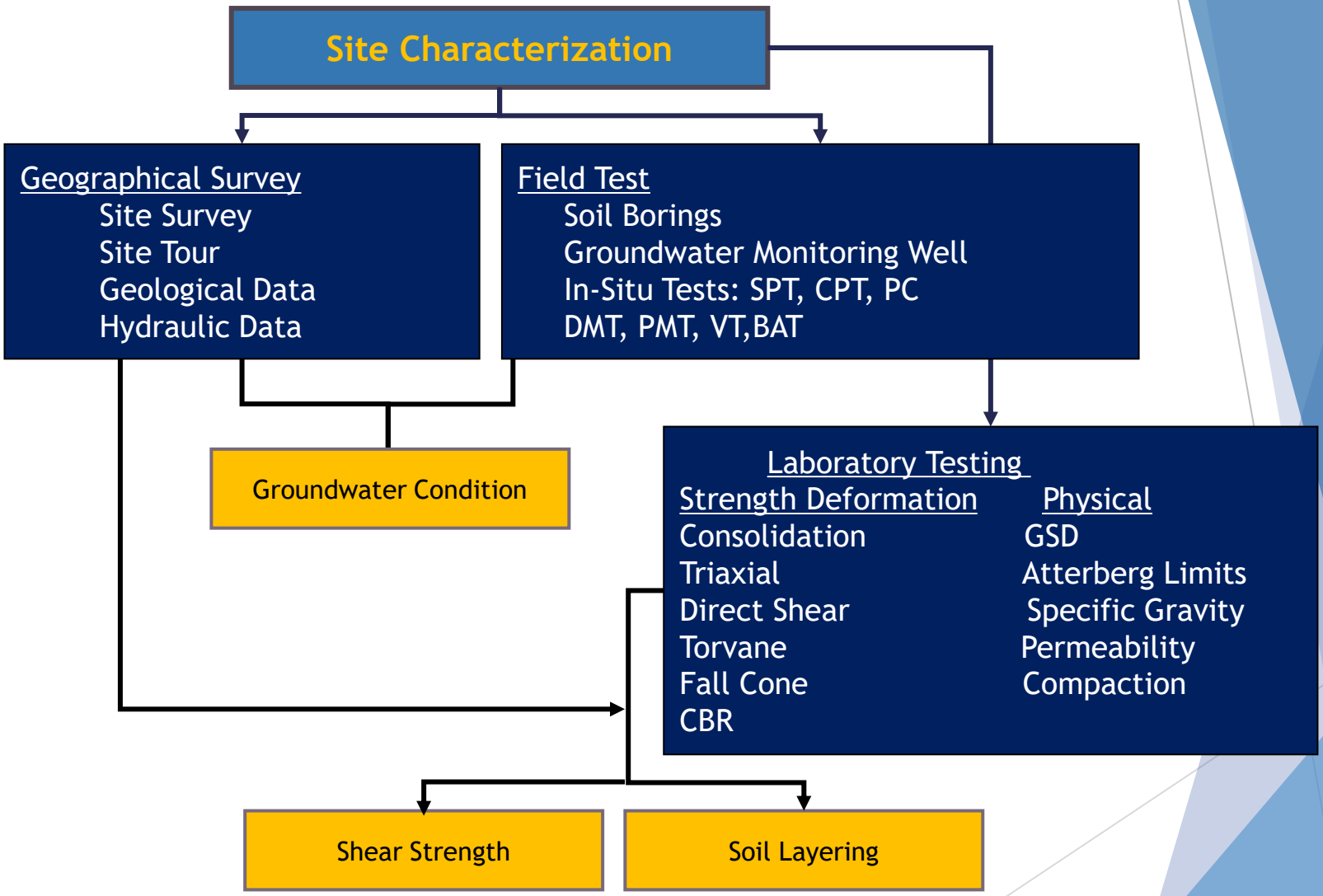
- **Overview of landfill planning, design and operation**
  1. Landfill layout and design
  2. Landfill operation and management
  3. The reactions occurring in landfills
  4. The management of landfill gases
  5. The management of leachate
  6. Environmental monitoring during landfilling
  7. Landfill closure and post-closure care

Overviewing of Landfill (cont.)



The Procedure for Landfill

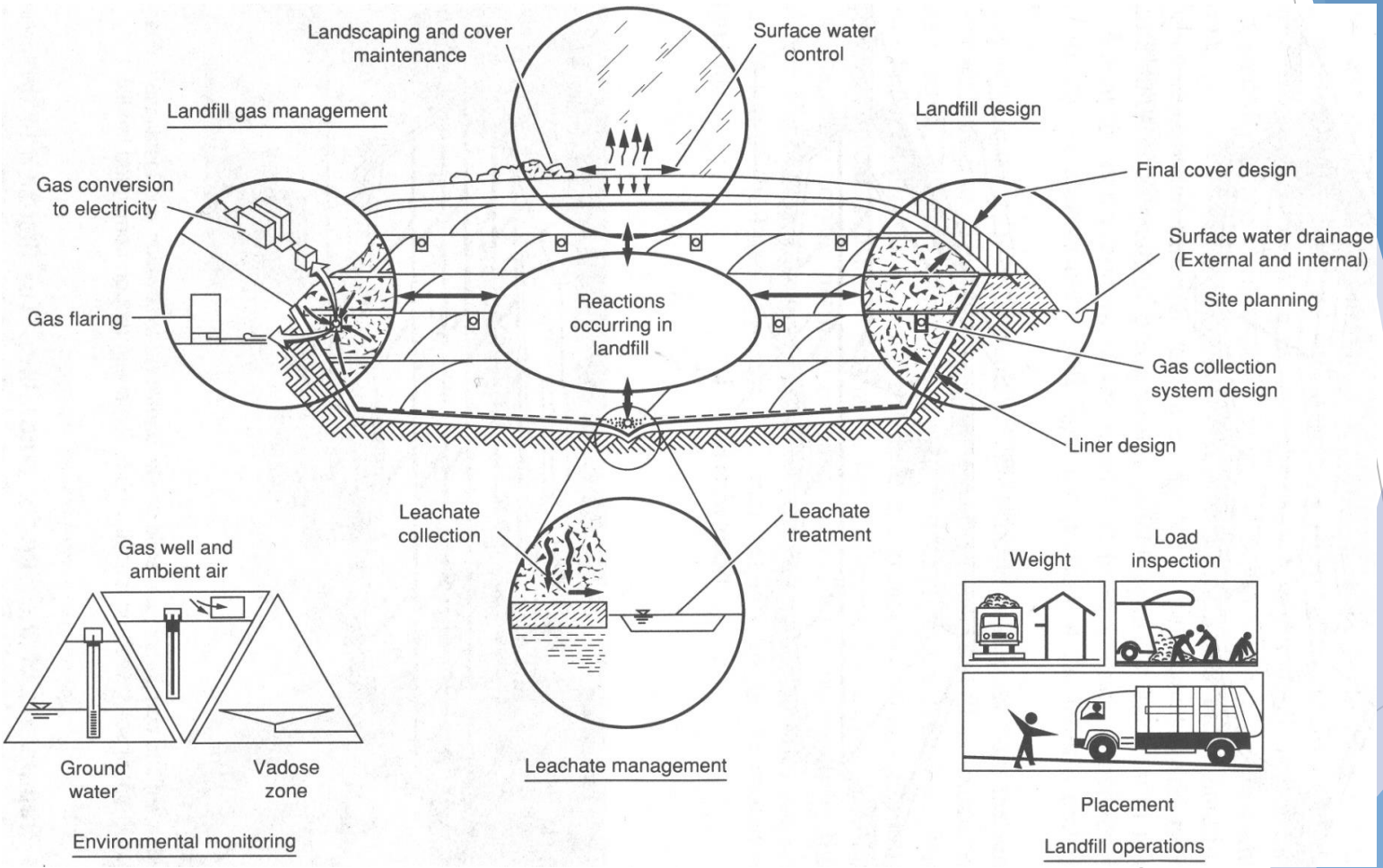
Overviewing of Landfill (cont.)



The Procedure of Site Characterization

Overviewing of Landfill (cont.)

① Landfill layout and design

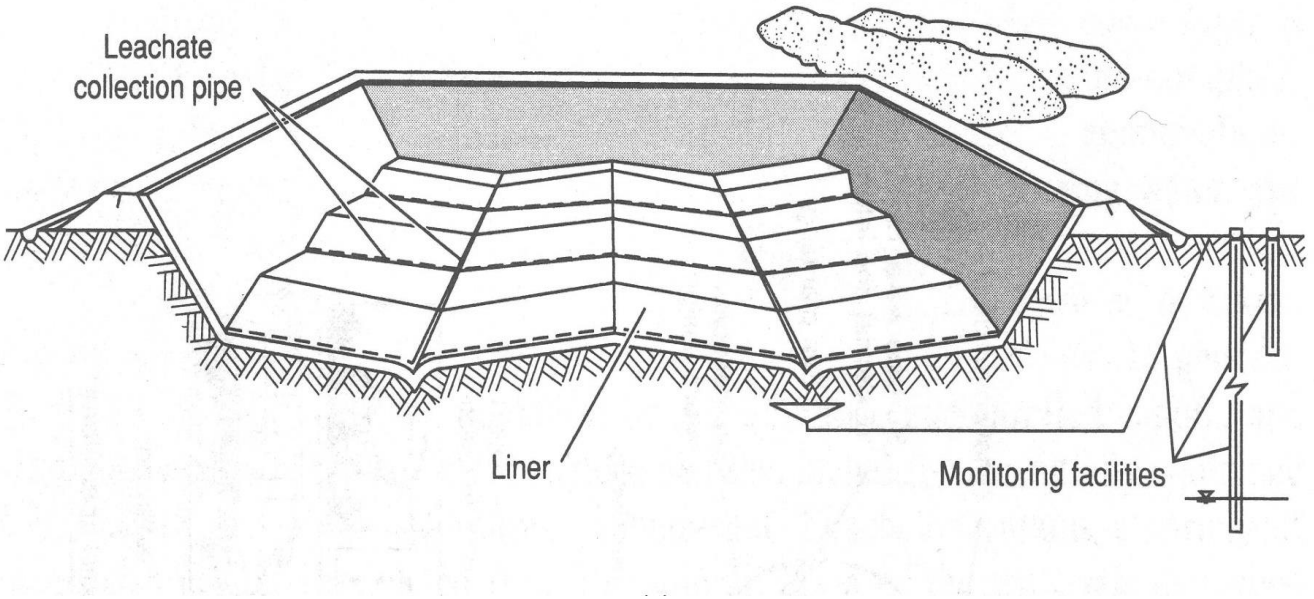


Layout for landfill operation and processes

Overviewing of Landfill (cont.)

② Landfill operation and management

- Site preparation for landfilling

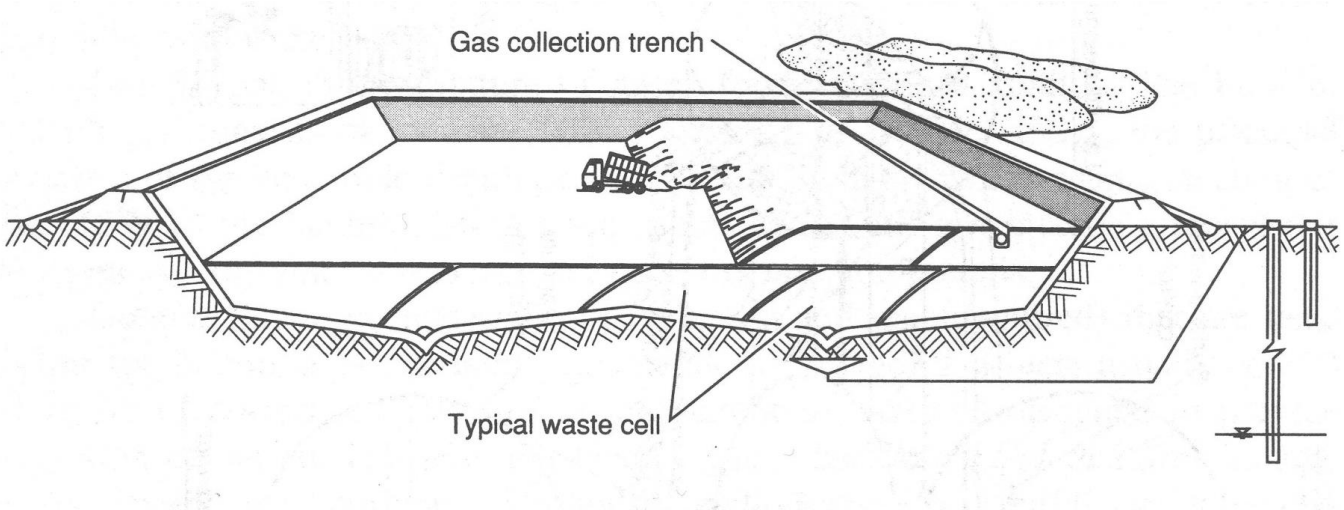


Site excavation and installation of landfill liner/leachate collection pipe

Overviewing of Landfill (cont.)

② Landfill operation and management (cont.)

- The placement of solid waste

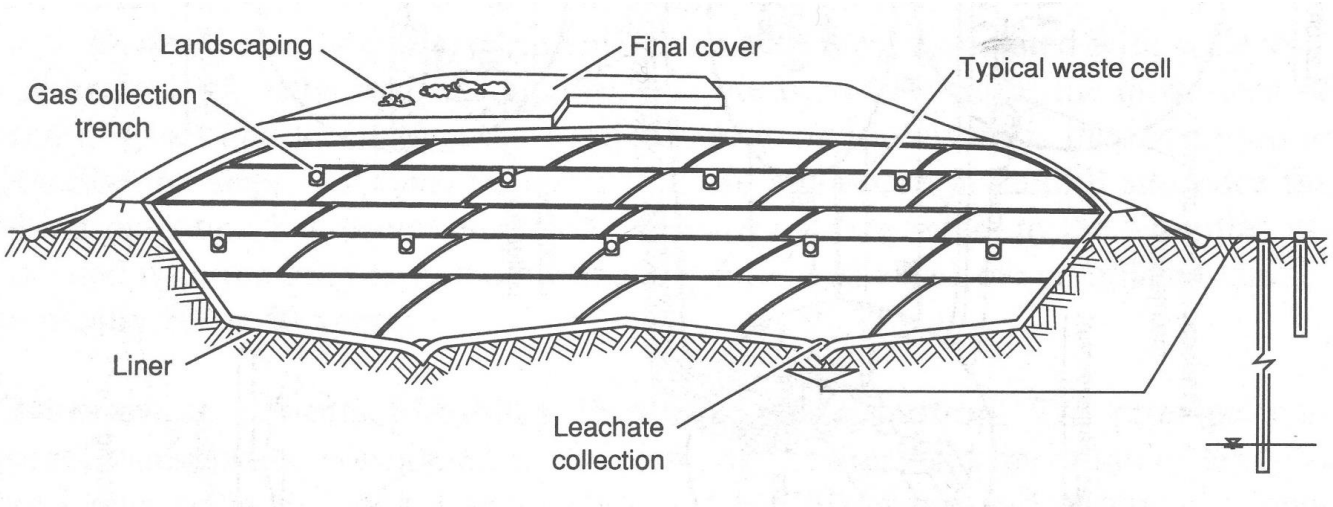


Placement of wastes in landfill (cell method)

Overviewing of Landfill (cont.)

② Landfill operation and management (cont.)

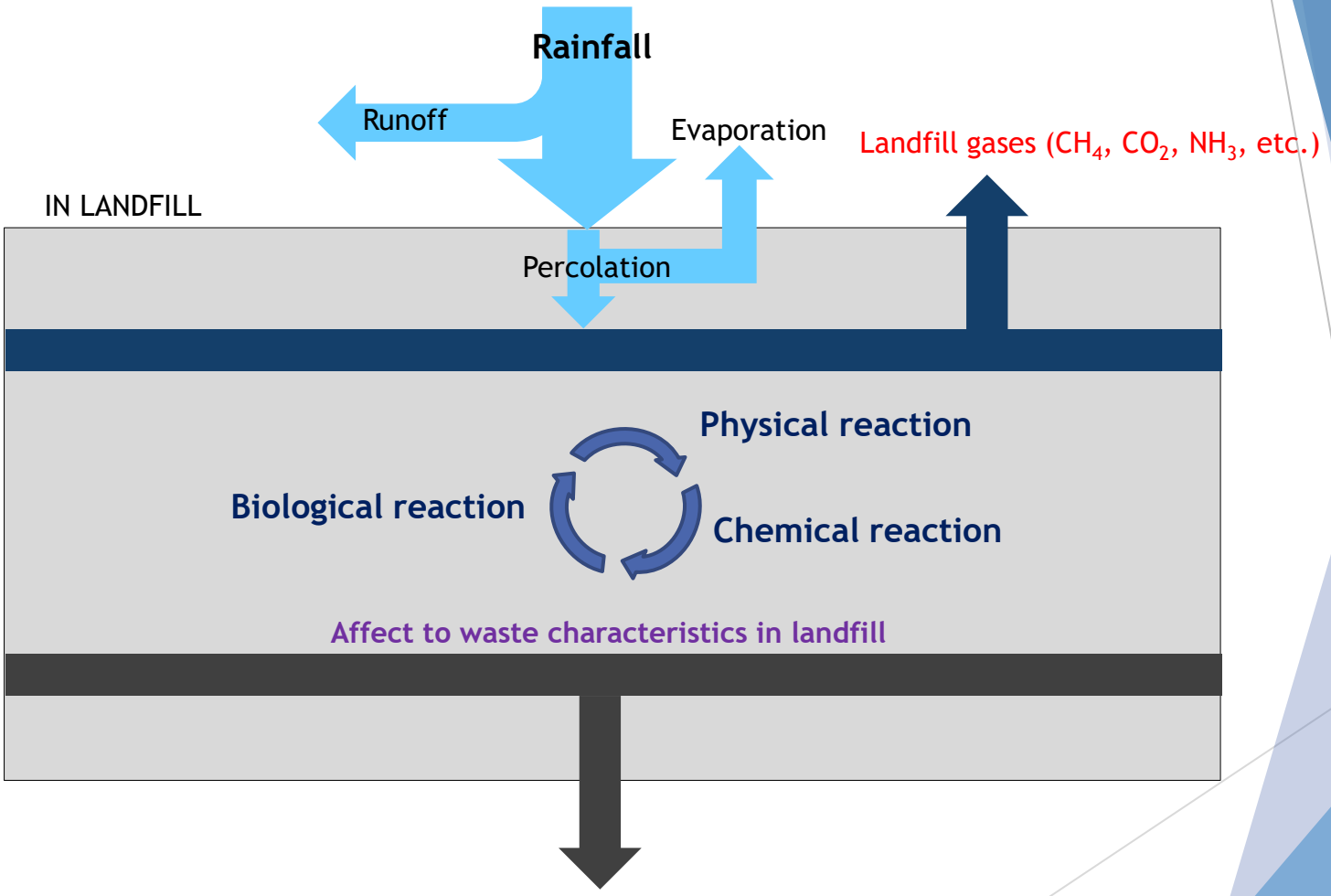
- Postclosure of landfill



Placement of wastes in landfill (cell method)

Overviewing of Landfill (cont.)

③ Reactions occurring in landfill



Concept and function of landfill system

Overviewing of Landfill (cont.)

③ Reactions occurring in landfill (cont.)

- Biological reaction

  : The most important biological reactions occurring in landfill are those involving the organic material in wastes that lead to the evolution of landfill gases and liquids

- Chemical reaction

  : Important chemical reactions that occur within the landfill include dissolution and suspension, evaporation, sorption, dehalogenation and decomposition, and oxidation-reduction reactions of landfill materials

- Physical reaction

  : Important physical reactions are the diffusion and emission of landfill gases, movement of leachate, and settlement caused by consolidation and decomposition of landfill materials

Overviewing of Landfill (cont.)

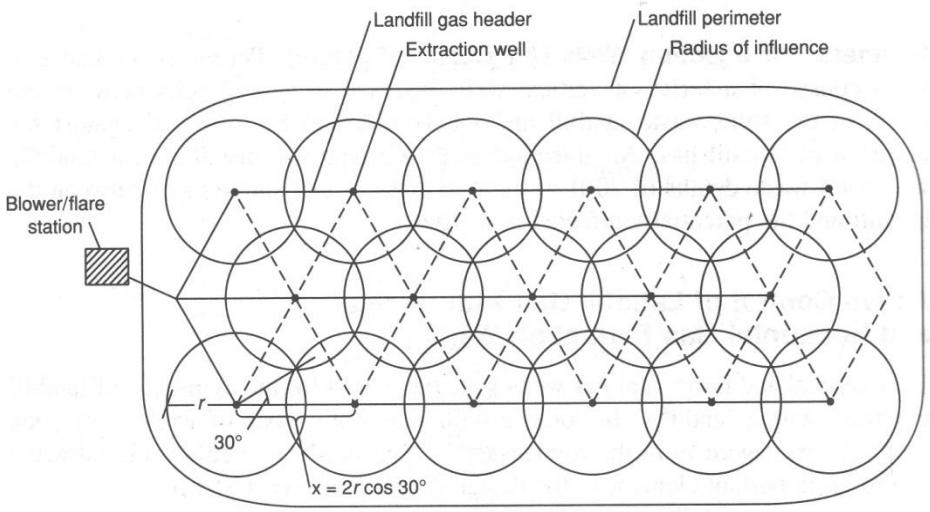
④ The management of landfill gases

- Landfill gas control systems are employed to prevent unwanted movement of landfill gas laterally and vertically into the atmosphere
- The treatment for landfill gases
  - Flaring of landfill gases
  - Landfill gas energy recovery systems (Electricity)
  - Gas purification and recovery

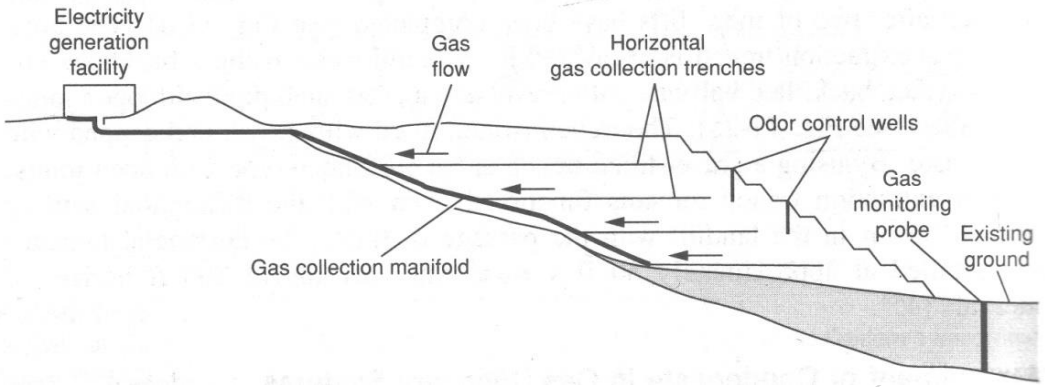
Overviewing of Landfill (cont.)

④ The management of landfill gases (cont.)

- Gas extraction/collection wells



Arrangement of vertical gas extraction well



Arrangement of horizontal gas collection well

Overviewing of Landfill (cont.)

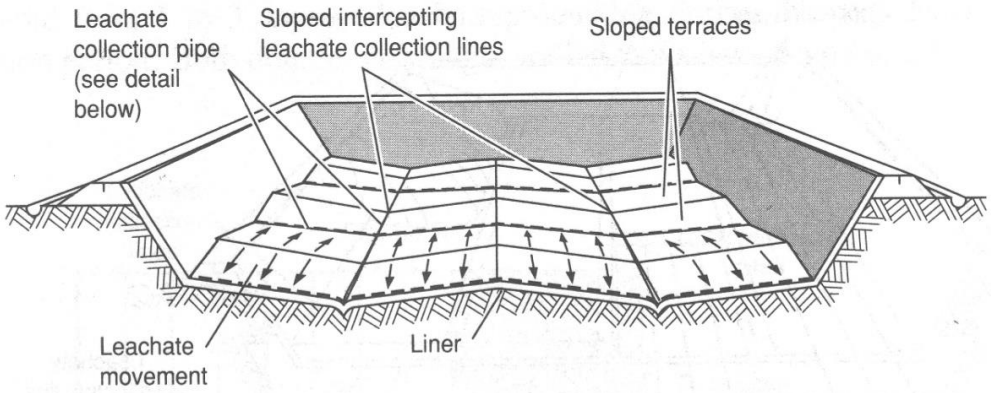
⑤ The management of landfill leachate

- Quantity of leachates depends on;
  - rainfall and groundwater percolation through the wastes
  - biochemical processes in wastes' cells
  - inherent water content of the wastes
  - the compaction of the wastes
- Control of leachate in landfill : to prevent the potential risks as subsidence of cells and environmental contaminant
- Leachate control facilities (U.S. EPA)
  - Synthetic flexible membrane liners (FMLs)
  - Bottom seals
  - Artificial earthen liners (Geosynthetic clay liners, GCLs)
  - Subsurface barriers

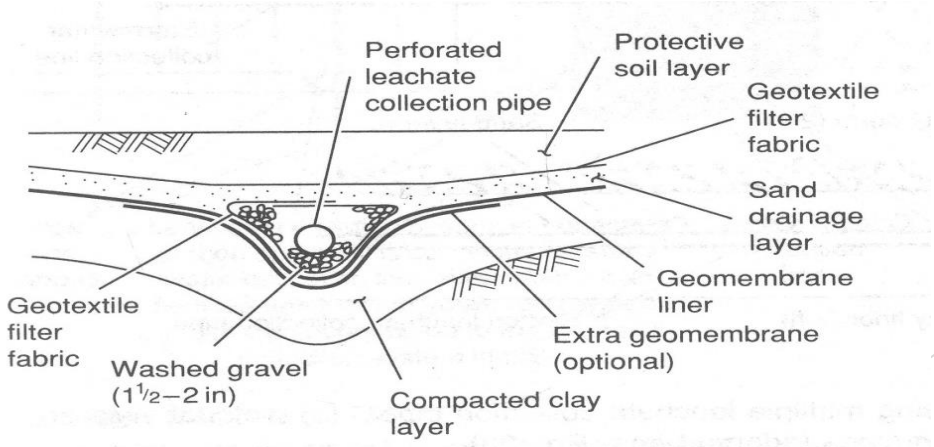
Overviewing of Landfill (cont.)

⑤ The management of landfill leachate (cont.)

- Leachate collection systems



Pictorial view of leachate collection system



Detail of typical leachate collection pipe

Overviewing of Landfill (cont.)

⑤ The management of landfill leachate (cont.)

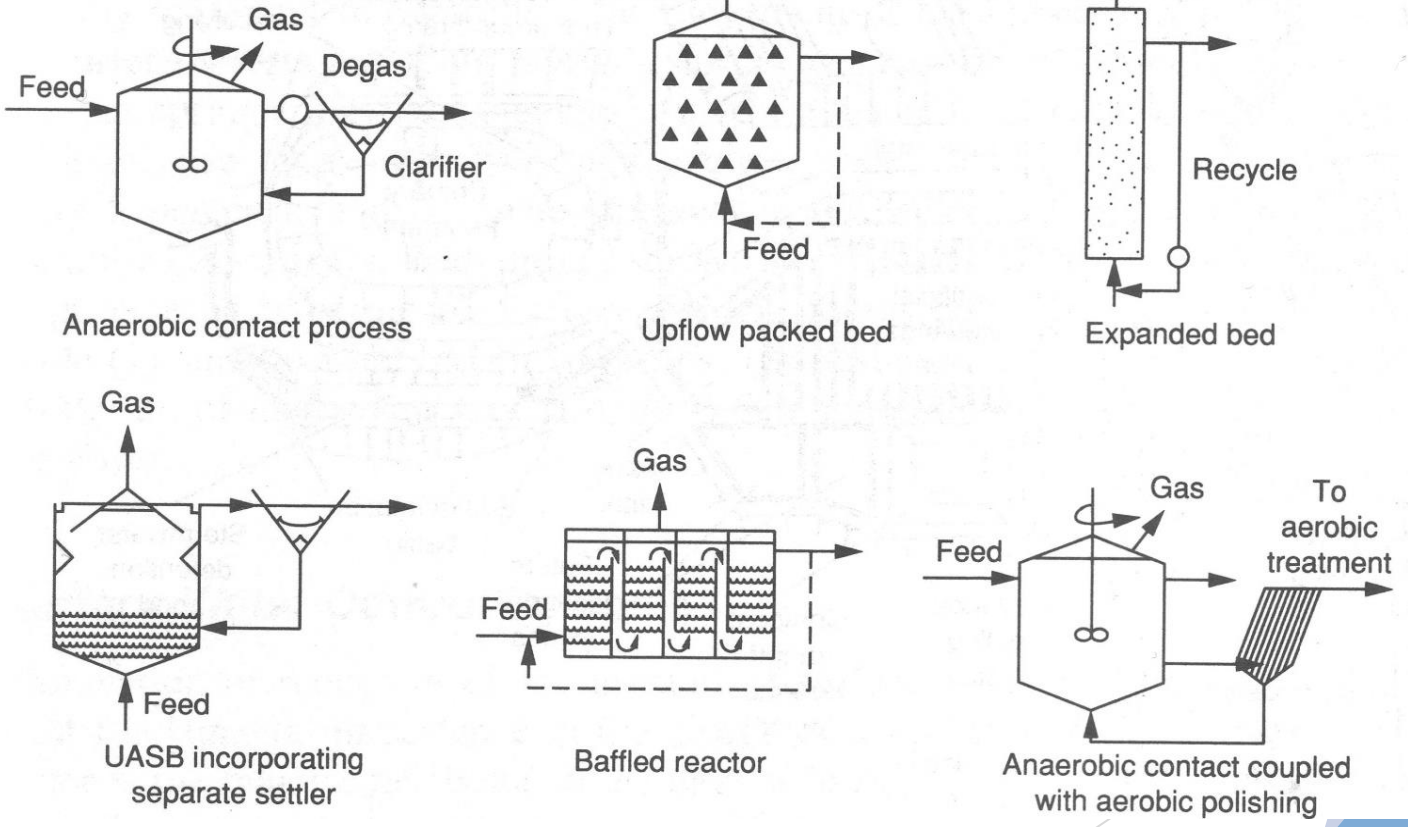
- Leachate collection systems
  - Leachate collection systems are integrated all liner system
  - Composed of gravel and sand or geonet along with a sequence of leachate collection conduits to drain the leachate to holing tanks for treatment
  - Leachate collection pipes are installed in the layer

Leachate collection pipes

Overviewing of Landfill (cont.)

⑤ The management of landfill leachate (cont.)

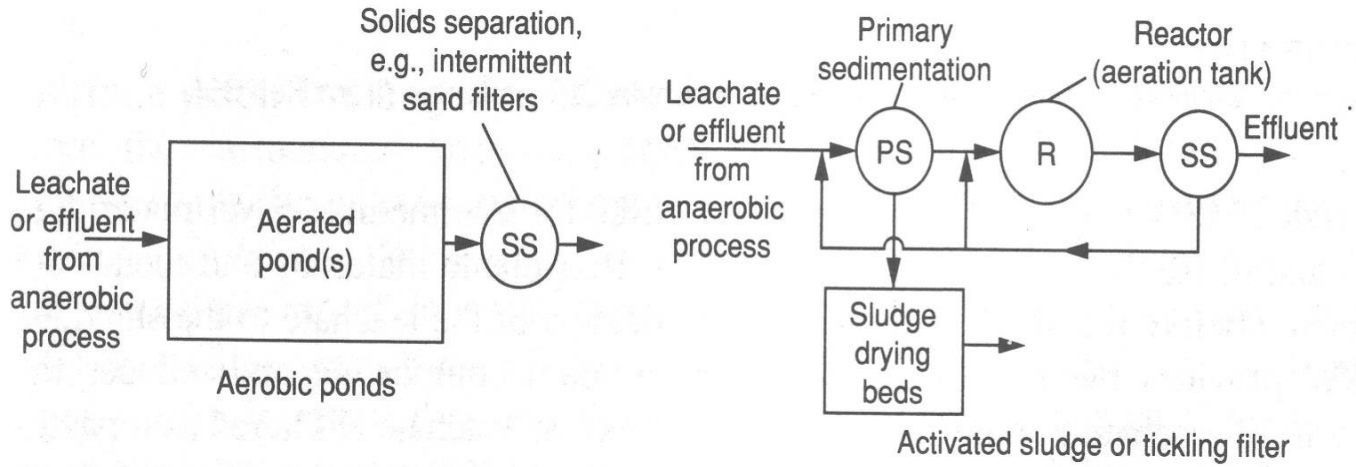
- Leachate treatment systems



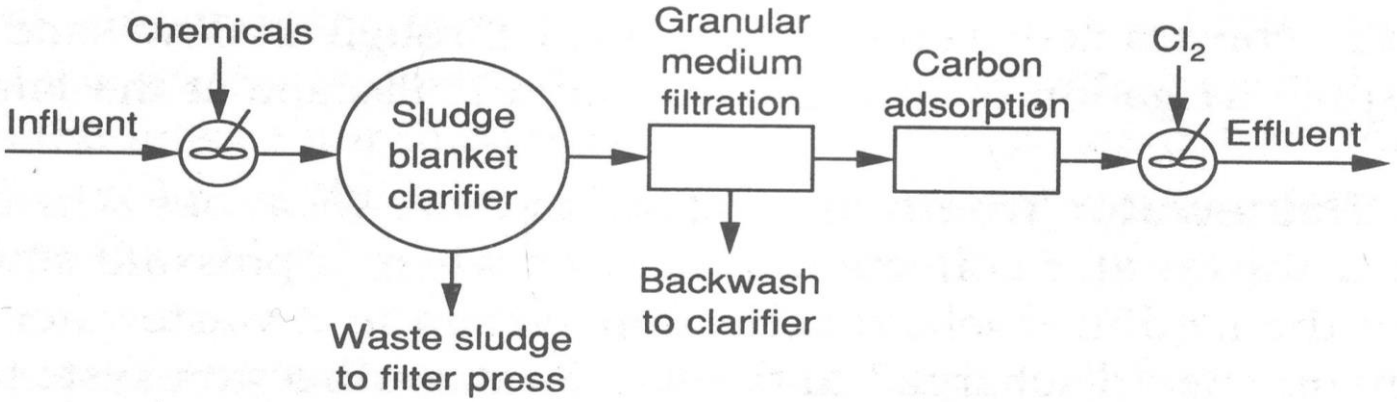
General anaerobic processes for leachate treatment

Overviewing of Landfill (cont.)

⑤ The management of landfill leachate (cont.)



General aerobic processes for leachate treatment



General chemical treatment for removal of heavy metals and selected organics in leachate

Overviewing of Landfill (cont.)

⑥ Environmental monitoring during landfilling

- Environmental monitoring should be conducted to ensure contaminants, that may affect public health and surrounding environment, are not released from the landfill
- Monitoring categories
  - Vadose zone monitoring for gases and liquids
  - Groundwater monitoring
  - Air quality monitoring

Overviewing of Landfill (cont.)

⑦ Landfill closure and post-closure care

- A landfill, as a waste management unit, must continue to function effectively with environmental control unit of wastes for a long time into the future
- **Typical elements** of landfill closure plan
  - Post-closure land use : designation and adoption
  - **Final cover design** : select the infiltration barrier final surface slopes and vegetation
  - Surface water and drainage control : calculate stormwater quantities for runoff and select perimeter channel location and sizes to collect runoff and to prevent runon
  - Control of landfill gases : select locations and frequency of gas monitoring and set the operations schedule for gas extraction wells and flare
  - Control and treatment of leachate : set the operation schedule for leachate removal and treatment
  - Environmental monitoring system : select sampling locations and frequency of monitoring as well as constituents to be measured

Overviewing of Landfill (cont.)

⑦ Landfill closure and post-closure care (cont.)

- **Final cover design parameter**
  - Design configuration
  - Final permeability
  - Surface slope
  - Landscape design
  - Method of repair as landfill settles
  - Slope stability under static and dynamic loading

Overviewing of Landfill (cont.)

⑦ Landfill closure and post-closure care (cont.)

- Surface water and drainage control systems

  : The artificial and natural features must be **effective in controlling run-on and run-off of surface water as well as preventing groundwater** from penetrating the landfill liner

- Control of landfill gases

  : **Landfill gases, which have possibility of explosion and subsidence must be controlled** for as long as they are expected to be generated after the landfill is closed

- Control and treatment of leachate

  : Leachate collection and treatment facilities are designed and built when the landfill first starts operation, and used after closure **to minimize the movement of leachate toward groundwater and the release of dissolved constituents**

- Environmental monitoring systems

  : Environmental monitoring, which is the final part of a closure plan, is **necessary to ensure that the integrity of the landfill in maintained with respect to the uncontrolled release of any contaminants** to the environment

Construction Materials of the Landfill

* **Earth materials: Clay, Gravel, Sand. Silt**

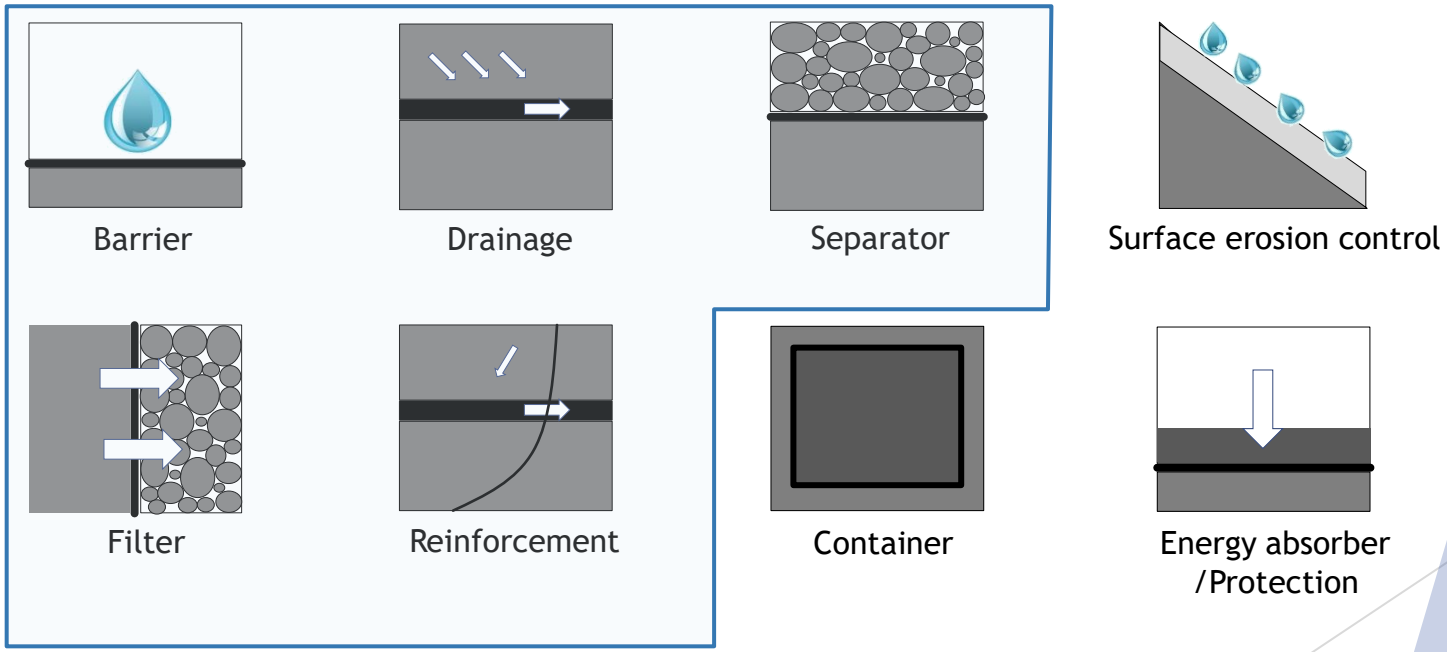
* **Geosynthetics???**

- **What are geosynthetics?**
  - Human-made materials made from various type of polymers used to enhance, augment and make possible cost effective
  - Application to geotechnical engineering as environment, transportation, construction
  - They are used to provide one or more of various function

Geosynthetics (cont.)

- Various function of geosynthetics

5 principal functions of geosynthetics



Categories of geosynthetics

① **Geotextile** : flexible, textile-like fabrics of controlled permeability used to provide filtration, separation or reinforcement in soil, rock and waste materials

② **Geomembrane** : essentially impermeable polymeric sheets used as barriers for liquid or solid waste containment

③ **Geogrids** : stiff or flexible polymer grid-like sheets with large apertures used primarily as reinforcement of unstable soil and waste masses

④ **Geonets** : stiff polymer net-like sheets with in-plane openings used primarily as a drainage material within landfills or in soil and rock masses

⑤ **Geosynthetic clay liners (GCLs)** : prefabricated bentonite clay layers incorporated between geotextiles and/or geomembranes and used as a barrier for liquid or solid waste containment

⑥ **Geopipes** : perforated or solid wall polymeric pipes used for the drainage of various liquids

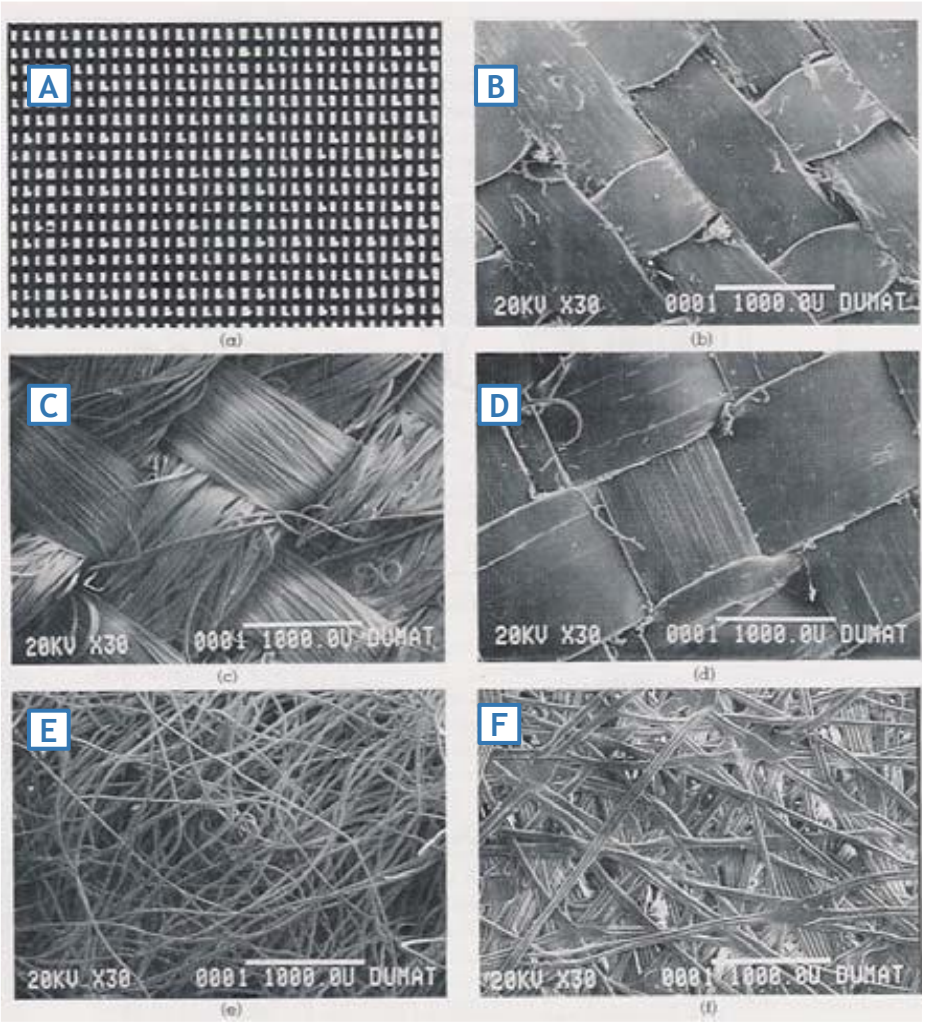
⑦ **Geocomposites** : hybrid systems of any, or all of the above geosynthetic types which can function as specifically designed for use in soil, rock, waste and liquid related problems

Geosynthetics (cont.)

① Geotextile

- Geotextiles form one of the two largest group of geosynthetics, and have been steadily growing in use during the past 30 years
- These synthetic fibers are made into a flexible, porous fabric by standard weaving machinery or are matted together in a random, or nonwoven
- Functional purpose : separation, reinforcement, filtration and drainage

Geosynthetics (cont.)



<Geotextile>

<A : woven monofilament, B : calendered woven monofilament,
C : woven multifilament, D : woven silt film,
E : nonwoven needle-punched, F : nonwoven heat-bonded>

Geosynthetics (cont.)

② Geomembrane

- Geomembranes represent the other largest group of geosynthetics and in dollar volume their sales are probably larger than that of geotextiles
- "Impervious" thin sheets of rubber or plastic material used primarily for linings and covers of liquid- or solid-storage or disposal facilities
- Manufactured from polymeric materials as PVC (Polyvinyl Chloride), HDPE (High Density Polyethylene), CSPE (Chloro Sulfonated Polyethylene), CPE (Chlorinated Polyethylene)
- Functional purpose : barrier, storage

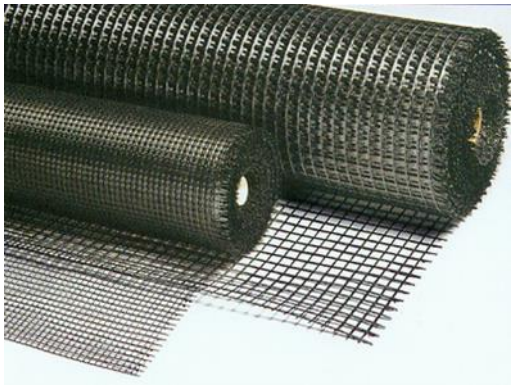
<HDPE geomembrane>

<Landfill preparation installed geomembrane liner>

Geosynthetics (cont.)

③ Geogrid

- Geogrids represent a rapidly growing segment within the geosynthetics area
- Rather than being a woven, nonwoven or knit textile or textile-like fabric, geogrids are plastics formed into a very open, gridlike configuration
- Geogrids are either stretched in one or two directions for improved physical properties or made on weaving machinery by unique methods
- Functional purpose : reinforcement

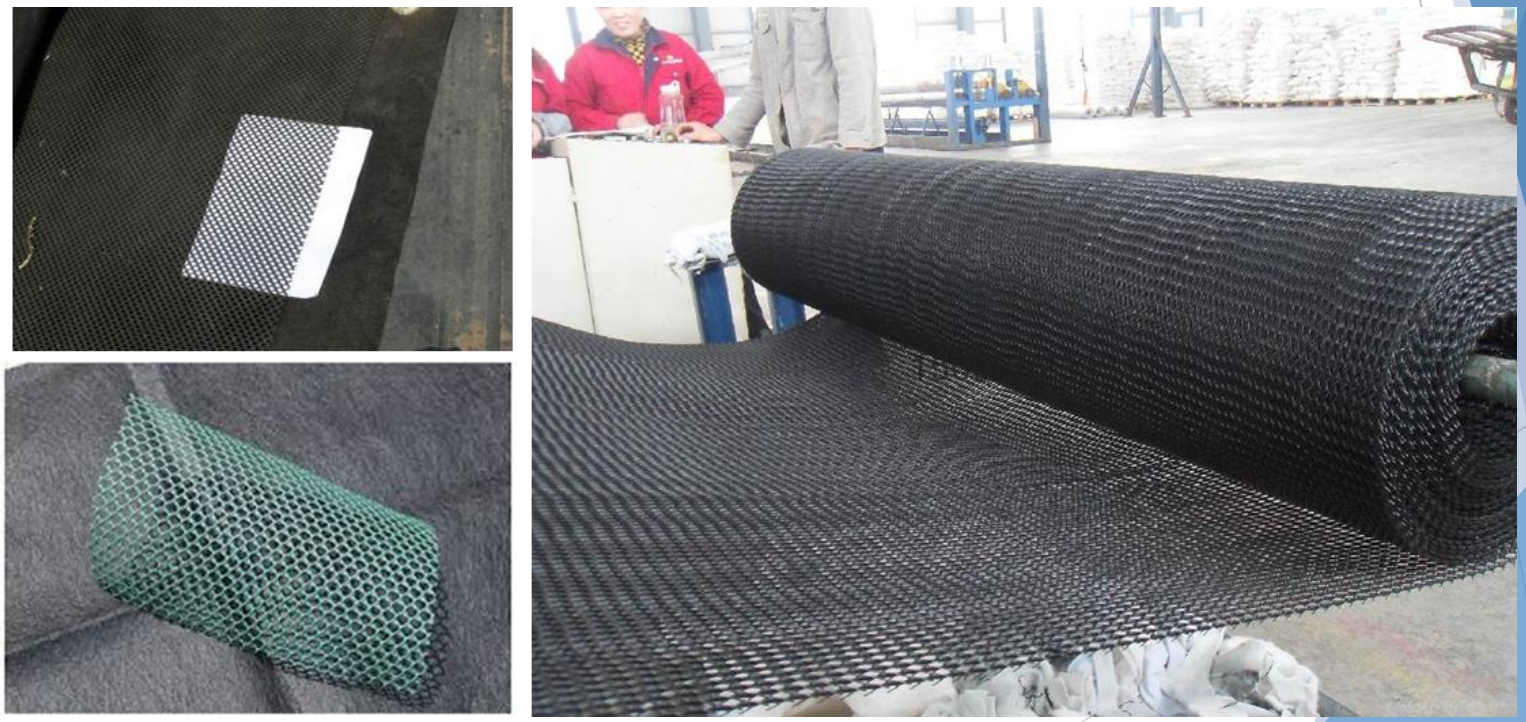


Representative geogrid and installation

Geosynthetics (cont.)

④ Geonet

- Geonets, called geospacers by some, constitute another specialized segment within the geosynthetic area
- They are usually formed by a continuous extrusion of parallel sets of polymeric ribs at acute angles to one another
- Functional purpose : drainage



Various types of geonet

Geosynthetics (cont.)

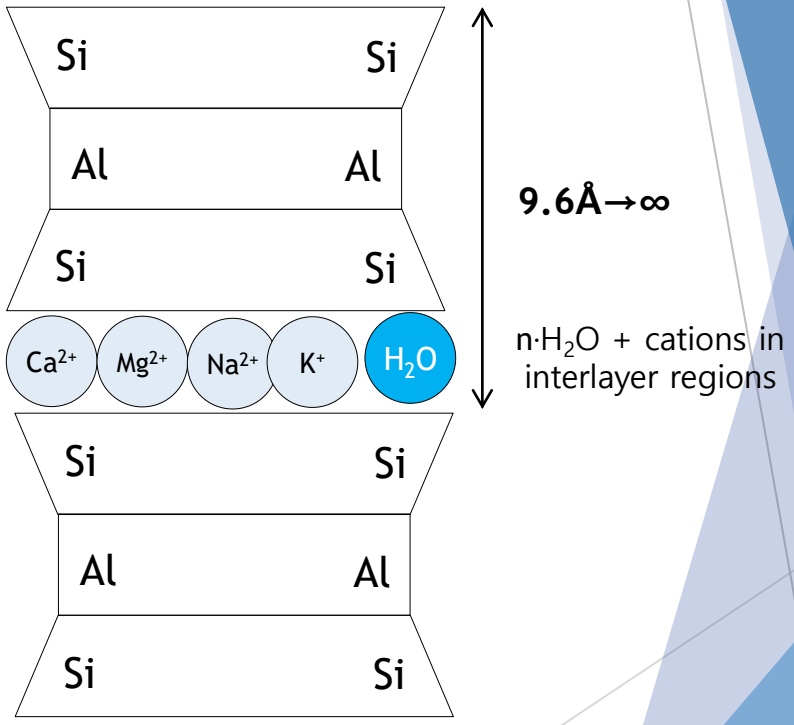
⑤ Geosynthetic clay liners (GCLs)

- GCLs are rolls of factory fabricated thin layers of bentonite clay sandwiched between two geotextiles or bonded to a geomembrane
- Structural integrity is maintained by needle punching, stitching or physical bonding
- They are seeing use as a composite component beneath a geomembrane or by themselves as primary or secondary liners
- Functional purpose : barrier, reinforcement

Geosynthetics (cont.)

<Bentonite>

- Hydrophilic clay minerals
- Tree-layer structure (2 Silica sheet and 1 Alumina sheet) with same as Montmorillonite
- Swelling properties when in contact with moisture because the binding force between the layers is weak
- Due to swelling properties, the permeability decreases



Structure of Momtmorillonite

Geosynthetics (cont.)

Geosynthetic Clay Liner

Landfill preparation installed GCLs

Geosynthetics (cont.)

⑥ Geopipe

- As known also buried plastic pipe
- being used in all aspects of geotechnical, transportation and environmental engineering with little design and testing awareness
- The critical nature of leachate collection pipes coupled with high compressive loads makes geopipe a bona-fide member of the geosynthetics
- Functional purpose : drainage

Geosynthetics (cont.)

Various geopipes

Geosynthetics (cont.)

⑦ Geocomposite

- A geocomposite consists of a combination of geotextile and geogrid; or geogrid and geomembrane; or geotextile, geogrid, and geomembrane; or any one of these three materials with another material
- This exciting area brings out the best creative efforts of the engineer, manufacturer, and contractor
- The application areas are numerous and growing steadily
- Functional purpose : **entire range of function** as separation, reinforcement, filtration, drainage, barrier

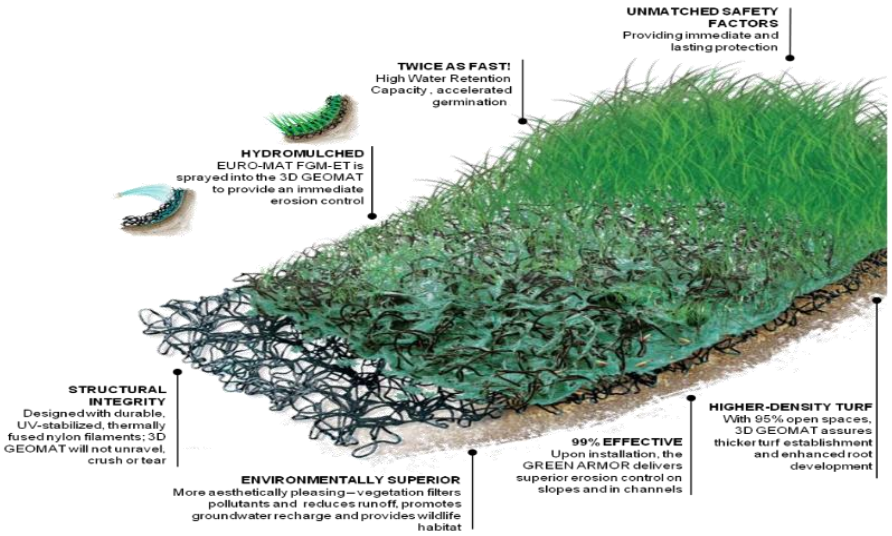
Geosynthetics (cont.)

Geocomposite with geotextile and geonet

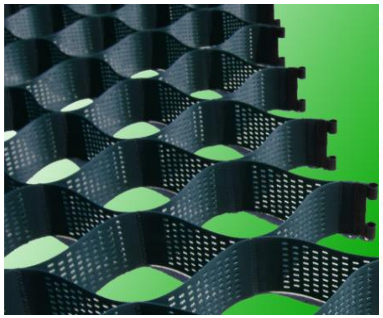
Geocomposite with geotextile and geogrid>

Geosynthetics (cont.)

⑧ Geo-others



Geomat for sloped-surface erosion control

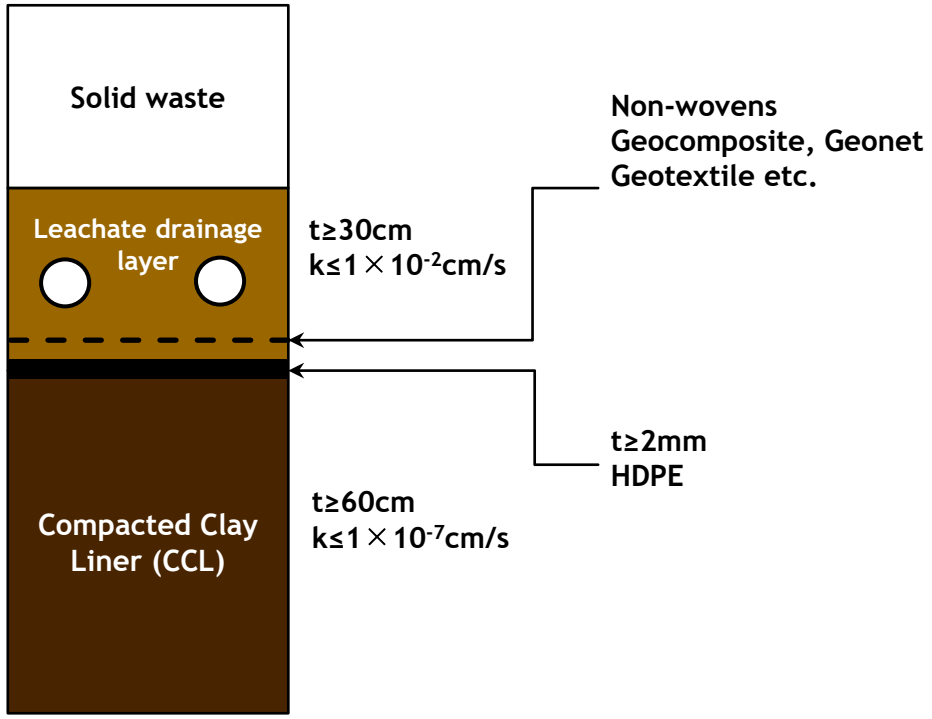


Geocell for ground reinforcement

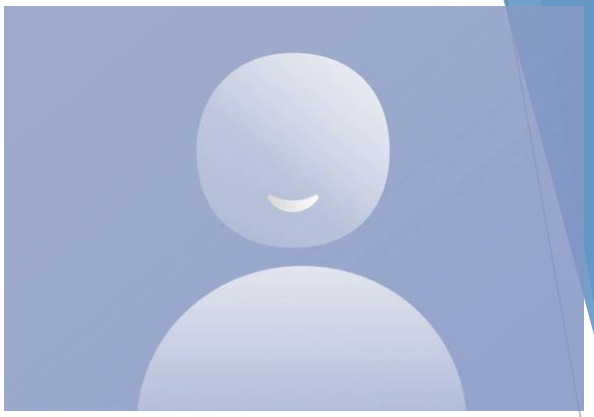
Landfill Liners

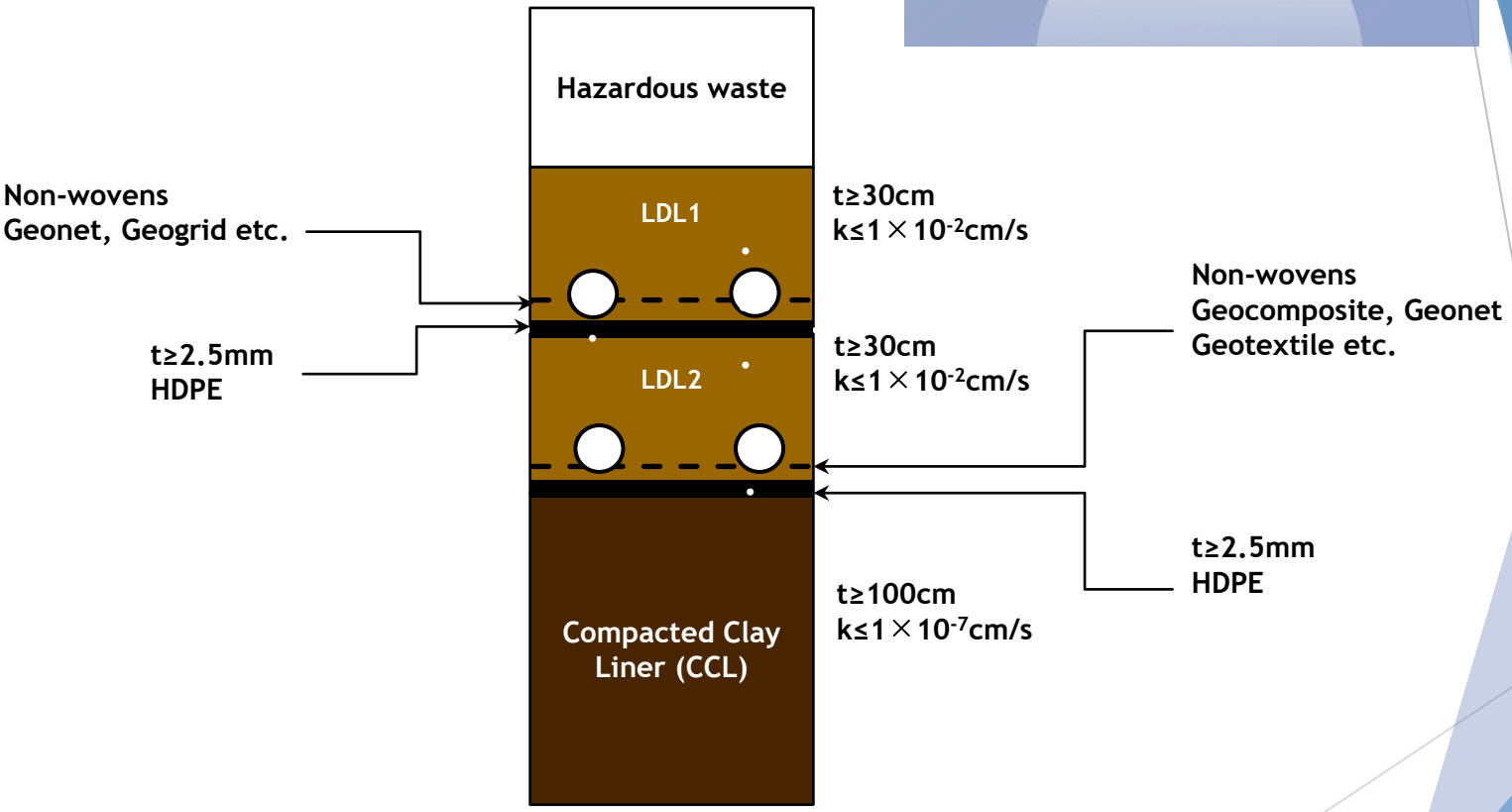
(Bottom liners, Side Slope and Final Cover Liners)

U.S. EPA



Bottom liners for municipal solid waste





Bottom liners for hazardous waste

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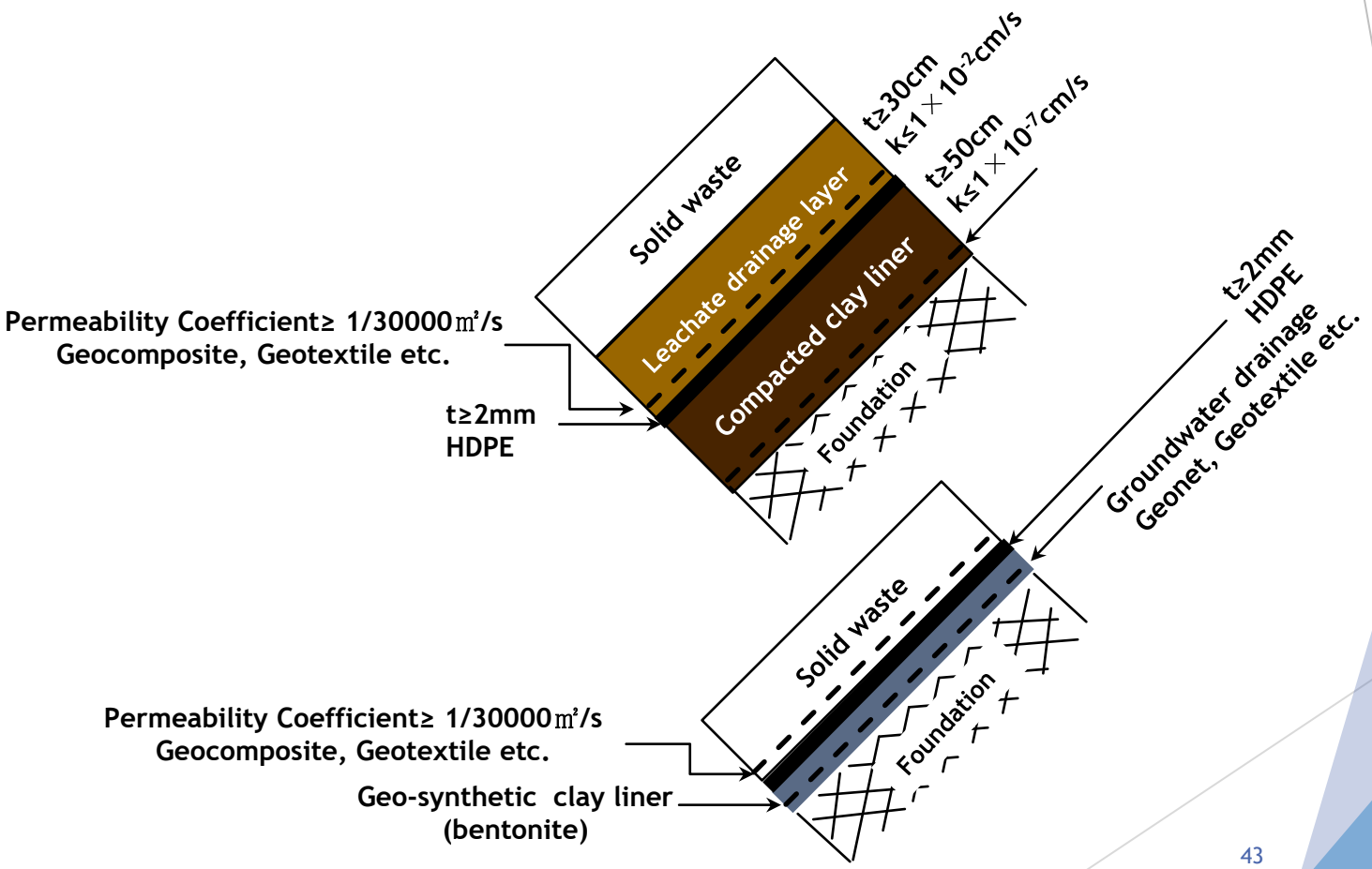

Side slope liners for municipal solid waste

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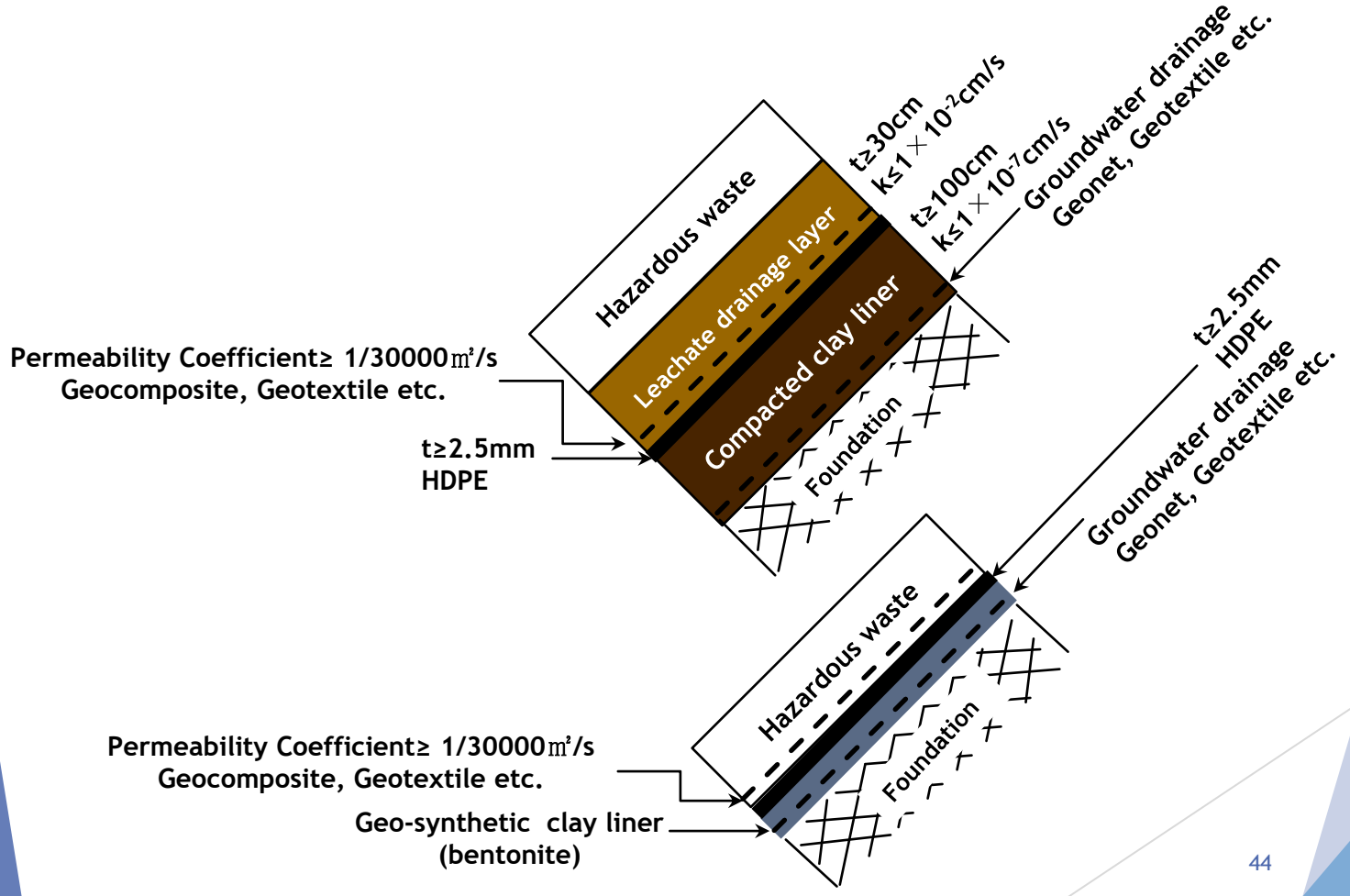
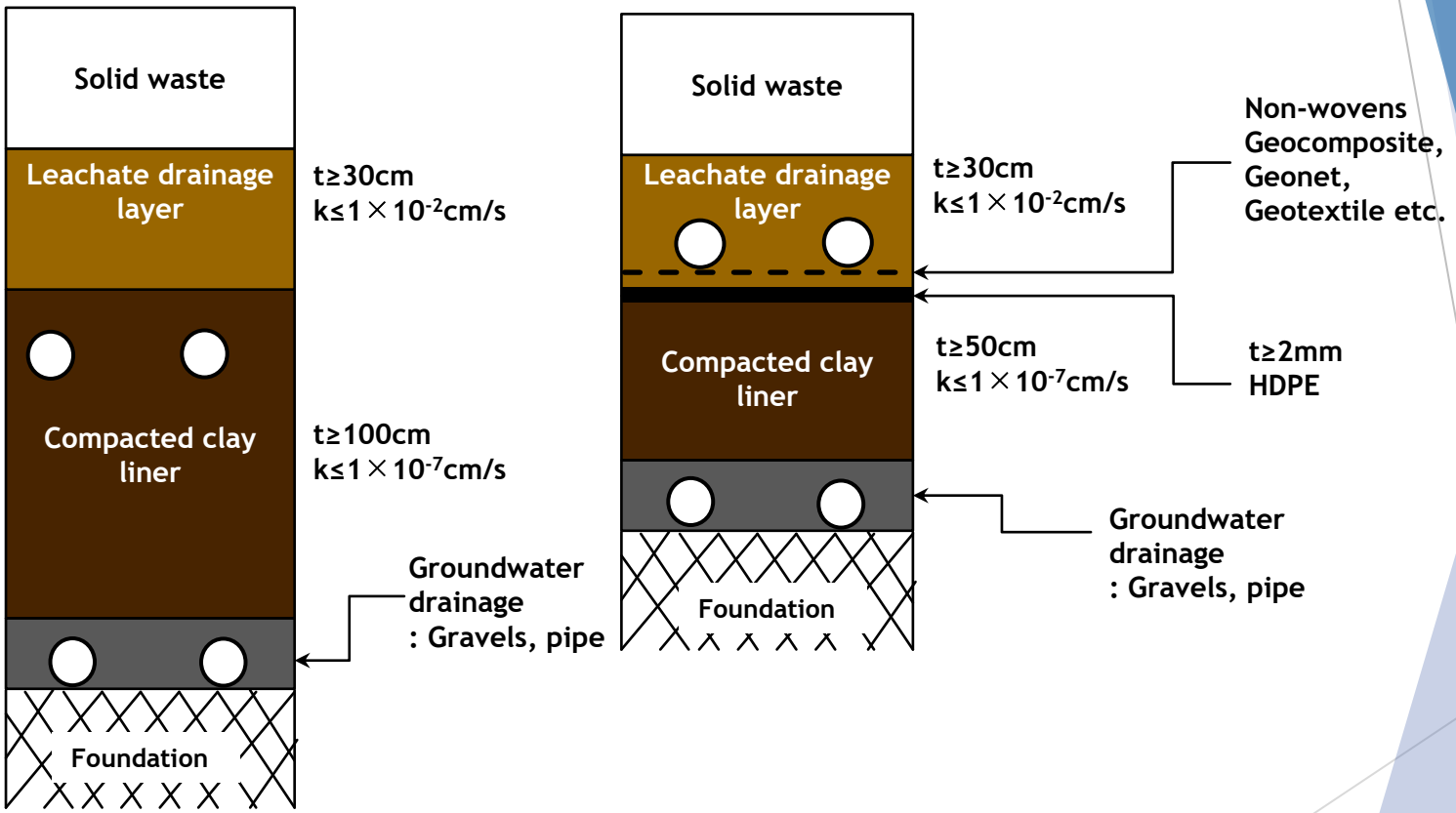


Side slope for hazardous waste

Ministry of Environment in **Korea**



Bottom liners for municipal solid waste

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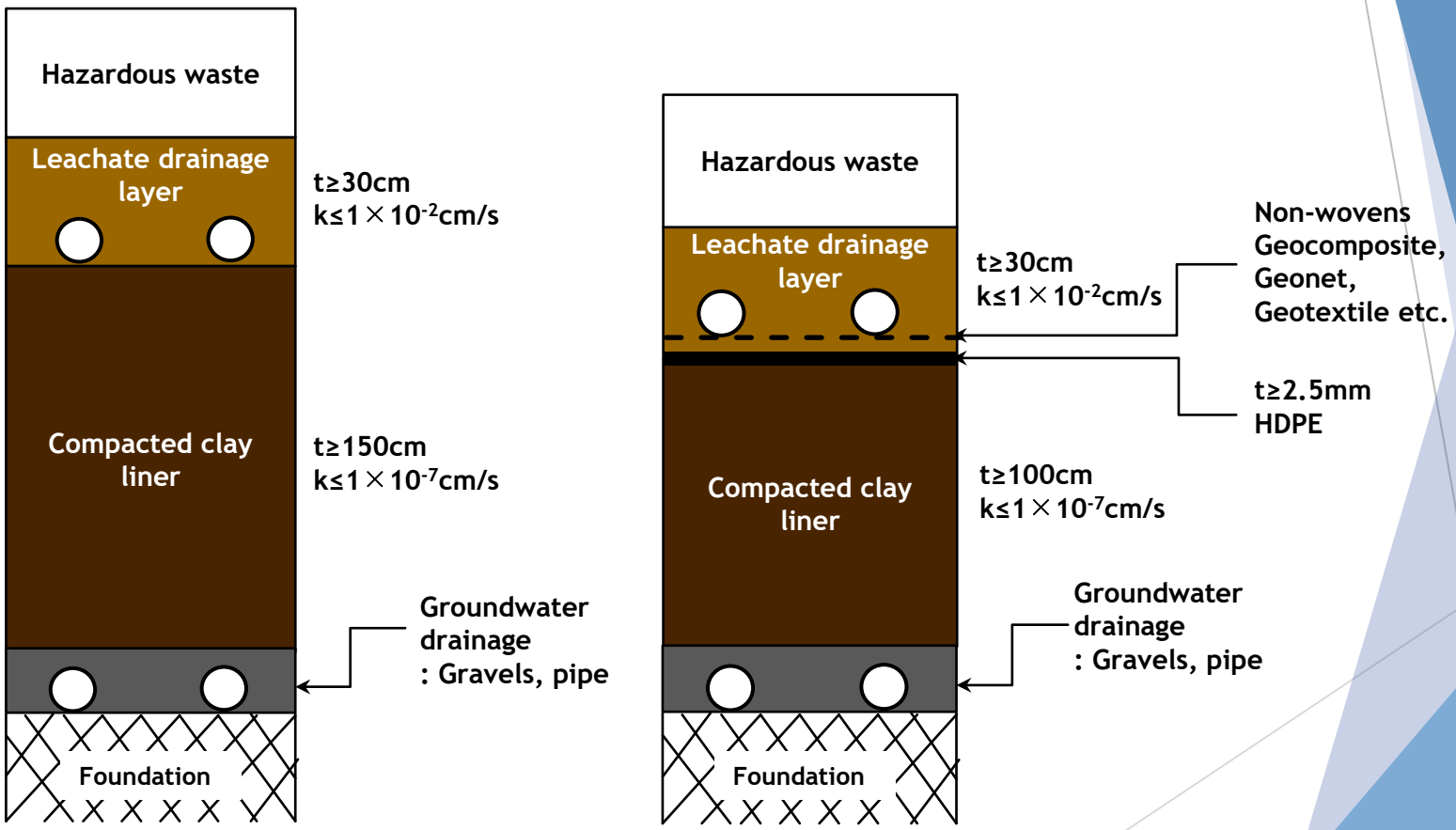

Bottom liners for hazardous waste

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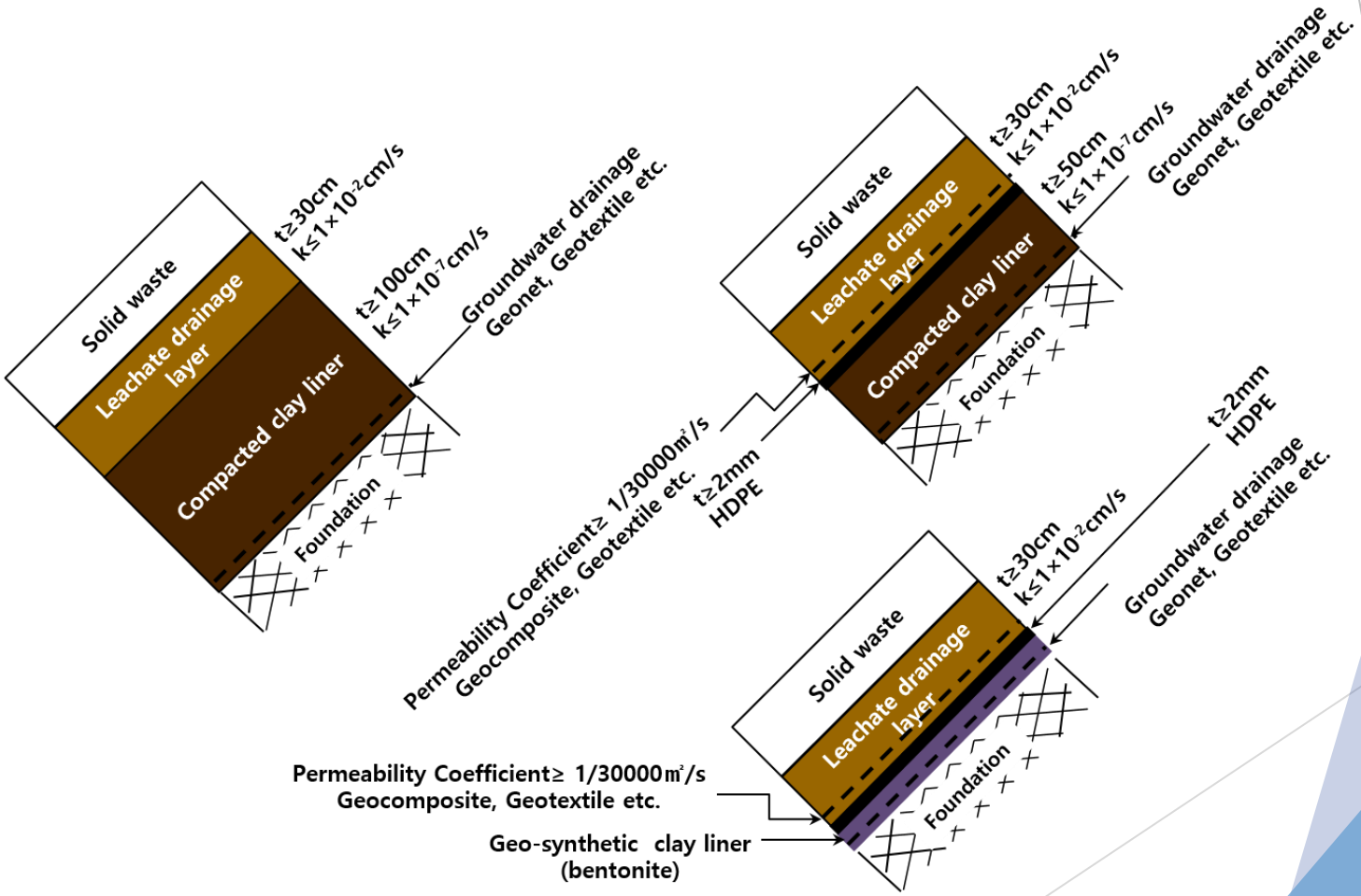
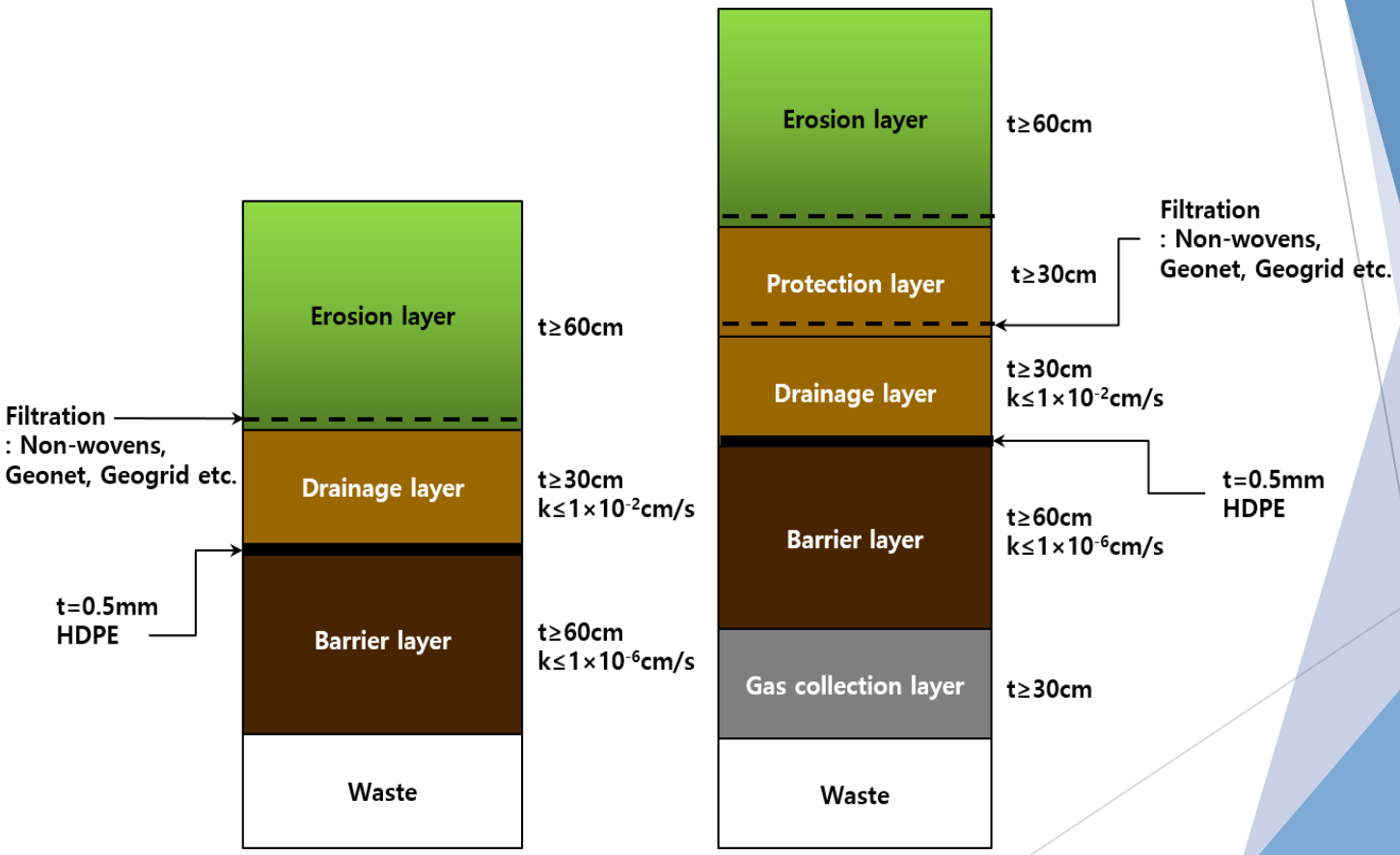


Side slope for hazardous waste

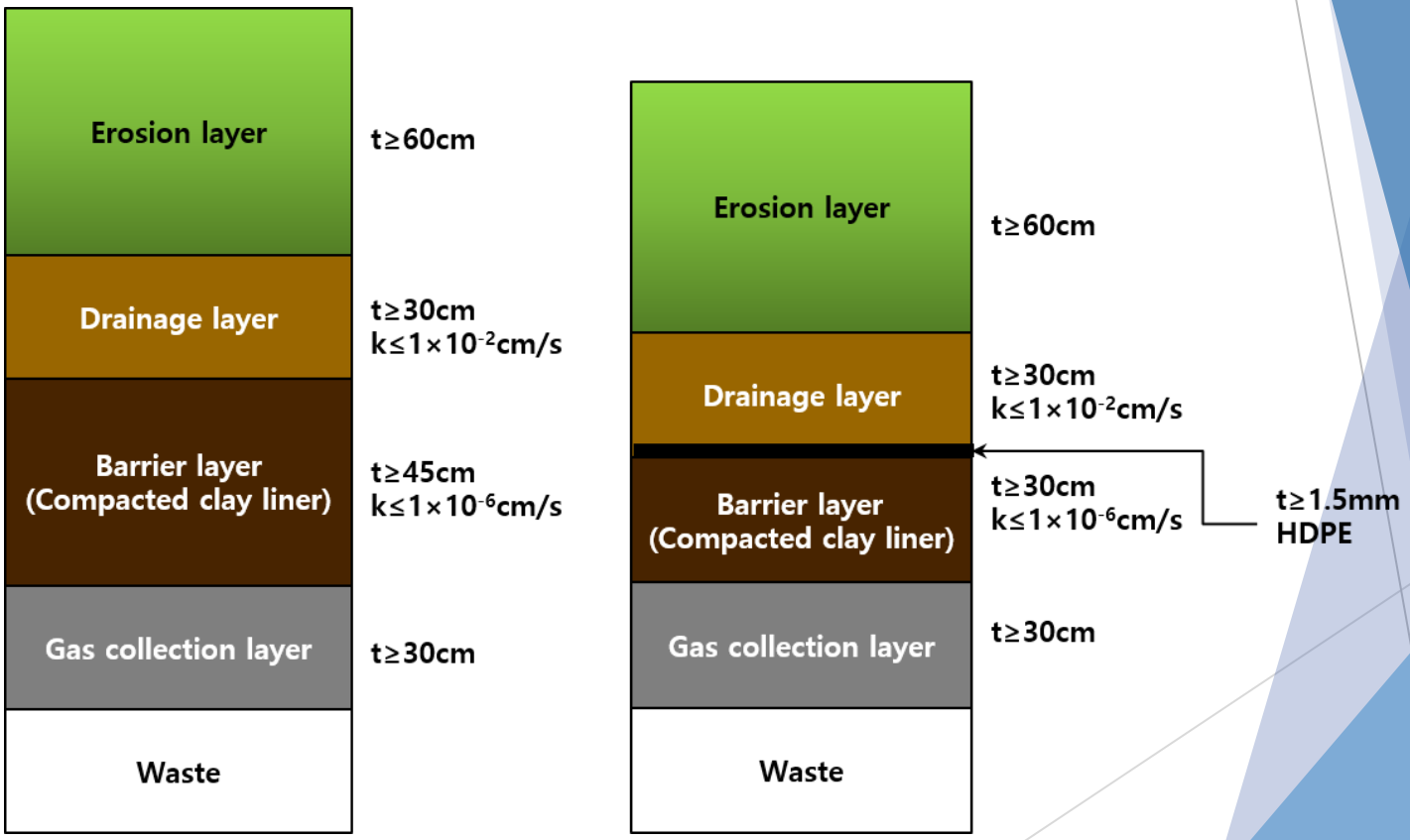
Final Cover Systems

U.S. EPA



Typical landfill final cover configurations in the U.S.

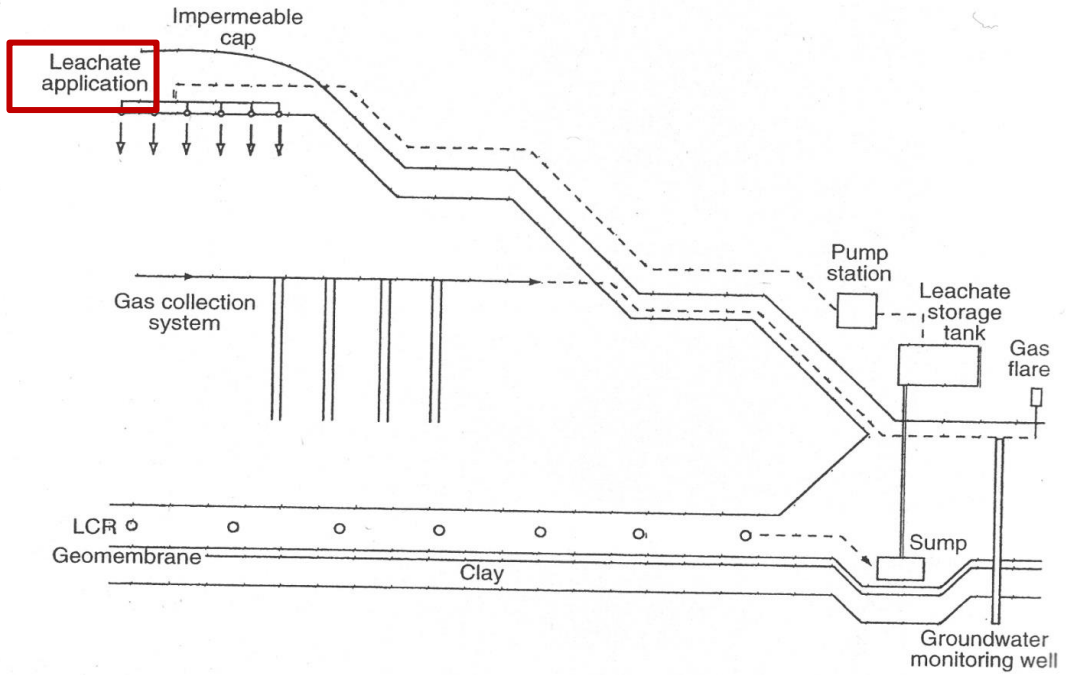
Ministry of Environment in **Korea**



Typical landfill final cover configurations in Korea

Bioreactor landfill

: rapid decomposition of waste and speeds stabilization of landfill **with <u>leachate circulation</u>**

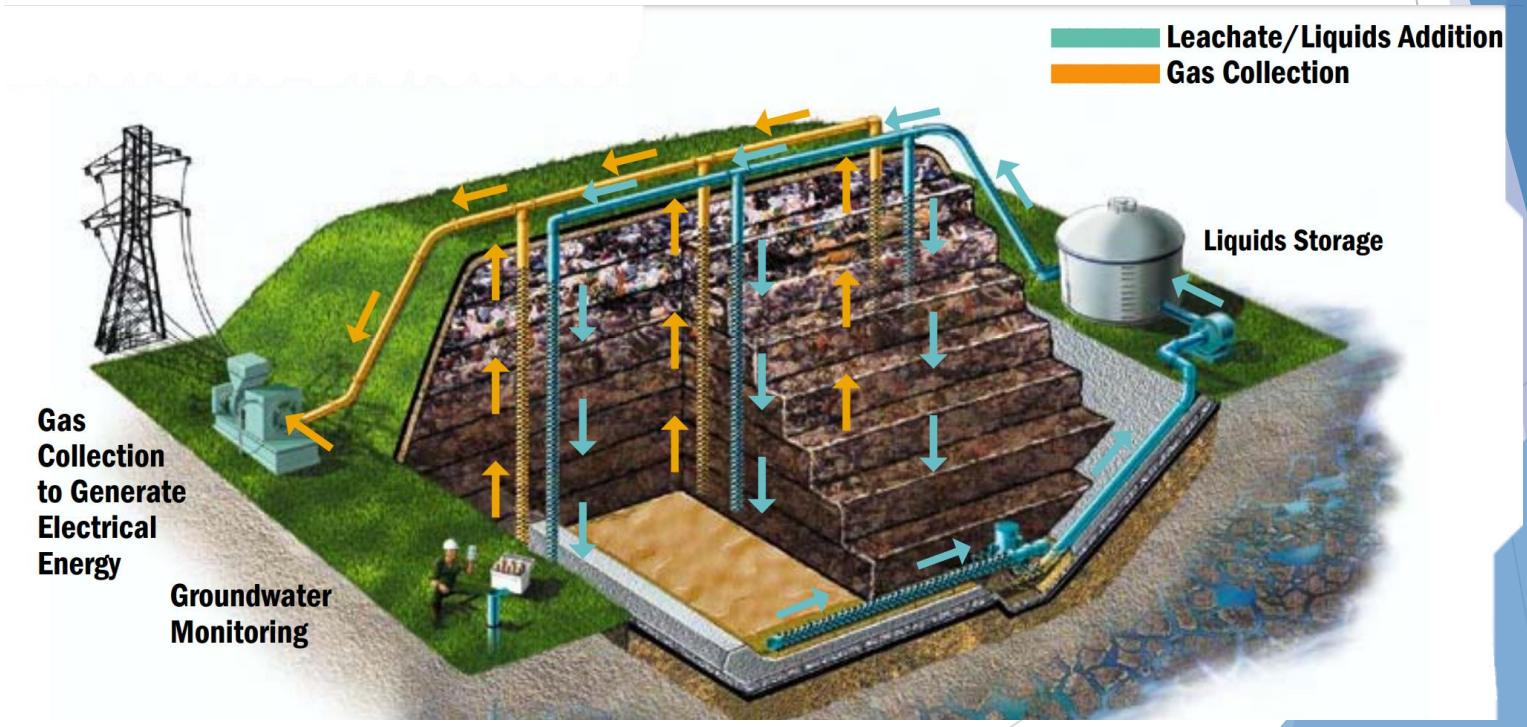


A Schematic of a bioreactor landfill

(cont.)

Benefits of anaerobic bioreactor landfill

- Leachate storage within the waste mass
- Increase rate of landfill settlement
- More rapid waste stabilization than conventional landfills
- Increase methane generation rate (200~250% increase typically)
- Lower post-closure costs



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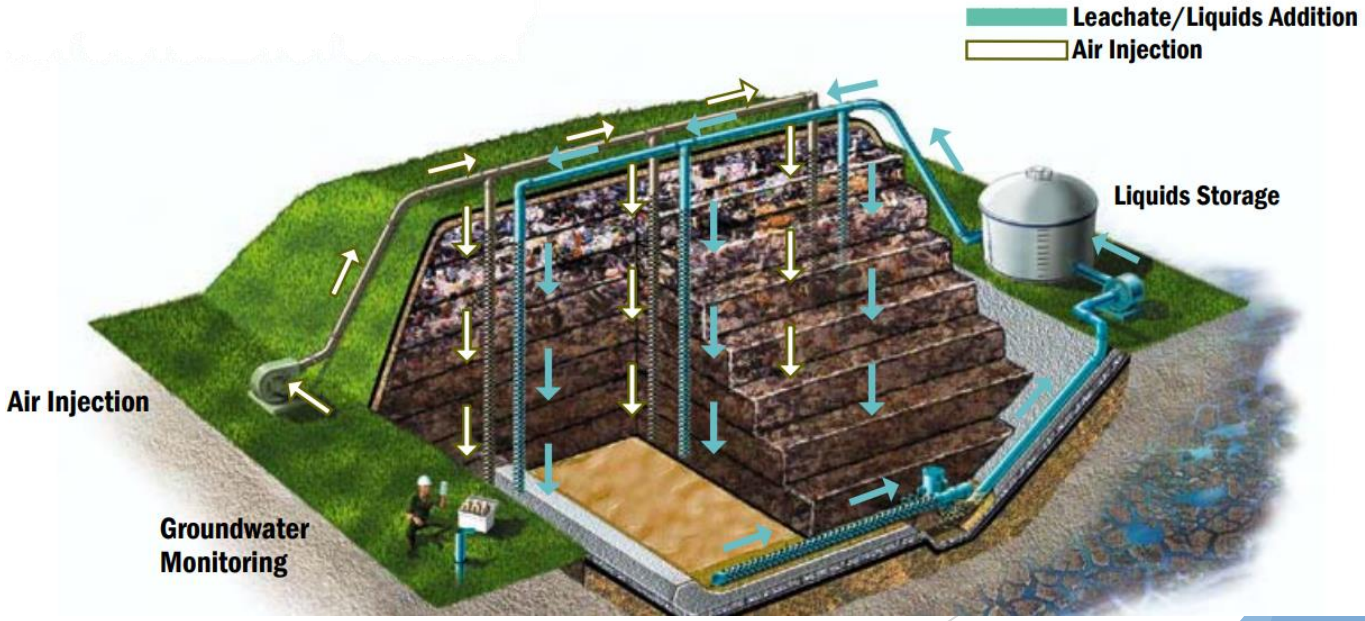
Benefits of aerobic bioreactor landfill

- More rapid waste and leachate stabilization
- Increased rate of landfill settlement
- Reduction of methane generation by 50~90%
- Capability of reducing leachate volume by up to 100% due to evaporation
- Potential for landfill mining
- Reduction of environmental liabilities



World Largest?: Sudokown Landfill Corporation

Sudokwon Landfill Corporation in Korea

- Location : Incheon, South Korea
- Size : 20 million square meter (World's largest sanitary landfill)
- Type of garbage : Municipal solid waste (2000 ton/day)
- Transform wastes into energy by utilizing combustibles, sludge and biogas
- Build the solar and wind generation plants
- Using landfill gases, 50MW power plant generates 30 million USD worth of electricity
- This landfill will be turned into the world's best ecological tourism – called DREAM PARK

<Establishment plan of Dream Park>

Sudokwon Landfill Corporation in Korea (cont.)

- Green Bio-Town
  - Supporting Center
  - Horse riding Course
  - Swimming Pool
  - Wetland Ecology
- 1st Landfill site : Sport Park
  - Public Golf Course
  - Sports Complex
  - Trekking Course
- 2nd Landfill site : Environmental Events Complex Park
  - Arboretum
  - Flower Garden
  - Botanic Garden
- 3rd Landfill site : Environment Center
  - Waste Resource Energy Town
  - Bio-Energy Town
  - Environmental Cultural Complex
- 4th Landfill site : Nature Observation Complex
  - Anamdo Island Cistern(Ornithological Ecological Park)
  - Nature Observation Zone

Sudokwon Landfill Corporation in Korea (cont.)

- The Clean Development Mechanism (CDM)
  - CDM is an arrangement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment
  - Sudokwon landfill site will receive the Certified Emission Reduction (CER) credit as a side CDM project

<Landfill gas CDM project overview>

Sudokwon Landfill Corporation in Korea (cont.)


- Facilities of landfill leachate
  : operating for the leachate treatment 6,700ton/day


- Facilities of solidification for organic sludge
  : operating for the solidification of organic sludge 600ton/day


- Facilities of extraction and management system for the landfill gases

<Facilities in the Sudokwon landfill site>

Sudokwon Landfill Corporation in Korea (cont.)

- Sudokwon landfill site is changing for building up the ecological tourism of reports and education

< The DREAM PARK in Sudokwon landfill site >

waste-bin race in Germany