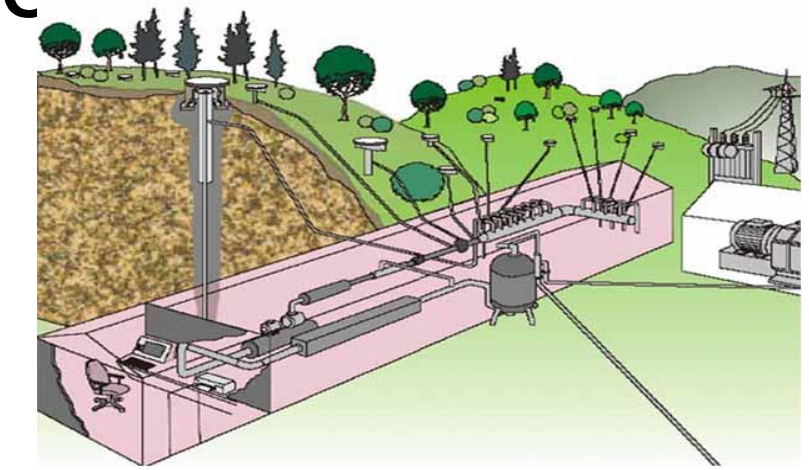
Lecture 4: Landfill

Gas collection and utilization system

- Gas collection system contains
  - Gas extraction wells/trenches
  - Pipelines
  - Compressor or blowing station
    - Leads gas to flare or generator for electricity production
  - Instrumentation and electrical equipment
- The gas is led to a burner –
  - with just a flame/flare
  - With a generator to produce electricity
- 1 m^3 gas contains 4 – 5kWh energy
  - 2 m^3 corresponds 1 l of oil
- 150m^3 gas is formed /1 ton waste
  - Will be less in the future – WHY??



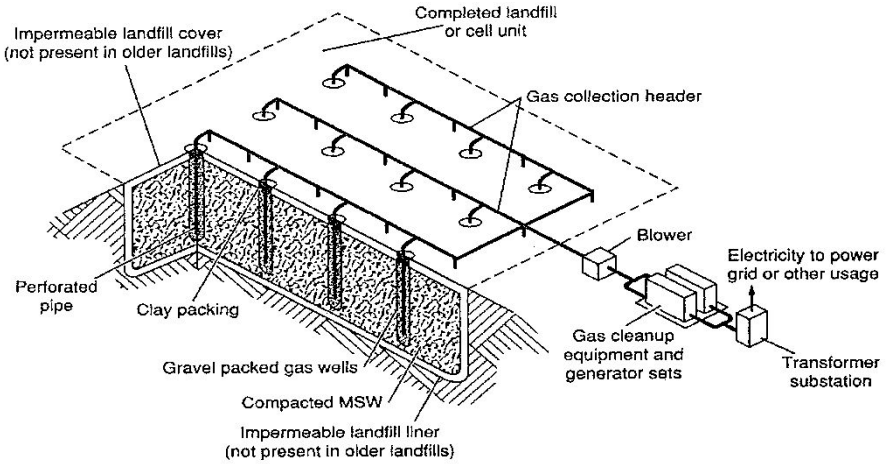


FIGURE 14.9 Landfill gas recovery system using vertical wells.

Planning of a landfill

- **Siting is a problem**: ”not in my backyard”
  - Land use plans and regulations
  - Distance form close-by
    - residential areas
    - water resources
    - recreation areas
  - Haul distance
  - Size of available land area
  - Soil conditions and topography
  - Geologic and hydrogeologic conditions
  - Surface-water conditions

- Screening of potential sites using several criteria in screening

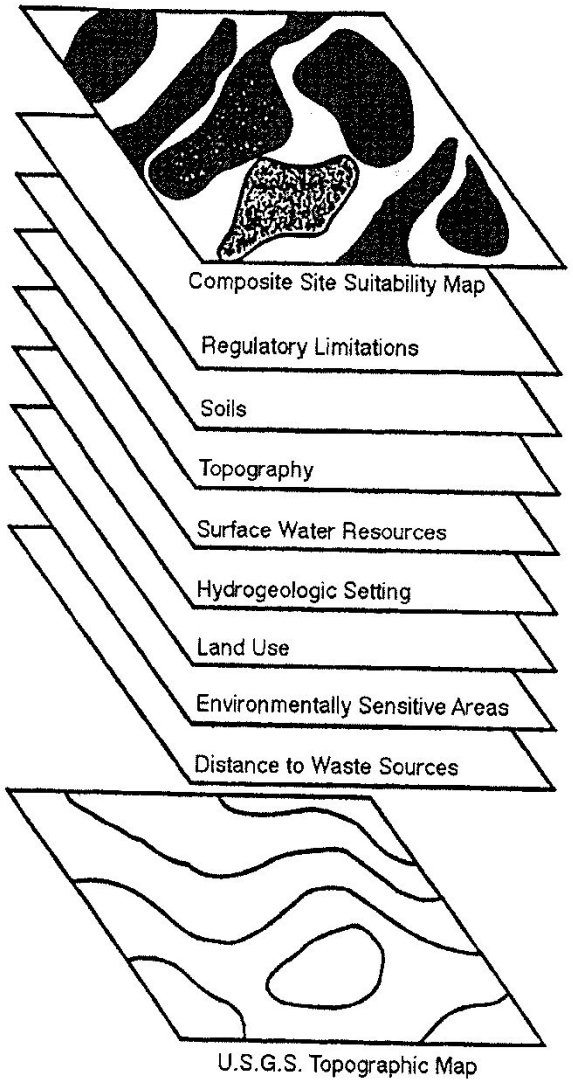


FIGURE 14.4 Overlay maps of various site criteria used in the screening of potential landfill sites. *(From Barlaz et al., 1989.)*

Gas formation in anaerobic processes

- Micro-organisms come from daily soil cover, sludge, recycled leachate
- **Phase I** - Initial adjustment
  - Aerobic bacterial decomposition starts
- **Phase II** – Transition phase
  - Anaerobic conditions develop
  - $NO_3^- + SO_4^{2-}$ □□ **N_2 + H_2S**
  - Organic acids and CO_2 formation □ pH decreases
- **Phase III** – Acid phase
  - Bacteria activated □ significant amounts of **acids** and **CO_2**
  - pH ≤ 5
  - Heavy metals solubilize
  - Essential nutrients into the leachate

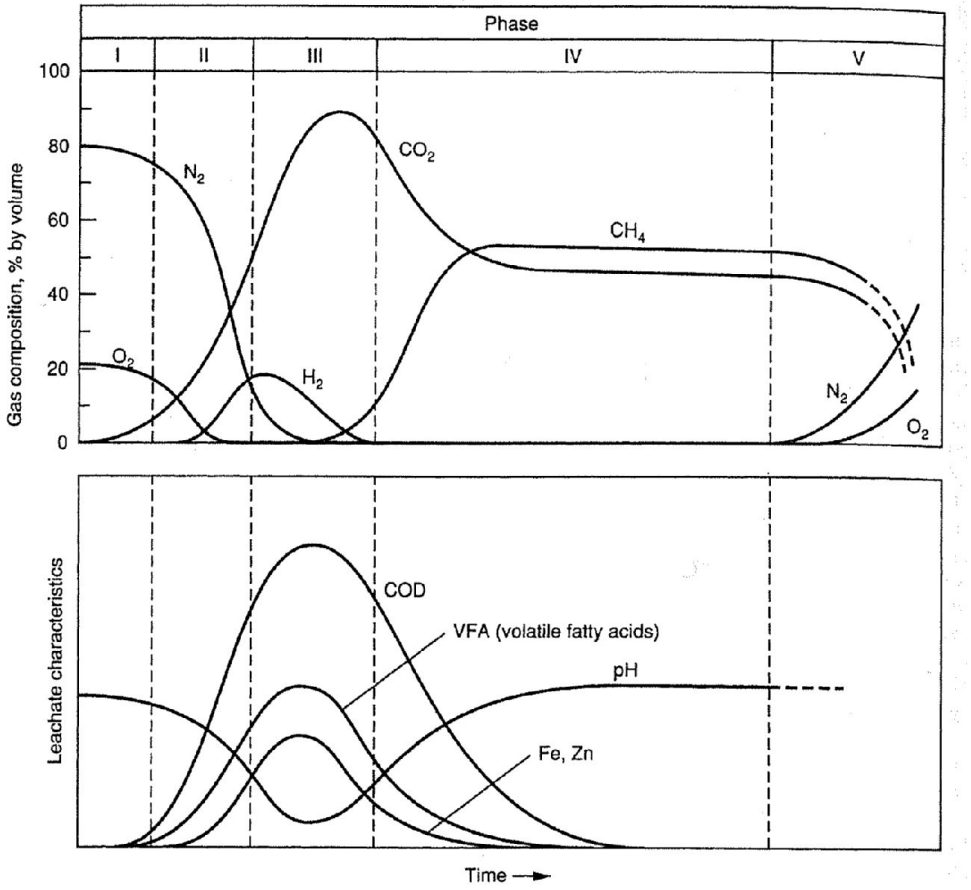


FIGURE 14.6 Generalized phases in the generation of landfill gases (I—Initial Adjustment, II—Transition Phase, III—Acid Phase, IV—Methane Fermentation, and V—Maturation Phase). *(Adapted from Farquhar and Rovers, 1973; Parker, 1983; Pohland, 1987; and Pohland, 1991.)*

Gas formation…

- **Phase IV** – methane fermentation phase
  - Bacteria transforms acetic acid and hydrogen gas into methane and carbon dioxide
    → **CH_4 + CO_2**
  - pH will rise to 6,8 – 8
  - BOD, COD and conductivity are reduced in the leachate
  - Heavy metal concentration reduced in the leachate
- **Phase V** – maturation phase
  - Readily available organic matter has been converted into CH_4 and CO_2 Moisture sinks through the waste
  - Some organic matter is converted
  - Some CH_4 and CO_2 are formed
- **Total reaction**
- Organic matter + H_2O + nutrients →
  new cells + resistant organic matter + CH_4 + CO_2 + NH_3 + H_2S + heat

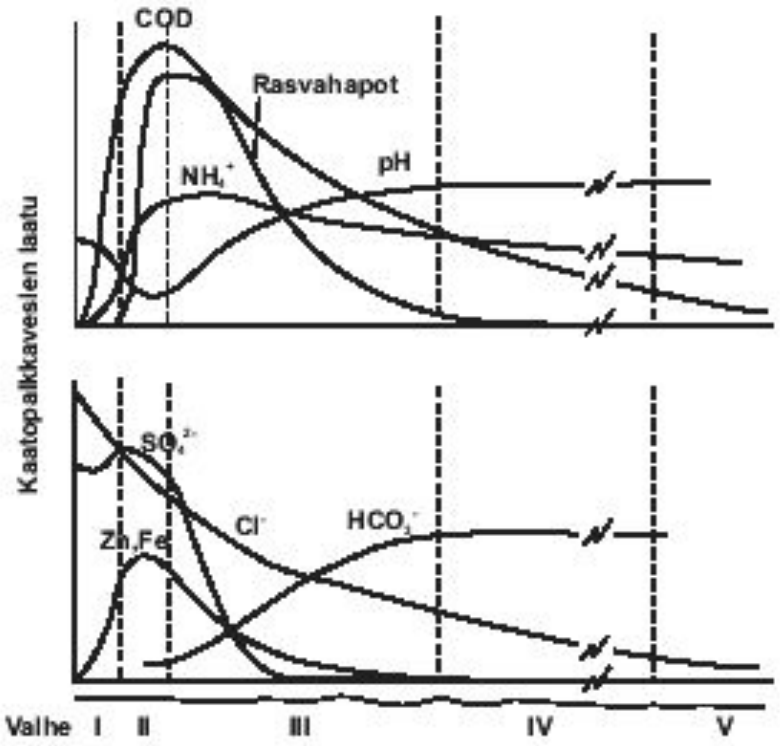
Formation of leachate

- Amount of leachate varies and depends on eg. season and weather
- Average amount is 7 – 16 m^3 /ha*d
- In a closed, well covered landfill 3-4 m^3/ha*d
- Volume can be reduced by
  - Plants growing on closed parts of a landfill
    - Willow 20-30%, grass 5-20%
  - Watering the surface of the landfill (evaporation)

- The leachate contains
  - Biodegradable components
  - More nitrogen and less phosphorus than municipal waste waters
  - Dissolved metals and salts (especially from ash)
    - Cd, Co, Cr, Cu, Fe, Ni, Mn, Pb, Zn –also As
    - Concentrations often lower than allowed for drinking water
  - Organic compounds
    - Chlorinated hydrocarbons, toluene, xylene, phenol, PCB
    - Concentrations are not high

Leachate

Quality of leachate depends on the phase of the biological processes



Leachate can also be circulated in the waste layers → nutrients and humidity to the microbes

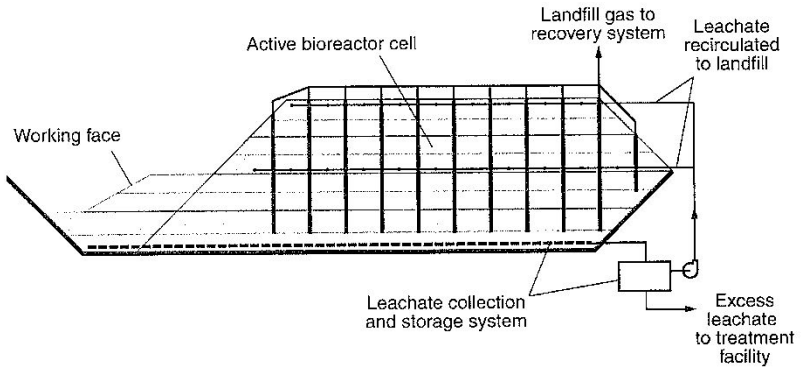


FIGURE 14.3 Bioreactor landfill with leachate recirculation and landfill gas recovery. *(Adapted from Solid and Hazardous Waste Education Center, University of Wisconsin–Madison, 2000.)*

Construction of a landfill before filling it

The landfill has to be specially founded

- Road construction
- Land construction and quarrying
- Re-inforcement of the bottom soil
- Waterproofing the bottom and walls
  - the landfill is segregated from the bottom soil with chemically and physically durable liner
  - prevents the ground water pollution
- Collection system for leachate and surface water
  - no water runs off uncontrolled
- Gas collection system
  - no gaseous emissions should be released
- Buildings (office, storage, reception..)

Filling

Filling system depends on topography

- Waste is placed onto the landfill in cells
- Waste is crushed and compacted
- Cells are covered daily with soil

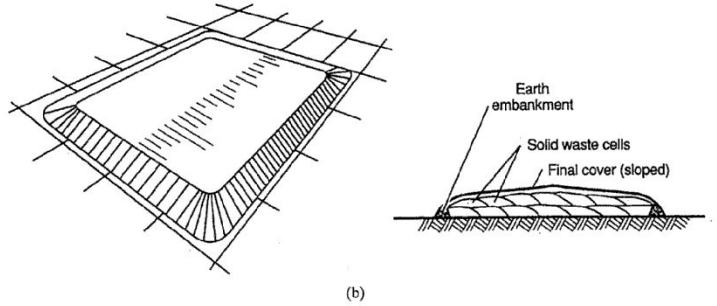
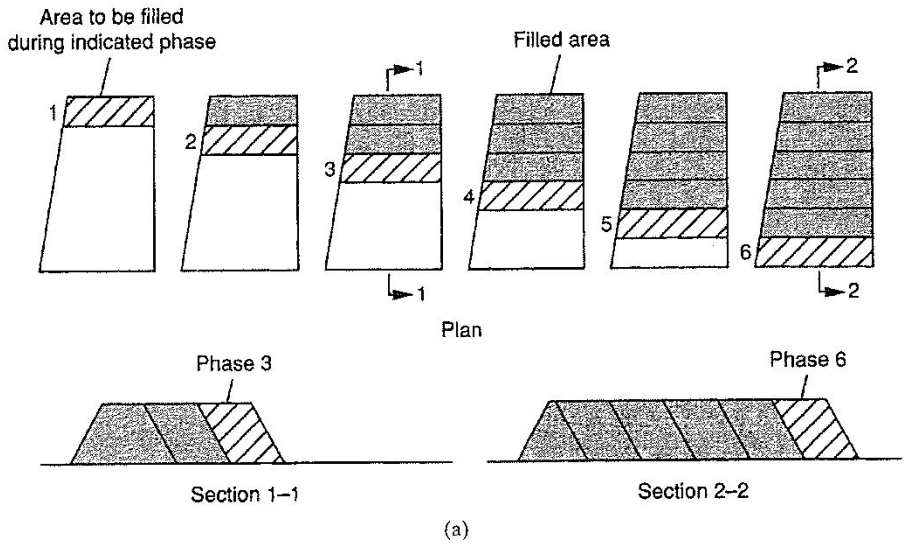


FIGURE 14.2 Commonly used landfilling methods: (*a*) excavated cell/trench; (*b*) area; (*c*) canyon/depression.



Waste layers in a landfill

a)

- Bottom layers are built
- Leachate collection pipes are installed

b)

- Waste is added as cells and layers of cells
- Daily layers are covered with soil
- Gas collection pipes are installed, surrounded with gravel

c)

- Final top layer is built

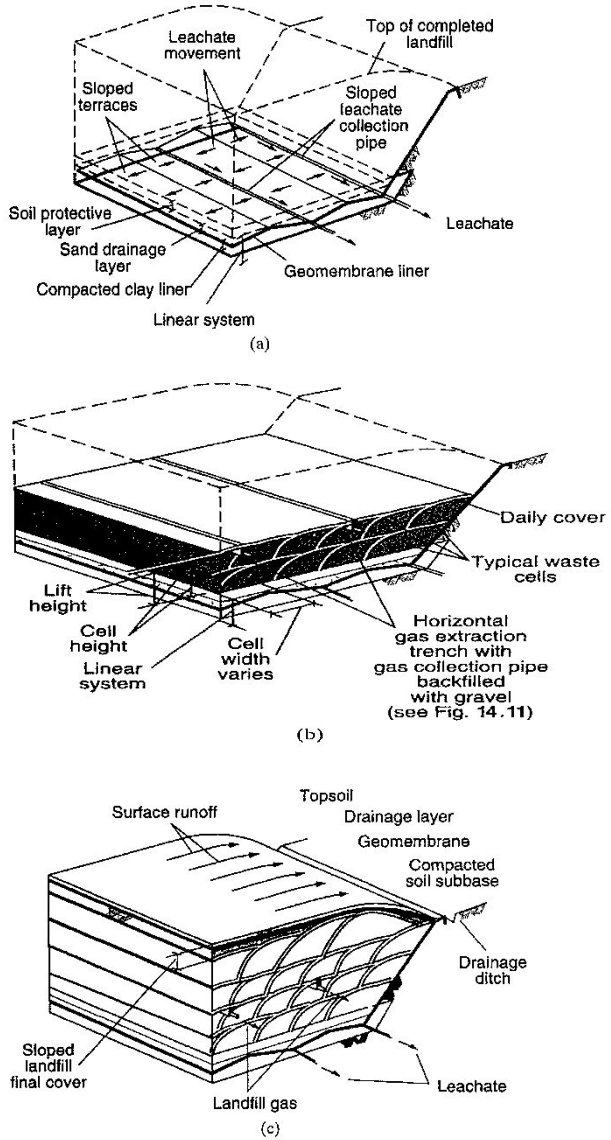


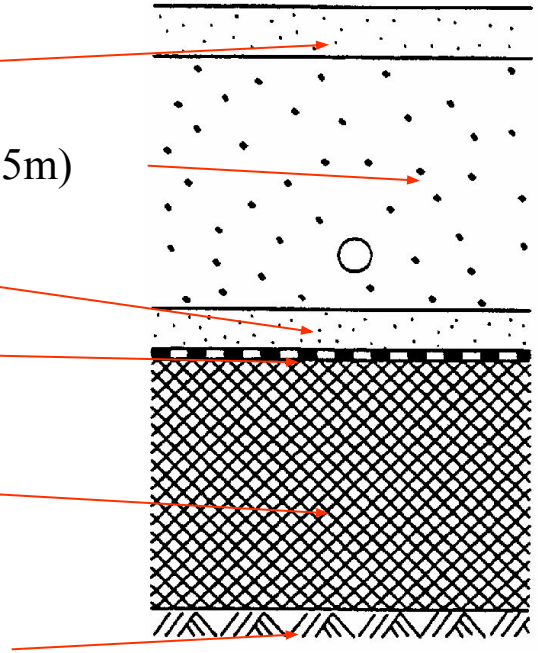
FIGURE 14.1 Cutaway views of a sanitary landfill: (*a*) after geomembrane liner has been installed over compacted clay layer and before drainage and soil protective layers have been installed; (*b*) after two lifts of solid waste have been completed; and (*c*) completed landfill with final cover installed.

Landfill Bottom Structure

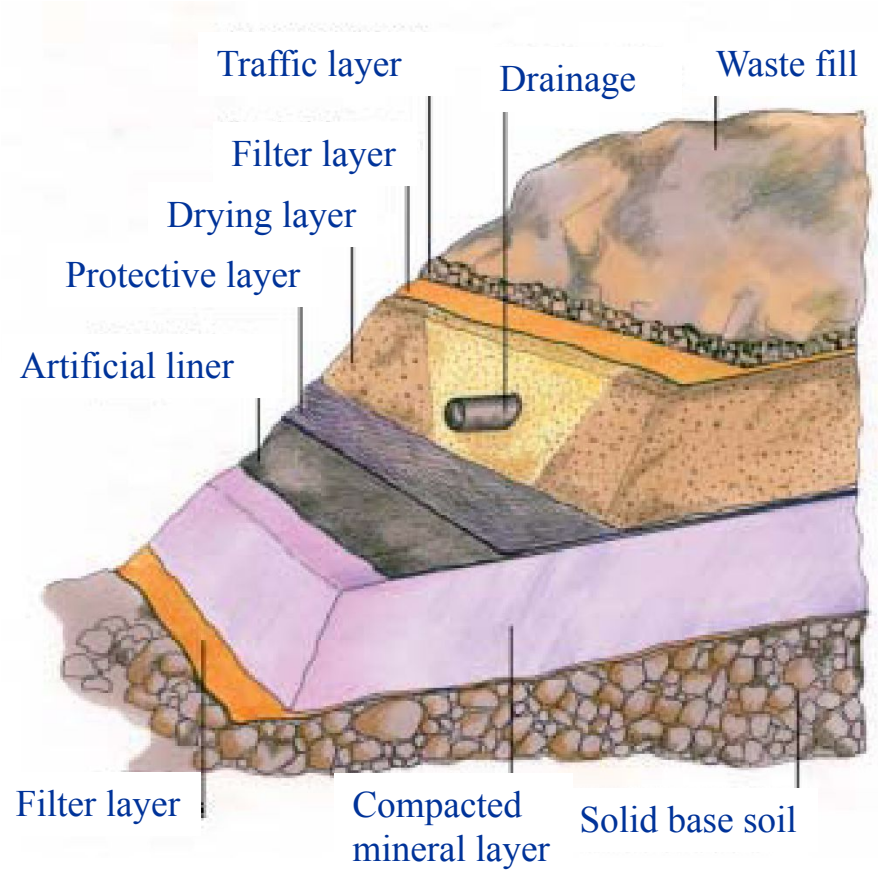
Soil quality is important

Structure contains several layers from top to the bottom:

- Waste layers
- Filtering material layer
  - Sand or geotextile
- Leachate collection pipes in soil layer (>0,5m)
- Protection layer
  - Sand or geotextile
- Artificial liner
  - Eg. Geomembrane
- Compacted layer of special mineral material or artificial separator >0,5m
- Natural bottom soil forms sturdy base



Landfill bottom structure



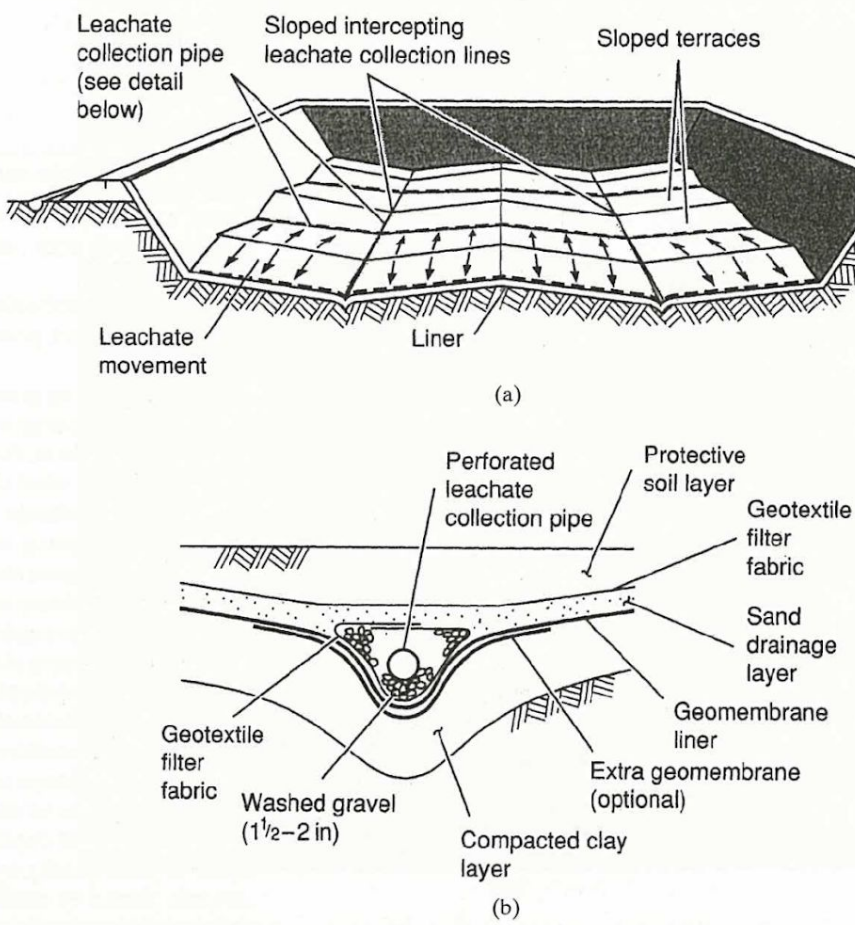


FIGURE 14.23 Leachate collection system with graded terraces: (*a*) pictorial view; (ical leachate collection pipe.

Required bottom layers

- Bottom layers
  - Base soil has to be bearing
  - Water permeability and thickness of bottom layers
    - Hazardous waste
      - $K \leq 1{,}0 * 10^{-9}$ m/s, layer ≥ 5 m
    - Regular waste
      - $K \leq 1{,}0 * 10^{-9}$ m/s, layer ≥ 1 m
    - Permanent waste
      - $K \leq 1{,}0 * 10^{-7}$ m/s, layer ≥ 1 m
  - Minimum compacted layer
    - hazardous waste 1 m
    - regular waste 0,5 m
  - If K-values are higher than given thicker compacted layer required

An example of bottom liners and leachate tubes